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The effect of a tailor-made exercise program on improving balance among older adults at risk of falling

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The Effect of a Tailor-made Exercise Program on Improving Balance among Older Adults at Risk of Falling

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DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of PhD at Hong Kong Baptist University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualification.

Signature: ____________________________

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ABSTRACT

Context: There is a paucity of information on well-designed exercise programs for the Primary Falls Prevention.

Objective: This study aimed to evaluate a tailor-made exercise program for improving balance and balance-related fitness among older adults without history of falls but who were at risk of falling.

Design, Setting, and Participants: A single-blind and randomized controlled trial for 61 older adults (age = 70 ± 3 years, males = 25%) with no history of falls but who were at risk of falling enrolled at the local senior center.

Intervention: Participants were randomly allocated into three groups. An intervention group receiving a tailor-made Exercise for Balance Improvement Program (ExBP; n = 20), an active control group receiving the 8-form Yang-style Tai Chi (TC; n = 20), and a no-treatment concurrent control group (CON; n = 21). The ExBP was developed based on demographic and clinical characteristics of old adults as well as on the most reported deficits in balance and balance-related systems. The movements chosen in ExBP were those used in previous studies for older adults. The movements were integrated with considerations of movement specificity, movement complexity and organization, movement safety, feasibility and gracefulness, as well as the transfer of exercise learning. Modifications of these movements were made following experts and end-users' evaluations. Training dosage was set at "90 minutes per session x 3 sessions per week x 16 weeks" with an 8-week follow-up.

Outcome Measurements: The primary outcome was a composite measure of balance capacities, including Fall Risk Test (FRT), Postural Stability Test (PST), Limits of Stability Test (LOS), and a modified Clinical Test of Sensory Organization and Balance (m-CTSIB). The secondary outcomes referred to those balance-related fitness including 30s Chair Stand Test (CS), Chair Sit-and-Reach Test (SR), 8ft Up and Go Test (UG), 2min Step Test (Step), Choice Stepping Response Time (CSRT), as well as Fear of Falling (FF). All the testing parameters were collected one week before the intervention (pre-test), at the end of 12th week (mid-test), at the end of 16th week (post-test), and at the end of 24th week (follow-up test). Analysis of variance with pre-test data as covariance and repeated measures analysis of variance were conducted to examine Group effect and Time effect, respectively.

Results: All testing parameters in the ExBP group demonstrated an improvement trend from pre-test to post-test, especially in FRT, m-CTSIB, CS, SR, UG, and FF ($p < .05$). In comparison with the CON group at post-test, there were significant improvements in the ExBP group in FRT, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, CS, UG, Step, and FES ($p < .05$), while the improvements at mid-test were only shown in UG and FF. There were no significant differences on any of the testing parameters between post-test and follow-up test. In addition, continuous improvements were shown in FRT, PST, m-CTSIB, SR, UG, CSRT, and FF during the follow-up period. In comparison with the TC group at mid-test, ExBP showed significantly more improvements in FRT, UG, Step and FF. Although without statistically significant group difference at post-test except in Step, improvements in FRT, PST in anterior-and-posterior direction, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, SR, UG, Step, and CSRT were more pronounced in the ExBP group. The losses of training effect from post-test to follow-up test in ExBP was lower than the Tai Chi especially in FRT, m-CTSIB with compromised vision and somatosensation, Step, and CSRT.

Conclusion: The ExBP can be applied as an effective exercise program for improving balance and balance-related fitness among older adults at risk of falling. In comparison with Tai Chi, training effects from ExBP occurred earlier and lasted longer.

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LIST OF SYMBOLS

ANCOVA	Analysis of covariance
CI	Confidence interval
F	Fisher's F ration
M	Mean
n	Number of cases in a sample
p	Probability
partial η^2	Partial et squared
r	Effect size
SD	Standard Deviation
t	Student's t test

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
APSI	Stability Index in Anterior-and-Posterior direction
BOS	Base of Support
COM	Center of Mass
COG	Center of Gravity
CS	Chair Stand Test
CSRT	Choice Stepping Response Time
ExBP	Exercise for Balance Improvement Program
FES-I	Falls Efficacy Scale – International Version
FF	Fear of Falling
FRT	Fall Risk Test
HR	Heart Rate
ITT	Intention to treat
LOS	Limits of Stability Test
m-CTSIB	Modified Clinical Test of Sensory Integration on Balance
MLSI	Stability Index in Middle-and-Lateral Direction
OSI	Overall Stability Index
PST	Postural Stability Test
ROM	Range of Motion
RPE	Rating of Perceived Exertion
SR	Chair Sit-and-Reach Test
Step	2min Step Test
TC	Tai Chi
UG	8ft Up and Go Test

CHAPTER 1 - INTRODUCTION

Study Background

With the advancements of technology as well as health and medical sciences, a human's average life expectancy has increased considerably over the last several decades. Taking Hong Kong as an example, the average life expectancy has increased from 67.8 years in 1961 to 80.5 years in 2011 for men, and 70.2 to 86.7 years for women; the average life expectancy has increased nearly 16 years (Census and Statistics Department of Hong Kong, 2011a). In addition to the increase in life expectancy, the number of older adults in Hong Kong rose from 87,918 to 941, 312 from 1961 to 2011; and the proportion of older adults has risen continuously from 2.8% to 13.3% (Census and Statistics Department of Hong Kong, 2011b). Such an epidemiologic transition has not yet ceased, causing Hong Kong to face considerable economic and social challenges due to this ageing society. On individual level, age-associated deterioration without proper intervention leaves older adults more susceptible to disease and adverse health conditions, which would adversely influence the quality of life in late years (Spirduso, Francis, & MacRae, 2005).

People of advancing age and decreasing physical activity in daily life are reported to have a higher probability of falls (Milanović et al., 2013). According to the World Health Organization (WHO, 2007), falls are the second main cause of accidental or unintentional injury deaths worldwide; and one out of three adults older than 65 years would fall every year (Tromp, Smit, Deeg, Bouter, & Lips, 1998). In Hong Kong, the rate of falls among older adults is said to be 27% (Chu, Chi, & Chiu, 2005), and falls are the principal cause of injury (50%) in older adults (Yeung et al., 2008). For people who do not report a fatal fall, injuries caused from falls could be fractures, head traumas, decreased functioning and loss of independence (Stevens, 2006). Moreover, post-fall syndromes, such as lower self-efficacy and higher fear of falling can limit participation in physical activities, which in turn make the adverse effects from falling more severe (Tinetti, Speechley, & Ginter, 1988). In addition to these health problems, the cost of medical treatments is of great concern. In 2010, the direct medical cost related to falling, adjusted for inflation, was $30 billion in the USA (Stevens, Corso, Finkelstein, & Miller, 2006). In Hong Kong, about 50,000 older adults received medical care every year due to falls, of which 32,000 needed to remain in hospital for further care and while 80% of these people suffered fractures, approximately 200 older adults died. The total cost was approximately HK$20 billion (Hong Kong Hospital Authority, 2010).

Although the problems resulting from falls are severe, there is no consensus on definition of falls to date (Lam, Jørstad-Stein, Hauer, & Becker, 2005). Clinically, a fall is defined as the sudden, unintentional change of position causing individuals to land on the ground, floor or any other object (Lam et al., 2005; WHO, 2007). In laboratory studies, a fall usually refers to the movement of the center of mass (COM) outside the limits of the base of support (BOS; Shumway-Cook & Woolacott, 2011). Factors causing falls have varied considerably, and over 100 variables have been identified as risk factors for falls among the Chinese population (Kwan, Close, Wong, & Lord, 2011). Generally, they are classified as intrinsic or extrinsic risk factors. Intrinsic risk factors are those age-associated and pathological changes in physiological and psychological functions within the human body (e.g., declined visual sensation, muscle weakness, and delayed response time). Extrinsic risk factors come from the outside environment and include slippery floors, dim lighting, unpredictable outside forces, and so on. Some studies also consider the complex relations among falls, tasks and risks (i.e., exposure to risk) as risk factors (e. g., Todd & Skelton, 2004). Although intrinsic factors usually account for less than extrinsic factors (39~53% vs. 41~55%) in older adults (Lach et al., 1991; Rubenstein, Josephson, & Robbins, 1994); intrinsic factors are the most important focus in the majority of related studies. The underlying reason for this could be that comparing with the unpredictability and uncontrollability of most extrinsic factors, improvements in intrinsic falling risk factors can enable the human body to cope with the various challenges and falling risks from the external, uncontrolled environment.

To maintain postural stability and prevent falls, there are at least three stages, 1) perception of a postural threat (sensory systems), 2) selection of an appropriate correction response (cognitive systems), and 3) proper response execution (motor systems; Lord, Sherrington, Menz, & Close, 2007). Treatment on any deficits involved in these three stages would be beneficial to balance maintenance and falls prevention. Among the various kinds of treatments, exercise has been found to be the most effective single intervention for preventing falls among older community-dwellers (Howe et al., 2011). Exercise can delay the speed and the extent of age-associated degradations in postural control (Spirduso, Francis, & MacRae, 2005). Compared with those age-matched sedentary older adults, people who persisted with an active lifestyle have reported higher functional fitness levels (Lord, Clark, & Wenster, 1991), better balance abilities, and lower falling rates (Steinhaus et al., 1988; Chodzko-Zajko et al., 2009). Additionally, exercise has positive effects on mental health, such as reducing depression, anxiety, and cognitive impairment (Lautenschlager, Almeida, Flicker, & Janca, 2004; Stathopoulou, Powers, Berry, Smits, & Ottos, 2006).

The rationales for exercise's ability to improve balance mainly come from the trainability of balance systems. From an updated perspective, balance is no longer considered to be a fixed set of reflex in the central nervous system (CNS), but a flexible, functional motor skill that can be improved through physical training (Horak, Henry, & Shummway-Cook, 1997). At least two kinds of exercise formats were found to be effective in balance improvement and fall prevention, one is machine based balance training (e.g., force-plate retraining system and Biodex Balance System[SD]), and the other is active exercise without any machine support (e.g., Tai Chi). Compared with active exercise, machine-based balance training is difficult for older adults to apply in daily life, due to the relatively high cost of machinery as well as the practical inconvenience. Additionally, just how much the effects from machine-based training can be transferred into real life balance abilities is in doubt (Winstein, Gardner, McNeal, Barto, & Nicholson, 1989). Hu and Woollacott (1994) found an unmatched transfer effect from machine-based exercise for functional walking in older adults suffering from strokes. In order to generalize into a wider population and for reasons of practicality, balance training without any specific requirements of equipment, time, or venue would be more suitable for older adults.

One consensus that almost every scientist and professional have reached is that there is no one-size-fits-all exercise. A common characteristic for the effective exercise programs is that they all contain balance training with a higher total dose and avoid walking as a single intervention program (Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011). From the physical training perspective, optimal exercise programs should be those that take into consideration the falling status, balance deficits, and clinical characteristics of the target population. Therefore, a tailor-made exercise program with specified balance foci is hypothesized to be more effective in improving balance and preventing falls than the general exercise program such as Tai Chi and walking.

In falls prevention, there are at least three stages, primary, secondary, and tertiary falls prevention; and each of them has different preventative foci (Al-Faisal, 2006). Primary prevention is implemented before a fall and is aimed to reduce the incidence of falling by reducing the occurrence of risk factors. Secondary prevention is conducted after one or more falls, and aims to identify falling risk at its earliest stage and apply prompt, effective treatment to alleviate any adverse consequences. Tertiary prevention is also conducted after a fall with the main purpose to reduce the progression and complications of fall-related injuries. As a result of a review of the literature, the majority of current well-structured exercise programs are developed for secondary (i.e., recovering from injuries) and tertiary prevention (i.e., decreasing disability), such as the FallProof, Falls Management Exercise (FaME), Otago Exercise Program, A Matter of Balance, and OsteoFit (Age UK, 2013). For the primary falls prevention stage, general exercise programs such as Tai Chi, dance, and walking are usually used to maintain balance abilities in the older non-fallers (Age UK, 2013). A research gap exists among the well-designed exercise program targeting primary falls prevention (Muir, Berg, Chesworth, Klar, & Speechley, 2010). One of the underlying reasons for this, as indicated by Rose (2010), would be the absence of falling risk factors for people with no falling experience.

However, the absence of a history of falls does not rule out the possibility of being at risk of falling with at least one or more risk factors. Muir and his colleague (2010) found that weakness in lower limbs, balance impairment, and more than 4 prescription medications were the modifiable risk factors for older adults who were in the transition from non-fallers to fallers. Hill and colleague found gait symmetry and gait double-support in a group of older females who were in the process to falling within 12 months (Hill, Schwarz, Flicker, & Carroll, 1999). In addition, they found that most falls occurred in general activities such as walking with altered sensory or environmental conditions, which indicates that older adults who were in the transition from non-fallers to fallers would have difficulties in coping with unexpected stimulations (i.e., declined reactive balance). In fact, older adults with no history of falls but who are at risk of falling are more vulnerable to experience fall given they do not have sufficient realization of potential fall risks, and do not make sufficient preparation for falls prevention. Whereas, several studies found older adults who are in the transition of frailty or in the process of losing balance can gain more from balance training compared to those with high risk of falling (Barnett, Smith, Lord, Williams, & Baumand, 2003; Buchner et al., 1997). Therefore, early identification of potential fallers plus proper implementation of effective balance training in this population is essential to avoid falls (Chiu, Au-Yeung, & Lo, 2003).

Statement of Problems

By reviewing previous studies targeting balance improvement and falls prevention, the following two issues were found.

Lack of Well-designed Exercise Program in Primary Falls Prevention

The main objective in the primary falls prevention stage is to reduce the incidence of falls by reducing the occurrence of falling risk factors; in other words, it is to delay or prevent the first fall. Most of the exercise programs for this stage are general exercise programs, such as Tai Chi, dance, strength training, and aerobic exercise. The effectiveness of these general exercise programs for balance improvement is inconsistent and questionable. As such this indicates a research gap that currently there is no exercise program specifically tailor-made to improve balance and prevent falls. However, the absence of these programs does not rule out the importance of proper balance treatment for older adults without falling experience. As indicated from the related studies, older adults with no previous falling experience but who were at risk of falling were more vulnerable to falls as they do not have sufficient realization of the potential falling risks, and thus do not prepare sufficiently for falls prevention. Early identification of potential fallers plus proper implementation of effective balance training in this population is considered essential. Given that there is no one-size-fits-all exercise program, a tailor-made exercise program with the main purpose to improve balance and balance-related fitness is worthy of further study.

Little Was Known About Whether a Tailor-made Exercise Program would be More Effective than Tai Chi in Balance Improvement

Among the various kinds of exercise for primary falls prevention, Tai Chi is the most commonly studied. Tai chi has been found to be effective in delaying the first fall, decreasing fear of falling, and improving static balance. However, there is increasing debate as to the generalizability of Tai Chi to a larger population. Given that Tai Chi is usually compared to a no-treatment control group, whether Tai Chi is more effective than a specific exercise for improving balance is unknown. It was thus deemed necessary to select Tai Chi as a bench mark to assess the effectiveness of the current tailor-made exercise for balance improvement.

Study Purpose

The main purpose of this study was to evaluate the effectiveness of a tailor-made exercise program for improving balance and balance-related fitness among older adults with no history of falls but who were at risk of falling.

Research Questions

In this study, the following research questions were posed:

1. Would the tailor-made exercise program be effective in improving either the primary or the secondary testing parameters after intervention?
2. Could any training effect from this tailor-made exercise program be sustained throughout the follow-up period?
3. Would the training duration be an essential factor in improving balance and balance-related fitness among the older adults?
4. Would the tailor-made exercise program be more effective than Tai Chi in improving outcome parameters after intervention?
5. Would the training effect occur earlier in the tailor-made exercise program than in Tai Chi?
6. Would the maintenance of training effect differ between the tailor-made exercise program and Tai Chi throughout the follow-up period?

Research Hypotheses

Based on these research questions, the following hypotheses were put forward:

1. Participants receiving the tailor-made exercise program would gain significantly greater improvements than those in Tai Chi and control groups after 12-week (mid-test) and 16-week (post-test) of intervention respectively in both the primary and secondary testing parameters.
2. There would be no significant difference on the testing parameters between post-test and follow-up test in the tailor-made exercise group.
3. The training effect from the tailor-made exercise program would persist longer than those of Tai Chi and control groups.

Significance of This Study

The contribution of this study would be of great interest to scholars in fitness training, physical rehabilitation, as well as preventive medicine. Given that the majority of related studies have been conducted in secondary falls prevention – to alleviate adverse consequence from falls including preventing multiple falls, this study is one of the few studies focusing on how to delay the first fall, as well as targeting older adults without falling experience but who were at risk of falling. Such populations were often ignored in related studies as they had no apparent falling symptoms. Results from this study can inspire scholars to profoundly discuss the optimization of balance-related exercise and physical training for older adults who are in the transition from non-fallers to fallers.

This is one of the few studies detailing the development, implementation, and validation of a tailor-made exercise program for improving balance in older adults. In contrast to other studies presenting vague physical training elements during exercise implementation, the current study has illustrated a clear intervention process according to the classic theory of three-stage learning and principles in exercise and physical training. The differences in the results at mid-test and post-test indicate that a longer physical training period plus proactive individual training is essential to optimize a training effect.

Finally, the most significance aspect of this study is that the results provide older adults with a scientifically evaluated exercise program for improving balance and balance-related fitness. In addition, this program is enjoyable, cost-effective, and practical for daily use.

Delimitations

This study was delimited to:

1) The participants of this study were older adults aged 65 to 74 years old with no falling experience in the preceding 12 months but who were identified as at risk of falling. Participants were registered with local senior service centers and living independently within Hong Kong communities. In addition, participants were apparently healthy and with no severe health problems that might limit their participation in exercise.
2) All participants did not have any regular Tai Chi training in the preceding 12 months.
3) Risk of falling status was evaluated using the Biodex Balance System^{SD} (BBS).
4) The entire study was lasted for 24 weeks, including a 16-week intervention and an 8-week follow-up.

Assumptions

The assumptions of this study were as follows:

1) All participants would be loyal to this study.
2) Participants would comply with the requirements of their coach and testers in each exercise training and test process.
3) Participants in the control group would be honest in maintaining their usual activities and to report any changes in their daily physical activity levels.

Definitions & Terms

For consistency of interpretation, the following terms were defined:

Center of Mass (COM) & Center of Gravity (COG): COM is the point at the center of the total body mass, which is determined by finding the weighted average of the COM of each body. The vertical projection of the COM is defined as the COG (Shumway-Cook & Woollacott, 2011).

Base of Support (BOS): It is the area of the body that is in contact with the support surface (Shumway-Cook & Woollacott, 2011).

Fall: A fall refers to the sudden, unintentional change of position that causes individuals to land on the ground, floor or any other object (WHO, 2007). In the context of laboratory tests, fall is defined as the COM outside the BOS (Shumway-Cook & Woolacott, 2011), or any touch of the safeguard, such as the handrail of the Biodex Balance System (SD), or the requirement for external support to maintain balance.

*Balance, Static Balance & Dynamic Balance***:** Balance is the ability to maintain the body's COM within its BOS (Shumway-Cook & Woolacott, 2011), which is also called postural stability. Clinically, balance is divided into static balance and dynamic balance. Static balance refers to the ability to maintain the COM within the BOS while standing or sitting, whereas dynamic balance is the ability to maintain the COM within the BOS while the COM and BOS are moving, and the COM is moving outside the BOS (Heyward, 2010).

Postural control & Balance: Postural control is the act of maintaining, achieving or restoring a state of balance during any posture or activity (Pollock, Durward, & Rowe, 2000). Postural control usually contains two parts, postural orientation and postural stability. Postural orientation is the ability to maintain an appropriate relationship between the body segments, and between the body and the environment for a task (Rowell & Shepard, 1996). Postural stability, as a term is often interchangeably with balance, is the ability to control the COM in relationship to the BOS (Shumway-Cook & Woolacott, 2011, p162).

CHAPTER 2 - LITERATURE REVIEW

In the process of formulating this study, several areas of the literature were reviewed. Since this is an intervention study which includes the development of an exercise program, the following aspects were reviewed sequentially: 1) Age-associated deficits in balance and the corresponding evidence of exercise effects, 2) Exercise programs in Primary Falls Prevention, 3) Measurements and Assessments of Balance, and 4) Balance-related Intervention Delivering Set.

Age-associated Deficits in Balance and the Corresponding Evidence of Exercise Effects

Further Clarification on Definitions of Postural Control and Balance

Introducing the definition of postural control here is to avoid the common confusion with balance. Postural control refers to the act of maintaining, achieving, or restoring a state of balance during any posture or activity (Pollock et al., 2000). Postural control contains two parts, postural orientation and postural stability. Postural orientation is the ability to maintain an appropriate relationship among the body segments, and between the body and the environment for a task (Horak & Macpjerson, 1996). Postural stability is the ability to control the COM in relationship to the BOS (Shumway-Cook & Woolacott, 2011, p162), which is also called balance. Balance contains static balance and dynamic balance. Static balance refers to the ability to maintain the COM within the BOS while standing or sitting, whereas dynamic balance is the ability to maintain the COM within the BOS while the COM and BOS are moving, and the COM is moving outside the BOS (Heyward, 2010). The focus of this study is balance (static balance and dynamic balance).

Balance and Balance-related Systems within Human Body

Body balance is the result of multifactorial interactions among balance systems. According to different partitioning methods, balance systems may involve the sensory, cognitive and motor systems (Spirduso, Francis, & MacRae, 2005), or alternatively only involve the musculoskeletal and nervous systems (Shumway-Cook & Woollacott, 2011). To be consistent with the majority of previous studies, balance systems in the present study include 1) sensory systems (i.e., visual, vestibular and somatosensory systems) for receiving sensory signals from outside environment, 2) cognitive systems for directing balance-related signals to action, and 3) motor systems for implementing actions, such as neural functions (e.g., response time, muscle synergy), muscle properties (e.g., muscle mass, strength, power) and joint' range of motion (ROM). Age-associated deficits in any balance system would adversely affect body balance and potentially be falling risk factors. The following section reviewed the common reported deficits in balance and balance-related systems from previous studies.

Ageing-associated Deficits in Balance Systems and Corresponding Exercise Effects

Sensory systems – Vision Numerous studies have identified the importance of visual sensory for older adults in maintaining body balance (Borger, Whitney, Redfern, & Furman, 1999; Lord & Menz, 2000; Poulain & Giraudet, 2008). Vision works for postural stabilization by providing the neural system with the updated information about the positions or movements of body segments in relation to each other as well as in relation to the outside environment (Lord & Menz, 2000). Due to the increasing prevalence of peripheral neuropathy with advancing age and the tendency of being dependent on visual information for postural control (Spirduso et al., 2005), visual information plays an important key role in older adults' body balance (Gleeson, Sherrington, Borkowski, & Keay, 2014; Tanaka & Uetake, 2005; Tobis, Reinsch, Swanson, Byrd, & Scharf, 1985). Older adults with visual dysfunctions, such as declined visual acuity, poor contrast sensitivity, inaccurate depth perception, and a narrowing visual field (particularly in the peripheral region), were reported to be at higher risk of falling (Spirduso et al., 2005).

Although there is little evidence showing exercise would have direct influence on visual acuity and contrast sensitivity, or visual field, an overall improvement on balance performance has been demonstrated in exercise programs involving proper visual-feedback movements. Reed-Jones and colleagues (2012) proposed a study which aimed to examine the exercise effects of obstacle course performance in older adults. Participants were required to adjust their COM with concurrent visual feedback using animated simulation of obstacles displayed on a Wii Fit display screen. Results showed a 22% improvement in obstacle course performance in terms of balance and agility after a 12-week training (Reed-Jones, Dorgo, Hitchings, & Bader, 2012). The authors suggested that visual training would benefit visual processing speed and attract more visual attention for the adaptive ability required to overcome obstacles. Additionally, mirror-based visual feedback training is a common method used in the rehabilitation and physical training fields (Vaillant et al., 2004; Watson & Peck, 2008). During physical training, a mirror provides participants with immediate feedback of their body image, which has been found to help in controlling the displacement of the COM in keeping an upright stance (Hlavackova et al., 2009), reducing falls during training process (Sihvonen, Sipila, Taskinen, & Era, 2004) and increasing exercise adherence (Uzor, Baillie, Skelton, & Rowe, 2013). Therefore, a mirror was included into the current intervention process to give participants immediately feedback on postural movements.

Sensory systems – Somatosensation The somatosensory systems, including the tactile and proprioceptive systems, work by discerning the position and movements of body segments (Hijmans, Geertzen, Dijkstra, & Postema, 2007; Waite, 1999). The tactile system refers to sensations of touch and pressure as well as vibration from cutaneous receptors. Proprioception is the sensation of muscle length and tension, joint position and joint angle changes (Kars, Hijmans, Geertzen, & Zijlstra, 2009). The plantar tactile sensation has been found to directly correlate with older adults' functional ability and balance performance (Menz, Morris, & Lord, 2005). Cutaneous receptors on the plantar surface provide information about the support surface and limb loading, and help the CNS determine the relative distance between the COM and stability limits (Maki & Mcllroy, 1999; Do, Bussel, & Breniere 1990; Do & Roby-Brami, 1991). Age-associated reductions are evident in both the number and the sensitivity of sense receptors in the cutis, muscles and joints. Meissner's corpuscle (MC) and Pacinian corpuscle (PC) are the two most commonly studied types of myelin-related mechanoreceptors (Fundin, Bergman, & Ulfhake, 1997). With advancing age, changes in MC and PC are found in structural modifications as well as decreasing numbers in different body areas (Bolton, Winkelmann, & Dyck, 1966; Bruce, 1980; Iwasaki, Goto, N., Goto, J., Ezure, & Moriyama, 2003). As a result, older adults would experience a two-to-tenfold increase in vibration threshold (Perret & Reglis, 1970), significantly longer response onset latencies, and unmatched response amplitude to outside stimulation (Inglis, Horak, Shupert, & Jones-Rycewicz, 1994).

Proprioception is composed of muscle spindle, Golgi tendon organ, and articular receptors. Muscle spindle works by muscle stretch-sensations and provides the CNS with information on muscle length and velocity of muscle contraction. The joint movement and position sensation are mainly received by muscle spindles. Age-associated declines in muscle spindles were found in reduced cell numbers, diameter of intrafusal, and decreased chain fibers (Kararizou, Manta, Kalfakis, & Vassilopoulos, 2005; Swash & Fox, 1972). Some researchers even pointed out that the functional decline of muscle spindles may be specific to certain muscles and only evident among older adults (Karaizou et al., 2005; Liu, Eriksson, Thomell, & Pedrosa-Domellof, 2005). The unconfirmed hypothesis behind this phenomenon is related to the local denervation in the transition process of type II to type I extrafusal fibers (Lexell & Downham, 1992; Jennekens, Tomlinson, & Walton, 1972). To date, results are still inconclusive regarding the age-associated declines in muscle spindles. Clinically, muscle spindle dysfunction would result in the decrease in the positioning sense of ankle joint (Madhavan & Shields, 2005; Verschueren et al., 2002; You, 2005), big toe (Kokmen, Bossemeyer, &Williams, 1978), and knee joint (Bullock-Saxton, Wong, & Hogan, 2001). Due to insufficient and delayed somatosensory information of balance with advancing age, there would be a higher risk of falling among the older population (Kars, et al., 2009).

Controversies exist about whether somatosensory systems (tactile and proprioceptive systems) can be improved through exercise interventions. With regards to proprioception, Ashton-Miller and colleagues have questioned exercise effect in the improvement of proprioception (Ashton-Miller, Wojtys, Huston, & Fry-Welch, 2001). The authors regarded the improvement of proprioception (e.g., higher accuracy of joint position sense and lower threshold for detecting joint movement) as a result of the overall improved adaptive abilities in central mechanisms, the efferent modulation of afferent information, increased attention to joint movements, and diminished utility of proprioception in time-critical tasks. The same challenge also applies to the tactile system. Evidence from related studies concluded that more practice in a virtual environment can be effective in improving somatosensation, which in turn can improve balance performance (Hong & Li, 2007; Horak et al., 1997).

Sensory systems – Vestibular system The vestibular system provides information about the position of the head in relation to gravity, and provides sensations related to how fast and which direction that head is accelerating. The vestibular system has two main clinical functions, one is to provide the absolute reference system with which visual and somatosensory systems can be compared and calibrated (Black & Nashner, 1985), and the other is to adjust the amplitude of automatic posture response to balance interruptions (Shumway-Cook & Woolacott, 2011). Age-associated declines are demonstrated in several aspects of this system. According to previous evidence, the intensity of hair cells begins to decline from the age of 30 to 40 years at a rate of 3% loss per decade, and the vestibular nucleus cells would reduce by 40% by 70 years old (Rosenhall & Rubin, 1975; Spirduso et al., 2005). The decreasing intensity and number of cells caused dysfunctions of the vestibular systems in terms of synapse morphology, electrophysiology, as well as the supporting microenvironment (Sloane, Baloh, & Honrubia, 1989). Dizziness and deficits in vestibular reflex would finally occur at a certain threshold during the dysfunctional process of the vestibular organs (Matheson, Darlington, & Smith, 1999). Consequently, older people with vestibular deficits would be at a higher probability of falling since the neurological systems have difficulty in dealing with sensory conflicts, which stems from concurrent input from visual and somatosensory sensations.

Cawthorne-Cooksey exercise, a vestibular rehabilitation program, has been used to treat people with dizziness (Eleftheriadou, Skalidi, & Velegrakis, 2012). Significantly positive effects were found in both static and dynamic balance among people with vestibular deficits (Eleftheriadou et al., 2012). However, the assessments for improvements are generally based on subjective self-perceptions, with few objective assessments of physiological indicators of the vestibular systems. The effective movements for vestibular rehabilitation are summarized as 1) hand-eye coordination with various body postures, 2) maintaining balance with decreasing BOS and increasing head-trunk orientation, and 3) challenging the vestibular sensory systems by adding upper limb tasks and gradual exposure to various sensory and motor environments (Han, Song, & Kim, 2011).

Multisensory deficits With advancing age, the dysfunction of sensory organs occurs in various body parts rather than in one particular body part. Older adults with mild pathologies in keeping balance usually reported with more than one sensory deficit, and the loss of more than one sensory input for keeping balance is termed multisensory deficit (Brandt & Daroff, 1979). Although the age-associated dysfunctions in vision, somatosensation and vestibule are inevitable, not all people in their old age would experience a fall. In most cases, the compensation among different balance sensory systems plays an important role for the loss of one sense with alternative senses. Moreover, the environment can influence the accurate selection of sensory information. For healthy people in a well-lit environment and a firm base of support, somatosensory accounts for 70% of all sensory information, whereas the visual and vestibular sensory systems account for 10% and 20%, respectively (Peterka, 2002). On a foam surface, visual and vestibular sensory would act as the dominant sensations to the CNS (Peterka, 2002). Thus, abilities in sensory channel reweighting and sensory reference selecting determine appropriate compensation for degenerated sensations among older adults.

Although there is no confirmed evidence to show exercise effect on the physiological improvement of sensory systems, repeated practice in virtual environments can help accelerate the CNS sensory re-weighting speed. Exercise programs can help older adults live with sensory deficits through sensory integration training (Horak et al., 1997). For older adults with permanent loss of sensory function, education is necessary in order to identify and avoid dangerous tasks and environments. Education regarding compensatory strategies such as using assistive devices is also necessary (Horak et al., 1997).

Cognitive systems The CNS plays an important role in detecting and anticipating balance disturbance as well as coordinating various sensorimotor systems, so as to keep the

COM within the BOS (Horak et al., 1997). The cognitive system has three parts - attention, memory, and intelligence; which are the foundations of postural control (Spirduso et al., 2005).

Postural control contains anticipatory and reactive elements. Differences between the two kinds of postural control exist in the sequential occurrence in the event of any balance disturbance. Regarding to the anticipatory postural control, postural muscles are activated prior to movement, and amplitude and velocity of postural adjustments are scaled in advance to balance any disturbance (Shumway-Cook & Woollacott, 2011). This therefore, allows more time to make any necessary postural responses in relation to external perturbations. Reactive postural control adjusts the dynamic relationship between COM and BOS during balance disturbance process. Usually, this involves automatic and voluntary responses. Regarding the automatic response, the human body has an innate ability to select the appropriate supporting muscles for postural changes (Cordo & Nashner, 1982). Muscle synergies, which are centrally organized patterns of muscle activity, would then respond to the initial conditions (Horak et al., 1997). Evidence from past research has verified the efficacy of these central patterns in the nervous system to optimize postural responses under new conditions (Chong, Horak, &Woollacott, 2000). In case of insufficient automatic responses, voluntary movements are able to suppress automatic movements and produce suitable postural responses given accurate anticipatory information about the upcoming disturbance (Burleigh, Horak, & Malouin, 1995). Evidence from previous studies has found that practice in virtual environments can help to modulate the amplitude and improve the accuracy of postural responses (Burleigh, Horak, Nutt, & Obeso, J., 1997).

Age-associated declines in cognitive abilities can result in improper reactions to balance disturbances. It is reported that around 10% adults over 65 years and 50% adults over 80 years have cognitive impairment including dementia (Yaffe, Barnes, Nevitt, Lui, & Covinski, 2001).

Older adults were found to be at higher risk of falling when testing included additional attention related tasks (Siu et al., 2008). “Stop walking when talking” is a general phenomenon among older population (Hyndman & Ashburn, 2004; Lundin-Olsson, Nyberg, & Gustafson, 1997). It is also a typical characteristic of individuals who have difficulties in dealing with interference of concurrent tasks that require attention (Woollacott & Shumway-Cook, 2002). Two theories were proposed to explain the interference of concurrent attention-required tasks. One is the Capacity Theory based on limited resources (e.g., attention capacity) in dealing with tasks; and the other is the Bottleneck Theory, which highlights the sequential nature of information processing for two or more simultaneous tasks (Fraizer & Mitra, 2008; Shumway-Cook & Woollacott, 2011). For example, unstable adults in walking along with other tasks (e. g., Auditory Stroop Test) simultaneously would tend to reduce their gait speed, take wider steps, and avoid obstacles so as to maintain postural stability. However, not all concurrent tasks would have detrimental effects on postural control. For older adults, the displacements of the COM were found to increase in balance tests with difficult cognitive tasks and to decrease in simple cognitive tasks (indicating more stability) (Huxhold, Schmiedek, & Lindenberger, 2006). Therefore, relationships between balance performance and difficulty in attention task warrant further study.

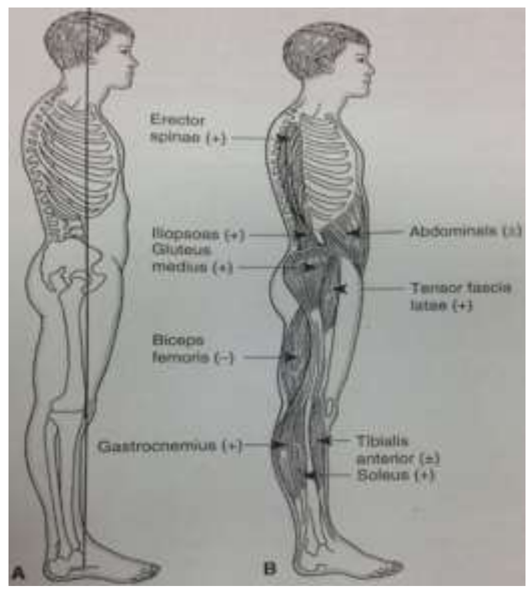
Motor systems – Neural system Almost 50% of falls are caused by a sudden motion of the BOS (Horak, Henry, & Shumway-Cook, 1997). Faster response in postural stability would be beneficial for the recovery from a sudden fall. Response here refers to the length of time measured between the presentation of an unexpected stimulus and the onset of postural adjustment (Horak et al., 1997). Although there is no significant age-related difference in the shortest muscular latency time and the overall response muscular activation patterns (Thelen et al., 2000), slower (27%) reaction time due to lengthened muscle response latency in the dynamic recovery trials is typically found with advancing age (Mackey & Robinovitch, 2006). Such a condition has also been found in other studies in which older adults reported significantly longer onset latency in muscles, smaller integrated electromyography (EMG), and greater extent of integrated EMG attenuation over time (Lin & Woollacott, 2002; Thelen et al., 2000). In order to compensate for any delayed postural response, anticipatory posture strategy and increased response magnitude usually take place (Horak et al., 1997). Through exercise intervention, older adults have demonstrated a "pre-lean" in the reverse direction of the perturbation through repeated exposure to a particular perturbation, and reduced response time through anticipatory movement practice (Macpherson, 1994).

Muscle synergy is defined as the functional coupling of groups of muscles that are constrained to act together as a unit (Shumway-Cook & Woollacott, 2011, p172). Different muscle synergies are involved in different movement strategies (i.e., ankle strategy, knee strategy and stepping strategy), where the sequence of muscle activation varied considerably. The ankle strategy actives the distal-to-proximal muscles first, while the hip strategy activates proximal hip and trunk muscle first. In the stepping strategy, hip abductors and ankle co-contraction are activated first (Horak & Nashner, 1986; Mcllroy & Maki, 1995). The improper sequence of muscle activation (proximal muscles prior to distal muscles) is a strong predictor for elderly falling (Shumway-Cook & Woolacott, 2011). The application of different movement strategies is dependent on postural perturbations, and the selection of movement strategies is the result of the "emergent neural control process" which requires the assessment for the task, environment, and internal constraints (Horak, 1992). In standing posture, human body looks like an inverted pendulum (pivoting at ankle), and the ankle strategy is used often when there is small perturbation of stability on a firm surface (Horak, 2006). With an increase of magnitude and velocity of postural perturbation, the hip strategy is implemented, especially when standing on more challenging surfaces, such as narrower or compliant surfaces. Older adults tend to apply the hip strategy even if there is small balance disturbance (Horak, 2006). The often application of hip strategy is reported with higher risk of falling (Adkin, Frank, Carpenter, & Peysar, 2000). In the case of strong balance disturbances, one or multiple steps are necessarily required for returning the COM to a stable position. In addition, the variability of sensory information could influence this selection. The activation of the hip strategy requires the normal functioning of vestibular systems; and the ankle strategy tends to be dependent on somatosensation (Horak, Nashner, & Diener, 1990).

Six gross muscle synergy groups were found in healthy adults to prevent forward, backward, and medial–lateral perturbations (Torres-Oviedo & Ting, 2007). The first one for backward perturbations is activated in the gastrocnemii, peroneus, and soleus, and is consistent with the "ankle" strategy. The second one works for forward perturbations and activates the tibialis anterior first. It also includes a number of extensors which are presumably activated to prevent knee and hip joint flexion during the "ankle" strategy in forward perturbations. Synergies three and four involve trunk and proximal muscles and are activated at later time points. The fifth is composed of the abductor gluteus medius and the lateral trunk muscles (external obliques), and is primarily used in the medial–lateral perturbations. The last one includes biceps femoris, knee flexor and hip extensor, ankle dorsiflexors tibialis anterior and the ankle evertor peroneus, as well as antigravity muscles during upright stance, and the erector spinae and soleus. The strengthened muscle synergies through exercise can not only improve muscle strength and power, but also faster the postural response to perturbations. As evidenced from previous studies, movement strategies can be learned gradually in a new environment (Horak & Nashner, 1986), and postural strategies become more efficient and effective through repeated exposure to a destabilizing stimulus (Horak, Diener, & Nashner, 1989; Horak et al., 1997).

Motor systems – Muscular system Muscles involving both type I and type II fibers were found to be interchangeable between postural and phasic muscles under certain conditions (Shumway-Cook & Woollacott, 2011). This helps to establish the theoretical potential for exercise improving muscle properties (i.e., mass, strength, and power).

Postural muscles, defined as anti-gravity muscles, play an important role in counteracting gravity influence. Contrast to phasic muscles' characteristics (i.e., faster twitch and containing more type II fibers), postural muscles have more type I fibers and twitch slowly (Liebenson, 1998). Differences of these two muscle types are also found in their functions, where postural muscle are more connected with posture maintenance whereas phasic muscles work for changing posture. Body alignment is mainly related to nine postural muscles. In the upper body there are erector spinae, lliopsoas, and abdominals, while in the lower body there is gluteus medius, tensor fascia latae, biceps femoris, gastrocnemius, tibialis anterior, and soleus (see the picture on the right) (Kendall & McCreary, 1983).



(Kendall & McCreary, 1983)

The inverted pendulum shape of human body (Li, Levine, & Loeb, 2012) has necessitated the importance of lower extremities in the support, locomotion and postural maintenance (Carr & Shepherd, 2000). Compared to muscles in upper body, muscle strength and muscle power of the lower limbs would decrease at faster rate (Dykes & Ameerally, 2002). This could be one of the underlying reasons that why most studies for balance improvement have focused training on functions of lower limbs. A study conducted in people living in nursing home and community found there were strong relationships among muscle strength and muscle power in lower limbs, balance and gait, and falls occurrence (Wolfson, Judge, Whipple & King, 1995).

Because of the age-related muscle weakness, the ability to recovery from postural instability in older adults tends to be difficult (Carty, Barrett, Cronin, Lichtwark, & Mills, 2012). Age-related muscle weakness in the lower limb has been identified as an independent risk predictor for falls in older adults (Lord et al., 1991; Puthoff & Nielsen, 2007; Tschopp, Sattelmayer, & Hilfiker, 2011). Nair (2005) found that muscle begins to degrade from the fourth decade of life in the human body. With regards to muscle strength, there is a 1~4 % decrease per year in lower limb muscle strength from the fifth decade (Goodpaster et al. 2006; Larsson, Grimby, & Karlsson, 1979; Lindle et al., 1997), and 70 years old have demonstrated a 20~40% loss in the absolute strength (Doherty et al., 1993). Because of the close relationships with the amount, type, and length of muscle fibers, muscle power (strength with the speed of contraction) is vulnerable to decrease especially in immobility and sedentary lifestyles (Lexell, Taylor, & Sjostrom, 1988; Skelton, Greig, Davies, & Young, 1994).

Although muscle strength and muscle power are intimated with each other, their roles are quite different for balance control. Mayson and colleagues (2008) demonstrated that muscle strength of the lower limbs was associated with unipedal stance, and muscle power was more important for dynamic balance including gait (Mayson, Kiely, LaRose, & Bean, 2008). Besides, muscle power is crucial for the recovery from a potential fall by correcting the COM with prompt adjustment of the BOS (Bassey et al., 1992), and it is a differential factor between young adults and those over 60 years (Johnson, Mille, Martinez, Crombie, & Rogers, 2004; Simoneau, Martin, & Van, 2005; Onambele, Narici, & Maganaris 2006).

Compared to people without history of falls, fallers demonstrated weaker muscle strength and power in lower extremities, with the greatest compromise in ankle dorsiflexion (Wolfson et al, 1995; Whipple, Wolfson, & Amerman, 1987). In addition, Daubney and Culham (1999) found that muscle power in ankle dorsiflexors was a valid indicator to predict falling status of older adults. As evidenced by Abd El-Kader and Rahmy (2004), balance-related testing parameters were improved significantly through an 8-week physical training on ankle dorsiflexors muscles. Disputes exist on the relationships between muscle strength of plantar flexion and the recovery ability in postural instability (Arampatzis, Karamanidis, & Mademli, 2008; Wojcik, Thelen, Schultz, Ashton-Miller, & Alexander, 2001). However, plantar tactility and muscle strength of toe plantar flexor along with ankle flexibility can be used together for the predictions of postural stability, which can explain 59% of the variance in balance tests (Menz et al., 2005). Knee extension muscles strength has a close relationship (r = .52 ~ .59) with the margin of stability in forward falls (Karamanidis, Arampatzis, & Mademli, 2008). Together with muscle strength and power of hip flexion, muscle weaknesses in knee extension can help to predict step strategies (i.e., single or multiple steps) would be used following the forward loss of balance in older adults (Carty et al., 2012). For some special population, muscle weakness in knee extension has other important implications. Suzeki and colleagues (2012) found knee extensor muscle strength was a significant predictor for independent living abilities among older adults with dementia. For people with osteoporosis, muscle strength of knee extension is a significant factor (p < .001) to determine the performance of static (10%) and dynamic (26%) balance (Carter et al., 2002). Carty and colleagues (2012) found that a unit decrease in ankle plantar flexion, knee extension, or hip flexion strength would cause a 1.7-2.5 times increase in the odds of adopting a multiple steps strategy. However, exercise-based interventions have demonstrated the positive effect of exercise on the improvement of muscle strength and muscle power (e.g., Borst, 2004).

Motor systems – Joint Range of Motion Greater joint range of motion (ROM) allows more freedom for body movements. Age-associated degradation in joints' ROM has been reported with an adverse effect on balance control (Bok, Lee, T. & Lee, S., 2013). Mecagni and colleagues (2000) found a significant correlation between the ankle ROM and balance performance (r = .29 ~ .63) in a group of community-dwelling older women (Mecagni, Smith, Roberts, & Sullivan, 2000). In addition, most findings from prior studies have suggested a close link between restricted ROM in lower limbs and higher risks for falling in older adults (Chiacchiero, Dresely, Silva, DeLosReyes, & Vorik, 2010). In induced forward fall, Wojcik and colleagues (2001) found that larger knee and hip ROM were required for increasing the initial lean angle for successful fall prevention.

Exercise Programs for Primary Falls Prevention

In recent years, many exercise-based interventions were conducted to improve balance and prevent falls among older population. However, there is little consensus on the optimal exercise programs for balance improvement and falls prevention. Age UK (2013) regarded that the most important exercise principle for falls prevention was to counter the effects of muscle deterioration, particularly those maintaining body alignment and enabling the body to walk without swaying. In the Best-practice Recommendations for Physical Activity to Prevent Falls in Older Adults, Sherrington and colleagues (2011) found that exercise that specifically challenged balance is the most effective physical activity intervention in preventing falls. From kinematic and kinetic perspectives, the American College of Sports Medicine (2009) has indicated that effective exercise programs should include dynamic movements that challenge the center of gravity and stress postural muscles. Other studies also suggest that fall-related multi-factorial programs which are performed at home, or in a group format, are most effective (Barnett et al., 2003; Zijlstra et al., 2007). In addition, a variety of guidelines have been put forward on this topic, among which tenets of exercise training have been summarized and listed. For example, exercise programs should be individually tailored so as to ensure safety and effectiveness, target balance deficits and postural muscles, and avoid using walking as the only exercise format (Skelton & Dinan, 1999).

However, no specific and detailed advice regarding the optimal exercise content, intensity, duration, movements or protocols have been introduced to date. A recent study on exercise improving balance among older adults has reviewed eight forms of exercise forms including 1) gait, balance, co-ordination and functional tasks; 2) strengthening exercise; 3) three-dimensional exercises; 4) walking; 5) cycling; 6) computerized balance training using visual feedback; 7) vibration platform interventions; and 8) multiple exercise types (Howe et al., 2011). The authors found insufficient evidence for the most effective exercise format for balance improvement due to various balance measurements used across different studies. For example, the Berg Balance Scale is a commonly used field test for assessing older adults' balance abilities. Exercise programs including gait, balance, co-ordination and functional tasks have been found to be more "effective" than other types of exercise if tested by this scale. Meanwhile, exercise involving strength training was found to be more effective if balance was tested by the Timed Up and Go test. The variety of balance measurements reflects the complexity for balance control.

However, the common characteristics shared by the effective exercise program, as summarized by Howe and colleagues (2011), were those containing dynamic challenge in standing posture, with a frequency of three times per week, and lasting for at least three months.

Another viewpoint for the effective balance exercise is exercise movements should target the improvements of risk factors for balance. Following this perspective, a set of multi-factorial exercise programs have been developed with the purpose of improving balance, aerobic capacity, strength, flexibility, agility, and so on (Stevens, 2010). For example, Barnett and colleague (2003) found significant improvements in balance by using a multi-factorial program that contained functional exercises (e.g., sit to stand, weight transference, and reaching), balance and coordination exercises (e.g., modified Tai Chi movements, stepping, and dance steps), strength work (e.g., wall press-ups and resistance bands), and aerobic activities (e.g., fast walking with varying pace and directions; Barnett et al., 2003). Significant improvements in balance were also demonstrated in the Falls Management Exercise (FaME) (Skelton & Dinan, 1999), which is a specific, tailored, progressive program focusing on bone loading, gait, dynamic posture, balance, reaction and coordination.

A common weakness in the current exercise programs is the demand for exercise equipment (e.g., chairs, therabands, hand balls, balance balls). This would limit the generalization of these exercise programs to larger population. For example, FallProof is a home-based comprehensive balance and mobility training program designed for older community-dwellers (Rose, 2008). It was found to be effective in increasing balance, mobility, strength and balance-related self-confidence (Ward, 2011). However, the high demanding on equipment and the comparatively complex training methods may limit older adults' participation when participants engage in these programs on their own. To counter the high demand for training equipment, Otago Exercise Program (OEP) was developed as a home-based, individually tailored strength and balance re-training program (Campbell & Roberson, 2003). This program is affordable and requires no special equipment. However, the various training protocols in the OEP inadvertently increase the complexity of this exercise program. Considering the age-associated decline in memory and attention, it would be challenging for older adults to practice these exercise by themselves without any qualified instructors present. The applicability and generalizability of these exercise programs would thus also be compromised.

Moreover, all these exercise programs were developed for the secondary or the tertiary falls preventions, little was done for the primary falls prevention. Also no clear difference was made in exercise programs among the three prevention stages, and exercise programs for the primary falls prevention stage are usually interchangeable with those in the secondary falls prevention stage (Age UK, 2013). However, even older adults without any falling experience before would be at the possibility of falling given the individual difference in a variety of fitness aspects, such as poorer functional balance and muscle strength. From the perspective of physical training and exercise, exercise should be more effective if it is designed specifically. From a thorough review of the literature, there was no well-developed exercise program for the primary falls prevention; and general exercise such as Tai Chi and aerobic dance are the most commonly studied and recommended forms for primary falls prevention.

Tai Chi

Among the various types of exercise programs, Tai Chi is the most studied and well recommended exercise form for improving balance in older adults (ACSM, 2009; Zijlstra et al., 2007). Its popularity comes not only from its safety and suitability for people of different ages or fitness levels, but also due to its therapeutic movements for improving postural stability. Tai Chi can be practiced in different styles, such as the Chen, Yang, Wu, Sun, and so on. The most commonly used style in previous researches is the Yang style Tai Chi (Verhagen, Immink, Meulen & Bierma-Zeinstra, 2004), although Wu style has been suggested to be a more appropriate form for balance training (Wu, 2002). Different styles have different movement patterns with considerable variability. However, most of the fundamental movements in leg, trunk, and arm movements are similar among Tai Chi styles. For example, all Tai Chi movements have three hand shapes, five different steps, and seven types of lower limb movements. In addition, all Tai Chi styles require relaxation and harmony, flowing motion, circular and natural movements, and whole body coordination (Lie, 1988).

Many studies have been conducted to examine the therapeutic characteristics and biomechanics of Tai Chi movements in improving balance abilities (Hong & Li, 2007; Li, Hong, & Chan, 2001). Tai Chi itself emphasizes steady shifting of the COM, relaxed and harmonious movements of the head, body, and extremities, as well as mind-body-environment interactions during practice. Ng (1992) identified that the essential parts of Tai Chi movements included postural alignment, relaxed shoulders, swinging elbows, and diaphragmatic breathing. Wolf, Coogler and Xu (1997) put forward seven therapeutic elements of Tai Chi for balance improvement. They are the continuous and slow movements, smaller to greater degrees of motion, progressive flexion of the joints, body alignment, trunk-head-extremity rotation, symmetrical and diagonal arm and lower extremity movements, and constant shifting of the COM. Based on these seven therapeutic elements, the 108 forms of Tai Chi was condensed into 10 forms by Wolf and his colleague (1997). Hong and Li (2007) analyzed the therapeutic effect of Tai Chi practice on balance improvement from a biomechanical perspective. The four main kinematic characteristics of Tai Chi movements were 1) even and slow tempo, 2) semi-squatting posture, 3) continuous shifting of the COM, and 4) longer duration in single stances and step cycle. In addition, the two main kinetic characteristics of Tai Chi movements were the wider plantar contact area, and the wider plantar pressure distribution. All these kinematic and kinetic features of Tai Chi movements have provided the rationale for using Tai Chi as an effective exercise to improve balance and prevent falls. For example, the even and slowed tempo of Tai Chi movements require well-controlled muscle coordination (Xu, Li, & Hong, 2003) and this is also beneficial to the sensory awareness of speed, force, and trajectory execution of movements. The alternate shifting of the COM during Tai Chi practice require continuous changing of ROM in lower extremities (Chan, Luk, & Hong, 2003), which could activate proprioception in the corresponding joints (Xu, Li, & Hong, 2003). The wider plantar contact area and the wider pressure distribution during Tai Chi practice can increase also plantar somatosensation (Szturm & Fallang, 1998), and activate additional muscles in the lower extremities (Nakamura, Tsuchida, & Mano, 2001). As a result of repeated Tai Chi practice, significant balance improvements can be expected.

Although Tai Chi is found to be effective in improving balance and preventing falls, the generalization of Tai Chi has been compromised. Chen and his colleague (2011) investigated the effect of Young style Tai Chi training on the soleus Hoffmann reflex and static balance in a group of Australian community-dwellers. Each session lasted 1 hour x 3 sessions per week x 12 weeks. Significant improvements were found in the soleus Hoffman reflex, but not in static balance (Chen, Zhou, & Cartwright, 2011). In Hong Kong, Woo and colleagues (2007) studied the effect of Tai Chi on bone health, muscle strength and balance in older people living in the New Territories Region. The loss of bone mass density was reduced, but no change was found in balance, flexibility and falling rate (Woo, Hong, Lau, & Lynn, 2007). In addition, a group of older adults from the Netherlands with high falling risk received Tai Chi training for 13 weeks (1 hour per session and two sessions per week), results revealed no decline in falling rate (Logghe et al., 2009). Therefore, how much of the training effect from Tai Chi could be transferred into reduced falling rate or balance improvements requires further exploration and study. The results of Tai Chi training are usually compared to an education group or a no-treatment concurrent control group, thus, whether Tai Chi is better than other kinds of exercise is unknown. Wolf and his colleague (1996 &1997) found that Tai Chi was more effective in delaying the onset of the first fall and reducing fear of falling, but Tai Chi was not better than the computerized balance training in improving the quantitative indicators of balance performance. Comparisons between Tai Chi and other exercise in similar participants under same measurements have been recommended for further studies.

The inconsistent results in the effectiveness of Tai Chi have raised discussions on the development of a unified, standardized Tai Chi program. However, it is quite difficult given Tai Chi is an exercise emphasizing not only the body but also the interactions among mind, body and outside environment. Additionally, it would be complicated to the evaluate exercise load or the exercise intensity of Tai Chi since the movements speed and postural position during Tai Chi practice are influential factors. When Tai Chi practice was conducted at a lower COM under supervision, it tends to be physically exhausting and be more challenging to maintain balance. All these inconsistencies have compromised the effect of traditional Tai Chi practice on balance improvement and falls prevention.

Dance

Since the turn of the century, dance has become a highly researched topic in exercise programs aiming to improve balance, such as Traditional Greek dance (Sofianidis, Hatzitaki, Douka, & Grouios, 2009), Argentine Tango (Hackney, Kantorovich, & Earhart, 2007), Turkish folk dance (Eyigor, Karapolat, Durmaz, Ibisoglu, Cakir, 2009), and Caribbean dancing (Federici, Bellagamba, & Rocchi, 2005). These dance programs have been found to be effective in improving static and dynamic balance among older adults (Cromwell, Meyers, P. M., Meyers, P. E., & Newton, 2007; Grant et al., 2002; Lin, Su, & Wu, 2005; Judge, 2003). However, therapeutic elements of these dance programs have not been well studied and summarized. The shared characteristics between dance and Tai Chi include the continuous changing of COM, single leg stance with multidirectional reach to the limits of the BOS, concurrent movements between hands and eyes, and upright posture (Keogh, Kilding, Pidgeon, Ashley, & Gillis, 2009). In addition, the cadence could be slow or fast allowing for a range of exercise intensities.

A review of the literature has found that few studies reported negative effectiveness from dance practice, and the majority was cross-sectional or intervention studies with the purpose of finding an effect of dance practice on health and fitness. These reflect that study examining the effect of dance in improving balance is still at an exploratory stage. Further studies exploring the rationale of therapeutic dance movements and comparative studies with other exercise programs are required. In addition, common therapeutic characteristics among various dance programs have yet to be discovered. It is thus necessary, as suggested by peers in this area (Keogh et al., 2009), to structure dance programs for older adults so as to maximize the gains in physical functioning while ensuring participant safety and enjoyment. Some dance-based aerobic exercise programs with specific training purposes were proposed, and have been demonstrated with significantly positive results in balance and balance-related fitness (Hopkins, Murrah, Hoeger, & Rhodes, 1990; Shigematsu et al., 2002; Young, Weeks, & Beck, 2007). Therefore, it is considered worthwhile to develop a tailor-made exercise program which contains a set of therapeutic movements which address balance deficits. Besides, one of the clear results from related intervention studies is the high adherence to the exercise programs, which highlights older adults' interest in rhythm-based exercise.

Measurements and Assessments of Balance

Outcome measurements can provide useful information about changes in balance performance before and after intervention. Generally, there are three main types of measurements in previous studies examining exercise effect on balance improvement. One is the discriminative measurements aim to distinguish individuals who have balance deficits from those who have not. The second one is the evaluative measurements with the purpose of assessing changes in balance performance over time. The third one is the predictive measurement, which is applied to predict falling occurrence and future balance abilities. Different types of measurements have different measuring foci. Choosing an appropriate measurement is thus dependent on the study objective(s).

Regarding the evaluative measurements, they were further divided into direct and indirect measurements, or functional and psychophysiological measurements. According to a systematic review on exercise for improving balance, the machine-based center of pressure test, and the limits of stability test are the most commonly used direct measurements. While the most often used indirect/functional measurements include functional reach, TUG, gait speed, single leg stance, parallel stance, tandem walk, tilt boards and BBS (Howe et al., 2011). Each measurement has advantages and disadvantages. The indirect and functional measures are cost-effective, simple to operate, but are not sufficiently sensitive to changes in balance; alternatively, direct measurements which require scientific equipment and professional operation information, are more sensitive. For example, timed single leg stance is a common functional measurement to evaluate the static balance of older adults, but it is not a sensitive test for measuring body sway (Maciaszek & Osi´nski, 2010). By measuring the length of sway in a particular direction, or the change of COM on a moveable platform, more precise information about the static or dynamic balance can be discovered. Apart from the high cost and high demand on professional knowledge for equipment-based measurements, further consideration should be given to how much of the results from direct measurements can be transferred to balance performance in daily activities.

Due to the complexity of balance control, there is no single balance test can be used to identify all the balance deficits for different individuals (Horak, 2006). In order to acquire comprehensive information regarding the change of balance abilities through exercise intervention, both direct and indirect balance measurements should be used concurrently. Prior to the selection of measurements, participant age, fitness level and balance status should be taken into consideration since some measurements may be too simple or difficult for a particular group. For example, BBS has been reported to demonstrate a ceiling effect when used in a group of active older adults without apparent balance deficits (Blum & Korner-Bitensky, 2008). The effectiveness of a balance intervention could be compromised if measurements are not properly selected.

Balance-related Intervention Delivering Set

Participants

In the previous related studies, there have been a variety of participants with various health statuses (e.g., healthy, frail), with one or more specific health conditions (e.g., stroke, Parkinson’s disease, and mental disease), with or without balance deficits, and without various falling statuses (e.g., low, moderate, and high risks). These varied clinical characteristics of participants have contributed a lot to the inconsistency of exercise effects on balance improvement and fall prevention (Barnett et al., 2003). Older adults without balance deficits or at high risk of falling would gain less improvement from exercise intervention in comparison with those who are in the transition from non-frail to frail stages (Logghe et al., 2009). As evidenced from related studies, older adults with low or moderate falling risks can gain the most benefit from exercise intervention (Sherrington et al., 2011). Therefore, a hypothesized inverted U-shape was put forward to describe the relationships between participants' falling status and the effect of exercise intervention on balance improvement (Logghe et al., 2009). As a result of literature review, the majority of related studies were conducted in older adults with moderate to high falling risk or with one or more recurrent falls.

Intervention Dosage

The intervention dosage is crucial for optimizing training effect. However, it has been varied considerably in past studies in terms of duration, frequency, and session length. To date, there is no optimal exercise dosage. The most used intervention dosage is 60 minutes per session x 3 times per week x 12 weeks (ACSM, 2009; Howe et al., 2011). In addition, it would be more desirable if the entire training period could be over 50 hours (Sherrington et al., 2011). However, longer training duration and higher frequency are reported with more human resource cost and higher risk to participants. Thus the optimal training dosage for balance improvement in people with or without risk of falls needs further study.

Some studies have found positive results from a light intervention dosage on balance improvement; however extrapolating these findings to other studies warrants caution. Sihvonen and colleagues (2004) conducted an individualized, specific balance exercise with a group of frail older adults over 4 weeks with 20~30 minutes per session, 3 times per week. Significant effects were found in reducing falling rate in the intervention group. Similar training effects may not be presented in other forms of exercise due to the specificity of the individualized exercise program they adopted. Suzuki, Kim, Yoshida, and Ishizaki (2004) discovered positive training effect from a combined form of exercise (strength, balance, gait training and Tai Chi) with only one session every two weeks and lasted for six months in a group of older Japanese women. Significant positive results were demonstrated in reducing falling rates. However, this study also included a self-supervised, home-based exercise (30min per day). Therefore training effects cannot just be explained from the group-based exercise dosage. In Cheung and colleague (2007) study which adopted a specified whole-body vibration (20Hz) training practice, even a dosage of "3-minutes per day x 3 days per week x 3 months" resulted in significantly improved balance ability in a group of older adults. In summary, the more specific an exercise program is, the more effective such exercise would be; otherwise longer durations with higher frequency are required.

Training Principles

There exists a set of principles in physical training to guide the achievement of an optimal training effect. Although without consistency among these principles, the most widely used principles for physical training and exercise would include the principles of specificity, overload, and progression (Oddsson, Boissy, & Melzer, 2007; Heyward, 2010). These fundamental principles are not only suitable for athletes to achieve higher sports performance, but also applicable to the general population without any restriction on age, gender or fitness level (Petrie, Matthews, & Howard, 1996). Differences only exist in the methods of implementing these principles (Welsch, Pollock, Brechue, & Graves, 1994). In the field of exercise for improving the balance of older adults, most exercise interventions were not conducted following these training principles. Strictly speaking, the implementation of these exercise intervention programs is less scientific support and thus the effectiveness of these exercise interventions would be compromised. Taking the application of principle of individual difference in to Tai Chi intervention as an example, if participants have no previous Tai Chi experience, certain intervention period is required for learning Tai Chi movements. Therefore significant effects from Tai Chi practice may not be expected if conducting general intervention duration of 12 weeks.

However, some evidence has shown that extending the duration alone may not guarantee an effect of the exercise intervention; in fact the difficulties of a task would have a greater effect on final results (Maciaszek & Osi´nski, 2010). This is what is known as the principle of specificity. Balance deficits in participants are recommended to be identified prior to exercise intervention. It is not surprising to find an exercise program to be ineffective if participants' postural instability comes from some sensory deficits (e.g., cataract) that may not be improved through exercise directly (Orr, Raymond, & Fiatarone Singh, 2008). Therefore, studies in exercise interventions should always follow the principles of physical training throughout the whole intervention process.

CHAPTER 3 - DEVELOPMENT OF AN EXERCISE PROGRAM FOR BALANCE IMPROVEMENT

Introduction

Unlike previous opinions that regarded balance as reactive response to sensory stimuli, balance is currently understood to be a fundamental skill that neuromuscular systems are able to learn to maintain balance during postural disturbances (Horak et al., 1997). This lays the foundation for exercise being capable of improving balance. According to the Physical Activity Guidelines for Americans (ACSM, 2009), balance training is recommended to be conducted by older adults on three days per week. In an updated statement (Garber et al., 2011), older adults have been recommended to engage in balance activities as well as balance related activities, such as those for agility, gait, coordination, and proprioception at least twice a week. In 2014, the ACSM recommended that older adults who have poor mobility and who are at risk of falling, to practice neuromotor exercises to improve balance, agility, coordination, and gait. Considering the ACSM's recommendations, balance and balance-related fitness should be an essential part of older adults' physical activities.

This chapter illustrates the developmental process of an Exercise for Balance Improvement Program (ExBP) for older adults without history of falls but who are at risk of falling. The main principle in the ExBP design is the viewpoint proposed by Shumway-Cook and Woollacott (2011), which is that the heart of balance training is practicing progressively challenging tasks and activities that facilitate the development of postural behaviors needed for the (re)acquisition of skilled functional movement. In light of the Cyclical Programming Model (CPM; Carpenter & Howe, 1985), detailed procedures were illustrated in the following seven sections, 1) An introduction to the physiological and social-psychological characteristics of the target participants; 2) The balance deficits which have been most commonly reported in related studies; 3) The training foci and corresponding strategies from practical experience and training evidence from related studies; 4) The rationales for the movements in ExBP; 5) A preliminary plan for the ExBP, 6) Expert and end-user evaluations; 7) Comparisons in the targeted balance deficits between the ExBP and the Tai Chi; and 8) Exercise implementation based on the Whole System Research approach (WSR; Verhoef, Lewith, Ritenbaugh, Boon, Fleishman, & Leis, 2005) which took into considerations the subsystems of physical training (i.e., exercise dosage, physical training principles, teaching approach, and environmental elements). Finally the ExBP was formulated and evaluated in a randomized controlled trial (see next chapter).

Target Participants

The ExBP was designed for older adults aged 65 to 74 years with no history of falls but who were at risk of falling. Participants had no any diseases which might prevent them from exercise.

People within this age range are at a turning-point of increasing physical declines (Spirduso et al., 2005). For example, the shortened length and decreased size of muscle fibers can result in muscle weakness; the decrease in neural cells number would adversely affect the sensitivity of sensory receptors and slow down the CNS leaf processing speed (Spirduso et al., 2005). Due to these age-associated physiological changes, balance abilities are decreased in the target group. In addition, these physiological changes would influence the psychological condition of older adults. Older adults with balance deficits and falling experience often reported with reduced self-efficacy and increased fear of falling.

From the sociological perspective, the majority of the target population is experiencing different levels of social isolation due to retirement. Comparing with previous generations, the older adults nowadays have more serious continual decline in physical and mental functions. Therefore, the target group requires additional ways of engaging in positive social interactions to receive peer' support and recognition. A group-based exercise program is preferable given that it could provide a kind of platform which can facilitate communication and since it can meet older adults' requirement for physical fitness, psychological health, and social interactions (e.g., Chodzko-zajko et al., 2009). In addition, older adults in this age range would consider their health more and many of them would spend more time on physical activities.

The target participants for the ExBP were older non-fallers who were at risk of falling. All the participants had balance deficits but may not seriously suffer from balance or balance-related degradations. As mentioned in the Introduction chapter, this group of people were more prone to falls given they had not made enough realizations on the potential falling risks and as a result may not make enough preparation for falls preventions. Thus early identification plus proper exercise interventions would be especially important for the target group.

Falling Risk Factors in Balance and Balance-related Systems

Table 3.1.

Summary of fall risk factors

Sensory system	Cognitive system	Motor system
Visual acuity*	Distribution of attention	Muscle synergies
Visual contrast sensitivity*	Information processing speed	Muscle strength
Visual filed dependence*	Postural strategies	Muscle power
Vestibular function*		Response time
Tactile sensibility*		Range of motion
Proprioceptive accuracy*		

Note. *No evidence to support exercise can improve these factors directly.

Age-associated degradations in balance and balance-related systems have been reviewed in Chapter 2. Since not all the risk factors are able to be improved through exercise intervention, this newly designed exercise program would only target those trainable factors as listed in Table 3.1. Three cognition-related factors (i.e., distribution of attention, information processing speed, and postural strategies) and five motor-related factors (i.e., muscle synergies, muscle strength, muscle power, response time, and range of motion) were the directly target parameters for the ExBP. Since there is no sufficient evidence for exercise improving the sensory deficits directly, improvements in sensory systems (*Table 3.1) were expected through an integration effect on the interactions between the sensory and other balance systems. Given the close interactions among balance systems, an overall balance improvement can be expected as a result of functional improvement in both the cognitive and motor systems as well as the enhanced cooperation among the three balance systems (Horak et al., 1997). Based on the previous evidence, the dynamic interactions among balance systems - sensory, cognitive, and motor systems were illustrated in Figure 3.1.

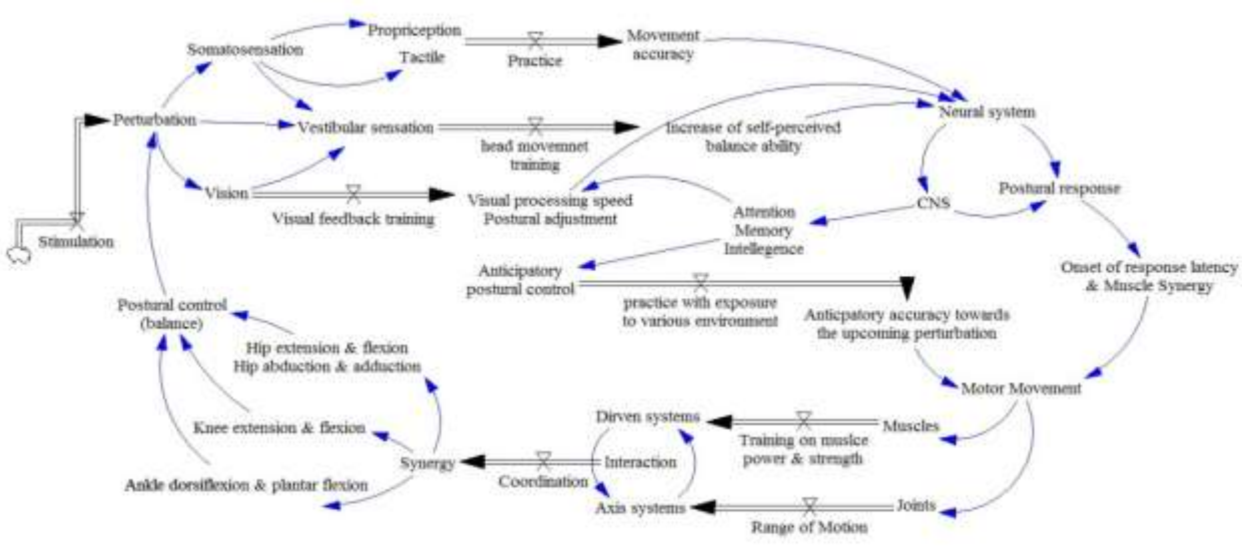


Figure 3.1. Dynamic interactions among balance systems

As Figure 3.1 demonstrates that, in case of a postural perturbation coming from the external environment, the sensory system would receive the information and become activated. Visual, vestibular and somatosensory systems identify the perturbations and transfer them into signals. If there exits any conflict in the visual and somatosensation information provided, the vestibular systems would send this reference information to assist the cognitive system in making corrections. The faster and more accurately the perceived information is received, the more accurate reaction strategies can be produced by the cognitive system, thus, allowing more time for the motor system to recruit additional muscles to produce the necessary corresponding movements. Because of the close relationships among balance systems, exercise on the risk factors in any part of the subsystems would also influence the functions on the adjacent parts. For example, exercise in muscle strength would also have positive effects on muscle power; distribution of attention training in the cognitive system would also increase the visual information processing speed; and vice versa.

Training Focus and Corresponding Strategies

All the falling risk factors, as mentioned in Table 3.1 were further analyzed and divided into different ExBP training foci followed by the corresponding training strategies which were evidenced in previous studies or related practical experience.

Table 3.2.

Training foci and strategies

Focus 1. Control of COM (Huxhold et al., 2006)

1) Reducing the BOS gradually (two leg stance, tandem, one leg support);
2) Continuous change of COM in different directions;
3) Frequently reaching LOS and hold postural stability at LOS.

Focus 2. Muscle strength & power in lower limbs (especially ankle dorsiflexion and knee extension)

4) Standing still in semi-squatting posture;
5) Weight-loaded training of different duration in single-leg stance;
6) Time-critical tasks;

Focus 3. Range of motion, especially in the ankle joint

7) Stretching movements in ankle, knee, and hip joints;
8) Adding full body stretching movements in the process of warm up and cool down;
9) Increase movement' scope gradually.

Focus 4. Plantar tactile sensitivity and joint proprioception around knee and ankle

10) Even and slow tempo for sensory awareness of the movement in lower limbs in terms of speed, force, and trajectory;
11) Activating additional plantar muscles and wider plantar contact areas (Hong & Li, 2007);
12) More practice in the virtual environment (Horak et al., 1997).

Focus 5. Gait pattern, Agility and Response time

13) Gradually increase strides length and walking speed;
14) Walking in different directions (i.e., forward, backward, left, right, and turn round);
15) Time-critical tasks with repeated practice (Horak & Nashner, 1986).

Focus 6. Balance control with compromised sensory input

16) Balance challenging exercise with gradually decreasing visual input;
17) Balance challenging exercise with sensory conflicts between vision and somatosention;
18) Synchronizing eye movement with body movements (i.e., the pivoting of the whole body, the twisting of the trunk, and the coordination of head and upper and lower limbs);
19) Simultaneous hand-eye movements with different body postures and movements.

Focus 7. Distribution of attention

20) Gradually increasing the complexity of body movements through coordination among body, arms, head, and legs;
21) Maintaining proper difficulty of tasks (Huxhold et al., 2006).

Focus 8. Increase confidence in balance required tasks and decrease fear of falling in daily activities

22) Challenging balance practice, such as postural control at the limits of stability and single-leg stance;
23) Education on how to avoid and recover from falling.

Rationale for Exercise Movements

Movement Specificity

Specificity is one of the principles of physical training and exercise. The specificity principle applied in this study indicated that movements in ExBP should be specific to balance deficits and training foci as identified in previous study. In addition, movements in ExBP should take into consideration the participants' ability of recovery from postural instability in a variety of contexts (e.g., slip, trip).

Movement Complexity and Organization

The complexity and organization of the movements in ExBP are established according to Gentile's two-dimensional taxonomy of motor skills. Totally, there are 16 skill categories which can be divided into "environmental context" (stationary or regulatory motion condition & intertrial or no intertrial variability), and "action function" (body stability or transport & object or no object manipulation) (Magill, 2004, p12). Movements in the ExBP did not include the "object manipulation", and thus had 12 types of motor skills. Therefore, movement' difficulties only covered 1) "stable movements" in a "stationary regulatory environment" without "intertrial variability" (i.e., standing still in a room), and 2) "mobile movement" under the "regulatory-motion condition" with "intertrial variability" (i.e., moving a basketball across defenders).

Safety, Feasibility and Gracefulness

Due to the age-associated decline in physical fitness, older adults have comparatively increased timing errors, greater variability, and decreased safety margins in movement control compared to young adults (Hasson & Sternad, 2014). Safety has always been of paramount concern in physical training of older adults. Given the physical and mental characteristics of older adults and their falling risk statuses, movements in ExBP were designed with due consideration to safety. However, in order to achieve an optimal training effect from exercise, all movements should be performed to older adults' full potential. This paradox could be resolved through proper implementation of training strategies and one-to-one guidance. The feasibility of movement is a concurrent concept along with movement safety. This emphasizes participants' acceptance to the ExBP and their subjective feelings during the practicing process. The gracefulness requires all movements in ExBP to be smooth, gentle, and enjoyable. What should be reached finally is that participants, by continuous practicing the ExBP, can not only potentially become physically healthier but also benefit from the positive psychological feedback.

Transfer of Learning

Transfer of learning is defined as the influence of previous experiences on the performance of a skill in a new context, or on learning a new skill (Magill, 2004, p232). This influence may be positive, negative, or neutral. In the present study, movements in the ExBP were designed with consideration of similarity of skills and context components as well as similarity of processing requirements. Given the purpose of the ExBP, all movements in the ExBP should be designed in line with the practical movements that older adults regularly engage in to prevent loss of balance, to recover postural instability, and to maintain COM within BOS.

The Preliminary Plan for the ExBP

The entire exercise program emphasized movements of the trunk and lower extremities, and was performed in standing posture. The main postures for the trunk included 1) straightening the body by pushing the chest forward and straightening the body upwards, and 2) bending the body forwards, sideways, and backwards if required. Movements in the lower extremities included marching, walking, step touch, forward heel tap, squatting, Ezy walk, V step, grapevine, calf raise, straightening of the leg, pointing the toes, keeping legs apart, and legs joined. The basic movements in the upper limbs included arm circles, arm crossovers, stretching arms, arms forward, arms upwards, arms sideways, arms obliquely upward, arms obliquely downward, swinging arms downward (forwards, backwards), bending arms, and hands on hips. The upper limb' movements were secondary to the lower extremity movements with the main purpose to increase the complexity and organization of movements. Several of these movements have been selected basis of their effectiveness as evidenced in previous studies (e.g., the squat), some were selected to challenge balance (e.g., calf raise), and others were selected as interim movements (e.g., walk). Moreover, all these movements were choreographed using with different directions, speeds and ranges, in accordance with the various requirements for physical training.

Expert and End-user Evaluations

Further Modification through Expert Consultation

The main purpose of the expert consultation was to improve the rationality, suitability and operability of the ExBP in light of their rich experience in related areas. The experts were delimited to those 1) having more than 10 years of working experience in a related area of exercise improving balance of older adults, and 2) having a title of associated professor and above, or senior physical therapist. Finally, two experts from exercise and physiotherapy areas accepted the invitation to provide their subjective evaluations in terms of effectiveness, suitability, and feasibility of exercise movements in ExBP. Effectiveness here refers to those exercise movements were able to improve the targeted balance deficits; suitability refers to those movements which were suitable for the target population to perform without harmful effects; and feasibility refers to those exercises which the older adults are able to practice in their daily lives. Two rounds of consultations were conducted with one month apart. The first round was conducted to gather detailed opinions from the experts. The assessments were made using the Likert 5-point scale (i.e., very bad = 1, bad = 2, neutral = 3, good = 4, and very good = 5). They were required to give comments and suggestions for any item with a score less than 4. Modifications were then conducted based on their opinions and suggestions. On occasions where 1) there were any disagreements in the experts' opinions, or 2) any queries or confusion about the experts' opinions, a confirmation letter was sent to them with appropriate explanations. The second round consultation referred to their final evaluation after modifications were made, in which experts made their final evaluation of the whole exercise program giving either pass or fail (pass ≥ 4 and fail < 4). The expert consultation form with detailed content is attached in Appendix C.

Table 3.3.

Expert evaluation on the Effectiveness, Suitability, and Feasibility of ExBP Movements

Forms	Form 1		Form 2		Form 3		Form 4		Form 5		Form 6		Form 7		Form 8	
Indicators	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Effectiveness	4	5	4	5	4	5	4	4	4	5	4	5	4	5	4	5
Suitability	4	5	4	4	3	5	4	5	4	4	4	5	4	5	4	4
Feasibility	4	5	4	5	3	5	4	5	4	5	3	5	4	5	3	3

Note: *the values represent the lowest score of the two experts; R = Round.

All the numbers listed in Table 3.3 were the lowest values given by experts. The comparatively low values were presented in the suitability and feasibility of Form 3 (Hops in four directions) in Round 1, the feasibility of Form 6 (Walking & Knees lifting) in Round 1, and the feasibility of Form 8 in both Round 1 and Round 2. Other values in corresponding items were all over 4, indicating that the movements (after modification) were suitable to be performed in the target population in terms of effectiveness, suitability and feasibility.

Changes Made after the 1st Round Expert Consultation

1. Form 1 (left and right walking): lowering the COM and increasing the bent angle of knee so as to increase the load and intensity of stimulation on quadriceps.
2. Form 2 (multi-directional walking): stressing the twist of upper body in moving and the synchronized movements between the upper body and head.
3. Form 3 (hops in four directions): single leg hops in four directions were suggested to be replaced with walking in four directions. The rationale of the original design of this movement was to improve muscle force, response time, and muscle synergies in case of falling. Therefore, this suggestion may not be suitable. Whether it could be operated by older adults out of laboratory environment would be assessed in the feasibility test.
4. No change was made to Form 4 (side twist). Improving vestibular functions can be achieved through continuous and synchronized movements of head and upper body.
5. No change was made in Form 5 (foot touch). One expert who gave a comparatively lower score had doubts as to the effect of this muscle endurance form (she asked why it was not muscle strength). One explanation for her question was that all the exercise movements were practiced with a bent knee. The duration for the stimulation of muscle strength would be long enough to have effects on both muscle endurance and muscle strength. In addition, the plantar sensitivity was deleted from training foci in Form 5.
6. Form 6 (walking & knee lifting). The main dispute for this exercise form was on the suitability and feasibility of the single leg hop movement, which may not be safe for

older adults. However, movements in Form 6 were retained given that it was demonstrated to be safe in the feasibility test.

7. No change was made in Form 7 (tap step).
8. Form 8 (revised Cha-cha step). One expert held the view that continuous changing of direction (360^o) may require too much for older adults. However, this movement was retained given the results from the feasibility test.

End-user Evaluation

An end-user evaluation on the initial ExBP was conducted prior to the main intervention study to assess the suitability and feasibility of this program, and to gather participants' feedback and opinions about this program (Appendix D). Six older adults were randomly selected from the qualified participants (males: n = 3; females: n = 3) to participate in the initial ExBP for two weeks, with 90min of exercise per session and 3 sessions per week. Their detailed biographic information was presented in Table 3.4.

Table 3.4.

Demographic characteristics of participants in the end-user evaluation

Age (yrs)	Height (cm)	Weight (kg)	Body Fat%	Blood Pressure		Heart rate (b/min)	Fall Risk Test	
				SBP	DBP		OSI	Deviation
69	154.2	56.8	26.9	137	83	68	4.88	4.18
(65, 71)	(147, 161)	(50, 63)	(15, 30)	(109,154)	(67, 100)	(62, 75)	(4.2, 6.3)	(2, 6)

Note. SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure; Fall Risk Test was conducted using the Biodex Balance System^{SD}.

Participants were required to give their evaluation and subjective feelings about the difficulty, confidence, and enjoyment of the exercise program. The numbers "1, 2, 3, 4, 5" were used to score subjective feelings about the above aspects. The higher the value the more difficult, or more confident, or more interesting the older adults consider the exercise program. Finally, average scores were summarized in Table 3.5 below.

Table 3.5.

Participants' evaluation on difficulty, confidence, and enjoyment of the ExBP

Forms	1st	2ed	3rd	4th	5th	6th	7th	8th	Overall
Difficulty	1	1	3	2	1	3	1	3	2
Confidence	4	5	4	5	5	5	5	5	4
Enjoyment	5	5	5	5	5	5	5	5	5

Summary of Participants' Feedback

- Forms 3, 6, 8 were regarded to be comparatively difficult due to the requirements of changing direction and single leg hops. Together with experts' suggestions, it was decided to lower the requirements for these three movements.
    - For Form 3 & Form 6, hops were replaced by walking.
    - For Form 8, the pace for changing body directions was reduced. The sequence of movement was also adjusted to reduce movement difficulties.
- The overall scores demonstrated that participants considered that this exercise program was not very difficult (overall score = 2), very interesting (overall score = 5), and participants were confident they could master it (overall score = 4).

Finally, the revised ExBP was summarized and illustrated in Table 3.6 below.

Table 3.6.

The tailor-made exercise program for improving balance performance (ExBP)

Name	Details			Focus
	Content	Trajectory	Direction	
Warm up (15 min)	The warm up process focus on the lower extremities, which adapts to the main purpose of each of the various training sessions			Flexibility; warming up body

Group 1. Left and right walking	1.1 Trunk 1.2 Step 1.3 Arm 1.4 Head	1.1 Straighten body; 1.2 Calf raise → leg apart → leg together (gradually changing into grapevine if possible); 1.3 Hands on hips; and 1.4 Lengthen neck.	Left side → right side	Control of COM; Muscle power in Knee extension, plantar flexion, & hip abduction; Agility.
				
Group 2. Multi-directional walking	2.1 Trunk 2.2 Step 2.3 Arm 2.4 Head	2.1 Lean forward 15^{o}; 2.2 V-step → one leg stance → toe tap backward; 2.3 Arms cross → Arms sideways; and 2.4 Head changes with the trunk.	Left diagonal front → right diagonal front → left diagonal back → right diagonal front → right diagonal front → left diagonal front → right diagonal back → left diagonal back	Vestibular functions; Control of COM; Muscle strength & power in plantar flexion, knee extension, & hip abduction; Hip abduction range.
				

Group 3. Hops in four directions	3.1 Trunk 3.2 Step 3.3 Arm 3.4 Head	3.1 Straighten the body; 3.2 Hop (or Ezy walk) → hip twist; 3.3 Circle with jazz hands in the front of body ; and 3.4 Lengthen the neck.	Forward → backwards → left → right	Muscle strength & muscle power of plantar flexion and knee extension; Agility; ROM of hip.
				
Group 4. Side twist	4.1 Trunk 4.2 Step 4.3 Arm 4.4 Head	4.1 Bend body forwards (left twist→ right twist); 4.2 Stance is still with the COM in the anterior soles of feet, bend the knee; 4.3 Swing arms forward & backward; and 4.4 Face right and left alternatively.	On the spot	Vestibular sensation; Proprioception in joints of knee & ankle; ROM of lumber spine.
				
Group 5. Foot touch	5.1 Trunk 5.2 Step 5.3 Arm 5.4 Head	5.1 Straighten body; 5.2 One leg stance and the other tapping (heel tap forward → toes tap left & right side → toe tap backward); 5.3 Bend arms→ stretching left (or right) side;	Forward - left-backward - right	Control of COM; Muscle endurance; ROM of ankle (dorsiflexion & plantar flexion) &

		and 5.4 Lengthen neck.		hip (abduction, flexion, extension); Plantar sensation.
				
Group 6. Walking & Knees lifting	6.1 Trunk 6.2 Step 6.3 Arm 6.4 Head	6.1 Straighten body; 6.2 walking and knees lifting; 6.3 Handclap; and 6.4 Straighten neck.	Forward - backward	Agility & Gait pattern; Vestibular system; Muscle strength & power in knee flexion
				
Group 7. Tap Step	7.1 Trunk 7.2 Step 7.3 Arm 7.4 Head	7.1 Bend body side-wards; 7.2 Single leg stance → foot anterior soles tap → toe touch & heel touch; 7.3 Hands on hips; and 7.4 Straighten neck.	On spot	Muscle strength, endurance & power in plantar flexion, knee extension & hip flexion; Control of COM; Planter sensation;

				ROM of ankle (i.e., dorsiflexion , plantar flexion)
				
Group 8. Revised Cha-cha step	8.1 Trunk 8.2 Step 8.3 Arm 8.4 Head	8.1 Straighten body; 8.2 Cha-cha step, hip rotation → body rotation (clockwise/anti-clockwise) 8.3 Arms obliquely upward/downward → arms sideward; and 8.4 Rotation with body 360^{o}	Right diagonal front → anticlockwise rotation → left diagonal front → clockwise rotation	ROM of lumber spine (New); Vestibule system; Control of COM; Agility. .
				
Cooling down (10 min)	Body stretching, adjusting breath, and relaxation			Flexibility, Relaxation

Comparisons in the Targeted Balance Deficits between the ExBP and the Tai Chi

Training Foci Involved in Each Form of the ExBP

Table 3.7.

Training foci in each exercise form of the ExBP

	F1	F2	F3	F4	F5	F6	F7	F8
Focus 1 (COM)	√	√			√		√	√
Focus 2 (Muscle)	√	√	√		√	√	√	
Focus 3 (Agility)	√	√*	√	√*	√*	√	√*	√
Focus 4 (Coordination)	√*	√*	√*	√*	√*	√*	√*	√
Focus 5 (ROM)		√	√	√	√		√	√
Focus 6 (Somatosensation)		√		√	√		√	√
Focus 7 (Attention)	√*	√*	√*	√*	√*	√*	√*	√*
Focus 8 (Fear of Falling)	√*	√*	√*	√*	√*	√*	√*	√*

Note. F = Form; √* in Foci 3 and 4 means these aspects may not be improved by the corresponding exercise forms directly, their improvements may be explained by repeated practice; √* in Foci 7 and 8 means improvements here may be the result of continuous increasing of movement' complexity and organization.

Comparisons between Tai Chi and the ExBP on the Targeted Balance Deficits

The ExBP was designed for older adults with no falling experience but who were at risk of falling. The main purpose of this program was to improve balance and balance-related fitness. In addition, this exercise program was expected to be cost-effective and practical for daily practice. Since Tai Chi has been the most commonly used form of exercise in the primary falls prevention stage, a brief comparison between Tai Chi and ExBP regarding the training effects on balance related deficits could provide a clear perspective of the two forms of exercises used in the current study.

Table 3.8.

Comparisons of the training focused deficits between Tai Chi and the ExBP

Factors	Ageing-associated balance deficits	Tai Chi	ExBP
Muscle weakness	**Muscle strength of the lower extremity** (Carr & Shepherd, 2000; Dykes & Ameerally, 2002; Li et al., 2012; Lord et al., 1991; Mayson et al., 2008; Puthoff & Nielsen, 2007; Tschopp et al., 2011; Wolfson et al., 1995)	**Inconsistency** Yes (Li, Xu, & Hong, 2009) No (Xu, Li & Hong, 2006; Woo et al., 2007)	e.g., semi-squatting posture, one-leg stance, different types of walking (step touch, V step, Ezy-walking), control of COM at the limits of BOS, etc. **Rationale**: weight-bearing training
	Muscle power of the lower extremity (Bassey et al., 1992; Carty et al., 2012; Lexell et al., 1988; Skelton et al., 1994; Simoneau et al., 2005; Onambele et al., 2006; Johnson et al., , 2004)	**No** Tai Chi alone may have less effect on muscle power (Chung et al., 2013)	e.g., hops, leg stretching-out fast, swift changing of COM, etc. **Rationale**: weight-loaded training and time-critical movements
	+ ***especially those being related with dorsiflexion and knee extension*** (Carty et al., 2012; Daubney & Cullham, 1999; El-Kader & Rahmy, 2004; Suzeki et al., 2012; Wolfson et al., 1995).	Yes (*only on muscle strength*) (Lu, Hui-Chan, & Tsang, 2013; Pereira et al., 2008)	e.g., heel forwards, knee lift, etc.
Range of Joint	**Range of motion** (Bok et al., 2013; Chiacchiero et al., 2010; Wojcik et al., 2001).	Yes (Hong, Li, & Robinson, 2000; Taylor-Pillae et al., 2005; Wolf et al., 1996)	e.g., hip twist, knee/ankle rotation, etc. **Rationale**: gradually increasing the scope of movements in joints of ankle, knee and hip
	+ ***especially the range of movement in the ankle*** (Mecagni et al., 2000).	Yes (Han et al., 2004; Liu & Frank, 2010).	e.g., toes/heel tap in different directions (forward, left, right and backward); dorsiflexion, plantar flexion, inversion/eversion, etc.
Neural systems	**Response time** (Horak, et al., 1997; Lin & Woollacott, 2002; Mackey & Robinovitch, 2006; Thelen et al., 2000)	Yes (Gatts & Woollacott, 2006; Wong, et al., 2009; Xu, li, & Hong, 2003)	e.g., hops, swift adjustment of COM, etc. **Rationale**: time-critical tasks with repeated practice (Horak & Nashner, 1986).
	Sequence of muscle activation (Muscle synergies) **(**Horak, et al., 1997; Horak & Nashner, 1986; Mcllroy & Maki, 1995**)**	**No**	e.g., straighten (or bend) body while foot tap in different directions with different speeds, hops in different directions (simulating falls in forwards, backwards, left and right directions), etc. **Rationale**: distal muscles being activated before proximal muscles

			(Shumway-Cook & Woolacott , 2011); and exposure to postural perturbation (Hork, et al., 1989; Macpherson, 1994).
Cognitive systems	**Distribution of attention & information processing speed** (Fraizer & Mitra, 2008; Hyndman & Ashburn, 2004; Lundin-Olsson et al., 1997; Shumway-Cook & Woollacott, 2011; Siu et al., 2008)	Yes (Hawkes, 2012)	e.g., gradually increasing the complexity of body movements through the coordination of body parts, arm, head, and leg, etc. **Rationale**: maintaining suitable difficulty for tasks (Huxhold et al., 2006).
	Anticipatory strategies (Burleigh, et al., 1995; Burleigh, et al., 1997)	Yes (Lee, 2010)	e.g., hops or walking in four directions (simulating falls in the forwards, backwards, left and right directions) , etc. **Rationale**: more practice in the virtual environment (Burleigh et al., 1995; Burleigh et al., 1997).
Sensory systems	**Plantar tactile sensitivity** (Chong et al., 2000; Menz et al., 2005; Shumway-Cook & Woollacott, 2011)	Yes (Mao, Li, & Hong, 2006; Szturm & Fallang, 1998)	e.g., toe tap forward, left, right and backward, **Rationale**: activating more plantar muscle and wider contact areas of plantar (Hong & Li, 2007).
	Proprioception around the knee (Fundin et al., 1997; Madhavan & Shields, 2005; Verschueren et al., 2002; You, 2005) **and ankle** (Bullock-Saxton et al., 2001).	Yes (Chen et al., 2012; Tsang & Hui-Chan, 2003; Xu, Li, Hong, & Chan, 2004)	e.g., knee rotation, squat, ankle rotation, toes touch forwards, left, right and backwards, etc. **Rationale**: more practice in the virtual environment (Horak et al., 1997).
	Vestibular rehabilitation (Eleftheriadou et al., 2012).	**No** (Wayne et al., 2004)	e.g., multidirectional walking, Cha-cha step with body rotation, head rotation (90^o), etc. **Rationale**: concurrent movements between eyes and extremities of limbs (Eleftheriadou et al., 2012).

Note. Yes = significant effect; No = no significant effect or no confirmative evidence.

Exercise Delivery Process

Although participants were expected to practice by themselves, a class-based format with the supervision of physical trainer was considered beneficial to assist participants to master the

ExBP in a comparatively short time. In each class, participants were required to mentally rehearsal what they had learned before practicing, since modern cognitive neuroscience has verified the fact that imagery can directly activate the same brain regions which are engaged in the actual performance (Decety, Jeannerod, Durozard, & Baverel, 1993). In addition, environmental influences are also important factors that should be considered during the training process. As such, safety and cleanliness of the outside environment ae recommended to be taken into consideration during exercise practice.

Principles of Physical Training and Exercise

Principles of physical training are largely ignored in related exercise interventions. However, to achieve optimal training effects as a result of exercise interventions, physical training principles should always be properly applied to an older population in a modified manner, as suggested by Oddsson and colleague (2007). Except for the commonly used training principles (i.e., Awareness, Continuity, Motivation, Overload and Periodicity), three principals were particularly emphasized in the implementation process of the ExBP. They are the Specificity principle, Progression principle, and Inter-individual Variability principle. The Specificity principle emphasizes the importance of consistency between exercise content and training purpose. The Progression principle is represented through suitable and adequate exercise stimulation with progression of balance improvement. Movement quality, exercise loads and intensity should be adjusted so as to meet the requirements for progression. In order to acquire effective stimulation from exercise training, the entire exercise training process maintained an appropriate overload stimulus on participants' balance systems. The Inter-individual Variability principle emphasizes the individual physiological and psychological differences among participants, which provides the rationale for the importance of personalized exercise prescriptions. In addition to following these principles strictly in the implementation of the exercises, the art of training in terms of coordination of training principles has always been taken into consideration to obtain an optimal training effect from exercise intervention.

Training Stages during the Intervention

The program delivery process was divided into three stages according to the classic learning stage model, which incorporates the Cognitive, Associated, and Autonomous stages (Fitts & Posner, 1967). Participants were asked to master exercise skills of varying degrees at different stages, and therefore various training strategies were used accordingly. According to the Cognitive stage, gross motor skills were taught with personal guidance to help participants understand and learn the ExBP, additionally to instill participants' interest to continue to attend the sessions. In the Associated stage, higher standard for movements' quality was required from participants, and appropriate feedback was given at the appropriate time. The "one-to-one" personal guidance was provided to correct movement. For example, to help participants to reach certain knee lifting height, a tutor may hold participant's knee at the required height to give them a sense of this height; or to accelerate the leg stretching out speed, the physical trainer would push a participant's leg at a certain speed to help him or her achieve the correct sensation for stepping-out. In the Autonomous stage, coordination among movements was the main training focus. Movements were perfected and participants were asked to perform the whole program fluently. Repeated practice was engaged in to strengthen memory and the quality of movements in a short time. A detailed timeline of the implementation plan is attached in Appendix A. Guidance from the physical trainer would vary depending on the participants' requirements at different learning stages. The proportion of various training methods (i.e., the mass vs. distributed practice, constant vs. variable practice, random vs. block practice, whole vs. part training, transfer, mental practice, guidance vs. discovery learning, etc.) were provided in line with the training foci.

Exercise Dosage

A commonly used dosage in published studies examining exercise to improve balance is three times per week for three months with each training session lasting for at least one hour (Howe, Rochester, Neil, Skelton, & Ballinger, 2011). However, most of these studies did not clearly indicate the effective training period or the entire trial period, thus creating confusion regarding effective training duration. In addition, insufficient exercise dosage is one of the main reasons for the inconsistent effects from previous exercise programs (Lopopolo, Greco, Sullivan, Craik, & Mangione, 2006; Sherrington et al., 2011). Therefore, a higher exercise dosage was suggested in practicing the ExBP “16 weeks x 3 times per week x 1.5 hours per session”. In each training session, there are five main sections including 1) 10-15 min warm up, 2) 25min first training part, 3) 5-10min break, 4) 25min second training part, and 5) 10-15min cool down.

Exercise Tempo and Intensity

Music tempo can play a role in controlling the pace of exercise and adjusting the environmental atmosphere, and additionally music is good beneficial for exercise practice. Modern Chinese music with a moderate pace (around 15 beats / 10 seconds x 4 min) was suggested to adopt in exercise practice. Feedback from participants on the suitability of this modern Chinese music demonstrated that all participants regarded this piece of music to be enjoyable; although a little bit fast paced in the beginning. Therefore, to be more consistent with the teaching and learning process, a group of music with different pace (0 beat to 20 beats / 10 seconds) was used. For community-dwelling older adults, exercise intensity was suggested to be set at a moderate to high intensity, with at least a 50-hour trial period (Sherrington et al., 2008;

Shubert, 2011). Considering the characteristics of the target participants, exercise intensity in the current exercise program was monitored using the Cantonese version of self-perceived rating of exertion scale (RPE), which has been verified in Chinese ($r = .70$, $p < .05$; $ICC = .78$; Chung et al., 2013; see Appendix I). Participants were required to remain the exercise intensity within the range of RPE 11 (light) to RPE 13 (somewhat hard).

CHAPTER 4 - METHODOLOGY

This study was a Randomized Controlled Trial (RCT) design with two control groups, one was a no-treatment concurrent control (CON group), the other was an active concurrent control (TC group). The overall trial was not double-blinded, although evaluators at each time point assessment were blind to participants' assigned treatment group.

Sample Size Calculation

One of the key tests in this study was the Fall Risk Test (FRT). Based on the changes of FRT performance, sample size was estimated from previous studies which examined the effect of aerobic exercise interventions using the FRT (as measured by Biodex Balance System^{SD}) among older adults who were independent community-dwellers. Results from related studies found that the most often reported effect size ranged from .37 to .70 (moderate to high) (Dekenah, 2012; Gusi, Carmelo Adsuar, Corzo, del Pozo-Cruz, Olivares, & Parraca, 2012; Madureira, Takayama, Gallinaro, Caparbo, Costa, & Pereira, 2007; Salsabili, Bahrpeyma, Forogh, & Rajabali, 2011; Wu, Zhao, Zhou & Wei, 2002). The effect size in the present study was estimated at .45. In order to have 80% probability that the present study could detect a treatment difference in the three repeated testing points (i.e., pre-test, mid-test, and post-test) with a two-sided 5% level of significance, a total of 51 participants were required using G-power 3.1.5 version. Considering the potential 20% drop out rate as well as allowing for additional variations (Howe et al., 2011), this study would recruit 60 participants (20 in each group).

Participant Recruitment

Considering the operational problems during the intervention process, as well as limited human resources, participants were recruited from one District Senior Center in the New

Territories, Hong Kong. The center is a multi-service center for older adults, and at the time of recruitment had over 2000 registered members. The majority of members were Hong Kong citizens who lived in Hong Kong for over 30 years. Three methods were used to recruit participants, which included 1) advertisements in the Senior Center Weekly News Report, 2) posters on bulletin board outside the Senior Center, and 3) a workshop named “Healthy Ageing”.

Inclusion criteria for qualified participants were:

1. apparently healthy adults aged from 65 to 74 years who lived independently in the community;
2. without history of falls in the preceding 12 months;
3. without any disease that would prohibit older adults from participating in exercise.

One hundred and twenty six participants showed interest in participating in this study. All of them accepted to attend a battery of screening tests, which was conducted two weeks prior to the intervention study. The screening tests were divided into two stages. In the first stage, we **excluded** those with any of the following symptoms:

1. Cognitive impairment, which was screened using the Chinese version of Mini-Mental Status examination (MMSE-C, $r \geq 0.75$, $p < 0.001$; Xu et al., 2003; see Appendix E). Scores for qualified participants should be over 24;
2. Apparent visual impairment or vestibular disorder, such as cataract or dizziness;
3. Poorly controlled hypertension [systolic blood pressure (SBP) > 160mmHg or diastolic blood pressure (DBP) > 90mmHg] and symptomatic orthostatic hypotension;
4. Neurologic disorders or peripheral neuropathy of the lower extremities, such as knee replacement;

5. Taking more than three types of medications including the psychoactive mediation use and antihypertensive use;
6. Regular (3 times/week and ≥ 30min/session) balance related training practice during the last 6 months; and
7. Regular Tai Chi training (3 times / week and ≥ 30-min / session) in previous 12 months.

One hundred and four older adults passed the first round of screening test. They were invited to participate in the Fall Risk Test (FRT; Biodex Balance System^{SD}) in the second round of screening tests. The FRT is an effective measurement to identify potential fallers and to assess balance abilities (Finn, Alvarez, Jett, Axtell, & Kemler, 1999). The selection of this measurement was based on the fact that the FRT provides the age-dependent normative values. Detailed information about this test was introduced in the following Instrument and Measurement section. Participants who were identified as at risk of falling were further assessed and excluded if they were identified as at high risk of falls. The high risk of falls was defined as having one more falling incidents in the previous 12 months; or having disturbed balance, mobility problem, dizziness; or taking any medicine to prevent fall occurrence (Logghe et al., 2009). Finally, a total of 69 participants qualified to participate in the intervention.

Participants Grouping

Among the 69 qualified participants, 61 participants agreed to sign consent forms after receiving a briefing on the intervention arrangements (i.e., time and place). These 61 individuals were randomly allocated into one of the following three groups by a draw of lots, in a ratio of

1:1:1, without any stratification: ExBP group (n = 20), Tai Chi group (n = 20), and control group (n = 21).

Intervention and Control Groups

Intervention Group

Participants received a series of training sessions using the ExBP.

Active Concurrent Control

According to a review of the literature, it was identified that the most commonly applied Tai Chi forms were the 24-form and the 8-form Yang-style Tai Chi (Leung, Chan, Tsang, Tsang, & Jones, 2011; Verhagen et al., 2004). According to this review, no study has examined the difference between their training effects. Considering that the therapeutic elements in the 8-form Yang-style Tai Chi have been identified (Wolf et al., 1997), together with the characteristics of the targeted participants (e.g., at risk of falling and without previous Tai Chi training), as well as the limited intervention period, the 8-form Yang-style Tai Chi was applied in this study. The eight forms are Repulse Monkey, Brush Knee Twist Step, Part Wild Horse's Mane, Wave Hands in Clouds, Golden Rooster Stand on one Leg, Heel Kick, Grasp Swallow's Tail, and Cross Hand.

No-treatment Concurrent Control

Participants in this group did not participate in any specific intervention during the whole study, but they were asked to keep a daily log on their physical activity, medicine, illness, diet, sleep quality and other information (e.g., attending healthy eating workshops). In addition, the control group was requested to report to their administrators if there was any change in these aspects. The administrators checked the daily logs of participants by telephone every two weeks.

Data from those who had changed their normal lifestyles (especially in physical activity or medicine) was deleted in the subsequent data analysis.

Training Dosage for Training Programs

Generally, an effective exercise program was conducted three times per week for 3 months (Howe et al., 2011). In an attempt to be more effective, a longer duration was adopted in this study by extending the intervention period to 16 weeks. A training dosage of 90min per session x 3 sessions per week x 16 weeks was adopted for the present study. The entire intervention and training phase was from 17th of March to 4th of July, 2014. Training classes were conducted every Monday, Wednesday, and Friday, from 8:00 am to 11:00 am (ExBP = 8:00 – 9: 30; Tai Chi = 9:30 – 11:00). At the end of the intervention period, an 8-week follow-up period was conducted to examine the maintenance effects as a result of the training.

Implementation Process

Set-up

Both ExBP and Tai Chi were conducted in classes. Qualitative research on older populations has demonstrated that the social aspect of a class-based exercise format was a prime motivator for older participants (Finch, 1997). This provides participants with a higher sense of belonging through social interaction, peer support and reductions in feelings of isolation. Additionally, the supervised training process allows more specificity of training, more progression from training, and faster feedback from participants and better safety during the exercise process (Young & Dinan, 1994). The whole training process was conducted in two types of venue, one was a public, open, air environment with which the older participants were familiar, and the other was a traditional dance room with a mirrored wall. The open-air environment was selected in consideration of environmental influences on information processing for balance control as well for the participants' continued practice after the intervention. The complexity of the open-air environment contains varying elements, which require additional attention and increased central processing load (Huxham, Goldie, & Patla, 2001). A familiar environment can assist participants to feel relaxed and would be beneficial for learning new exercise skills. The traditional dance room with a mirrored wall was used at certain training stages according to the training requirement. A mirror during training can help participants acquire immediate feedback related to posture and movements, and enable the correction of movements at the appropriate time.

Personnel Allocation

At each training session, there was a physical trainer and an assistant. The trainer was in charge of exercise training, prescribing exercise intensity and preventing exercise-related injuries during practice. The assistant took responsibility for assessing exercise intensity, reminding time, data collection, as well as coordination of class order on site. A portable CD player with music was used for each class. As previously described, music can adjust the training atmosphere and help monitor exercise rhythm. To ensure a friendly and safe exercise environment, the challenge point framework (CPF) was applied for the organization of the training environment by taking into considerations the participants characteristics, the learning task, and the practice conditions (Guadagnoli & Lee, 2004).

Delivery Process

There were three stages for delivering the training programs according to the Classic Learning Stages – Cognitive, Associated, and Automatic Stages. The Cognitive Stage refers to the period where participants learned the exercise within 24 sessions lasting 8 weeks. In addition to the guidance from tutor during the class, a tutorial CD for either the ExBP program or the Tai Chi program was provided to participants to help them practice at home. By the end of the 8th week, participants were expected to perform ExBP or Tai Chi by themselves (without guidance from physical trainer). The following 16 sessions over 4 weeks was the Associated Stage. During this stage, exercise training was mainly conducted in an integrated format. Participants were expected to perform the whole exercise program (ExBP or Tai Chi) independently and fluently. The mid-testing point was conducted at the end of the 12th week to examine any training effect on balance and balance-related parameters during the learning and associated stages. The last 12 sessions over 4 weeks was the Automatic Stage focusing on the quality of exercise performance through repeated practice. At the end of the 16th week, the post-test was conducted to determine the training effect on outcome parameters. In order to see how long any such training effect might persist, a follow-up test was carried out at the end of the 8-week follow-up period. An outline for training arrangement for the three stages is attached in Appendix A, and the detailed information about training content and progression can be found in Appendix J.

Exercise Intensity

For each training session, there were five phases, including 1) 10-15 min warm up, 2) 25min first training part, 3) 5-10min break, 4) 25min second training part, and 5) 10-15min cool down. Exercise intensity was monitored using the Cantonese version of Rating of Perceived Exertion (Cantonese RPE) scale and Heart Rate monitor (Polar S810, Finland). Exercise intensity was recorded at the end of each phase. Self-perceived exercise intensities ranged from light (RPE 11) to somewhat hard (RPE13). Results of the heart rate showed that exercise intensity of ExBP group (ExBP = 100 ~ 120 bpm; Figure 4.1) was higher than that of Tai Chi group (Tai Chi = 80 ~ 95 bpm; Figure 4.2). In each training session, the highest intensity occurred in the second training part of the session. In addition, exercise intensity comparatively increased with the process of learning at the same training part (i.e., Automatic Stage > Associated Stage > Cognitive Stage).

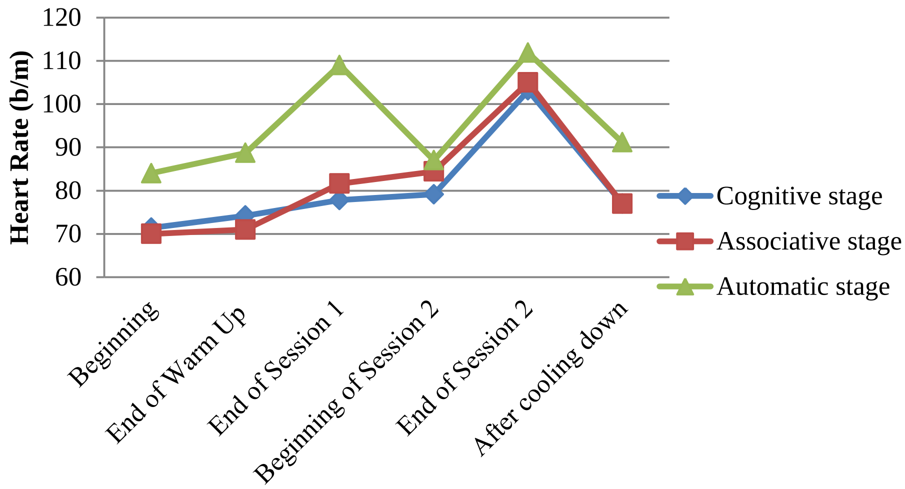


Figure 4.1. Changes in exercise intensity during an ExBP training session

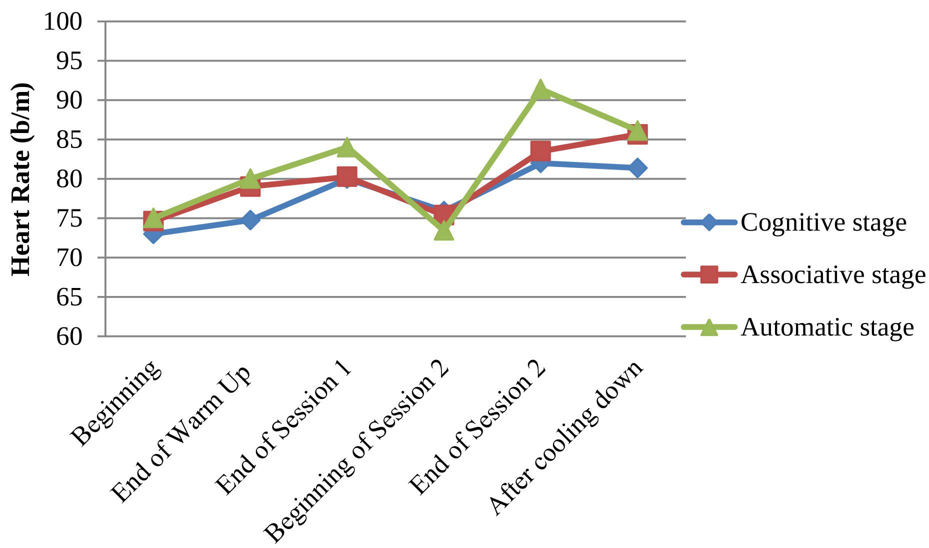


Figure 4.2. Changes in exercise intensity during a Tai Chi training session

Safety Consideration

Safety is of paramount concern in gerontology. In the present study, the falls prevention during training was considered to be the most important safety issue. Apart from the general considerations about exercise injuries, dehydration, and overload training effects, the following steps were executed carefully:

1. An appropriate warm up was fully executed at each class;
2. At each training session, a physical trainer and an assistant were all on site to deal with any emergency;
3. The training process including the rest interval was strictly adhered to; and
4. All participants were educated to slow down or stop if they experienced any adverse health signals during exercise.

Instruments and Measurements

Demographic and Clinical Data Collections

Qualified participants who had signed the consent form (Appendix B) were asked to report their demographics and clinical information by completing a questionnaire at the briefing workshop (Appendix F). For those who were unable to read or write, a well-trained assistant was arranged to assist them to fill in the questionnaire. There were four sections in the questionnaire: sociological factors, fall history and balance-related deficits, self-perceived physical health, and daily physical activities. Details are presented as follows:

1) Sociological indicators include age, gender, education background, living status (alone or with family), working status (volunteer/paid work or nothing);
2) Fall history includes date, place, reason for falls; balance-related deficits include visual, vestibular, upper limbs, legs, and feet problems;

3) Self-perceived physical health includes any medicine taken daily; and
4) Daily physical activities include exercise content, frequency, and duration of the activities.

Some of the physiological parameters, including height, weight, body mass index (BMI), body fat percent (% BF), blood pressure (BP), and heart rate at rest (HRrest), were also tested during this briefing workshop.

Primary Outcomes

All the primary test parameters were measured using a commercially available balance device, the Biodex Balance System^{SD} (BBS; Medical Systems, New York, USA). This consists of a movable balance platform which provides up to 20° surface tilt in a 360° range of motion. The platform is interfaced with computer software (Biodex, Version 3.1) which enables it to serve as an objective assessment of balance. By adjusting the COM relationships between the body and the platform, BBS can measure both static and dynamic balance. Varying resistance to tilting allows varying stabilities of the platform which range from the most stable (level 12) to the least stable (level 1). In addition, the display on the BBS can provide synchronous feedback about the position of the center of pressure. Participants are required to stand barefoot on the platform, with hands at their sides, eyes open or closed and looking straight ahead. Tests are ended if any part of body touches the hand-rail. Four testing protocols were adopted in this study, 1) Fall Risk Test (FRT) for distinguishing participants with or without risk of falls and measuring dynamic balance; 2) Postural Stability Test (PST) for measuring static balance; 3) Limits of Stability Test (LOS) for assessing postural control at the limits of stability in different directions; and 4) Modified Clinical Test of Sensory Organization and Balance (m-CTSIB) for evaluating balance with one or more compromised sensations. A battery of result sample is attached in Appendix G.

Foot placement in the Biodex Balance System[SD] Foot placement is a key factor for balance control, especially on a moveable platform for measuring dynamic balance (e.g., FRT). Different foot positions result in different stability scores, since the relative distance between foot position and center of platform will change the way that balance is maintained (Chiari, Rocchi, & Cappello, 2002; Schmitz & Arnold, 1998). Regarding the correct foot position, disagreements have arisen in previous studies (Mcllroy & Maki, 1997; Wrisley & Whitney, 2004). Some studies suggest applying a standardized foot placement, which can facilitate between-studies comparison. For example, the international Society of Posturography (ISP) has suggested a 30^{o} angle between the medial borders of the feet with heels together (DIRECTIONS, 1983; Salsabili et al., 2011). Some authors require feet to be placed together and side by side (Black, Wall III, Rockette Jr, & Kitch, 1982). Yet other have limited foot placement to keep heels together with feet forming an angle of 20^{o} (Allet et al., 2010). However, constraining feet placement into a "standardized position" without considering individual preference or between-subject variability could easily cause participants to adopt an abnormal posture which would affect the accuracy of postural responses. To prevent any effect from abnormal foot placement on balance control, participants in some related studies adopted a natural or comfortable foot position during tests (Arnold & Schmitz, 1998; Costa, Graves, Whitehurst, & Jacobs, 2009; Hinman, 2000; Ku, Abu Osman, Yusof, & Wan Abas, 2012; McIlroy & Maki, 1997; Sekulic, Spasic, Mirkov, Cavar, & Sattler, 2013). However, the wide between-subject variability and an intended broader stance area are usually reported (McIlroy & Maki, 1997), which may bias the results. Considering there is no golden standard regarding foot placement, this study instructed participants to find a suitable position from which they can keep platform stable. The suitable position in terms of the angle and distance between heels should be similar to their usual foot placement when standing still on ground. The individual foot placement was recorded from coordinates on the platform grid at the first trial test (baseline data tests), and were used for all subsequent tests to ensure the same stance.

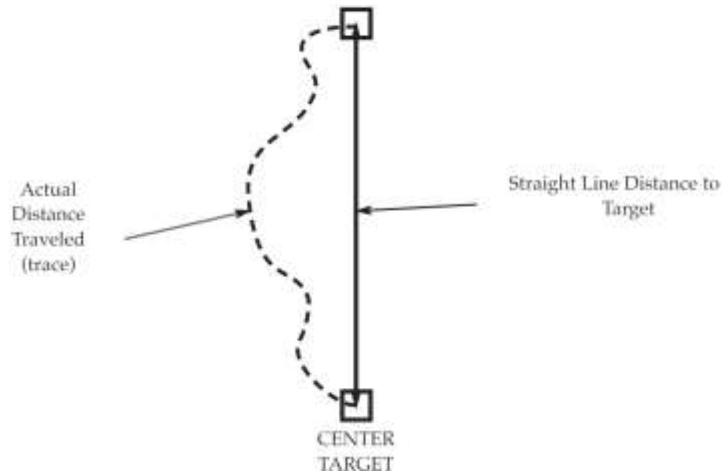
Fall Risk Test The Fall Risk Test (FRT) is a recommended, reliable measurement for assessing the status of falling risk, and can be used to demonstrate the progress of balance during interventions (Parraca et al., 2011). The FRT is also taken as a dynamic balance test because of the moveable base of the supporting platform (BMS, 1999; Gusi, et al., 2012). It is suggested in the BBS operational manual, that resistance levels should range from Level 12 to Level 8 within 20s (Testing Section). Three trials with two practice trials were performed with 10 s apart for rest. Participant's performance was noted as the overall stability index (OSI; or fall risk score) and standard deviation (SD). Testing results were compared to age-dependent normative data (54-71 years: 1.79-3.35; 72-89 years: 1.90-3.50) and therefore allows for identification of potential fall candidates. Previous studies have demonstrated the effectiveness of FRT in distinguishing balance abilities among participants of different genders and ages (Finn et al., 1999), as well as acceptable testing reliability (*ICC* = .80) (Parraca, Olivares, Carbonell-Baeza, Aparicio, Adsuar, & Gusi, 2011).

Postural Stability Test The Postural Stability Test (PST) assesses participants' ability for maintaining the COM on a stable or a moveable platform. The BSS can calculate the anterior-posterior stability index (APSI), the medial-lateral stability index (MLSI) and the overall stability index (OSI) using the relative position of tilt of the X and Y axes. Stability index (SI) represents the displacement from a level platform position. A higher stability index shows greater deviations from the center and is indicative of difficulty in maintaining balance. The overall stability index is calculated by considering the displacement from level in both the anterior - posterior sagittal plane (Y axis) and medical – lateral frontal plane (X axis), just as the following formulas highlights.

$$\text{OSI} = \sqrt{\frac{\varepsilon(0-Y)^2 + \varepsilon(0-X)^2}{samples}} \qquad \text{APSI} = \sqrt{\frac{\varepsilon(0-Y)^2}{samples}} \qquad \text{MLSI} = \sqrt{\frac{\varepsilon(0-X)^2}{sample}}$$

A moderate test-retest reliability of the OSI was found on a static balance test (*ICC* = .69) (Parraca et al., 2011). In this study, PST was only conducted at Level 12 to measure the static balance. In order to remove any potential learning effect, there was an adaptation phase with 3 practices attempts prior to the formal test. Finally, three 20s trials were performed with 10s apart.

Limits of Stability Test The Limits of Stability Test (LOS) challenges participants' postural control ability at the limits of their BOS in different directions. The LOS test has been proposed as a dynamic balance measurement with a moveable standing platform. However, it was found to be challenging even for healthy, middle aged adults (Hinman, 2000). Considering the characteristics of the target participants, the platform was set to stable. During the testing process, participants were instructed to keep their body straight and to use their ankles as the primary axis of rotation. They were asked to quickly and smoothly hit the random light targets in eight directions and hold the cursor on the light target until it turns dark (> .25 s). Outcomes were time (s) and accuracy of transferring the COM to reach the eight targets (direction control based on 100% being a straight line). Target placement was pre-set at a mid-level (75% of the maximal LOS), which was 9^{o} in the anterior-posterior direction and 12^{o} in the medial-lateral direction. Direction control is a measure of movement accuracy, and is calculated by "scores in different directions % = straight line distance to target / actual distance traveled x 100", just as showed in the chart below. The overall direction control score is an average score compromised of the scores of all eight targets.



(Cited from Balance System SD operational manual, 2007)

Poor scores in any direction suggest further assessment for corresponding muscles strength & power in the lower extremities as well as related sensory deficits, if any. The test-retest reliability of the LOS test has been demonstrated as good for direction control (*ICC* = .72) and low for test duration (*ICC* = .54; Pickerill & Harter, 2011). The low test-retest reliability of testing duration indicates a learning effect, which necessitates practice before the formal test. Therefore, at least three trials were performed before formal testing.

Modified Clinical Test of Sensory Organization and Balance The modified Clinical Test of Sensory Organization and Balance (m-CTSIB) is a short and modified version of the original CTSIB, which can identify sensory deficits in balance control (i.e., vision, vestibular, and somatosensation). The m-CTSIB requires participants to stand with stability under four conditions, 1) eyes open firm surface (baseline), 2) eyes closed firm surface (compromised vison mainly dependent on somatosensory), 3) eyes opens foam surface (compromised somatosensation mainly dependent on vision), and 4) eyes closed foam surface (compromised vision and somatosensation mainly dependent on vestibular systems). Results from this test assessed the ability of the integration of various senses in balance control while one or more senses are compromised. Outcomes include the stability index and the sway index. The stability index is the average position from the center and the sway index is the standard deviation of the stability index. Given that the foam pad would probably bias stand placement from the center of platform, the sway index instead of the stability index was reported as the main indictor for the m-CTSIB. The more unsteady people are, the larger the sway index is likely be. The efficacy of the m-CTSIB has been testified with good predictive and discriminant validity (Di Fabio & Anacker, 1996). The test-retest reliability of the m-CTSIB was conducted among a group of older community-dwelling adults, and results demonstrated good reliability (r = .75; Anacker & Di Fabio, 1992).

Secondary Outcomes

30s Chair Stand Test The 30s Chair Stand Test (CS) is an easy and common used field test for muscle strength, endurance, and power in the lower limbs in older populations (ACSM, 2009). Jones, Rikli and Beam (1999) found close relations between CS and maximum weight-adjusted leg-press test in a group of older community-dwellers (male: r = .78; female: r = .71) as well as good test-retest reliability (*ICC* = 0.84 for males; *ICC* = 0.92 for females). This indicates that the CS is a valid and reliable testing tool for muscle strength in the lower limbs of older adults. Milena and colleagues (2012) used the CS to assess muscular endurance in a group of older adults (70.4 ± 7.3 years), and they found good test-retest reliability and agreement between trials (r = .78). Smith and colleagues (2010) found that the muscle power of the lower limbs can be predicted by the total power in the initial 20 s of the CS in a group of active older adults (76 ± 7.19 years), peak power (W) = −715.218 + 13.915 body weight (kg) + 33.425 stands in 20s (R^2 = 0.811, $p < .01$). Correlations were assessed between the CS predicted outcomes and analysis from force-platform and high-speed motion. Results demonstrate high correlations between the estimated muscle power and the tested muscle power (r = .90, p < .001). This indicates that the 30s chair stand test is valid to evaluate muscle power of lower limbs among older adults..

Chair Sit-and-Reach Test The Chair Sit-and-Reach Test (SR), developed from the floor sit and reach test, is a commonly used test for assessing the flexibility of the lower body (Rikli & Jones, 2012). Participants are required to extend one leg while maintaining the other leg in a bent position, which would be more suitable for older adults with functional limitations such as lower back pain, hip and knee injuries. Jones and colleagues (1998) tested the reliability and validity of the SR in a group of older adults (mean age = 70.5 years). Results demonstrated high consistency between the two trials (males: r = .92; females: r = .96), indicating good test-retest reliability of the SR. Validity of this test was assessed by comparing with the goniometer-measured hamstring flexibility, high correlations between the two tests were demonstrated (r = .81 for women, and r = .76 for men) (Jones, Rokli, Max, & Noffal, 1998). Outcome from this test is the distance (cm) between middle finger and the toe.

The 8ft Up and Go Test The 8ft Up and Go test (UG) is a modified version of the original timed "up and go" test (Podsiadlo & Richardson, 1991), where the distance between the starting and the turning point has been reduced from 10 feet to 8 feet. The shorter distance is said to be more feasible for performance in a home setting (Rose, Jones, & Lucchese, 2002). No significant difference was found in testing accuracy between the 8ft and 10ft UG tests (Cavani, Mier, Musto, & Tummers, 2002; Rikli & Jones, 1999). In addition, the 8ft UG test was found to be able to discriminate between physically independent and dependent older female adults (Jones, Rose, & Newsome, 1999) as well as between older fallers and nonfallers (Rose et al., 2002). In addition, it has been used as an effective assessment tool for dynamic balance and agility

(Herman, Giladi, & Hausdorff, 2011; Rikli & Jones, 2012). Moderate and high correlations between the 8ft UG test and the Berg Balance Scale (r = .81), Gait Speed Test (r = .61), and Barthel Index of ADLs (r = .78) were found in older population (Podsiadlo & Richardson, 1991). In addition, the cut-off value of 8.5s in this test has been used as an indicator for increased risk of falling (Rose et al., 2002). Related intervention studies have also used the 8ft UG test as a valid tool to assess the progress of dynamic balance and agility in a various population (Cavani et al., 2002).

2min Step Test Aerobic endurance has been taken as a key indicator for differentiating fallers from nonfallers (Maciaszek, 2010), and has a negative relationship with falling risks (Toraman & Yıldırım, 2010). In contrast to a group of self-paced aerobic endurance tests, such as the Harvard Step Test (Brouha, 1943) and the Queen College Step Test (McArdle, Katch, Pechar, Jacobson, & Ruck, 1972), the 2min Step Test (Step) was developed in consideration of older adults who are not able to maintain a prescribed stepping cadence (Rikli & Jones, 2012). Step is also an alternative test to the 6min walk test and can be used in confined spaces or during inclement weather. In contrast to the 6min walk test, the 2min step test requires participants to lift their knees to a height equaling the mid- level between the patella and iliac crest (Rikli & Jones, 2012). The intensity and duration of single-leg support is comparatively greater than the standard step, therefore performance of the 2min step test requires additional balance abilities. Criterion validity of the Step test has been established in comparison with other well-evidenced aerobic endurance measurements. Dugas (1996) found a moderate correlation between the Step test and Rockport 1mile walk test (r = .73) among 24 older males and females aged around 70. Johnston (1998) also found a moderate correlation between the Step and the treadmill test (r = .75) in a similar group of older adults.

Choice Stepping Response Time Test Stepping strategy is often used as method to test for the maintenance of balance when COM is outside the BOS among older population (Maki et al., 2008). To conduct the stepping strategy, initially a fast stepping response is necessary. However it is difficult to measure the actual time of the stepping response in falls given that most falls occur without any warning. In laboratory studies, fall inducing apparatus is used to simulate the situation of a fall by releasing participants from a harness which holds them in a leaning position (Thelen, Wojcik, Schultz, Ashton-Miller, & Alexander, 1997). Studies have since demonstrated that balance disturbances deduced from such situations would cause people to step more laterally, which may affect the testing accuracy of stepping responses (McIlroy & Maki, 1996). Outside the laboratory, the Choice Stepping Response Time (CSRT) test is one commonly used field tests for assessing this stepping out response time. Participants have been required to step using any leg according to a spot that randomly lights up; therefore, this allows a similar balance transfer process for both legs (Lord & Fitzpatrick, 2001, Pijnappels, Delbaere, Sturnieks & Lord, 2010). The CSRT evaluates participants' reactions and weight transferring speed when facing multiple options (Patla, Frank, Winter, Rietdyk, Prentice, & Prasad, 1993). Pijnappels and colleagues (2010) assessed the association between CSRT and falls in older adults using a path analysis model in terms of a physiological path (quadriceps strength and visual contrast sensitivity) and a cognitive path (cognitive processing). Results from this regression indicated that the choice of stepping response time was able to predict multiple falls (Pijnappels et al., 2010). Furthermore, the CSRT was reported as a good indictor with which to discriminate fallers from nonfallers among older adults (Lord & Fitzpatrick, 2001).

To date, there is no commercially available stepping response device. For the purpose of this study, a similar device was manufactured according to the description of the CSRT device in

"Choice stepping reaction time: A composite measure of falls risk in older people" (Lord & Fitzpatrick, 2001). The newly manufactured device requires that participants stand on a nonslip platform (0.8 m x 0.8 m) which contains four rectangular panels (32 cm x 13 cm), one panel in front and one at the side of each foot. Each panel is a numbered from 1 to 4 (front-left side = 1, front-right side = 2, left side = 3, right side = 4). A speaker automatically reads numbers out in a random order, and participants are instructed to step on to the corresponding panel as quickly as possible. The left foot only allows stepping on the two left panels (front and side) and the right foot only the two right panels (front and side). Participants stand with their feet 10 cm apart and in line with the two side panels. In this study, a total number of 12 trials with 4 practice trials were conducted and the average value of the 8 formal trials was taken as the outcome from the CSRT test. A picture illustrating the settings and apparatus was attached in Appendix H.

Fear of Falling Fear of falling (FF) is an important psychological factor that is reported by older fallers and frail individuals. There appears to be no clear definition and agreement of fear of falling among researchers (Greenberg, 2012). The original definition refers to a phobic reaction to standing or walking due to concerns about falling (Bhala, O'Donnell, & Thoppil, 1982). The application of such definition is usually restricted to those with sever balance problems. Recently, the definition of fear of falling has been more related to "self-efficacy and confidence" while conducting daily activities (Yardley et al., 2005). The Falls Efficacy Scale-International (FES-I) is a widely administered tool to measure the level of concern regarding falls during physical activities in everyday life (Greenberg, 2012). The FES-I uses a 4-point Likert scale ranging from 1 (not at all concerned) to 4 (very concerned) to assess the level of concern regarding possibilities of falling while performing daily activities (e.g., taking a bath or shower). It has excellent internal validity (Cronbach's alpha = .96) as well as good test-retest reliability (*ICC* = .96) in its original version (Yardley et al., 2005). In the past decade, it has been translated into various languages, among which, the Chinese version of FES-I was validated by Kwan and colleagues among 399 community-dwelling Chinese older adults aged from 61 to 93 years. Results demonstrated that the Chinese version of FES-I has good overall structure and measurement properties in terms of internal consistency (*r* = .94), test-retest reliability (*ICC* = .89), and inter-rater reliability (*ICC* = .95) (Kwan, Tsang, Close, & Lord, 2013).

The standard test procedures for secondary outcomes were outlined in Appendix H.

Data Analysis

Means and standard deviations were presented for all data. The independent variables (IVs) were Group [i.e., ExBP, TC, and CON] and Time (pre-test, mid-term test, post-test, follow-up test). Dependent variables (DVs) were the parameters reflecting balance abilities from both physiological and psychological perspectives, which were divided into primary and secondary outcome parameters. The primary outcomes were the composite of balance parameters including the fall risk score in fall risk test (FRT), overall stability index (OSI), Anterior-Posterior stability index (APSI) and Medium-Lateral stability index (MLSI) in postural stability test (PST), overall direction control (score) and completion time (s) in the limits of stability test (LOS), sway index in the modified clinical test of sensory integration and balance (m-CTSIB) (i.e., compromised vision, compromised somatosensation, and compromised vision and somatosensation). The secondary outcomes were the composite of balance-related parameters including time (s) to finish 8ft up and go test (UG), number (rep.) of 30s chair stand test (CS), distance (cm) in chair sit-and-reach test (SR), steps (number) in 2min Step test, response time (ms) in choice stepping response test (CSRT), and scores for fear of falling (FF).

The primary parameters were analyzed using an intention-to-treat approach. Therefore, all the qualified participants (n = 61) were included into analysis, and a sensitivity test was conducted using the available data afterwards. All missing data were replaced using the Last Observation Carried Forward (LOCF) method. For the secondary parameters, the per-protocol analysis was conducted using the available data. Statistically significance level was set at $p < .05$. All the data were analyzed using Statistical Package for Social Science (SPSS) version 22.0 (IBM, Chicago, IL).

Group Differences in Changes from Pre-test to Mid-test, Post-test, and Follow-up test

A one-way ANCOVA with the baseline value as a covariate was conducted at mid-test, post-test, and follow-up test to determine Group effect for each outcome parameter. Subsequently, the differences between ExBP vs. CON and ExBP vs. TC were analyzed through planned contrasts. The effect size *r* was calculated manually by $r = \text{sqrt}\ [t^2/(t^2 + df)]$. According to Cohen (1988), $r = .10$, .30, and .50 represent the small, medium and large effects.

Time Effect in each Treatment Condition

A one-way repeated measure ANOVA was applied to each group to show the change(s) of each outcome parameter across the four time points (i.e., pre-test, mid-term test, and post-test, and follow-up test). Whenever there were violations in the sphericity assumption, the Greenhouse-Geisser correction was used if epsilon < .75 or the Huynh-Feldt if epsilon > .75 (Girden, 1992). Post hoc analysis with Bofferoni correction was carried out to explore the difference between pre-test vs. mid-test, pre-test vs. post-test, and post-test vs. follow-up test. Mean difference with 95% confidence interval (95% CI) are reported.

This study was conducted according to the international Good Clinical Practice Guideline. Ethical approvals were sought from the Hong Kong Baptist University research ethics committee.

All participants in this study were assumed to be truthful in responding to the balance intervention and usual physical activity. Participants have the right to drop out at any time during this study, and were informed of this option during the intervention briefing.

CHAPTER 5 - RESULTS

The results chapter includes four sections: 1) participant flow and adherence, 2) demographic and clinical characteristics of the study population, 3) training effects on primary and secondary outcomes, and 4) summary of the key findings.

Participant Flow and Adherence

A total of 129 older adults were screened for eligibility, of which 69 older adults were confirmed to meet the eligibility criteria. Eight older adults were further excluded from this study given they had time conflict with intervention arrangement. Finally, 61 older adults were randomly assigned into three groups: ExBP group (n = 20), TC group (n = 20), and CON group (n = 21). Recruitment was started in January, 2014 and ended in early March, 2014. Screening tests and grouping of participants were conducted one week prior to the intervention and training. The intervention and training lasted for 16 weeks (17^{th}, March ~ 6^{th}, July), with 8 weeks follow-up (7^{th}, July ~ 31^{th}, August). Six participants dropped out at the beginning of intervention and training (in the first two weeks; three in each group). The main reasons of drop-out through self-report included low confidence to master exercise skills (two participants), and time inconvenience (four participants). For the remaining participants, attendance rates were high (ExBP: means = 92.1% and TC: means = 88.5%). The main reason for being absent from training classes was travelling inconvenience due to rainy weather. The rainy season in Hong Kong is normally between April to September with particularly heavy rain during May and June. Considering the potential weather influence on the attendance rate, the exercise venue was situated in a public place, which is quite near to participants' residential areas. However, results demonstrated that heavy rain and slippery floor were the main obstacles for older adults in engaging in outdoor activities.

No adverse effect was found in both ExBP group and Tai Chi group during training and testing process. According to participants' self-report of falling occurrence during the intervention and the follow-up period, three participants in the CON group individually reported a fall in the follow-up period, and one participant reported two falls in the middle and at the end of intervention. Reasons for falling included slippery floors in the bathroom or toilet (n = 2), missing a step when walking downstairs due to carelessness (n = 2), and being knocked down by a passerby in a restaurant (n = 1).

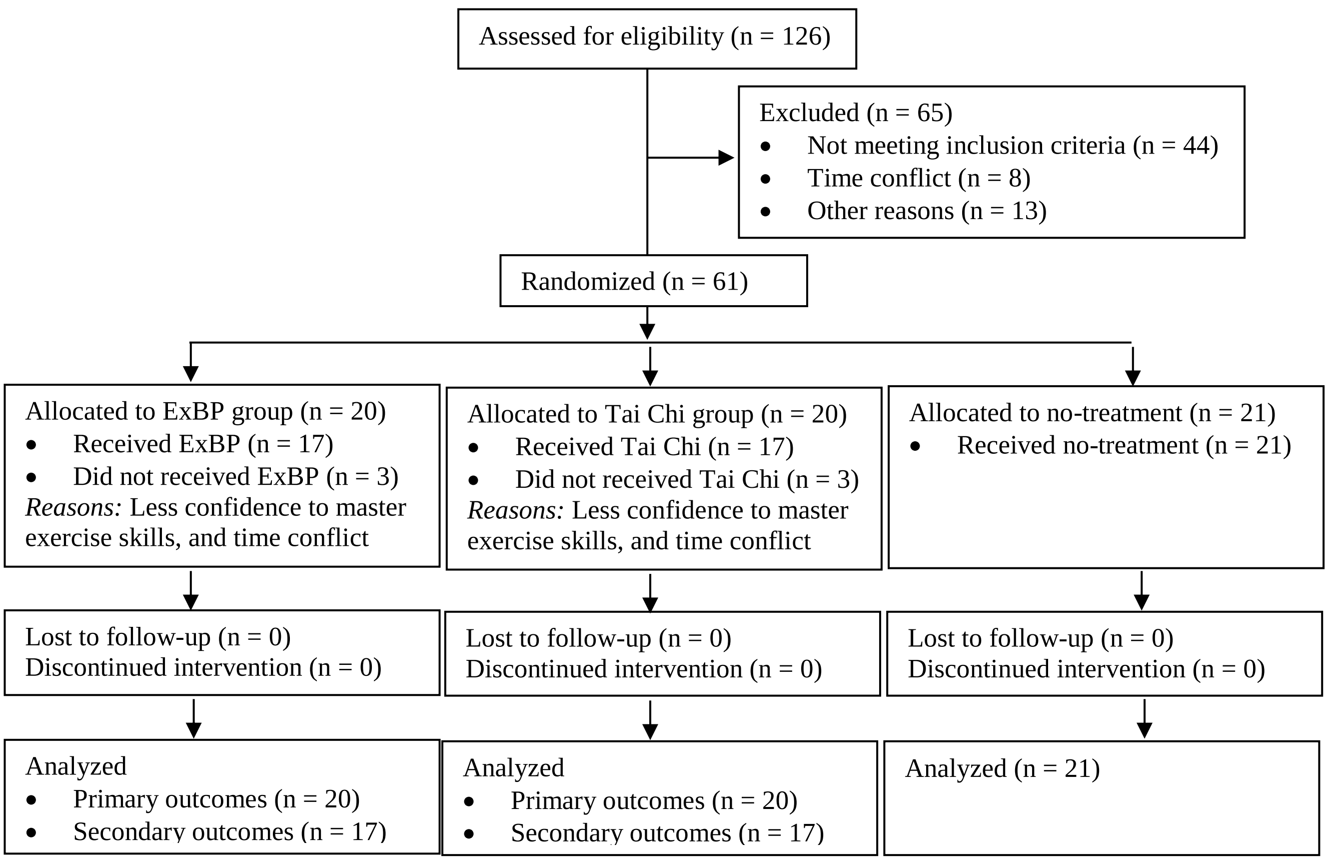


Figure 5.1. Participants Flow

Demographic and Clinical Characteristics of Study Population

Participants had an average age of 69.6 years (SD = 3.4). There was a high percentage of females in this study (ExBP = 65%, TC = 70%, and CON = 71%, respectively). Most participants were educated (84%). For those 10 participants who were not able to read and write, testers had read the questions out and assisted them to complete the questionnaires. Nearly 80% participants reported taking regular exercise in their daily lives, which mainly included walking and stretching, with duration over 30 minutes per session and over three times per week. The relative high frequency and long duration in participating in exercise reflected that the older adults believed exercise could benefit to their heath. However, the limited exercise options might be related to various chronic diseases of the participants, such as thrombus, gout, diabetes, and hypertension. About 85% participants perceived their health conditions as not good enough. The most reported symptoms were cataract, presbyopia, gout, arthralgia, tinnitus, gout, and arthralgia, making them to be higher risk of falling. Detailed information about participants' demographic and clinical characteristics was presented in Table 5.1.

Table 5.1.

Baseline demographic and clinical characteristics for each group

	ExBP (n = 20)	TC (n = 20)	CON (n = 21)
Age (years)	68.8(3.0)	70.2(3.9)	69.9(3.3)
Female (%)	13(65%)	14(70%)	15(71.4%)
Height (cm)	156.9(10.8)	156.0(6.0)	156.4(6.9)
Weight (kg)	58.5(9.5)	61.1(9.9)	56.5(8.8)
%BF	25.8(9.7)	30.3(6.2)	28.7(8.5)
Blood pressure			
SBP (mmHg)	124.2(17.9)	130.2(18.2)	134.4(17.2)
DBP (mmHg)	70.1(10.5)	68.9(8.5)	67.0(16.1)
Resting HR (beat/minute)	77.7(15.8)	77.8(13.1)	75.9(12.9)
Education background			
Illiteracy	0	3(15%)	7(33%)
Primary school or equivalent	8(40%)	10(50%)	10(48%)
High school or equivalent	11(50%)	6(30%)	4(19%)
College/University or equivalent	1(5%)	1(5%)	0
Living alone	7(35%)	5(25%)	4(19%)
Exercise habits			
Frequency			
0 (times/week)	5(25%)	7(35%)	2(10%)
1-2 (times/week)	2(10%)	3(15%)	0

3-4 (times/week)	7(35%)	3(15%)	7(33%)
> 5 (times/week)	6(30%)	7(35%)	12(57%)
Duration per session			
< 30min	3(20%)	3(23%)	4(19%)
30~60 min	7(47%)	8(62%)	15(71%)
>60 min	5(33%)	2(15%)	2(10%)
Main Exercise Content (multiple choices)			
Walk / Run / Hiking / Stretch exercise	6 (40%)	7 (54%)	7(37%)
Ball games (e.g., Badminton)	6 (40%)	0	2(11%)
Fitness-related Chuan (not included Tai Chi)	7 (47%)	4 (31%)	7(37%)
In-door cycling	0	2 (15%)	0
Swimming	0	1 (8%)	1 (5%)
Self-perceived physical condition			
Good	0	3(15%)	6(29%)
Fair	13(65%)	10(50%)	10(48%)
Poor	6(30%)	6(30%)	5(24%)
I have no idea	1 (5%)	1(5%)	0
Medical background			
Healthy (no pill)	5(25%)	7(35%)	10(48%)
Daily used Medicine(multiple choice)			
Thrombus related	5(33%)	0	1(5%)
Gout	0	3(23%)	6(29%)
Diabetes	1(7%)	5(38%)	2(10%)
Hypertension	7(47%)	6(46%)	6(29%)
Others	3(20%)	1(8%)	1(5%)
Body disease(multiple choice)			
Visual disease (e.g., presbyopia)	6 (30%)	13(65%)	10(48%)
Ear disease (e.g., tinnitus)	6 (30%)	4(20%)	11(52%)
Upper limb disease (e.g., periarthritis, arthralgia)	3 (15%)	4(20%)	1(5%)
Lower limb disease (e.g., gout, arthralgia)	6 (30%)	8(40%)	6(29%)
Foot disease (e.g., gout, arthralgia)	6 (30%)	4(20%)	2(10%)

Note. Data are means (SD) or numbers (%). ExBP = Exercise for improving Balance Program; TC = Tai Chi; CON = Control group. %BF = percent body fat, SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure.

Training Effects on Primary Outcomes

Fall Risk Test

Table 5.2.1.

Group differences on scores of Fall Risk Test at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted difference⁋ 95% (CI)
Pre-test					
ITT	4.86 ± 1.46	5.24 ± 1.37	--	5.29 ± 1.61	--
Sensitivity test	4.95 ± 1.56	5.29 ± 1.35	--	5.29 ± 1.76	--
Mid-test					
ITT	3.41 ± 1.82	4.60 ± 2.45	-.941 (-2.40, .52)	4.51 ± 1.93	-.82 (-.2.30, .65)
Sensitivity test	3.25 ± 1.93	4.70 ± 2.57	-1.14 (-2.80, .51)	4.37 ± 2.07	-.90 (-2.59, .80)
Post-test					
ITT	2.68 ± .91	4.19 ±2.57	-1.34 (-2.67, -.02)*	3.62 ± 1.45	-.76 (-2.10, .58)
Sensitivity test	2.38 ± .62	4.11 ± 2.53	-1.47 (-2.85, -.08)*	3.32 ± 1.37	-.67 (-2.14, .80)
Follow-up					
ITT	2.30 ±1.06	4.19 ± 2.05	-1.86 (-3.08, -.64)*	3.38 ± 1.38	-1.05 (-2.28, .19)
Sensitivity test	1.90 ± .62	4.14 ± 2.14	-2.18 (-3.47, -.88)*	3.05 ± 1.21	-1.09 (-2.43, .25)

Note. Means ± SD; **p* < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TC⁋ by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test shows a significant Group effect in the fall risk test (FRT) score, $F(2, 57) = 3.15$, $p = .05$, partial $\eta^2 = .10$. Planned contrasts revealed that the mean FRT score in ExBP group was significantly lower than the CON group, $t(57) = 2.51$, $p = .02$, $r = .32$, but was similar with the TC group, $t(57) = 1.39$, $p > .05$, $r = .18$. These findings demonstrate that ExBP is effective in increasing dynamic balance in the target group, and ExBP and TC have similar effect on the FRT score immediately after 16-week of intervention and training. Results at mid-test show no significant Group effect, $F(2, 57) = 1.48$, $p = .24$, partial $\eta^2 = .05$, indicating that neither the ExBP nor the TC be able to increase dynamic balance within the 12-week training period. Results at follow-up test found significant Group difference, $F(2, 57) = 7.11$, $p = .002$, partial $\eta^2 = .20$. Planned contrasts revealed that the FRT score in ExBP group was significantly lower than that of CON group, $t(57) = 3.77$, $p < .0005$, $r = .45$, and that of TC group, $t(57) = 2.09$, $p = .041$, $r = .27$. Table 5.2.1 presents the detailed FRT scores for each group. Results from the sensitivity test on the available data were consistent with the results from ITT analysis.

Table 5.2.2. *Changes in the scores of Fall Risk Test within each group*

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	1.45 (30%)*	.36~2.55	2.18 (45%)*	1.16~3.19	.39 (14%)*	.13~.64
TC	.79 (15%)	.36~1.93	1.68 (32%)*	.77~2.58	2.35 (7%)	-.90~1.37
CON	.65 (12%)	.83~2.13	1.06 (20%)	-.55~2.67	-.01 (1%)	1.86~1.85

Note. $^*p < .05$

There was a significant Time effect on the FRT score in ExBP group, $F(1.99, 37.8) = 22.7$, $p < .0005$, partial $\eta^2 = .55$ and the TC group, $F(2.19, 41.7) = 8.32$, $p = .001$, partial $\eta^2 = .304$; but not in the CON group, $F(3, 60) = 1.69$, $p > .05$, partial $\eta^2 = .08$. Pairwise comparisons revealed a 30% decrease in the FRT score from pre-test to mid-test ($p < .05$) and a 45% decrease from pre-test to post-test, indicating that ExBP can improve dynamic balance and reduce risk of falls after 12-week and 16-week training periods, and that longer training period of ExBP would be more beneficial. Compared with TC group, a training effect of ExBP was higher both in the mid-test (30% vs. 15%) and the post-test (45% vs. 32%). The significant decrease of FRT score from post-test to follow-up test in ExBP group indicates a good sustainability of training effect in ExBP group (14%, $p < .05$). The overall trends on the FRT score for each group are illustrated in Figure 5.2. Results from the sensitivity test on the available data were in line with the results from ITT analysis.

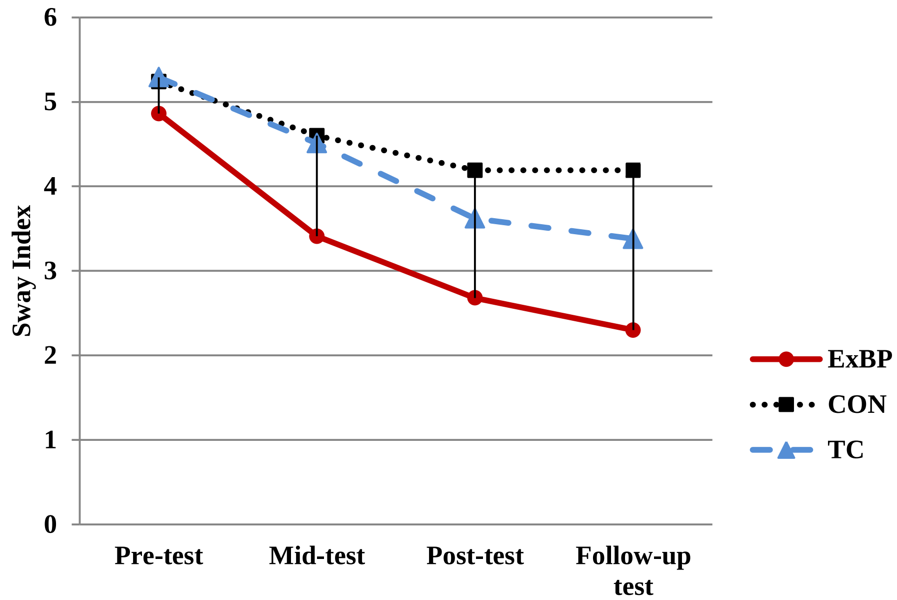


Figure 5.2. Changes in the scores of Fall Risk Test across four time points

Postural Stability Test

Table 5.3.1.

Group differences in the Postural Stability Test at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted difference⌖ 95% (CI)
Overall Stability Index (OSI)					
Pre-test					
ITT	1.27 ± .70	1.17 ± .50	--	1.28 ± .65	--
Sensitivity test	1.28 ± .77	1.16 ± .49	--	1.28 ± .71	--
Mid-test					
ITT	.88 ± .39	.87 ± .32	.004 (-.37, .36)	1.08 ± .64	-.21 (-.57, .16)
Sensitivity test	.81 ± .39	.91 ± .30	-.10 (.16, .90)	1.05 ± .70	-.24 (-.65, .18)
Post-test					
ITT	.82 ± .52	1.02 ± .43	-.22 (-.56, 12)	.84 ± .34	-.02 (-.36, .32)
Sensitivity test	.74 ± .55	1.03 ± .43	-.30 (-.66, .07)	.76 ± .31	-.02 (-.39, .36)
Follow-up					
ITT	.87 ± .45	1.15 ± .48	-.45 (-.76, -.13)*	.75 ± .30	-.047 (-.36, .27)
Sensitivity test	.60 ± .37	1.19 ± .49	-.59 (-.91, -.27)*	.65 ± .21	-.053 (-.39, .28)

Anterior / Posterior Stability Index (APSI)					
Pre-test					
ITT	.97 ± .39	.86 ± .41	--	.72 ± .26	--
Sensitivity test	.97 ± .42	.87 ± .40	--	.69 ± .27	--
Mid-test					
ITT	.69 ± .30	.77 ± .37	-.10 (-.41, .22)	.77 ± .51	-.12 (-.44, .21)
Sensitivity test	.64 ± .30	.82 ± .37	-.18 (-.53, .17)	.75 ± .55	-.14 (-.52, .23)
Post-test					
ITT	.65 ± .47	.84 ± .37	-.21 (-.50, .09)	.58 ± .26	.05 (-.26, .35)
Sensitivity test	.60 ± .51	.85 ± .37	-.26 (-.58, .06)	.52 ± .24	.05 (-.30, .40)
Follow-up					
ITT	.53 ± .35	.84 ± .44	-.31 (-.58, -.04)*	.51 ± .42	.02 (-.27, .30)
Sensitivity test	.45 ± .33	.87 ± .46	-.42 (-.71, -.13)*	.45 ± .15	.004 (-.31, .32)
Medial / Lateral Stability Index (MLSI)					
Pre-test					
ITT	.49 ± .20	.58 ± .43	--	.85 ± .74	--
Sensitivity test	.64 ± .79	.56 ± .44	--	.90 ± .79	--
Mid-test					
ITT	.41 ± .28	.34 ± .17	.07 (-.18, .31)	.57 ± .43	-.16 (-.41, .10)
Sensitivity test	.37 ± .29	.34 ± .18	.02 (-.25, .30)	.58 ± .47	-.21 (-.49, .08)
Post-test					
ITT	.37 ± .26	.41 ± .26	-.04 (-.23, .15)	.46 ± .22	-.07 (-.27, .13)
Sensitivity test	.32 ± .26	.42 ± .26	-.10 (-.31, .11)	.44 ± .24	-.12 (-.34, .11)
Follow-up					
ITT	.41 ± .33	.59 ± .32	-.18 (-.40, .05)	.40 ± .19	.02 (-.22, .25)
Sensitivity test	.36 ± .36	.62 ± .30	-.26 (-.50, -.02) *	.38 ± .19	-.01(-.27, .24)

Note. Means ± SD *$p < .05$; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[‡] by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test showed that there was no significant Group difference on the overall stability index (OSI), $F(2, 57) = 1.55$, $p > .05$, partial $\eta^2 = .05$; anterior/posterior stability index (APSI), $F(2, 57) = 2.58$, $p > .05$, partial $\eta^2 = .08$; and medial/lateral index (MLSI), $F(2, 57) = 2.51$, $p > .05$, partial $\eta^2 = .08$. Planned contrasts did not result in any significant group difference in OSI, APSI, and MLSI (all $p > .05$). No statistically significant group differences were found at mid-test. At follow-up test, significant Group effects were found in OSI, $F(2, 57) = 7.53$, $p = .001$, partial $\eta^2 = .21$, and APSI, $F(2, 57) = 5.70$, $p = .006$, partial $\eta^2 = .17$; but not on MLSI, $F(2, 57) = 2.82$, $p > .05$, partial $\eta^2 = .09$. Compared with CON group, ExBP group had a significantly lower OSI, $t(57) = 3.52$, $p = .001$, $r = .42$, and APSI, t (57) = 2.81, $p = .007$, $r = .35$. No significant group differences were found in OSI, APSI, and MLSI between ExBP and TC groups. The detailed values for OSI, APSI, and MLSI are presented in Table 5.3.1. Results from the sensitivity test were in line with the results from the ITT analysis, except for the MLSI at follow-up test between ExBP and CON groups, ITT: t (57) = 1.97, $p = .054$, $r = .25$; Sensitivity test: t (50) = 2.69, $p = .010$, $r = .54$,

Table 5.3.2.

Changes in the Postural Stability Test within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
OSI						
ExBP	.40 (32%)	-.14~.93	.46 (36%)	-.06~.97	.12 (15%)	-.08~.31
TC	.20 (16%)	-.35~.75	.45(35%)*	.00~.89	.09 (11%)	-.13~.31
CON	.30 (25%)	-.06~.65	.14 (12%)	-.29~.58	-.12 (12%)	-.41~.16
APSI						
ExBP	.28 (29%)	-.06~.62	.32 (33%)	-.04~.67	.12 (19%)	-.07~.31
TC	-.06 (9%)	-.40~.29	.14 (20%)	-.06~.34	.07 (21%)	-.12~.25
CON	.10 (12%)	-.20~.39	.02 (23%)	-.35~.39	.01 (12%)	-.29~.30
MLSI						
ExBP	.08 (17%)	-.10~.26	.12 (25%)	-.05~.28	-.04 (11%)	-.15~.08
TC	.28 (33%)	-.27~.82	.39 (46%)	-.09~.87	.06 (13%)	-.13~.24
CON	.24 (41%)	-.07~.55	.17 (29%)	-.17~.50	-.17 (41%)	-.40~.06

Note. *$p < .05$

Results from the one-way repeated measure ANOVA in ExBP group found significant Time effect in OSI, $F(1.63, 31) = 6.59$, $p = .007$, partial $\eta^2 = .26$, and APSI, $F(2.20, 5.45) = 7.08$, $p = .002$, partial $\eta^2 = .27$. Pairwise analysis found significant difference only exist between pre-test and follow-up test (OSI: mean difference = .57, 95% CI = .08~1.07; and APSI: mean difference = .435, 95% = .12~.75). For TC group, significant Time effect was found in OSI, $F(2.22, 12.37) = 5.41$, $p = .006$, partial $\eta^2 = .222$, where mean values of OSI at post-test were significantly lower than that at pre-test. No significant Time effect was found in CON group. Results from the sensitivity test on the available data were in line with the results from ITT analysis. The overall changes in mean values of OSI, APSI, and MLSI for each group across the four time tests are illustrated in Figure 5.3.1, 5.3.2, and 5.3.3, respectively.

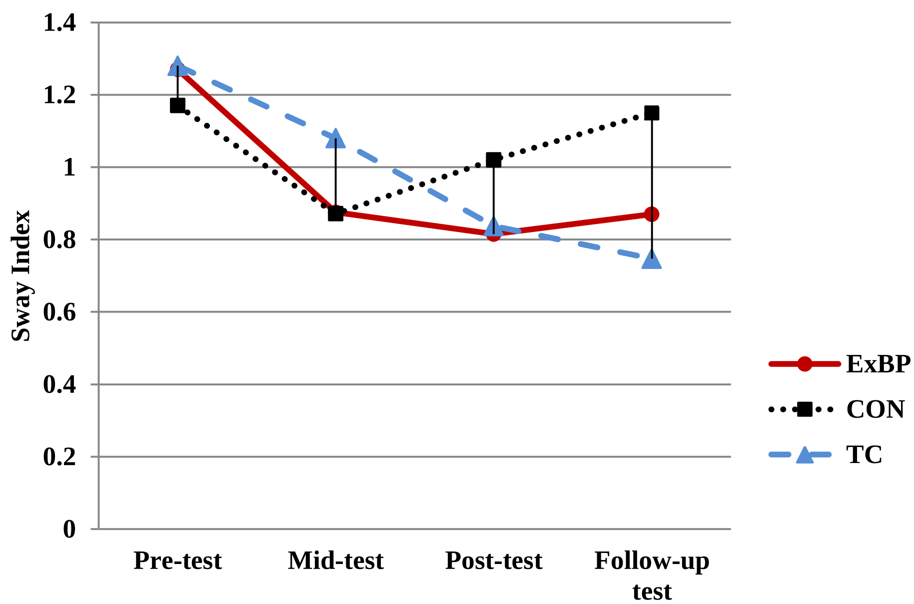


Figure 5.3.1. Changes in the Overall Stability Index in Postural Stability Test across four time points

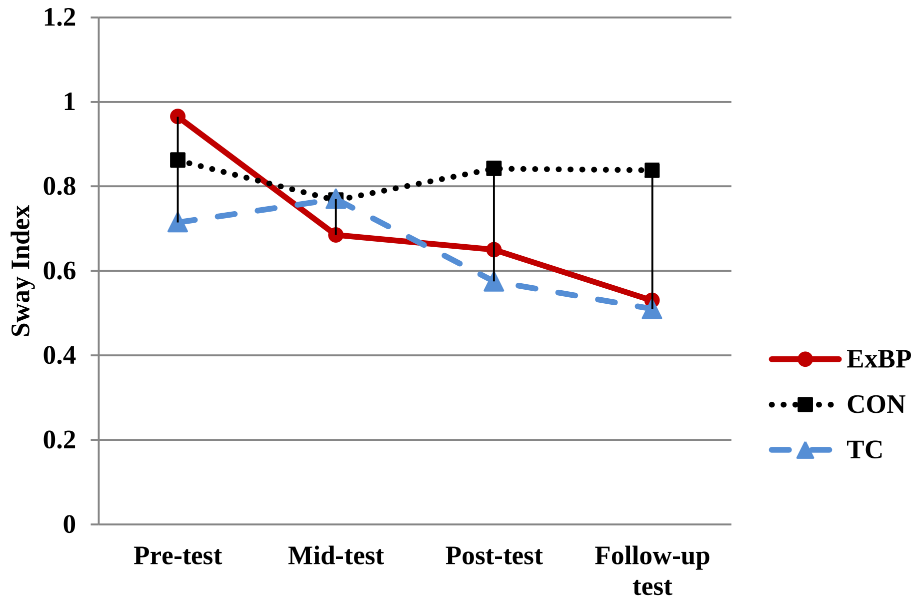


Figure 5.3.2. Changes in Anterior-Posterior Stability Index in Postural Stability Test across four time points

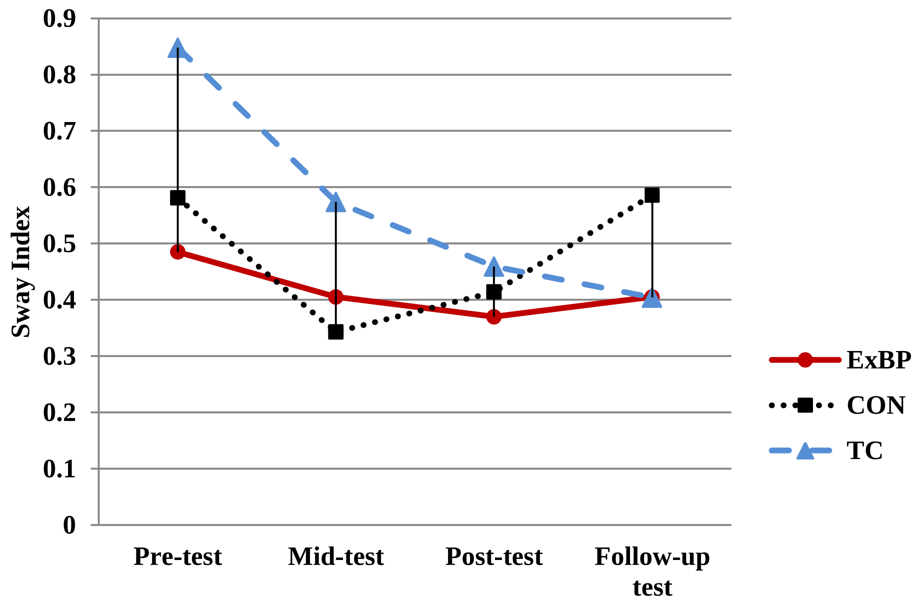


Figure 5.3.3. Changes in Medium-Lateral Stability Index in Postural Stability Test across four time points

Limits of Stability Test

Table 5.4.1.

Group differences in overall score and completion time of the Limits of Stability test at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted difference† 95% (CI)
Overall scores					
Pre-test					
ITT	29.7 ± 10.5	26.4 ± 7.39	--	23.6 ± 8.70	--
Sensitivity test	29.8 ± 11.4	26.7 ± 7.31	--	23.6 ± .9.48	--
Mid-test					
ITT	30.6 ± 9.72	27.3 ± 8.03	1.62 (-3.89, 7.12)	25.5 ± 7.28	1.94 (-3.79, 7.67)
Sensitivity test	30.9 ± 10.6	27.5 ± 7.90	1.75 (-4.19, 7.68)	25.8 ± 7.88	1.81 (-4.65, 8.27)
Post-test					
ITT	33.2 ± 9.49	26.0 ± 12.5	5.21 (-1.44, 11.9)	26.2 ± 7.40	3.30 (-3.62, 10.2)
Sensitivity test	33.9 ± 10.2	26.3 ± 12.2	5.76 (-1.37, 12.9)	26.7 ± 7.97	3.50 (-4.26, 11.3)
Follow-up test					
ITT	31.3 ± 8.83	22.7 ± 7.42	6.57 (1.01, 12.1)*	27.2 ± 10.4	.248 (-5.53, 6.02)
Sensitivity test	31.7 ± 9.57	23.4 ± 8.03	6.26 (.157, 12.4)*	27.9 ± 11.2	-.163 (-6.80, 6.48)
Completion time					
Pre-test					
ITT	64.2 ±20.6	78.3 ± 27.1	--	79.5 ± 13.8	--
Sensitivity test	64.2 ± 22.4	78.0 ± 26.5	--	79.8 ± 15.0	--
Mid-test					
ITT	63.5 ± 17.5	74.6 ± 16.8	-5.37 (-17.5, 6.72)	76.0 ± 17.7	-6.23 (-18.5, 6.08)
Sensitivity test	63.4 ± 19.0	74.4 ± 16.4	-5.41 (-18.5, 7.65)	75.6 ± 19.3	-5.85 (-19.8, 8.08)
Post-test					
ITT	59.4 ± 17.0	78.6 ± 32.7	-10.5 (-27.0, 5.90)	72.1 ± 19.6	-3.30 (-20.0, 13.4)
Sensitivity test	58.5 ± 18.3	78.0 ± 32.1	-10.9 (-28.6, 6.81)	70.1 ± 21.1	-2.87 (-21.8, 16.0)
Follow-up test					
ITT	60.1 ± 14.5	80.1 ± 27.1	-10.3 (-26.9, 6.36)	72.7 ± 31.1	-2.06 (-19.0, 14.9)
Sensitivity test	59.4 ± 15.7	79.0 ± 26.9	-10.1 (-28.1, 7.88)	71.7 ± 33.8	-1.55 (-20.7, 17.6)

Note. Means ± SD *$p < .05$; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TC† by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test found no significant Group effect in the overall scores in LOS, $F(2, 57) = 1.89$, $p > .05$, partial $\eta^2 = .062$, and completion time, $F(2, 57) =$

1.35, $p > .05$, partial $\eta^2 = .045$. This suggests that either ExBP or TC may not be able to improve the overall direction control within a 16-week training period. Additionally, no significant group difference was found at mid-test. At follow-up test, there was a significant Group effect for overall LOS scores, F (2, 57) = 5.64, $p = .006$, partial $\eta^2 = .17$, but not for the completion time, F (2, 57) = 1.36, $p > .05$, partial $\eta^2 = .05$. Planned contrast revealed that overall LOS scores in ExBP group were higher than that in CON group, $t(57) = -2.92$, $p = .005$, $r = .36$, but were similar to that of TC group, $t(57) = -.11$, $p > .05$, $r = .01$. The detailed values are presented in Table 5.4.1. Results from the sensitivity test on the available data were in line with the results from ITT analysis.

Table 5.4.2.

Changes in overall score and completion time of the Limits of Stability test within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
Scores						
ExBP	-.90 (3%)	-6.48~4.68	-3.50 (12%)	-9.26~2.26	1.95 (6%)	-1.78~5.68
TC	-1.9 (8%)	-6.72~2.92	-2.6 (11%)	-7.85~2.65	-1.05 (4%)	-5.81~3.71
CON	-.86 (3%)	-6.43~4.72	.43 (2%)	-6.25~7.11	3.33 (13%)	-2.61~9.27
Time						
ExBP	.70 (1%)	-7.23~8.63	4.85 (8%)	-6.01~15.7	-.70 (1%)	-5.72~4.32
TC	3.55 (5%)	-6.93~14.0	7.40 (9%)	-4.72~19.5	-.55 (1%)	-11.6~13.5
CON	3.71 (5%)	-13.6~21	-.29 (0%)	-18.5~17.9	-1.4 (2%)	-13.6~10.8

Note. *$p < .05$

Results from one-way repeated measure ANOVA for each group revealed no significant Time effect ($p > .05$). Although there was no statistical significance, the overall scores and completion time represented around 10% of improvements at post-test for both ExBP and TC groups, with not much change between post-test and follow-up test. The overall trends for the changes of scores and completion time in each group are illustrated in Figure 5.4.1 and Figure

5.4.2, respectively. Results from the sensitivity test based on the available data were consistent with the results from ITT analysis.

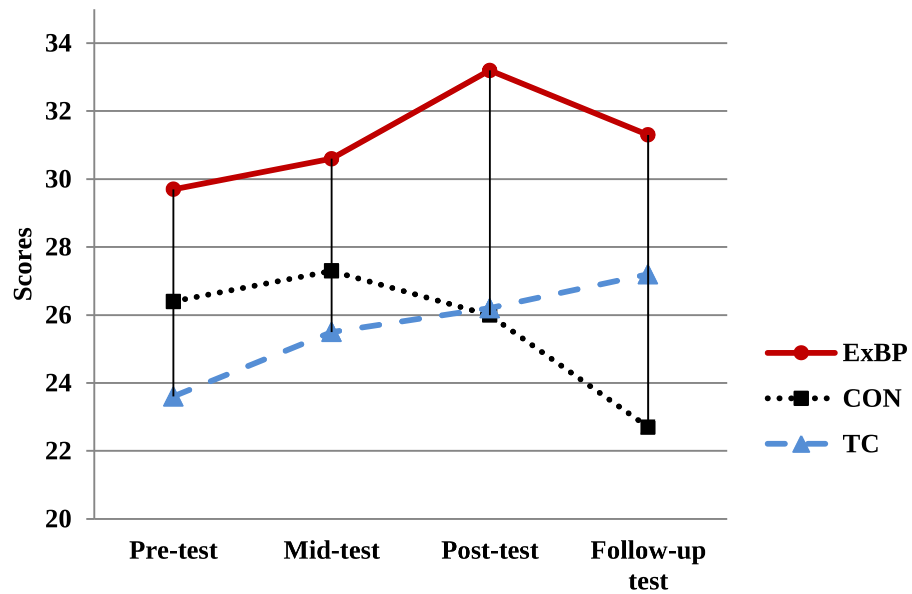


Figure 5.4.1. Changes in overall score in Limits of Stability Test across four time points

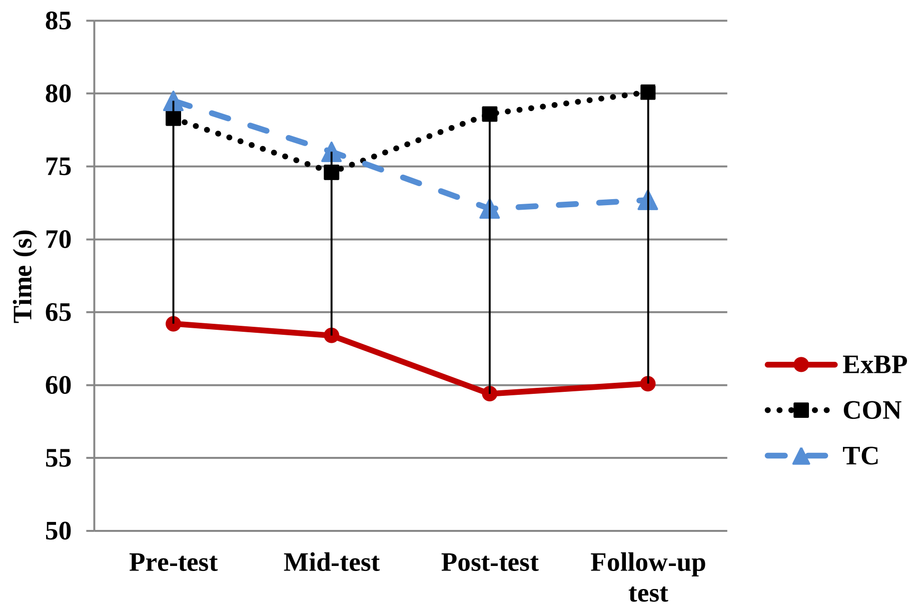


Figure 5.4.2. Changes in completion time in the Limits of Stability Test across four time points

Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB)

Static balance with compromised vision

Table 5.5.1.

Group difference in the sway index in m-CTSIB with compromised vision at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted differenceΦ 95% (CI)
Pre-test					
ITT	1.20 ± .30	1.24 ± .32	--	1.25 ± .35	--
Sensitivity test	1.20 ± .27	1.21 ± .35	--	1.25 ± .38	--
Mid-test					
ITT	1.15 ± .31	1.16 ± .46	0 (-.29, .29)	1.19 ± .35	-.03 (-.32, .26)
Sensitivity test	1.14 ± .33	1.13 ± .46	.01 (-.31, .32)	1.18 ± .38	-.03 (-.36, .31)
Post-test					
ITT	1.11 ± .40	1.08 ± .39	.06 (-.20, .31)	1.10 ± .33	.04 (-.21, .30)
Sensitivity test	1.10 ± .43	1.06 ± .40	.04 (-.23, .31)	1.07 ± .35	.06 (-.23, .35)
Follow-up test					
ITT	1.06 ± .38	1.10 ± .28	-.11 (-.37, .15)	1.10 ± .28	-.03 (-.29, .23)
Sensitivity test	1.04 ± .41	1.16 ± .36	-.11 (-.39, .17)	1.08 ± .29	-.03 (-.32, .27)

Note. Means ± SD *p < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TCΦ by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA revealed no significant Group effect at post-test, $F(2, 57) = .16$, $p > 05$, partial $\eta^2 = .01$; mid-term test, $F(2, 57) = .04$, $p > .05$, partial $\eta^2 = .001$; and follow-up test, $F(2, 57) = .58$, $p > .05$, partial $\eta^2 = .02$. Planned contrast also found no significant group difference. Results from the sensitivity test on the available data were in line with the results from ITT analysis.

Table 5.5.2.

Changes in the sway index of m-CTSIB with compromised vision within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	.05 (4%)	-.20~.30	.09 (7%)	-.14~.32	.05 (4%)	-.22~.31
TC	.06 (5%)	-.17~.29	.15 (12%)	-.07~.37	-.01 (1%)	-.20~.19
CON	.09 (7%)	-.28~.45	.16 (13%)	-.07~.39	-.10 (9%)	-.36~.16

Note. *$p < .05$

Results from the one-way repeated measure ANOVA showed no statistically significant changes among each groups at the four time points (all $p > .05$). However, just as the Figure 5.5 shows, the mean trend for the sway index of each group demonstrate substantial decreases during the intervention and training, ExBP group was the only group demonstrated a continuous decrease in the follow-up test. Means of sway index for TC and CON groups began to increase after post-test. These were consistent with the results from the sensitivity test based on available data.

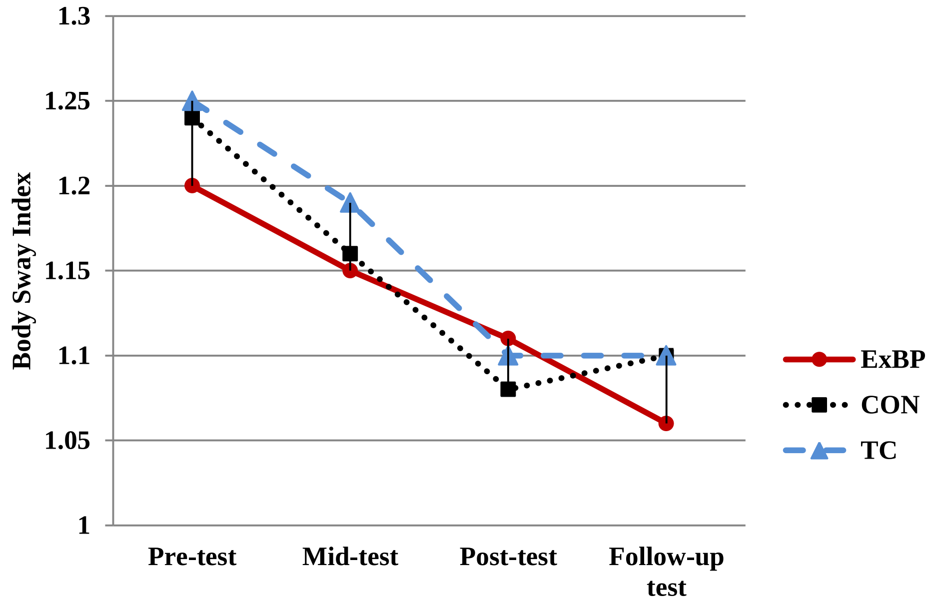


Figure 5.5. Changes in the sway index in m-CTSIB with compromised vision across four time points

Static balance with compromised somatosensation

Table 5.6.1.

Group differences in the sway index in m-CTSIB with compromised somatosensation at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted differenceᶲ 95% (CI)
Pre-test					
ITT	1.61 ± .74	1.84 ± .77	--	1.78 ± .53	--
Sensitivity test	1.61 ± .81	1.81 ± .77	--	1.78 ± .58	--
Mid-test					
ITT	1.42 ± .43	1.81 ± .71	-.30 (-.67, .07)	1.71 ± .46	-.22 (-.60, .15)
Sensitivity test	1.38 ± .46	1.79 ± .71	-.32 (-.72, .08)	1.70 ± .51	-.24 (-.67, .18)
Post-test					
ITT	1.37 ± .38	1.82 ± .70	-.40 (-.77, -.03)*	1.62 ± .53	-.18 (-.55, .19)
Sensitivity test	1.33 ± .40	1.84 ± .70	-.42 (-.82, -.03)*	1.60 ± .57	-.19 (-.61, .23)
Follow-up test					
ITT	1.26 ± .35	1.76 ± .73	-.47 (-.86, -.07)*	1.48 ± .35	-.20 (-.60, .20)
Sensitivity test	1.18 ± .34	1.76 ± .73	-.55 (-.99, -.11)*	1.43 ± .35	-.22 (-.68, .24)

Note. Means ± SD *$p < .05$; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[ᶲ] by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA revealed a significant Group effect at post-test, $F(2, 57) = 3.66$, $p > .05$, partial $\eta^2 = .11$. Planned contrasts revealed that the sway index in ExBP group was significantly lower than that of CON group, $t(57) = 2.70$, $p = .009$, $r = .33$, but was similar to that of TC group, $t(57) = 1.20$, $p > .05$, $r = .40$. These demonstrate that ExBP is effective in increasing static balance with compromised somatosensation, and ExBP may have similar training effect as TC on static balance with compromised somatosensation immediately after a 16-week intervention and training. No significant Group effect was found at mid-test, $F(2, 57) = 2.11$, $p > .05$, partial $\eta^2 = .069$. At follow-up test, there was a significant Group effect in the sway index, $F(2, 57) = 4.31$, $p = .018$, partial $\eta^2 = .13$. Planned contrasts found that the sway index in ExBP group was significantly lower than that of CON group, $t(57) = 2.92$, $p = .005$, $r = .36$, but similar to that of TC, $t(57) = 1.23$, $p > .05$, $r = .16$. The detailed sway indices of the three groups are illustrated in Table 5.6.1. Results from the sensitivity analysis on the available data were in line with the results from the ITT analysis.

Table 5.6.2.

Changes in sway index in m-CTSIB with compromised somatosensation within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	.19 (12%)	-.31~.70	.24 (15%)	-.25~.72	.11 (8%)	-.05~.27
TC	.07 (4%)	-.36~.49	.15 (9%)	-.28~.59	.14 (9%)	-.26~.55
CON	.03 (2%)	-.23~.28	-.03 (2%)	-.28~.21	.12 (6%)	-.50~.73

*Note. *p < .05*

Results from the repeated measure ANOVA in each group did not find any significant differences in the sway index across the four time points. However, just as Figure 5.6 illustrates, the means of the sway index in both the ExBP and TC demonstrate a continuous decrease from pre-test to follow-up, while not much change was found in the CON group. This suggests that either the ExBP or TC could be helpful in increasing the static balance with compromised somatosensation.

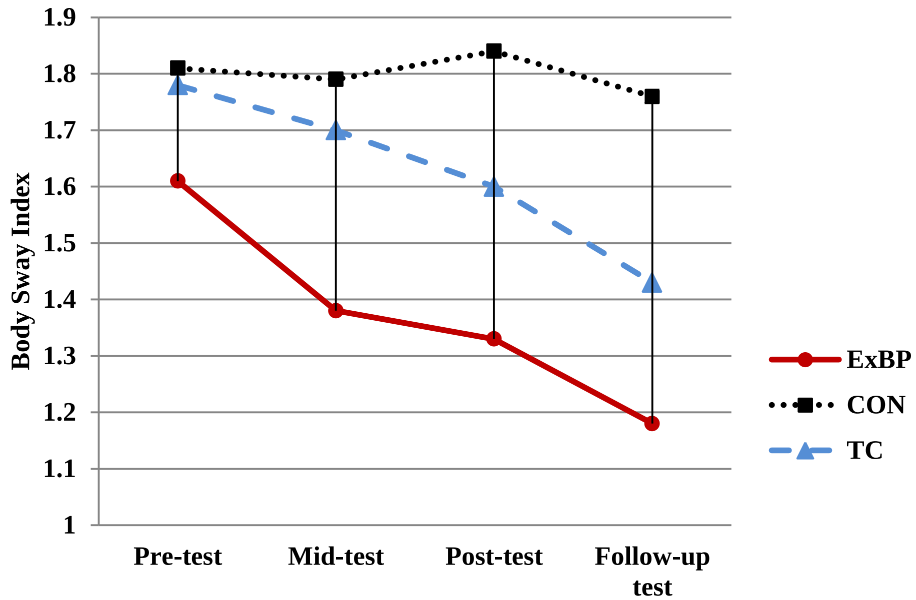


Figure 5.6. Changes in the sway index in m-CTSIB with compromised somatosensation across four time points

Static balance with compromised vision and somatosensation

Table 5.7.1.

Group difference in the sway index of m-CTSIB with compromised vision and somatosensation at each time point

Tests	ExBP (n = 20)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 20)	Adjusted difference⌖ 95% (CI)
Pre-test					
ITT	4.04 ± 1.18	4.05 ± 1.04	--	4.49 ± 1.41	--
Sensitivity test	4.05 ± 1.16	4.01 ± 1.03	--	4.49 ± 1.54	--
Mid-test					
ITT	4.08 ± .990	4.08 ± 1.03	-.19 (-.83, .45)	4.27 ± .79	-.18 (-.83, .48)
Sensitivity test	3.86 ± 1.23	4.04 ± 1.02	-.19 (-.89, .50)	4.24 ± .86	-.16 (-.91, .59)
Post-test					
ITT	3.59 ± .981	4.39 ± 1.18	-.80 (-1.47, -.13)*	4.23 ± 1.07	-.39 (-1.08, .29)
Sensitivity test	3.51 ± 1.05	4.34 ± 1.18	-.85 (-1.57, -.13)*	4.19 ± 1.16	-.43 (-1.20, .35)
Follow-up test					
ITT	3.51 ± .82	4.38 ± 1.13	-.86 (-1.53, -.19)*	4.48 ± .25	-.751 (-1.44, -.06)*

Sensitivity test	3.43 ± .89	4.33 ± 1.12	-.94 (-1.68, -.20)*	4.48 ± 1.21	-.850 (-1.64, -.06)*

Note. Means ± SD *$p < .05$; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[ǂ] by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test revealed a significant Group effect in the sway index with compromised vision and somatosensation, $F(2, 57) = 4.37$, $p = .017$, partial $\eta^2 = .13$. Planned contrasts revealed that sway index means in the ExBP group were much lower than the CON group, $t(57) = 2.96$, $p = .005$, $r = .37$, and were similar to TC group, $t(57) = 1.42$, $p > .05$, $r = .19$. This demonstrates that the ExBP program is effective in improving static balance with compromised vision and somatosensation within a 16-week training period, and the ExBP and TC may have a similar training effect on static balance with compromised vision and somatosensation as a result of the 16-week intervention. No statistically significant Group effect was found at mid-test, $F(2, 57) = .32$, $p > .05$, partial $\eta^2 = .01$. At follow-up test, there was a significant Group effect in the sway index, $F(2, 57) = 5.82$, $p = .005$, partial $\eta^2 = .17$. Planned contrasts revealed that the ExBP group showed a significantly lower sway index than the CON group, $t(57) = 3.16$, $p = .003$, $r = .37$, and TC group, $t(57) = 2.69$, $p = .009$, $r = .34$. The values for the sway index can be found in Table 5.7.1. Results from the sensitivity test on the available data were in line with results from ITT analysis.

Table 5.7.2.

Changes in the sway index in m-CTSIB with compromised vision and somatosensation within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	.16 (4%)	-.25 ~ .56	.46 (11%)*	.06 ~ .85	.08 (19%)	-.24 ~ .39
TC	.22 (5%)	-.43 ~ .87	.26 (6%)	-.42 ~ .94	-.25 (6%)	-.77 ~ .28
CON	-.03 (7%)	-.89 ~ .83	-.34 (8%)	-1.14 ~ .46	.02 (4%)	-.66 ~ .70

Note. *$p < .05$

Results from the repeated measures ANOVA revealed that a significant Time effect was only found in the ExBP group, $F(3, 57) = 7.18$, $p < .0005$, partial $\eta^2 = .27$. Sway index means show a continuous decrease from pre-test to follow-up test. The significant group difference between ExBP and CON groups, together with the non-significant difference between post-test and follow-up test (19%, $p > .05$) indicate good persistence of a training effect from the ExBP. No significant Time effect was found in TC and CON groups. The mean trends for the sway index in each group are presented in Figure 5.7. Results from sensitivity test on the available data were in line with the results from ITT analysis.

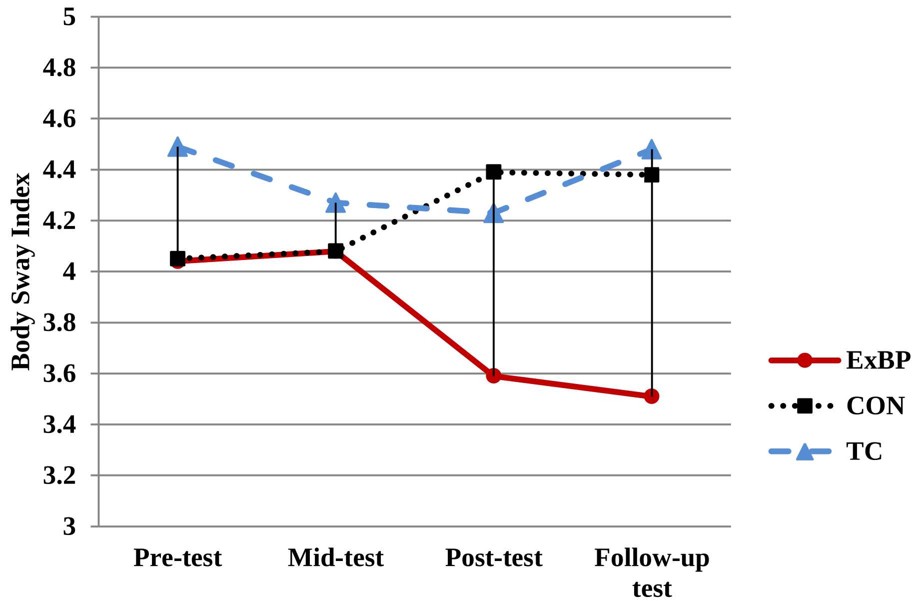


Figure 5.7. Changes in the sway index in m-CTSIB with compromised vision and somatosensation across four time points

Training Effects on Secondary Outcomes

30s Chair Stand Test

Table 5.8.1.

Group difference in 30s Chair Stand Test at each time pointt

	ExBP	CON	Adjusted difference#	TC	Adjusted difference⌖

Tests	(n = 17)	(n = 21)	95% (CI)	(n = 17)	95% (CI)
Pre-test	13.9 ± 4.29	13.5 ± 5.04	--	11.2 ± 3.36	--
Mid-test	16.1 ± 3.84	14.4 ± 3.83	1.51 (-.74, 3.77)	12.6 ± 2.87	2.15 (-.28, 4.59)
Post-test	18.5 ± 5.51	14.9 ± 3.55	3.33 (.03, 6.62)*	16.2 ± 4.54	1.06 (-2.54, 4.66)
Follow-up	17.9 ± 5.09	14.6 ± 3.70	3.05 (.04, 6.070*	14.8 ± 4.00	1.94 (-1.35, 5.23)

Note. Means ± SD *p < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TC† by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test revealed a significant Group effect in CS, $F(2, 51) = 3.51$, $p = .037$, partial $\eta^2 = .12$, and follow-up test, $F(2, 51) = 3.36$, $p = .043$, partial $\eta^2 = .12$. Planned contrasts revealed that CS means in the ExBP group were much higher than the CON group at post-test, $t(51) = -2.55$, $p = .014$, $r = .34$, and at follow-up test, $t(51) = -2.51$, $p = .015$, $r = .33$. No significant group difference was found between the ExBP and TC at post-test or follow-up test (all $p > .05$). This indicates that immediately after the intervention, the ExBP program is able to improve the muscle strength of the lower limb for the target group, and may have similar training effect to TC after a 16-week training period. There was no significant Group effect in CS at mid-test, $F(2, 50) = 2.88$, $p > .05$, partial $\eta^2 = .10$. Detailed values for CS are presented in Table 5.8.1.

Table 5.8.2.

Changes in 30s Chair Stand Test within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	-2.24 (16%)	-4.70~.23	-4.59 (33%)*	-7.48~-1.70	.53 (3%)	-.66~1.72
TC	-1.35 (12%)	-3.93~1.23	-5.00 (45%)*	-9.41~-.59	1.47 (9%)	-.12~3.06
CON	-.93 (7%)	-3.14~1.28	-1.12 (8%)	-3.35~1.12	.29 (2%)	-.64~1.21

Note. *p < .05

Results from the one-way repeated measure ANOVA found a significant Time effect in the ExBP group, $F(3, 48) = 14.4$, $p < .0005$, partial $\eta^2 = .48$, and TC group, $F(1.38, 22.1) = 10.0$, p

= .002, partial η^2 = .39, but not in CON group, F(1.72, 32.1) = 1.41, p > .05, partial η^2 = .07. Analysis from pairwise comparisons revealed significant increases in CS for both the ExBP (33%) and TC (45%) during the intervention, as Figure 5.8 shows. The non-significant difference between post-test and follow-up test in either the ExBP group (3%) or TC group (9%), suggest that a training effect from either the ExBP or TC can be maintained for at least 8 weeks immediately after intervention.

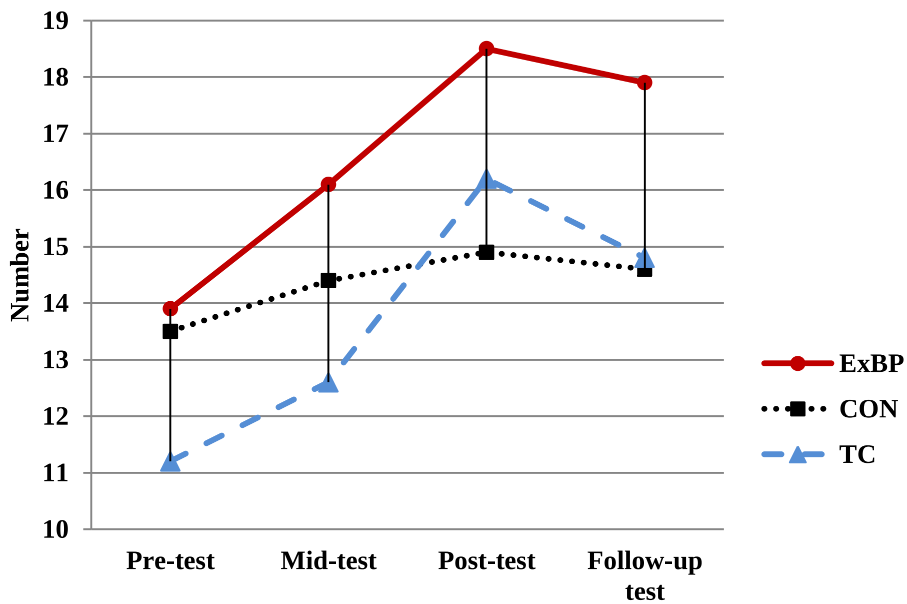


Figure 5.8. Changes of 30s Chair Stand Test across four time points

Chair Sit-and-Reach Test

Table 5.9.1.

Group difference in Chair Sit-and-Reach Test for each group at each time point

Tests	Tests	ExBP (n = 17)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 17)	Adjusted differenceᶲ 95% (CI)
Pre-test	Pre-	-1.29 ± 10.8	-.891 ± 12.0	--	-1.64 ± 16.4	--
Mid-test	Mid-	1.28 ± 8.81	1.87 ± 9.65	-.318 (-6.05, 5.41)	-2.15 ± 14.8	3.21 (-2.88, 9.29)
Post-test	Post-	2.90 ± 9.54	1.92 ± 9.59	1.20 (-4.51, 6.91)	2.06 ± 14.3	.561 (-5.49, 6.61)
Follow-up	Follow-up	4.19 ± 7.06	1.46 ± 9.70	2.92 (-3.13, 8.960	2.05 ± 14.3	1.80 (-4.60, 8.21)

Note. Means ± SD *$p < .05$; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[ǂ] by covariance analysis adjusted for baseline value.

There was no significant Group effect in SR at post-test, $F(2, 51) = .137$, $p > .05$, partial $\eta^2 = .005$, follow-up test, $F(2, 51) = .712$, $p > .05$, partial $\eta^2 = .027$, and mid-test, $F(2, 52) = 1.33$, $p > .05$, partial $\eta^2 = .049$. Planned contrasts revealed no significant difference between the ExBP and the CON group or between the ExBP group and TC at mid-test, post-test and follow-up test (all $p > .05$). CS values for each group at each test can be found in Table 5.9.1.

Table 5.9.2.*Changes in Chair Sit-and-Reach Test for each group*

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	-1.64 (100%)	-7.00~3.70	-4.12 (100%)*	-8.22~-.02	1.29 (45%)	-7.99~5.41
TC	.51(31%)	-5.75~6.77	-3.70(100%)	-10.8~3.37	-.09 (44%)	-5.48~5.30
CON	-2.76 (100%)	-8.10~.89	-2.81(100%)	-8.27~2.65	.46 (24%)	-2.85~3.78

Note. *$p < .05$

Results from the repeated measure ANOVA in the ExBP group found a significant Time effect, $F(3, 45) = 3.10$, $p = .036$, partial $\eta^2 = .17$. Post-hoc analysis revealed a significant increase between pre-test to post-test (mean difference = 4.12 cm), and this increase continued as measured at follow-up (mean difference = 1.29). This suggests that the ExBP could be helpful in improving the flexibility of the lower limbs and that a longer training period would be more beneficial for the target group. No significant Time effect was found in the CON group, $F(1.86, 39.1) = 1.55$, $p = .226$, partial $\eta^2 = .069$, or the TC group, $F(3, 48) = 2.80$, $p = .05$, partial $\eta^2 = .15$. The overall trends for each group are illustrated in Figure 5.9.

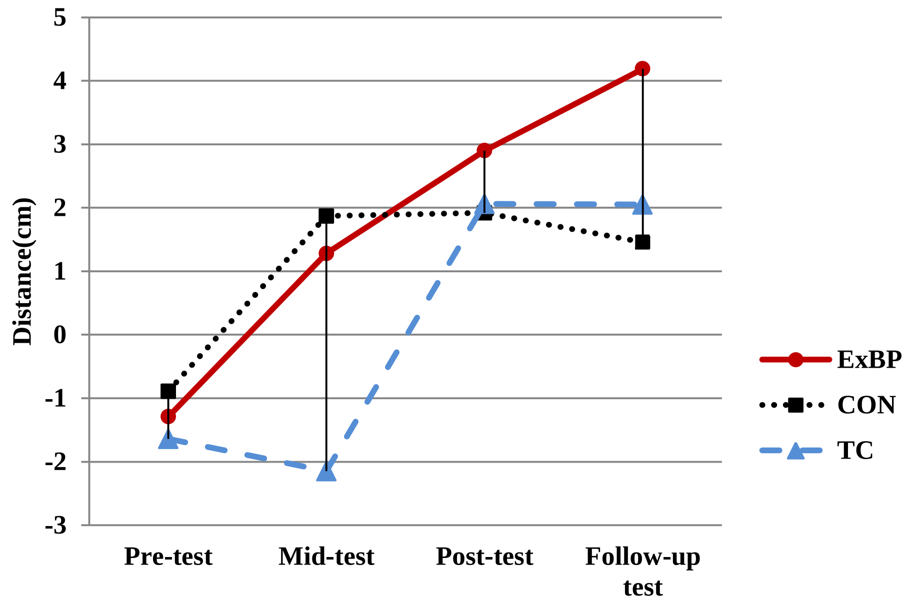


Figure 5.9. Changes in the distance in Chair Sit-and-Reach Test across four time points

The 8ft Up and Go Test

Table 5.10.1.

Group differences on the 8ft Up and Go Test for each group at each time point

Tests	ExBP (n = 17)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 17)	Adjusted difference⌖ 95% (CI)
Pre-test	7.16 ± 1.36	7.38 ± 1.42	--	7.52 ± 1.95	--
Mid-test	5.99 ± 1.03	7.30 ± .98	-1.12 (-1.92, -.32)*	6.78 ± 1.81	-.58 (-1.42, .26)
Post-test	5.96 ± .77	7.01 ± .91	-.90 (-1.64, -.16)*	6.52 ± 1.53	-.42 (-1.20, .36)
Follow-up	5.85 ± .86	7.05 ± 1.22	-1.04 (-1.81, .27)*	6.40 ± 1.39	-.37 (-1.18, .44)

Note. Means ± SD **p* < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TC⌖ by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test showed a significant Group effect in UG, $F(2, 51) = 4.55$, $p = .015$, partial $\eta^2 = .15$; mid-test, $F(2, 51) = 5.99$, $p = .005$, partial $\eta^2 = .19$; and follow-up test, $F(2, 51) = 5.88$, $p = .005$, partial $\eta^2 = .19$. Planned contrasts at each time point revealed that UG in the ExBP group was significantly lower than in the CON group at post-test, $t(51) = 3.00$, $p = .004$, $r = .40$, mid-test, $t(51) = 3.46$, $p = .001$, $r = .45$, and follow-up test, $t(51) = 3.35$, $p = .002$, $r = .43$. No significant group difference was found between the ExBP and the TC groups at each time test. This indicate that the ExBP is effective in improving mobility and dynamic balance within a 12-week and 16-week training period, and that training effects as a result of the ExBP and TC were similar within the limited period. UG values for each group can be found in Table 5.10.1.

Table 5.10.2.

Changes in 8ft Up and Go Test within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	1.16 (16%)*	.04~2.29	1.20 (17%)*	.20~2.20	.10 (2%)	-.22~.42
TC	.75 (10%)*	.10~1.39	1.00 (14%)	-.09~2.09	1.26 (18%)	-.50~.75
CON	.08 (11%)	-.66~.83	.38 (5%)	-.34~1.09	-.04 (1%)	-.35~2.67

Note. *$p < .05$

Results from the repeated measures ANOVA in the ExBP group revealed a significant Time effect in UG, $F(3, 48) = 8.04$, $p < .0005$, partial $\eta^2 = .33$. Analysis from pairwise comparison showed a continuous decrease in UG mean time from pre-test to post-test ($p < .05$), and no significant difference was found between post-test and follow-up test (mean difference = .10). For the TC group, the Time effect was also significant, $F(3, 48) = 4.67$, $p = .006$, partial $\eta^2 = .23$. The mid-test UG values were significantly lower than at pre-test (mean difference = .75). Post hoc analysis in the ExBP and TC groups found no significant difference between post-test and follow-up test, as showed in Figure 5.10. No significant Time effect was found in the CON group.

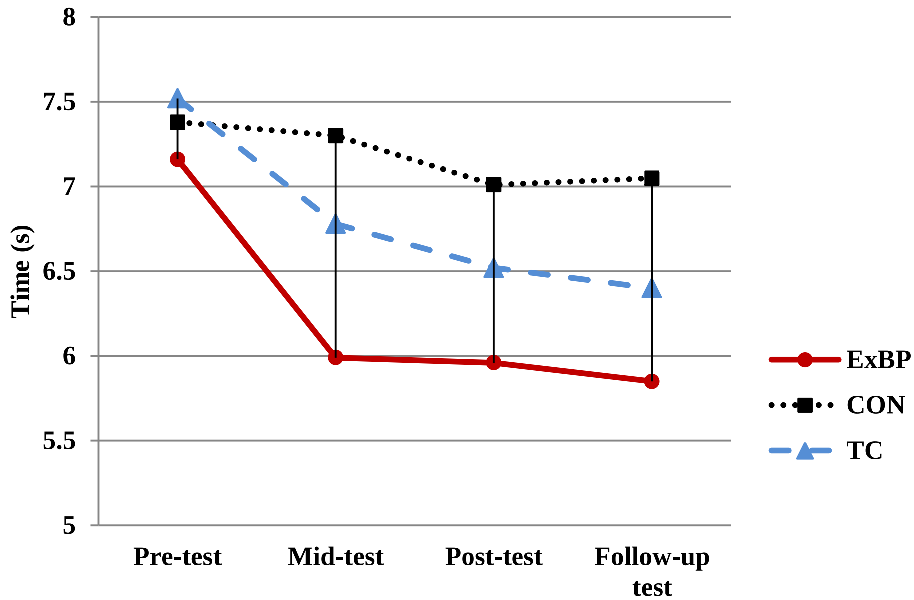


Figure 5.10. Changes in 8ft Up and Go Test across four time points

The 2min Step Test

Table 5.11.1.

Group difference in the 2min Step Test at each time point

Tests	ExBP (n = 17)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 17)	Adjusted difference⸸ 95% (CI)
Pre-test	84.2 ± 17.3	79.0 ± 24.0	--	72.4 ± 18.9	--
Mid-test	87.1 ± 20.0	75.8 ± 17.5	9.69 (-3.39, 22.8)	69.0 ± 13.9	14.4 (.25, 28.6)*
Post-test	94.0 ± 15.4	76.9 ± 20.3	15.8 (1.81, 29.9)*	76.5 ± 18.6	13.7 (1.46, 25.9)*
Follow-up	92.6 ± 16.1	80.3 ± 14.5	10.6 (-.62, 21.9)*	76.5 ± 15.6	12.4 (.19, 24.6)*

Note. Means ± SD *p < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[⸸] by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA revealed significant Group effect at post-test, $F(2, 51) = 4.32$, $p = .019$, partial $\eta^2 = .15$; mid-test, $F(2, 51) = 3.33$, $p = .044$, partial $\eta^2 = .11$; and follow-up test, $F(2, 52) = .64$, $p = .03$, partial $\eta^2 = .13$. Planned contrasts revealed that participants receiving the ExBP completed more steps than the CON group at post-test, $t(51) = -2.80$, $p = .007$, $r = .37$, and follow-up test, $t(51) = -2.34$, $p = .023$, $r = .31$. This indicates that the

ExBP program is effective in improving aerobic endurance during a 16-week training period. In addition, there were significant group differences between the ExBP and TC groups in Step at mid-term test, $t(51) = -2.52$, $p = .015$, $r = .33$, post-test, $t(51) = -2.25$, $p = .029$, $r = .30$, and follow-up test, $t(51) = -2.51$, $p = .015$, $r = .33$. Taken together, this demonstrates that the ExBP is more effective than TC in improving aerobic endurance for the target group. Table 5.11.1 detailed the Step for each group.

Table 5.11.2.

Changes in 2min Step Test in each groups within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	-2.88 (3%)	-16.8~11.1	-9.82 (12%)	-20.3~.63	1.41 (2%)	-7.21~10.0
TC	3.35 (5%)	-13.0~20.0	-4.12 (6%)	-20.0~11.5	0	-14.7~14.7
CON	3.14 (4%)	-11.7~18.0	3.29 (4%)	-14.0~20.6	-3.00 (4%)	14.7~8.66

Note. *$p < .05$

Results from the repeated measures ANOVA in each group revealed no statistically significant differences across the four time tests for all groups ($p > .05$). However, the mean trend for Steps in the ExBP group (Figure 5.11), has demonstrated a substantial increase from pre-test to post-test (12%). This indicates that a longer training period would be necessary to determine a training effect of the ExBP on Step. No significant Time effect was found in the TC or CON groups ($p > .05$).

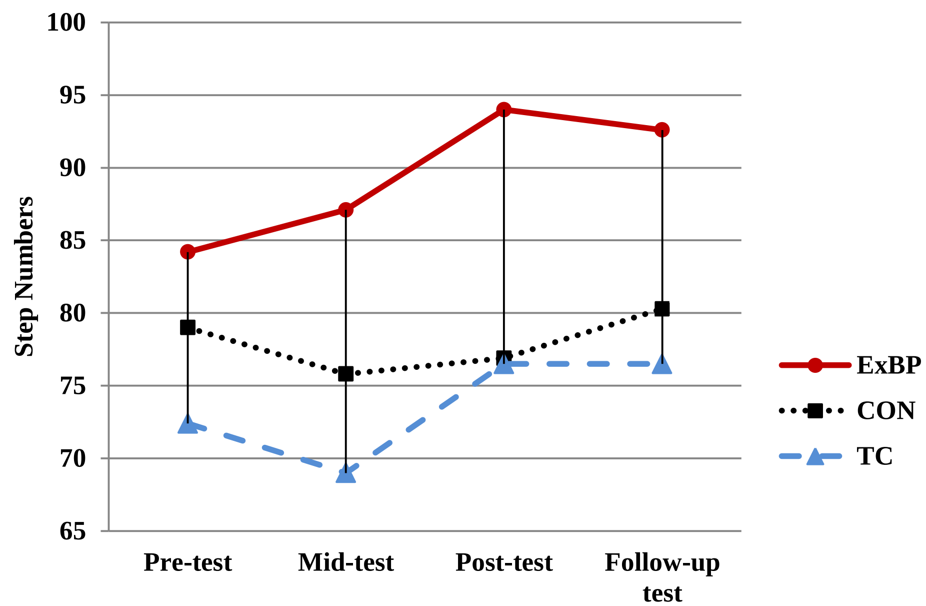


Figure 5.11. Changes in the 2min Step Test across four time points

Choice Stepping Response Time

Table 5.12.1.

Group difference in the Choice Stepping Response Time (ms) at each time test

Tests	ExBP (n = 17)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 17)	Adjusted difference⌖ 95% (CI)
Pre-test	1060 ± 144	1081 ± 420	--	1052 ± 154	--
Mid-test	1036 ± 213	1114 ± 406	-79 (-320, 162)	1099 ± 193	-62 (-318, 194)
Post-test	1028 ± 174	1076 ± 190	-43 (-177, 90)	1099 ± 178	-73 (-215, 68)
Follow-up	1006 ± 159	1066 ± 168	-56 (-175, 64)	1103 ± 154	-99 (-226, 28)

Note. Means ± SD **p* < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON[#] and of ExBP vs. TC[⌖] by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test did not find significant Group effect, $F(2, 51) = .83$, $p > .05$, partial $\eta^2 = .03$; mid-test, $F(2, 51) = .35$, $p > .05$, partial $\eta^2 = .01$; and follow-up test, $F(2, 51) = 1.85$, $p > .05$, partial $\eta^2 = .07$. Planned contrasts did not find any significant difference between groups at the four time tests. This indicates that either the ExBP or

TC may not be able to significantly improve CSRT response time within the 16-week intervention. Table 5.12.1 presents values for each group at each time test.

Table 5.12.2. *Changes in Choice Stepping Response time within each group*

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	25 (2%)	-101~150	33 (3%)	-61~127	28 (3%)	-53~96
TC	-46 (4%)	-149~56	-47 (5%)	-174~81	-4 (0)	-91~83
CON	-32 (3%)	-440~375	5 (1%)	-235~245	10 (1%)	-82~102

Note. **p* < .05

Results from the repeated measures ANOVA revealed no significant Time effect in the ExBP, TC and CON groups. Although without statistical significance, the mean trends for CSRT have demonstrated continuous decreases in response time in the ExBP group from pre-test to post-test. While for TC and CON groups, not much decline in CSRT values was found. The overall changes for the CSRT in each group are presented in Figure 5.12.

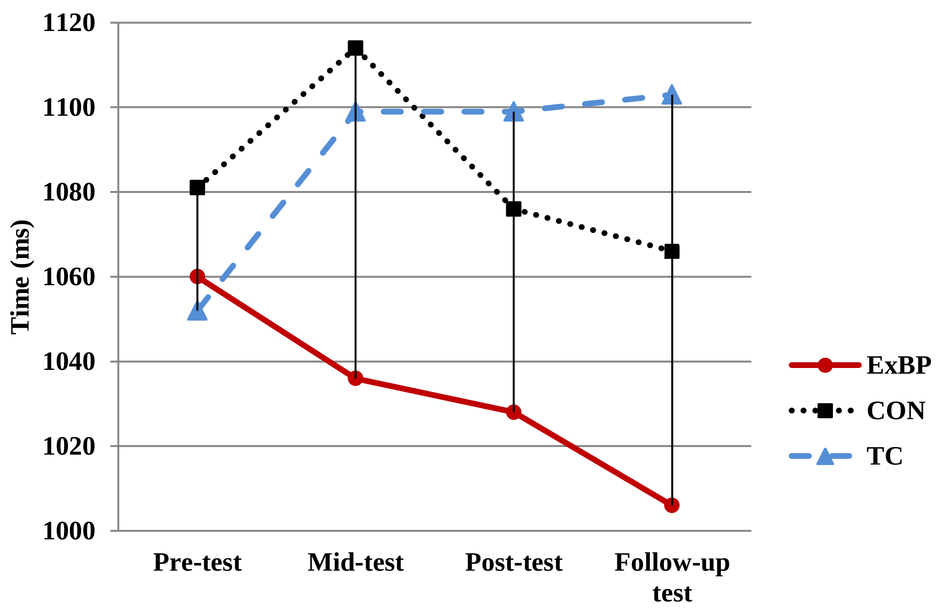


Figure 5.12. Changes of the Choice Stepping Response time across four time points

Fear of Falling

Table 5.13.1.

Group differences on Fear of Falling at each time point

Tests	ExBP (n = 17)	CON (n = 21)	Adjusted difference# 95% (CI)	TC (n = 17)	Adjusted difference⸸ 95% (CI)
Pre-test	34.6 ± 13.6	30.1 ± 13.4	--	41.5 ± 10.3	--
Mid-test	27.9 ± 12.7	26.0 ± 8.18	-1.06 (-7.64, 5.53)	28.8 ± 8.82	2.53 (-4.43, 9.49)
Post-test	26.0 ± 6.56	26.8 ± 9.04	-2.50 (-7.76, 2.75)	27.1 ± 7.62	1.33 (-4.32, 6.98)
Follow-up	21.9 ± 5.44	22.6 ± 6.62	-2.33 (-6.18, 1.53)	23.8 ± 5.61	.347 (-3.70, 4.39)

Note. Means ± SD *p < .05; Change means and 95% confidence intervals are the differences of ExBP vs. CON# and of ExBP vs. TC⸸ by covariance analysis adjusted for baseline value.

Results from the one-way ANCOVA at post-test revealed no significant Group effect, $F(2, 51) = 1.55$, $p > .05$, partial $\eta^2 = .06$; mid-test, $F(2, 51) = .81$, $p > .05$, partial $\eta^2 = .03$; and follow-up test, $F(2, 51) = 1.60$, $p > .05$, partial $\eta^2 = .06$. Given that there were significantly higher FF values in the ExBP and TC groups compared to the CON group at pre-test, $F(2, 55) = 3.89$, $p = .027$, the non-significant group difference at mid-test and post-test indicate that both ExBP and TC can be effective in reducing fear of falls within a 12 or 16-week training period. The scores for fear of falling for each group were presented in Table 5.13.1.

Table 5.13.2.

Changes in Fear of Falling within each group

Groups	Pre-test vs. Mid-test		Pre-test vs. Post-test		Post-test vs. Follow-up test	
	Difference (%)	95% CI	Difference (%)	95% CI	Difference (%)	95% CI
ExBP	6.71 (19%)*	.94~12.5	8.65 (25%)*	.52~16.8	4 (15%)*	4.35~20.9
TC	12.7 (31%)*	5.37~19.9	14.4 (35%)*	7.62~21.1	3.35 (12%)*	.44~6.27
CON	2.9 (10%)	-4.62~10.4	1.9 (6%)	-2.39~6.19	4.7 (18%)*	.69~8.71

Note. *p < .05

Results from the one-way repeated measure ANOVA in ExBP group showed significant Time effect in FF, $F(1.84, 29.4) = 11.3$, $p < .0005$, partial $\eta^2 = .41$. The mean score trend in FF demonstrates substantial decreases in FF from pre-test to mid-test (19%) and post-test (25%). The Time effect in the TC group also reach statistical significance, $F(1.75, 28.0) = 36.3$, $p < .0005$, partial $\eta^2 = .69$. The changes in FF in the TC group have demonstrated a similar trend as the ExBP group, and greater improvements than ExBP group (i.e., 31% and 35%, respectively). The significant decreases in FF mean scores between post-test and follow-up test in either the ExBP group or the TC group demonstrate a persistent training effect. For the CON group, the time effect was also significant, $F(1.84, 34.9) = 4.61$, $p = .02$, partial $\eta^2 = .20$. Post-hoc analysis revealed significant decrease in FF from pre-test to follow-up test (mean difference = 6.6) as well as from post-test to follow-up test (mean difference = 4.7).

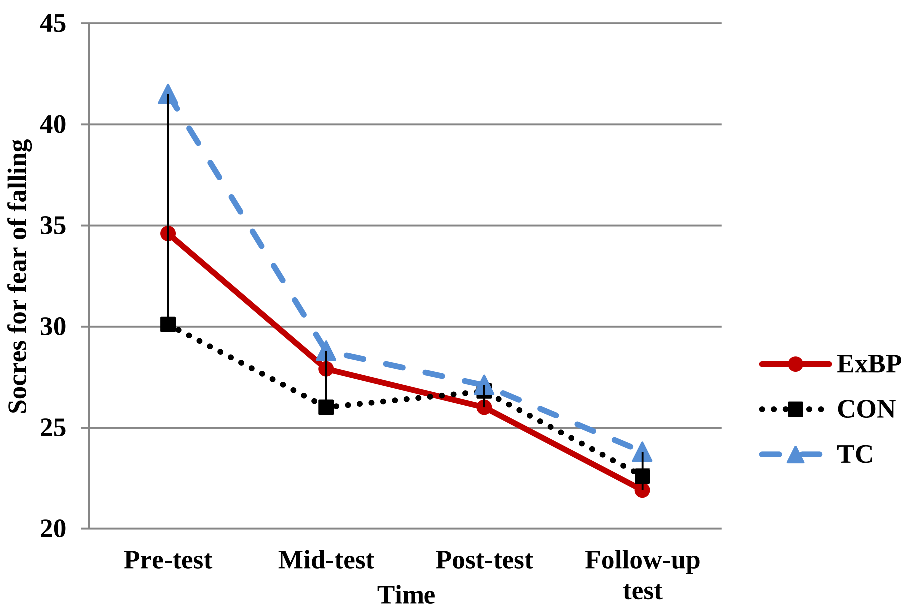


Figure 5.13. Changes in Fear of Falling across four time points

Summary of Key Findings

Table 5.14.

Summary of the key findings from this study

Testing parameters	ExBP Pre vs.Post	Mid-test ExBP vs. CON	Mid-test ExBP vs.TC	Post-test ExBP vs. CON	Post-test ExBP vs. TC	Follow-up test ExBP vs. CON	Follow-up test ExBP vs. TC
FRT	√	×	×	√	×	√	√
PST (OSI)	×	×	×	×	×	√	×
PST (APSI)	×	×	×	×	×	√	×
PST(MLSI)	×	×	×	×	×	√	×
LOS (Score)	×	×	×	×	×	√	×
LOS (Time)	×	×	×	×	×	×	×
m-CTSIB (compromised vision)	×	×	×	×	×	×	×
m-CTSIB (compromised somatosensation)	×	×	×	√	×	√	×
m-CTSIB (both)	√	×	×	√	×	√	√
CS	√	×	×	√	×	√	×
SR	√	×	×	×	×	×	×
UG	√	√	×	√	×	√	×
Step	×	×	√	√	√	√	√
CSRT	×	×	×	×	×	×	×
FF	√	√	×	√	×	×	×

Note. √ = $p < .05$; × = $p > .05$

Prior to the intervention of this study, six research questions were proposed. Based on these six questions, methods for data analysis were purposefully selected to address these questions. The following paragraphs present the key findings for each of the research questions.

Research Question 1

Would the tailor-made exercise program be effective in improving either the primary or the secondary testing parameters after intervention?

In ExBP group, the changing mean trend for each testing parameter has demonstrated improvements from pre-test to post-test. This indicates that the ExBP is able to improve balance and balance-related fitness for the target group after a 16-week training period. Through analysis of variance by controlling the pre-test values, significant differences between ExBP and CON groups were found in FRT, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, CS, UG, and Step. Additionally, analysis on FF from pre-test to post-test in ExBP group showed significant reduction of values in FF than the CON group. This demonstrates that ExBP is effective for older adults to improve dynamic balance, static balance with compromised somatosensation, static balance with compromised vision and somatosensation, muscle strength of lower limbs, mobility and dynamic balance, aerobic endurance, and fear of falling after a 16-week training period.

Research question 2

Could a training effect from this tailor-made exercise program be sustained over an 8-week follow-up period?

There were no significant differences in all testing parameters between post-test and follow-up test. However, certain testing parameters demonstrated continuous improvements during follow-up period, such as FRT, PST, m-CTSIB, SR, UG, CSRT, and FF. This suggests that a training effect from ExBP on balance and balance-related parameters can be maintained at least 8 weeks immediately after the 16-week training period.

Research question 3

Would training duration be an essential factor for exercise to improve balance and balance-related fitness among the older adults?

Compared with the CON group at mid-test, the ExBP group showed significant improvements only in UG and FF, indicating that the ExBP is effective in improving mobility and agility as well as fear of falling through a 12-week training period. For those testing parameters which continually improved during the follow-up period (i.e., FRT, PST, m-CTSIB, SR, UG, CSRT, and FF) and which have demonstrated significant group difference at follow-up testing (i.e., PST, LOS, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, CS, UG, Steps), longer training period (i.e., > 16 weeks) would be more suitable for the targeted participants.

Research question 4

Would the tailor-made exercise program be more effective than Tai Chi in improving outcome parameters after intervention?

Except for Steps, there were no significant differences among all the testing parameters between ExBP and TC groups immediately after the 16-week training period. However, improvements in FRT, APSI of PST, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, SR, UG, Step, and CSRT were all more pronounced in the ExBP group, whist the TC group demonstrated greater improvement in the MLSI of PST and FF.

Research question 5

Would the training effect occur earlier in the tailor-made exercise program than in Tai Chi?

A significant group difference between ExBP and TC at mid-test was found only in Steps. However, ExBP has demonstrated greater improvements than TC at mid-term tests on all other testing parameters, except on MLSI of PST, LOS, and FF. All this suggests that training effect from ExBP would come earlier than the TC on all testing parameters, except for static balance in the medial-lateral direction, postural control at limits of stability and fear of falling.

Research question 6

Would the maintenance of training effect be different between the tailor-made exercise program and Tai Chi throughout the follow-up period?

As evidenced from the differences between ExBP and TC on follow-up test and the changing trend during the follow-up period, reduction of any training effect from the ExBP was much less when comparing with Tai Chi on FRT, m-CTSIB with compromised vision and somatosensation, Step, and CSRT. All these suggest ExBP would have better maintenance of training effect on dynamic balance, static balance with compromised vision and somatosensation, aerobic endurance, and stepping response time.

CHAPTER 6 - DISCUSSION

The current study presented the development of a tailor-made exercise program for balance improvement, and has examined its effectiveness in improving balance and balance-related finesses in a group of older adults without history of falls but who were at the risk of falling. This chapter discussed the key findings of each research question and compared the current results with relevant findings of previous studies so as to provide the best explanation to the findings of this study.

Effectiveness of ExBP on Balance and Balance-related Fitness

The changing trends from pre-test to post-test on each testing parameter demonstrates that ExBP can improve balance and balance-related fitness among older adults with risk of falling. Compared with CON, ExBP showed significantly more improvements on fall risk test, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, chair stand test, 8ft up and go test, and 2min step test. These findings indicate that, after a 16-week training period, ExBP can effectively improve dynamic balance, static balance with compromised somatosensation, static balance with compromised vision and somatosensation, muscle strength of lower limbs, mobility and agility, aerobic endurance, and fear of falling for the target group.

Dynamic balance, defined as the ability to keep the body balanced during motion, is an essential factor in maintaining postural stability and reducing the risk of falling during daily actives, such as walking, turning, and sudden stopping during motion. As found in previous studies, the majority of falls occurred during older adults' normal and non-hazardous daily activities (Soriano, DeCherrie, & Thomas, 2007). Individuals who reported having a history of falling were found to be significantly less able in dynamic balance when compared with nonfallers (Rose et al., 2002). Given the close relationships between declining dynamic balance and increasing risks for falling, dynamic balance was recognized as an important indicator in assessing the falling risk status and predicting falls (BMS, 1999; Gusi et al., 2012). Results from the current study found that ExBP group had significantly lower values in the fall risk score, indicating that ExBP is effective in improving dynamic balance and reducing risk of falling after a 16-week training period. The underlying mechanisms for the effectiveness of ExBP come from movement properties of ExBP since a main principle in designing movements of ExBP is to challenge participants' relative positions between their base of support and center of body mass in motion. Additionally, training strategies in ExBP such as the gradually reduced BOS, continuously adjusted the COM, and postural control at the limits of stability can help to interpret the effectiveness of ExBP in improving dynamic balance. This is in line with previous studies which have demonstrated the effectiveness of these training strategies in balance improvements (Huxhold et al., 2006).

At post-test, there was no significant group difference in the Postural Stability Test, the Limits of Stability Test, the m-CTSIB with compromised vision, the Chair Sit-and-Reach Test, or the Choice Stepping Response Time.

Regarding static balance as reflected from the Postural Stability Test, there is no absolute static state for human body even while standing still. All the related balance systems are dynamically interacted with each other so as to maintain the center of body mass within the base of support (Shumway-Cook & Woollacott, 2011). Due to age-associated degradation in physical fitness, older adults often report enlarged and high-frequency spontaneous body sway (Kouzaki & Masani, 2012). However, this study did not find obvious change of body sway in the current participants, since all the participants recruited were those apparently healthy older adults, aged from 65 to 74 years, living in communities independently. The Postural Stability Test would be too simple for them to perform given this test only asks participants to stand still on a stable platform. This was in line with the results from a previous study, which indicated that it was hard to find group difference in static balance under simple conditions among older adults (Lin, Wong, Chou, Tang, & Wong, 2000). Thus, the non-significant improvement of static balance in ExBP group in comparison with the no-treatment control group can be explained by a "ceiling effect" of the Postural Stability Test. In a more complicated condition, such as static balance with deprived sensation (e.g., m-CTSIB), significant differences in body sway were found between the ExBP and CON groups.

The modified clinical test of sensory interaction on balance (m-CTSIB) is a commonly used test to assess postural stability under compromised sensations (i.e., vision, vestibular, and somatosensation). Compared with those in the no-treatment control group, participants of ExBP group showed greater improvements in m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, but not in m-CTSIB with compromised vision. Under the compromised vision, balance sensation was dominated by somatosensation. Therefore, the present results indicate that ExBP may not be able to improve static balance when somatosensation is the dominant sensation for postural control. Somatosensation contains tactile and proprioceptive sensations, and works for discerning position and movements of body segments (Hijmans et al., 2007; Waite, 1999). Altered somatosensation has been reported in people with joint diseases such as the osteoarthritis (Kavchak et al., 2012; Wylde, Palmer, Learmonth, & Dieppe, 2012). In Hong Kong, Osteoarthritis (OA) is a common medical condition among older adults, which restricts people's daily activities and impacts their quality of life in late years (Woo et al., 2003). In this study, about one-third of participants reported lower limbs joint discomfort, which may thus help to explain the non-significant between-and-within group difference in static balance with the somatosensation as the predominant balance sensory. The true training effect from ExBP on static balance with compromised vision would warrant further investigation. Moreover, additional studies are needed to assess any training effect of ExBP on somatosensation in people with OA.

The limits of stability (LOS) is defined as the maximum angle that a person can incline from the upright position in any direction without falling or altering the base of support (Clark, Iltis, Anthony, & Toews, 2005). In the Limits of Stability Test of Biodex Balance System, participants stood on a fixed support base and were required to complete the test as quickly and accurately as possible. The test demonstrated not only dynamic balance ability but also the accuracy of neuromuscular control (i.e., postural control) at the limit of stability and the speed of signal transduction plus information processing speed of the nervous system (i.e., response time). To some extent, performance on the LOS test is also dependent on the adopted movement strategies (i.e., ankle strategy and hip strategy) (Maughan, 2008; Jbadi, Boissy, & Hamel, 2008). With age-associated declines in balance capacities older adults were reported to tend to use the hip strategy rather than ankle strategy (Maughan, 2008). Although muscle synergy involved in the ankle strategy was one of the training foci of ExBP, changes in subsystems of postural control using ankle strategies cannot be interpreted at this moment given that the electromyography data is unavailable. Shortened incline angle and distance were demonstrated by the present participants. Jbabdi and colleagues in their study showed that independent older adults were only able to reach about 72% of the theoretical LOS in a forward direction and approximately 54% in a lateral direction (Jbabdi et al., 2008). Therefore, the LOS test used would be difficult for some participants even though it was reduced to 75% of the theoretical leaning maximum (mid-level of LOS) in this study. Difficulties for participants in performing the LOS test were presented at the start of this test. The majority of participants tended to touch the light spot while keeping their center of mass within the base of foot using the hip strategy. When they were guided to move their center of mass and hold body balance by using the ankle joints during the practice trials, some participants were able to finish the test quickly while other continued to demonstrate difficulties. Therefore, the non-significant between-and-within group difference on direction control could be partly explained by the relatively higher challenges of the LOS test to participants in this study. Additionally, results of the LOS test reflect the lower training effects of ExBP on postural control at the limits of base of support. Further modification on movements of ExBP should be made by emphasizing balance control at the limits of postural stability.

Response time and reactive stepping along with perception of threat are essential to avoid a fall (Lord & Fitzpatrick, 2001). Previous studies have reported delayed response time with advancing age (Gobbo et al., 2014), and even the simple finger-press response time can discriminate fallers from nonfallers in the older population (Woolley, Czaja, & Drury, 1997). Results on the Choice Stepping Response Time (CSRT) revealed no significant group difference at post-test. Only ExBP group showed a continuous decrease on the stepping time score from pre-test to post-test. This indicates that ExBP is beneficial in improving stepping response time, but the 16-week training period may still not be sufficient. In addition to extending the training period to more than 16 weeks, more speed-challenging tasks are suggested to be added into ExBP, such as increasing the repetition for leg stretching-out within certain time, increasing weight transferring frequency between two legs, and so on. Hatta and colleagues (2005) examined the difference in response time and cognitive processing between sedentary and physically active older adults, and found that older adults who insisted on regular exercise would demonstrate faster cognitive processing speed along with shorter reaction times and greater parietal sites amplitude. Therefore, adding a secondary cognitive task (e.g., doing calculation and singing a song) to exercise practice is worthwhile for improving response time in postural control.

Different opinions on the relationships between joint ROM and balance ability are still existed (Mecagni et al., 2000). Some studies hold the opinion that restricted ROM in the lower limbs would result in the deterioration of balance control (Bok et al., 2013; Chiacchiero et al., 2010; Wojcik et al., 2001). Others have found no difference in flexibility between older fallers and non-fallers (Maciaszek, 2010). Although this study is not aimed to clear the relationship between joint ROM and balance, the current results have showed no significant between-and-within group in the flexibility of the lower body even with the increase of balance performance. This indicates that, at least for the target group, the relationships between joint ROM and balance abilities still warrant further study. In addition, the non-significant between-and-within group difference in Chair Sit-and-Reach Test is understandable given the potential effects from joint discomfort among the present participants. However, only participants receiving the ExBP have demonstrated a continuous increase in flexibility, indicating that ExBP may be beneficial for lower body flexibility. However, a longer training period would be required to confirm this result.

Training Duration

Training duration, along with intensity and frequency, are the three essential factors to guarantee exercise effects. It is also the basic element for the application of physical training principles in exercise intervention, e.g., awareness, continuity, motivation, overload, periodicity, progression, and specificity (Oddsson et al., 2007). A common problem in exercise intervention is the ambiguous training duration. Depending on participants' demographic and clinical characteristics as well as training purposes, intervention duration may vary considerably. However, training duration for balance intervention is often determined according to previous related studies or is arbitrarily set to fit an available time slot. As a result of a review of studies on exercise improving balance, training duration has ranged from four weeks (Gunendi, Ozyemisci-Taskiran, & Demirsoy, 2008) to two years (Duncan & Earhart, 2014), and the commonly used is the 12-week duration (Howe et al., 2011). Since the present participants had no previous experience in Tai Chi or ExBP, a 16-week training duration including three stages was adopted. The program was divided into the Cognitive Stage (8 weeks for learning), the Associated Stage (4 weeks for mastering), and the Automatic Stage (4 weeks for strengthening). In related studies, results have usually been reported immediately after the cessation of supervised intervention, which may only contain Learning and Associated Stages. In the present study, participants received a 12-week exercise intervention under the guidance of professional trainer, following by a immediately test at the end of 12th week (i.e., mid-test). In addition, extra 4 weeks of self-practice under the supervision was added into the intervention. During this period, participants were required to practice the organized exercise program by themselves with a peer leader. If they need any guidance or assistance, the physical trainer would provide guidance and correct their movements on site. The Automatic Stage can strengthen the training effect, and allow participants to be more confident in their self-practice after the cessation of the intervention. To some extent, the continuation of practice during the follow-up period has confirmed the importance of Automatic Stage in exercise intervention.

Compared with CON group at mid-test, ExBP showed significant improvements in the 8ft up and go test and fear of falling. The 8ft up and go test (UG) is a modified version of the timed “up and go” test (Podsiadlo & Richardson, 1991), in which the distance has been reduced from 10ft to 8ft. The shorter distance is more feasible for use in a home setting (Rose et al., 2002), and has been used to discriminate between physically independent and dependent older female adults (Jones et al., 1999) as well as between fallers and non-fallers (Rose et al., 2002). In addition, this test is an effective assessment tool for dynamic balance and mobility (Herman et al., 2011; Rikli & Jones, 2012). A previous study evaluating the psychometric properties behind the timed “up and go” test has indicated that the rationales of this test were correlated with dynamic balance and mobility (Herman et al., 2011). The timed “up and go” test is quite a complex test despite its apparent simplicity. It contains multiple components associated with capacities of living-independence, such as standing up from a seated position, walking, turning, stopping and sitting down (Wall, Bell, Campbell, & Davis, 2000). Successful completion of each component involves balance abilities (Podsiadlo & Richardson, 1991). For instance, movement from sit-to-stand, from the kinematic perspective, is defined as a transitional movement to the upright posture requiring movement of the COM from a stable position to a less stable position over extended lower limbs (Vander Linden, Brunt, & McCulloch, 1994). This involves at least three stages including forward movement, acceleration, and the stabilization of the COM. In addition, the two turns during this test have been found to be challenging for older adults’ balance abilities (Nordin, Rosendahl, & Lundin-Olsson, 2006). Given the purpose of this tailor-made exercise program as well as many shared characteristics with FRT, it is easy to understand the significant group differences as demonstrated by the UG as the result of a relatively short training period.

Fear of falling is an often reported problem not only related to falling experience but also with age-associated dysfunctions (Liu-Ambrose, Khan, Eng, Lord, & McKay, 2004). Participants in the present study reported an extremely high fear of falling at pre-test (ExBP = 34.6). This was in line with lower scores on self-perceived health before intervention. At the end of the 12-week training, there was about a 20% decrease in mean scores in fear of falling (mean difference from pre-test to mid-test = 6.7, $p < .05$). This suggests that ExBP is able to reduce fear of falling after a 12-week training period. The particular characteristics of ExBP such as emphasizing postural control at the limits of stability and longer single-leg stance as well as education on how to avoid a fall and how to effectively recover from falling may be a part of a larger mechanism responsible for the significant reduction in fear of falling.

For the other testing parameters, no significant between-and-within group effects were found at mid-test; although improvements were still found at post-test. This demonstrates that exercise interventions that only cover Cognitive stage and Associated stage may not be able to generate a proper training effect among older adults. This should stimulate discussion and reflection on previous training programs which have reported non-significant training effects in balance. In addition, the need for a longer intervention period (> 16 weeks) is emphasized by testing outcomes which demonstrated continual improvements during the follow-up period (i.e., FRT, PST, m-CTSIB, SR, UG, CSRT, and FF) as well as those demonstrating significant group difference at follow-up test (i.e., PST, LOS, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, CS, UG, Step).

Differences in Training Effects between ExBP and Tai Chi after 16-week Training

Recent studies have confirmed the beneficial effects of Tai Chi on postural stability and balance control (Wu, 2002), improving functional balance (Li, Harmer, Fisher, & McAuley, 2004), reducing fear of falling (Li et al., 2005; Justina & Man, 2014), delaying the first fall (Wolf et al., 1996), and so on. However, in these studies Tai Chi was compared with no-treatment control group or education group. Whether Tai Chi is better than other well-designed balance specific programs with same training dosage has yet been confirmed (Li et al., 2005; Oddsson et al., 2007). In the current study, results demonstrated no significant difference in all the testing parameters between ExBP and TC groups at post-test, except for the 2min Step test. However, improvements on FRT, APSI of PST, m-CTSIB with compromised somatosensation, m-CTSIB with compromised vision and somatosensation, SR, UG, Step, and CSRT were all more pronounced in participants of ExBP, whereas participants of TC showed greater improvements in the MLSI of PST and FF.

In comparison with those in Tai Chi, participants in ExBP demonstrated lower mean scores in FRT at the mid-test and post-test. This indicates that participants receiving ExBP can benefit more in dynamic balance compared with those in Tai Chi group. The lower training-gains from Tai Chi is in line with results from a previous study, which found that short term practice of Tai Chi was not able to achieve tangible improvements on balance-related parameters (Li et al., 2005). The rationale behind this may do with the characteristics of Tai Chi movements. Since most Tai Chi movements are conducted in a slow and even tempo (Wolf et al., 1997), muscle power which is essential to dynamic balance cannot be sufficiently stimulated. On the contrary, most movements in ExBP are mainly emphasized with muscle power and movement speed.

Regarding the different effects on postural stability between ExBP and Tai Chi, it can be explained by the ExBP and Tai Chi movement properties. For ExBP, most movements (especially Form 6 and Form 7) are mainly performed by the continuous transfer of the COM in the anterior-posterior routine, which is beneficial to strengthening of muscle qualities of the quadriceps and hamstrings as well as the anterior-posterior compartment muscles in lower limbs. Whereas the therapeutic movements of Tai Chi are focused on the continuous changing of COM between left leg and right leg (Wolf et al., 1997), which would require more neuromuscular control on the inversion and eversion muscles of lower limbs. Therefore, the greater improvements on the APSI of ExBP group and MLSI of TC group could be explained by these movement properties. Given that the lateral instability of older adults has been reported as being more evident in those at higher risk of falling (Arnold & Schmitz, 1998), movement for strengthening medial-lateral stability should be included into a future ExBP.

Fear of falling is a common age-associated problem even in older independent community-dwellers (12-65%), and is more severe in people with falling experience (29-92%) (Patil, Uusi-Rasi, Kannus, Karinkanta, & Sievänen, 2013). In the past two decades, disagreements were occurred regarding the relationships between falls and fear of falling, causing a debate akin to the “chicken or egg” (Friedman, Munoz, West, Rubin, & Fried, 2002). Results from the present study demonstrate a significant decrease in the fear of falling for the two active groups, between which the Tai Chi group demonstrated a greater improvement. Results in the Tai Chi group were consistent with most of the previous studies, which have identified Tai Chi as the single intervention that can reduce fear of falling in older population (Li et al., 2005; Justina & Man, 2014; Wolf et al., 1996). Wu (2002) in a systematic review indicated that a high frequency short-term Tai Chi program was able to produce a positive effect on most balance-related parameters. Following this finding, a randomized controlled study found that an eight-week high-frequency Tai Chi training was able to reduce fear of falling in less robust older adults (Zhang, Ishikawa-Takata, Yamazaki, Morita, & Ohta, 2006). However, little was known about the underlying mechanisms of this finding. A study has indicated that the potential mechanism for increasing confidence of postural control was slow and repetitions of transferring center of mass during continuous motion. Another potential mechanism could be the combination of deep diaphragmatic breathing and relaxation, along with slow gentle movements within a Tai Chi program that gives the practitioner a sense of mental control that results in a reduced fear of falling" (Zhang, Ishikawa-Takata, Yamazaki, Morita, & Ohta, 2006). Thus, further studies are required to confirm the underlying relationships between Tai Chi practice and reduction in fear of falling.

Prior to the initiation of the current intervention, significant group differences were found in the baseline test (TC > ExBP > CON). Mean fear of falling scores for the three groups were all over 26, indicating that all the participants were at risk of falling (Ersoy, MacWalter, Durmus, Altay, & Baysal, 2009). This was in line with the screening tests (FRT) that demonstrated all participants were at the risk of falling. Given the large group differences in the initial levels of fear of falling, participants in the Tai Chi group demonstrated greater improvements in the fear of falling (35%) compared with those in the ExBP group (25%). These results are in line with prior research, which explained that participants with higher fear of falling at the pre-test tend to respond positively and improve after intervention (Gusi et al., 2012).

The non-significant change in the CSRT test means found in Tai Chi group is unexpected given the related evidence demonstrating the efficacy of Tai Chi in improving response time in previous studies. A comparative study between older Tai Chi practitioners and active older community-dwellers found that older Tai Chi practitioners who were with four years of experience in Tai Chi practice have better dual feet response especially in forward-backward, forward-right and forward-left directions (Wong et al., 2009). A literature review on stepping characteristics of older Tai Chi practitioners found that only a few studies achieved conclusive evidence on the effect of Tai Chi on stepping response time. Among these studies, Wu (2012) found that older Tai Chi practitioners had shorter preparation and foot contact time in stepping comparing with that of age-matched active people. As proposed by a previous study on age-associated changes in the initiation of stepping (Patla et al., 1993), older adults would have a proportionately larger increase in weight transfer time compared to reaction time. But the CSRT evaluates not only reaction time and weight transfer time (Patla et al., 1993) but also the speed and accuracy of stepping. Considering the characteristics of Tai Chi movement, such as the continuous changing of COM between both legs (Wong, Pei, Lan, Huang, Lin, & Chou, 2009), whether Tai Chi could be beneficial to the speed of step stretching-out is unknown. Thus, further studies are needed to examine the true potential effects.

Differences in Training Effects between ExBP and Tai Chi after 12-week Training

Significant group differences between ExBP and Tai Chi at mid-test were found only on the 2min Step test, which indicates that ExBP is more effective than Tai Chi on improving aerobic endurance within a 12-week training period. Given the same exercise duration and frequency between the two exercise programs, the main mechanism for interpreting this result could be the difference in exercise intensity as well as the movement properties of these two types of exercise programs.

Exercise intensity, one of the key indicators for achieving an exercise effect, is the accumulation of power output in certain time. Generally, Tai Chi is taken as a low-to-moderate exercise (Chao et al., 2014), with heart rate ranged from 110 to 130 bpm in older population (Lan, Chen, & Lai, 2004). In the present study, participants in Tai Chi group showed somewhat lower heart rate (80-95 bpm) compared to those of previous studies. The comparatively lower values in the present study may have many interpretations. As identified in a related study, the practicing speed and postural position during Tai Chi practice is of great influence to exercise intensity

(Lan, Chen, Lai, & Wong, 2013). Additionally, diverse durations of the different Tai Chi styles and heart rate testing times may cause ambiguity in Tai Chi practice. For example, Lan and colleagues in their study collected heart rate data at the last 10 seconds with a 2min interval, and found the mean heart rate of males practicing Yang-style Tai Chi was 120 bpm. However, they failed to report the Tai Chi form which was used in their study (e.g., 8-form, 24-form, or other kinds of forms) and the duration of their Tai Chi practice. In the present study, we applied the 8-form Yang style Tai Chi and asked for repeated measures over two training slots within a training session, one after the warm-up and the other after the break. Heart rate was collected at the end of each phase (i.e., warm-up, training session one, break, training session two, and cooling-down). Only the heart rate data in the last class for each training stage was taken into the calculation of the mean heart rate. Moreover, it was found that mean heart rate over continuous bouts of exercise without intervals was much higher than that from single practice. In future studies the reporting exercise intensity should be standardized by using unified measurement tools and standardized protocols.

Results have found that participants receiving ExBP showed higher mean heart rate values than those in Tai Chi group at each training stage (ExBP = 100 ~ 120 bpm; Tai Chi = 80 ~ 95 bpm). Additionally, heart rate in both groups increased from the Cognitive Stage to the Automatic Stage, indicating that exercise intensity could be increased as a result of increased familiarity and movement accuracy. This may help to explain the improvements on outcomes from mid-test to post-test and this once again confirms the importance of the Automatic Stage in an exercise intervention. Given the important role that aerobic endurance that plays in preventing falls among older adults (Maciaszek, 2010), exercise intervention in future studies should further explore the effect of aerobic endurance training.

Differences in the Maintenance of a Training Effect between ExBP and Tai Chi

There were no significant differences between post-test and follow-up test on all testing parameters, demonstrating that a training effect of ExBP on balance and balance-related abilities can persist for at least 8 weeks immediately after the 16-week training. In addition, several testing parameters were continuously improved from post-test to follow-up test, such as FRT, PST, m-CTSIB, SR, UG, CSRT, and FF. This is unexpected given that training effects would generally decrease after the cessation of intervention. However, as indicated by Howe (2012), continuation in organized exercise after intervention is recognized as an essential part of maintaining an exercise benefit. In the present study, most participants in ExBP and Tai Chi groups reported continuous practices of at least one hour sessions, twice per week. This can help interpret the persistent effects. Furthermore, spontaneous continuation in exercise can increase participants' motivation and self-efficacy in testing outcomes (Binda, Culham, & Brouwer, 2003), which could explain the continuous progress at the follow-up test. The spontaneous participation in exercise programs after intervention is in itself a good omen. As Jacobs said, only the daily act of going outdoors would be important for long-term functional and health benefits in older community-dwellers (Jacobs et al., 2008). Thus, the present results indicate the acceptance and feasibility of ExBP program as a suitable daily activity for the older adults.

According to the overall trend for each testing parameter as well as the differences between post-test and follow-up test, reduced training effect in ExBP was much lower than that in the Tai Chi on FRT, OSI of PST, m-CTSIB with compromised vision, m-CTSIB with compromised vision and somatosensation, CS, SR, CSRT, and FF. These findings indicate that the effects gains from the 16-week ExBP practice persist longer than that of Tai Chi practice on dynamic balance, static balance, static balance with compromised vision, static balance with compromised vision and somatosensation, muscle strength, flexibility of lower body, choice stepping response time, and fear of falling. A longer follow-up period may be applied in future studies to further confirm such training effect maintenance.

Implications

Results from this study have demonstrated that ExBP and Tai Chi programs can improve older adults' balance and balance-related fitness. Based on the differences on the testing parameters between ExBP group and the two control groups, it is confirmed that a tailor-made exercise program (ExBP) is more effective than the general exercise (Tai Chi) in improving balance deficits for older adults with risk of falling. In addition, the ExBP can be used as an effective exercise program to improve balance and balance-related fitness in older adults who are at risk of falling.

The positive results on testing parameters from this exercise intervention could not be obtained without the proper implementation of the physical training principles. Although physical training principles were originally proposed for elite sport, the results from this study have shown that these physical training principles with appropriate alterations could be applied to an exercise intervention for older adults. The spontaneous and high rate of the continuation of exercise after the cessation of intervention here also partly confirmed the necessity of applying physical training principles into exercise interventions.

CHAPTER 7 – CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Results from the present study support the study hypotheses. Compared to those receiving general physical activities, older adults at risk of falling can improve their balance and balance-related fitness through practicing this tailor-made balance program (i.e., ExBP) regularly for 16 weeks. Thus, the ExBP program can be applied as a substitute exercise program for improving balance and balance-related fitness among older adults who are at the risk of falling.

When comparing the 16-week training effects between the ExBP and the Tai Chi, only aerobic endurance was found significantly different. In the current study, it could be concluded that the ExBP and the Tai Chi achieved similar training effects on the testing parameters. Training effects of the ExBP and Tai Chi can persist at least 8 weeks immediately after a 16-week intervention and training. The maintenance of training effect was more pronounced in the ExBP group.

A 12-week training period which only includes exercise Learning and Associated Stages was insufficient for ExBP and Tai Chi to produce proper training effect on the majority of the testing parameters. A 16-week or longer training duration with properly applied physical training principles is necessary for exercise programs to improve balance among the target older adults.

Limitations

It is acknowledged that there are certain limitations in this study, among which the following four aspects would have more or less influence on the conduction of intervention and interpretation of results.

Firstly, there may be some potential bias in the results of this study, as it is a single-blinded study design. However, such limitation is a common problem in related exercise intervention studies since it is not possible to blind participants to their group allocation (Jones & Alfano, 2013). To reduce the effect of this potential bias, several procedures were applied in this study, including attracting all participants' attention from balance improvements to skill learning of the ExBP or Tai Chi, application of objective testing parameters (except for the fear of falling), and testing assessors were all concealed from participant's allocation.

Secondly, participants were recruited from a local senior center. To minimize any potential effect of treatment contamination between exercise groups and no-treatment control group, participants in the no-treatment control group were allowed to learn/practice the ExBP or Tai Chi immediately after the follow-up test. Any changes in lifestyles especially in physical activities were monitored and recorded on time. In addition, given the limited sample size, it should be cautious in generalizing these results to a larger population.

Finally, conducting the outdoor intervention during rainy season is also a limitation of this study. Given that the limited funding for renting indoor venue and with the consideration that older adult used to do outdoor exercise in daily life, the current intervention was conducted outside in a public area. The intervention period began in March and ended in July, 2014, which is the rainy season in Hong Kong. Although participants with severe joints disease were excluded from the study, some participants showed more or less weather-related joint discomfort (i.e., rainy weather). Therefore, training effects of the ExBP or Tai Chi would be underestimated especially on the balance abilities with somatosensation as the dominant sensation, and the flexibility of lower body. Future studies are suggested to consider weather-related potential effects on testing outcomes before the study.

Suggestions for Future Studies

Apart from the suggestions mentioned in the discussion sections, the following suggestions are proposed and summarized as a result of this study.

1. A longitudinal study is suggested for monitoring the changes of all the testing parameters for present participants as well as their falls occurrence, including the first fall, to examine the training effect on all testing parameters and the programs ability on delaying the first falling.
2. Larger sample size is suggested for studies aiming to evaluate the effectiveness and applicability of the ExBP among older adults from different cultural backgrounds and with different clinical characteristics.
3. Additional measurement tools are recommended with which to assess more specific aspects of balance and falls in order to comprehensively evaluate on this tailor-made balance program (ExBP).

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APPENDICES

Appendix A. Timeline of Exercise Intervention

Training stages	Week - Session	Form 1	Form 2	Form 3	Form 4	Form 5	Form 6	Form 7	Form 8
Cognitive process	1-1								
	1-2								
	1-3								
	2-4								
	2-5								
	2-6								
	3-7								
	3-8								
	3-9								
	4-10								
	4-11								
	4-12								
	5-13								
	5-14								
	5-15								
	6-16								
	6-17								
	6-18								
	7-19								
	7-20								
	7-21								
	8-22								
	8-23								
	8-24								
Associated process	9-25								
	9-26								
	9-27								
	10-28								
	10-29								
	10-30								
	11-31								
	11-32								
	11-33								
	12-34								
	12-35								
	12-36								
Automatic process	13-37								
	13-38								
	13-39								
	14-40								
	14-41								
	14-42								
	15-43								
	15-44								
	15-45								
	16-46								
	16-47								
	16-48								

Note: The deeper the color, the more complexity of movements and higher mastering degree.

Appendix B. Recruitment Announcements and Consent Form

Hong Kong Baptist University

(Consent Form)

You are invited to participate in a research study about "Effectiveness of a Tailor-made Exercise Program for Improving Balance of Older Adults with Low or Moderate Risk of Falls". The purpose of this study is to examine the effectiveness of a tailor-made exercise program for improving balance of older adults with low or moderate risk of falls.

INFORMATION

Sixty older adults, 65-74 years old, will be recruited for this study. You will firstly be given an assessment on your falling risk status by standing on a movable platform. The qualified participants are those who will be identified with low or moderate risk of falls, and without any illness that may not be suitable to do exercise. If you are in such condition, you will be provided with a series of tests for the control of center of mass and subsystems of balance (i.e., strength of lower extremity, agility, flexibility, leg response time, and fear of fall).

You will be randomly divided into one of the three groups, an exercise group for balance improvement, Tai Chi group, and a control group (keeping usual daily activity). Each group has less than 20 participants. Each training session is about 1.5 hours, and three sessions for each week. The total training duration lasts for 16 weeks. You are also required to report your exercise experience in the three months after intervention period.

During the whole study period, there are four times of assessments for your balance progress, in the beginning of this study (as mentioned earlier), the 12th week, the 16th week, and the end of the whole study. All these assessments are about your balance performance and risk of falls.

BENEFITS

From this study, you will get comprehensive knowledge about your balance abilities and risk of falls, as well as your physical fitness level. You will be provided with personal physical training and exercise guidance during the intervention process. This is also an opportunity for you to learn one exercise skill, either Tai Chi or the balance exercise. For those who are divided into the control group, they can choose to learn Tai Chi or this newly designed balance exercise program after the whole study immediately.

CONFIDENTIALITY

All the testing records of each participant will be filed with participant's name as the file name. All the files will be kept in the laboratory and classified as confidential. The results of the tests of all participants will be reported in aggregate terms and individual responses will not be described unless it is necessary. The subjects' personal recorded and all the files' name will be erased after the completion of the study and the testing results of each subject therefore cannot be identified.

CONTACT

If you have questions at any time about the study or the procedures, or you experience adverse effects as a result of participating in this study, you may contact Ms. Zhao Yanan, at AAB, Ninth floor, 927, HKBU, 3411 6403 (Tel) or email 11467304@hkbu.edu.hk.. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the Committee on the Use of Human and Animal Subjects in Teaching and Research by email at hasc@hkbu.edu.hk or by mail to Graduate School, Hong Kong Baptist University, Kowloon Tong, Hong Kong.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.

CONSENT

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.

Signature of the Subject ____________________________ Date ______________________

Signature of the Parent(s) / Guardian(s) ________________ Date ______________________

Signature of the Investigator __________________________ Date ______________________

香港浸會大學

（同意書）

一 研究題目與目的

您將受邀參加一項研究，題目是《運動鍛煉對長者平衡能力的影響》。此研究之目的在於檢驗運動鍛煉是否可增強長者平衡能力，從而降低長者跌倒的風險。

二 參與者

獲得本人或監護人同意書之 60名（65-74歲）長者， 男女不限。可讀、講中文。

此外，還應符合下列條件：

（1） 參加我們的跌倒風險測試，結果顯示具有一定跌倒（摔倒）風險；

（2） 沒有不適合參加運動的身體疾病；

（3） 沒有高度高血壓癥狀（高壓<160mmHg, 低壓< 90mmHg）；

（4） 過去一年中沒有專門針對平衡能力的運動訓練；

（5） 每周有一定空閑時間。

三 研究程式

符合要求的長者被隨機分為三組（20人一組），一組參加簡易太極拳運動（楊氏八式太極拳）， 一組參加有氧韻律平衡操訓練，另外一組為控制組（接受健康生活方式課程，不參加額外的運動鍛煉）。實驗時間為16周，每周3次，每次1.5個小時。在之後的3個月時間內，我們還會關註您的體力活動狀況。

此外，我們會於實驗開始前，實驗中（第12周），實驗後（第16周），以及實驗三個月後（共計4次）測量您的平衡能力和跌倒狀況。測試具體項目包括靜態平衡測試，動態平衡測試，下肢肌肉力量與爆發力測試，下肢反應速度測試，靈敏性測試，以及跌倒風險測試。

四 風險評估

存在之風險/不適. 常見有大強度運動所引起之風險/不適均有可能出現於本研究過程中。如呼吸強度大，肌肉疲勞、酸痛。但這些不適均可以得到緩和。呼吸強度過大可於運動測試結束即刻得到緩和。肌肉疲勞、酸痛可能會持續幾個小時。

風險/不適之緩和方法. 運動前適當的熱身運動以及測試後的緩和運動有助緩解存在之風險/不適。研究人員亦會於測試過程中密切觀察參加者的生理反應；同時，請參加者保持與研究人員的良好溝通，並遵守研究人員的指示。

五 緊急醫療操施

萬一於測試過程中發生身體損傷，我們會根據實驗室的緊急醫療程式進行處理。請及時報告於測試過程中發生之任何身體損傷。參加者會獲得免費的醫療保障，但不會獲得賠償。此保障將於參加者離開實驗室時失效。

六 研究效益

（1） 參加者可獲得進一步了解自身健康體能的機會；

（2） 參加者可接受專業的運動鍛煉指導；

（3） 參加者可增加身體平衡能力，降低跌倒（摔倒）風險；

（4） 參加者可習得一門運動鍛煉方式，如太極拳或有氧韻律平衡操。

七 私隱保障

所有參加者的私隱會得到保障。所有資料將只應用於本研究，並在研究結束時銷毀。

八 聯絡資料

如有任何有關此研究專案之查詢，請聯絡專案負責人趙亞楠小姐，其辦公室位於香港浸會大學，AAB 九樓927 室，電話：3411 6403。

九 參與條款

參與此研究純屬自願。參加者可在任何時間退出此研究而不需受到任何限制。但若情況允許，請盡可能參加此研究直至結束。

同意書

我已經閱讀以上所有資訊，並同意（我的被監護人）_____________參加此項研究。

本人/監護人簽署_____________ 日期________________

研究人員簽署_______________ 日期________________

Appendix C. Expert Consultation Form

Round 1

Dear ____,

We are going to design an exercise program with the purpose to *improve balance ability in a group of older adults without history of falls but who are at risk of falling*. This exercise program has been recorded into a video as attached behind for your reference. Here, we would like to get your evaluation on the following indicators about this exercise program. Please give your score in the following table according to 5-Likert Scale (1 = very weak, 2 = somewhat weak, 3 = neutral, 4 = good, 5 = excellent).

Forms	Form 1	Form 2	Form 3	Form 4	Form 5	Form 6	Form 7	Form 8	*Others*
Effectiveness									
Suitability									
Feasibility									
Others									

Please list your opinions/suggestions regarding to any movement you scored less than 4.

Form 1:____

Form 2: ____

Form 3: ____

Form 4: ____

Form 5: ____

Form 6: ____

Form 7: ____

Form 8: ____

Signature ____________

Round 2

Dear_____,

Thank you so much for your kind comments and good suggestions on the design of this exercise program for balance improvement for older adults. Below were the revisions I made according to your comments.

Revisions

Form 1:____

Form 2: ____

Form 3: ____

Form 4: ____

Form 5: ____

Form 6: ____

Form 7: ____

Form 8: ____

Please give your score in the following table according to 5-Likert Scale (1 = very weak, 2 = somewhat weak, 3 = neutral, 4 = good, 5 = excellent).

Forms	Form 1	Form 2	Form 3	Form 4	Form 5	Form 6	Form 7	Form 8	*Others*
Effectiveness									
Suitability									
Feasibility									
Others									

Finally, please give a total evaluation on this program**.** ***Pass*** ***Fail***

*Any other suggestion?*____

Signature _____________

Appendix D. Ender User Evaluation (Exit Interview)

- Please give your opinions on the suitability of this music, difficulties of movements, your confidence to finish this group of movement.
- 請將您對音樂的適合性，動作的難度，您通過學習完成這些動作的信心，動作的有趣性（您是否喜歡）四個方面做出您的評價。
- You may choose any one number from 1, 2, 3, 4, 5 to show your assessment (larger number means being more difficult or more confident etc.).
- 請從 1，2，3，4，5 數字中選取您認為最能代表您意見的數字（數字越大代表動作越難或您的信心越大或您越喜歡）。

Music 音樂	This music is ___ for exercise practice. 音樂是否適合鍛煉？ Suggestions（建議）:								
Forms	1	2	3	4	5	6	7	8	Total
Difficulty 动作难度									
Suggestion *建議*									
Confidence 完成动作的信心									
Suggestion *建議*									
Enjoyment 趣味性									
Suggestion *建議*									

Signature（簽字）__________ Date（日期）__________

Appendix E. Chinese version of Mini-Mental Status Examination (MMSE)

序 號	項 目	評	
1	今年的年份？	1	0
2	現在是什麼季節？	1	0
3	今天是幾號？	1	0
4	今天是星期幾？	1	0
5	現在是幾月份？	1	0
6	你現在在哪一省（市）？	1	0
7	你現在在哪一縣（區）？	1	0
8	你現在在哪一鄉（鎮、街道）？	1	0
9	你現在在哪一層樓上？	1	0
10	這裏是什麼地方？	1	0
11	復述：皮球	1	0
12	復述：國旗	1	0
13	復述：樹木	1	0
14	100-7 是多少？	1	0
15	93-7 是多少？	1	0
16	86-7 是多少？	1	0
17	79-7 是多少？	1	0
18	72-7 是多少？	1	0
19	回憶：皮球	1	0
20	回憶：國旗	1	0
21	回憶：樹木	1	0
22	辨認：手錶	1	0
23	辨認：鉛筆	1	0
24	復述：四十四隻獅子	1	0
25	按圖片做動作：閉眼睛	1	0
26	按口頭指令做動作：用右手拿紙	1	0
27	按口頭指令做動作：將紙對折	1	0
28	按口頭指令做動作：放在大腿上	1	0
29	說一句完整句子（含主語、動詞）	1	0
30	按樣作圖: 	1	0
		總 分：	

Appendix F. Psychosocial and Demographic Data Collection Form

Name_______ Age_____ Gender____ Contact Number______ NO.______

Part A Social life

Education background______ Living alone: Yes____, No____

Daily work or job: No__; Yes, volunteer___, house work___, taking care family member___

Part B Falls-related conditions

Fall history: Yes___/ No___ When______ Where_______ How________________

Self-report of physiological deficits (√, if any) Visual deficits________________________

Vestibular deficits_________________________ Somatosensation deficits______________

Neuromuscular deficits_____________________ Fear of fall __________________________

Part C Medical history and health status checkup

Self-perceived health status: Good__, Apparent healthy__, Bad__, Don't know__

Medicine_________________________________ Purposes____________________________

Part D Daily physical activity

Forms___________________________________ Frequency___________________________

Duration_________________________________ *Others*_______________________________

Part E Physiological parameters

Height _______ Weight ________ BMI________ Body fat (%) ________

Resting blood pressure__________________ Resting heart rate ____________________

Others ____

Appendix G. Collection Form of Primary Outcomes

Fall Risk Test Results

Name: Joe Biodex
Height: 65"-73"
Age: 85
Date: 04/25/2006 10:19 AM

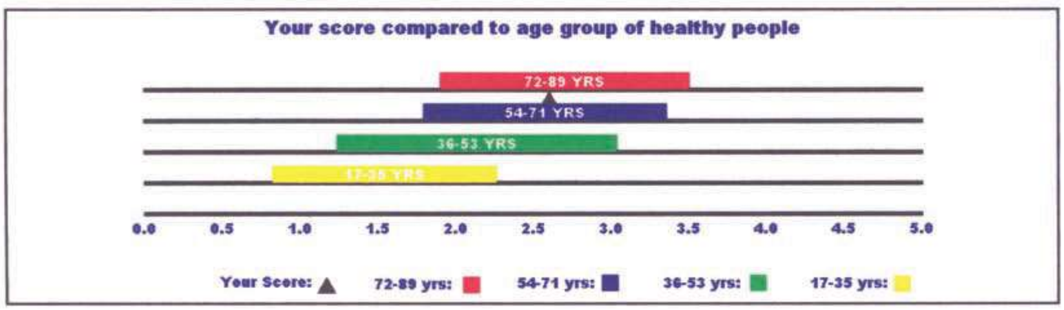
Foot Placement

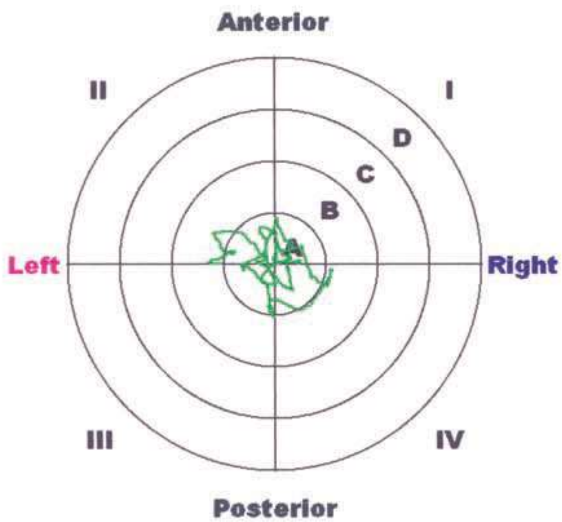
Foot Angle:
Heel Position:

Protocol

Platform Setting 8
Test Trial Time 20
Test Trials 3

	Actual Score	STD Dev.
Overall Stability Index:	2.6	1.78





Comments: ______________________________

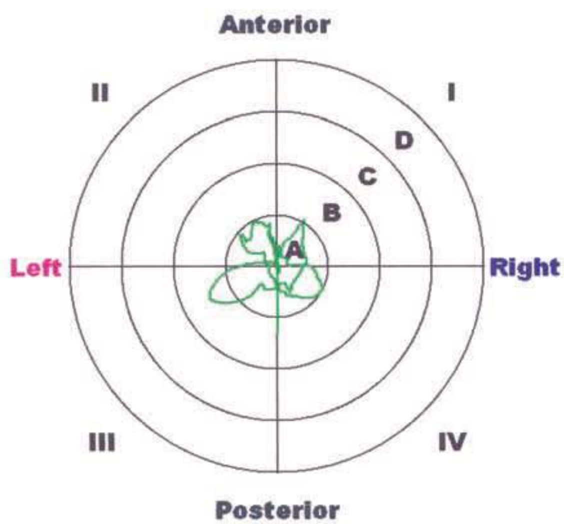
Clinician: ______________________________

Postural Stability Test Results

Name: Joe Biodex			Date: 04/25/2006 9:33 AM
Height: 65"-73"		Age: 43	
Foot Placement			Protocol
			Platform Setting STATIC
Foot Angle:			Test Trial Time 20
Heel Position:			Test Trials 3

	Actual Score	STD Dev.
Overall:	1.8	1.57
Anterior/Posterior Index:	1.3	1.34
Medial Lateral Index:	0.9	1.15

% Time in Zone:	A	95	B	5	C	0	D	0
% Time in Quadrant:	I	22	II	17	III	8	IV	53



Comments:

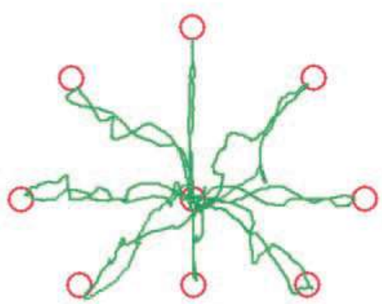
Clinician:

Limits of Stability Test Results

Name: Joe Biodex		Date: 04/25/2006 9:37 AM
Height: 65"-73"	Age: 43	
Foot Placement		Protocol
		Platform Setting STATIC
Foot Angle:		Test Trial Time -1
Heel Position:		Test Trials 3

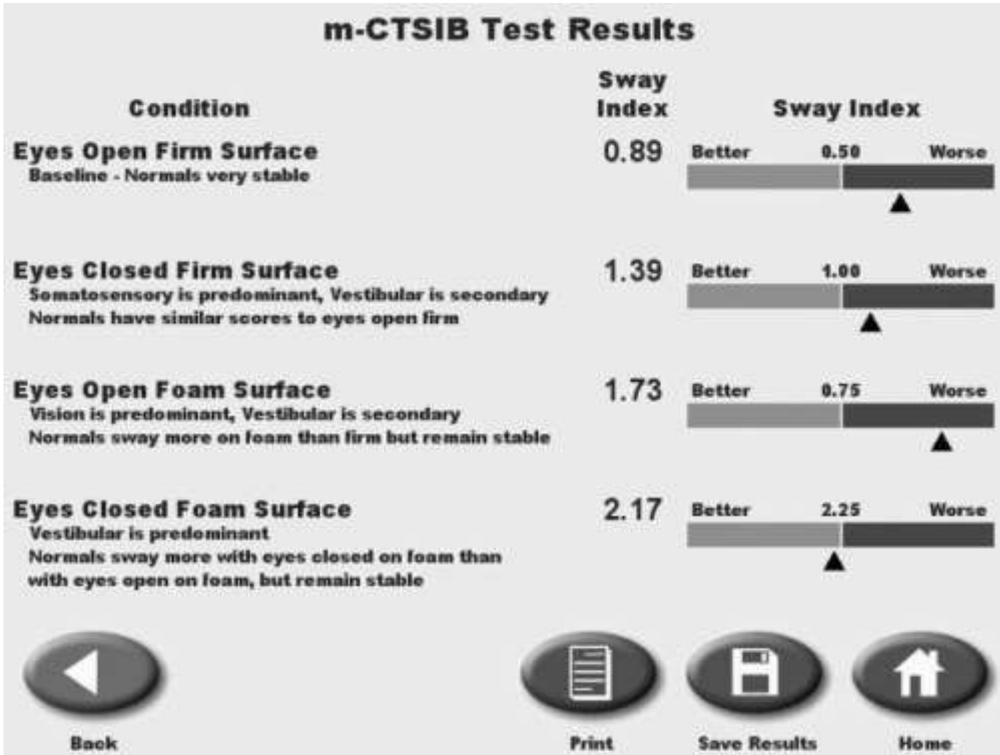
Skill level: Medium
Time to Complete Test: 59

Direction Control	Actual	Goal
Overall:	78	>65
Forward:	96	>65
Backward:	72	>30
Right:	87	>65
Left:	78	>65
Forward/Right:	73	>65
Forward/Left:	83	>65
Backward/Right:	72	>65
Backward/Left:	78	>65



Comments: ______________________________

Clinician: ______________________________


m-CTSIB Test Results
Condition
Sway Index
Sway Index
Eyes Open Firm Surface
Baseline - Normals very stable
0.89
Better 0.50 Worse
Eyes Closed Firm Surface
Somatosensory is predominant, Vestibular is secondary
Normals have similar scores to eyes open firm
1.39
Better 1.00 Worse
Eyes Open Foam Surface
Vision is predominant, Vestibular is secondary
Normals sway more on foam than firm but remain stable
1.73
Better 0.75 Worse
Eyes Closed Foam Surface
Vestibular is predominant
Normals sway more with eyes closed on foam than with eyes open on foam, but remain stable
2.17
Better 2.25 Worse
Back
Print
Save Results
Home

Appendix H. Detailed Procedures for Secondary Outcomes

30s Chair Stand Test

Equipment

A straight back or folding chair without arm rests (seat 17 inches/44 cm high), stopwatch.

Testing procedures

Place the chair against a wall, or otherwise stabilize it for safety. The subject sits in the middle of the seat, with their feet shoulder width apart, flat on the floor. The arms are to be crossed at the wrists and held close to the chest. From the sitting position, the subject stands completely up, then completely back down, and this is repeated for 30 seconds. Count the total number of complete chair stands (up and down equals one stand). If the subject has completed a full stand from the sitting position when the time is elapsed, the final stand is counted in the total.

Scoring

The score is the number of completed chair stands in 30 seconds. Below is a table showing the recommended ranges for this test based on age groups (from Jones & Rikli, 2002; see picture as below).

Chair Sit-and-Reach Test

Equipment

Ruler, straight back or folding chair (about 17 inches/44 cm high).

Testing procedures

The participant sits on the edge a chair (placed against a wall for safety). One foot must remain flat on the floor. The other leg is extended forward with the knee straight, heel on the floor, and ankle bent at 90°. Place one hand on top of the other with tips of the middle fingers even. Instruct the subject to Inhale, and then as they exhale, reach forward toward the toes by bending at the hip. Keep the back straight and head up. Avoid bouncing or quick movements, and never stretch to the point of pain. Keep the knee straight, and hold the reach for 2 seconds. The distance is measured between the tip of the fingertips and the toes. If the fingertips touch the toes then the score is zero. If they do not touch, measure the distance between the fingers and the toes (a negative score), if they overlap, measure by how much (a positive score). Perform two trials.

Scoring

The score is recorded to the nearest 1/2 inch or 1 cm as the distance reached, either a negative or positive score. Record which leg was used for measurement (Jones & Rikli, 2002; see pictures as below).

2min Step Test

Equipment

Stopwatch, tape measure, masking tape, and a tally counter.

Testing procedures

Before the test, a setup for step height is needed for accurate measurements. Participant is required to stand near the wall, and the stepping height is the middle point between the kneecap and the front hip bone. It can be determined using a tape measure or by simply stretching a piece of cord from the middle of the patella to the iliac crest, and then fold it over and marking this point in the wall. When tests start, participants should be stepping in place as many times as possible in a 2min period. Both knees should rise to the correct height, and only the times for the right knee are counted. It is allowed to rest in this period, but keep the time running. Picture below illustrated the 2min step test (Rikli & Jones, 2012).

Scoring

The score is the number of full steps completed in 2min (i.e., only the number of the times of the right knee).

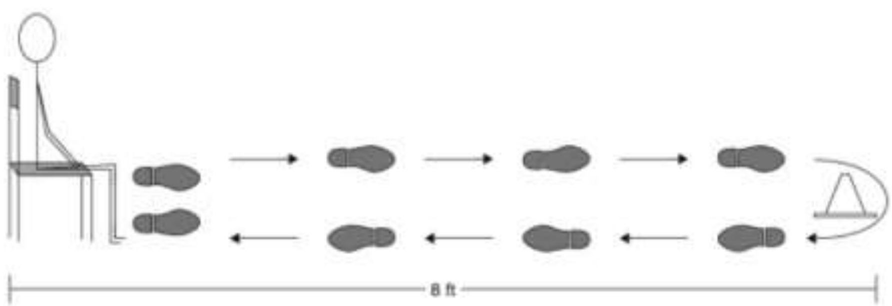
8ft Up and Go Test

Equipment

Stopwatch, straight back or folding chair (about 17 inches/44 cm high), cone marker, measuring tape, area clear of obstacles.

Testing procedures

Place the chair next to a wall (for safety) and the marker 8 feet in front of the chair. Clear the path between the chair and the marker. The subject starts fully seated, hands resting on the knees and feet flat on the ground. On the command, "Go," timing is started and the subject stands and walks (no running) as quickly as possible (and safely) to and around the cone, returning to the chair to sit down. Timing stops as they sit down. Perform two trials. Place the chair next to a wall (for safety) and the marker 8 feet in front of the chair. Clear the path between the chair and the marker. The subject starts fully seated, hands resting on the knees and feet flat on the ground. On the command, "Go," timing is started and the subject stands and walks (no running) as quickly as possible (and safely) to and around the cone, returning to the chair to sit down. Timing stops as they sit down. Perform two trials and choose the best values.

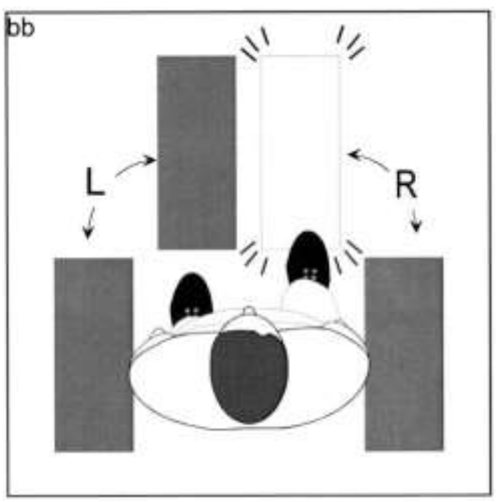


Walking routine (Rikli & Jones, 1999)

Choice Stepping Response Time Test

Equipment & Testing procedures

Subjects stood on a nonslip black platform (0.8 m × 0.8 m) that contained four rectangular panels (32 cm × 13 cm), one in front of each foot and one to the side of each foot. The panels were illuminated in a random order. Subjects were instructed to step onto the illuminated panel as quickly as possible, using the left foot only for the two left panels (front and side) and the right foot only for the two right panels. Each panel contained a pressure switch to determine the time of foot contact. Subjects stood with their feet 10 cm apart and in line with the two side panels. Subjects had between four and eight practice trials involving the four possible responses. Twenty trials were then conducted with five trials for each of the four stepping responses. All trials were included in the analysis because anticipation was not helpful in this test due to the subjects being equally likely or unlikely to predict which leg was required for each step. CSRT was measured as the time period between the illumination of a panel and the foot making contact with it, and the average time of the 20 trials was used in the analysis. The CSRT device is shown in the figure below.



Choice stepping response time (CSRT) device (Lord & Fitzpatrick, 2001)

自評跌倒關注程度量表 (Falls Efficacy Scale International – FES-I)

我們現在要問一些關於你關注自身可能跌倒的問題.

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。若是說你現在沒有在做這項活動 (如 有人 幫你買菜)，請想像你若是現在要你做這 項活動，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
1. 家居清潔	☐	☐	☐	☐
2. 穿脫衣服	☐	☐	☐	☐
3. 煮飯	☐	☐	☐	☐
4. 洗澡、淋浴	☐	☐	☐	☐
5. 買東西、購物	☐	☐	☐	☐
6. 從椅子上站起來/坐下	☐	☐	☐	☐
7. 上/落樓梯	☐	☐	☐	☐
8. 在家附近行走	☐	☐	☐	☐
9. 拿高過頭頂/撿地上的東西	☐	☐	☐	☐
10. 趕接電話	☐	☐	☐	☐
11. 走在濕滑的地面上	☐	☐	☐	☐
12. 拜訪親友	☐	☐	☐	☐
13. 在人很擠的地方走	☐	☐	☐	☐
14. 走在崎嶇不平的路上 （如 保養不善或沒鋪砌之路面）	☐	☐	☐	☐
15. 上/落斜坡	☐	☐	☐	☐
16. 出去參加活動，如去活動中心、教會	☐	☐	☐	☐
				總分:_______

Appendix I. Borg's Rating of Perceived Exertion Scale (Cantonese Version)

主觀感覺疲勞程度表

6
7 非常，非常輕
8
9 非常輕
10
11 頗輕
12
13 有些累
14
15 累
16
17 非常累
18
19 非常，非常累
20

Appendix J. Training Progression and Schedule

Training content of the 1st week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (gross muscles)	
1st Training part (Form 1)	25min	1st class: Basic steps 2nd class: Basic steps + postural training 3rd class: Integrated Form 1	1st class: Basic steps 2nd class: Basic TC steps + postural training 3rd class: Integrated From 1
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 1)	25min	1st class: Posture training 2nd class: Upper body movements 3rd class: Repeated practice	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching (gross muscles)	

Training content of the 2nd week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (especially on gross muscles in leg & foot)	
1st Training part (Form 2)	25min	1st class: Steps in different directions 2nd class: Step & Postural training 3rd class: Integrated Form 2	1st class: Basic steps 2nd class: Basic TC steps + postural training 3rd class: Integrated From 2
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 2)	25min	1st class: Steps in different directions 2nd class: Upper body movements 3rd class: Repeated practice	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching (gross muscles)	

Training content of the 3rd week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (gross muscles especially in trunk)	
1st Training part (Form 3)	25min	1st class: Form 1 & Form 2 & Basic steps 2nd class: Step + postural training 3rd class: Integrated From 3	1st class: : Form 1 & Form 2 & Basic steps 2nd class: Basic TC steps 3rd class: Integrated From 3
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 3)	25min	1st class: Organization of Steps + Postural training 2nd class: Upper body movements 3rd class: Repeated practice	1st class: Postural training 2nd class: Postural & Upper body movements 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching	

Training content of the 4th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (especially on muscles in Waist)	
1st Training part (Form 4)	25min	1st class: Review Form 1 ~3 &Twist of body and head 2nd class: Postural of lower body plus arm movements 3rd class: Integrated Form 4	1st class: Review Form 1 ~3 & Posture of Truck 2nd class: Basic TC steps + postural training 3rd class: Integrated From 4
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 4)	25min	1st class: Posture of lower body 2nd class: Twist of body 3rd class: Repeated practice on Form 1~4	1st class: Arm movements 2nd class: Step & head movements 3rd class: Repeated practice on Form 1~4
Cooling-down	15min	Whole body Stretching (gross muscles)	

Training content of the 5th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (especially on the ankle and foot muscles)	
1st Training part (Form 5)	25min	1st class: Postural training on trunk 2nd class: Step + postural training 3rd class: Integrated Form 5	1st class: Basic steps 2nd class: Basic TC steps + postural training 3rd class: Integrated From 5
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 5)	25min	1st class: Step training 2nd class: Step Training 3rd class: Repeated practice	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching	

Training content of the 6th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (especially on gross muscles in lower extremities)	
1st Training part (Form 6)	25min	1st class: Leg lift training 2nd class: Postural training 3rd class: Integrated Form 6	1st class: Training on lower extremities 2nd class: Heal kick+ postural training 3rd class: Integrated From 6
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 6)	25min	1st class: Steps in different directions 2nd class: Upper body movements 3rd class: Repeated practice on Form 5~7	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice on Form 5~7
Cooling-down	15min	Whole body Stretching	

Training content of the 7th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body (especially on muscles of lower body)	
1st Training part (Form 7)	25min	1st class: Movements of lower body 2nd class: Basic steps + postural training 3rd class: Integrated Form 7	1st class: Upper body movements 2nd class: Basic TC steps + postural training 3rd class: Integrated From 7
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 7)	25min	1st class: Posture training 2nd class: Upper body movements 3rd class: Repeated practice on Form 3~7	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice on Form 3~7
Cooling-down	15min	Whole body Stretching	

Training content of the 8th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body	
1st Training part (Form 8)	25min	1st class: Steps in different directions 2nd class: Step & Postural training 3rd class: Integrated Form 8	1st class: Basic steps 2nd class: Basic TC steps + postural training 3rd class: Integrated From 8
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part (Form 8)	25min	1st class: Steps in different directions 2nd class: Upper body movements 3rd class: Repeated practice on Form 1~8	1st class: Postural training 2nd class: Upper body movements 3rd class: Repeated practice on Form 1~8
Cooling-down	15min	Whole body Stretching	

Training content of the 9th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body	
1st Training part	25min	1st class: Review on Form 1 2nd class: Movements correction on Form 1 3rd class: Movements corrections on Form 1	1st class: Review on Form 1 2nd class: Movements correction on Form 1 3rd class: Movements corrections on Form 1
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Review on Form 2 2nd class: Movements correction on Form 2 3rd class: Movements corrections on Form 1	1st class: Review on Form 2 2nd class: Movements correction on Form 2 3rd class: Movements corrections on Form 1
Cooling-down	15min	Whole body Stretching	

Training content of the 10th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body	
1st Training part	25min	1st class: Review on Form 3 2nd class: Movements correction on Form 3 3rd class: Movements corrections on Form 3&4	1st class: Review on Form 3 2nd class: Movements correction on Form 3 3rd class: Movements corrections on Form 3&4
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Review on Form 4 2nd class: Movements correction on Form 4 3rd class: Movements corrections on Form 1~4	1st class: Review on Form 4 2nd class: Movements correction on Form 4 3rd class: Movements corrections on Form 1~4
Cooling-down	15min	Whole body Stretching	

Training content of the 11th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body	
1st Training part	25min	1st class: Review on Form 5 2nd class: Movements correction on Form 5 3rd class: Movements corrections on Form 5&6	1st class: Review on Form 5 2nd class: Movements correction on Form 5 3rd class: Movements corrections on Form 5&6
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Review on Form 6 2nd class: Movements correction on Form 5&6 3rd class: Movements corrections on Form 3~6	1st class: Review on Form 6 2nd class: Movements correction on Form 5&6 3rd class: Movements corrections on Form 3~6
Cooling-down	15min	Whole body Stretching	

Training content of the 12th week

Sections	Time	ExBP	TC
Warm-up	15min	Whole body	
1st Training part	25min	1st class: Review on Form 7 2nd class: Movements correction on Form 7 3rd class: Movements corrections on Form 8	1st class: Review on Form 7 2nd class: Movements correction on Form 7 3rd class: Movements corrections on Form 8
Break	10min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Review on Form 8 2nd class: Movements correction on Form 8	1st class: Review on Form 8 2nd class: Movements correction on Form 8

		3rd class: Movements corrections on Form 5~8	3rd class: Movements corrections on Form 5~8
Cooling-down	15min	Whole body Stretching	

Training content of the 13th week

Sections	Time	ExBP	TC
Warm-up	10-15min	Whole body	
1st Training part	25-30min	1st class: Integrated training with leader Form 1~4 (focusing on familiarization) 2nd class: Group training with leader Form 1-4 3rd class: Movement correction by tutors	1st class: Integrated training with leader Form 1~4(focusing on familiarization) 2nd class: Group training with leader Form 1-4 3rd class: Movement correction by tutors
Break	10-15min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Integrated training with leader Form 5~6(focusing on familiarization) 2nd class: Group training with leader Form 5~6 3rd class: Movement correction by tutors	1st class: Integrated training with leader Form 5~6(focusing on familiarization) 2nd class: Group training with leader Form 5~6 3rd class: Movement correction by tutors
Cooling-down	15min	Whole body Stretching	

Training content of the 14th week

Sections	Time	ExBP	TC
Warm-up	10-15min	Whole body	
1st Training part	25min	1st class: Group training with leader 2nd class: Movements correction by team members 3rd class: Group practice (focusing on familiarization)	1st class: Group training with leader 2nd class: Movements correction by team members 3rd class: Group practice (focusing on familiarization)
Break	10-15min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Group Training without leader 2nd class: Group training without leader 3rd class: repeated practice	1st class: Group Training without leader 2nd class: Group training without leader 3rd class: repeated practice
Cooling-down	15min	Whole body Stretching	

Training content of the 15th week

Sections	Time	ExBP	TC
Warm-up	10-15min	Whole body	
1st Training part	25min	1st class: Movement perfection with leader (focusing on accuracy) 2nd class: Self-practice 3rd class: Group-practice with leader	1st class: Movement perfection with leader (focusing on accuracy) 2nd class: Self-practice 3rd class: Group-practice with leader
Break	10-15min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Group practice without leader 2nd class: Group practice with leader 3rd class: Repeated practice	1st class: Group practice without leader 2nd class: Group practice with leader 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching	

Training content of the 16th week

Sections	Time	ExBP	TC
Warm-up	10-15min	Whole body	
1st Training part	25min	1st class: Movement perfection with leader (focusing on accuracy) 2nd class: Self-practice 3rd class: Group-practice with leader	1st class: Movement perfection with leader (focusing on accuracy) 2nd class: Self-practice 3rd class: Group-practice with leader
Break	10-15min	Relaxation/Drinking/Toilet	
2nd Training part	25min	1st class: Group practice without leader 2nd class: Group practice with leader 3rd class: Repeated practice	1st class: Group practice without leader 2nd class: Group practice with leader 3rd class: Repeated practice
Cooling-down	15min	Whole body Stretching	

Note. ExBP = The group receiving the newly-designed exercise program; TC = The group receiving the Tai Chi practice; Form 1 in ExBP = The left and Right Walking, Form 1 in TC = Repulse Monkey; Form 2 in ExBP = Multi-directional walking, Form 2 in TC = Brush Knee Twist Step; Form 3 in ExBP = Hops in four directions, Form 3 in TC = Part Wild Horse's Mane; Form 4 in ExBP = Side-twist, Form 2 in TC = Wave Hand in Clouds; Form 5 in ExBP = Foot Touch, Form 5 in TC =Golden Rooster Stand on one Leg; Form 6 in ExBP =Walking & Knee lifting, Form 6 in TC = Heel Kick; Form 7 in ExBP = Tap Step, Form 7 in TC =Grasp Swallow's Tail; Form 8 in ExBP = Revised Cha-cha Step, Form 8 in TC = Cross Hands.

CURRICULUM VITAE

Education background:

- Received the degree of Master of Education in Sports Humanistic Sociology from Nanjing Normal University, China, June 2012.
- Received the degree of Bachelor of Education in Physical Education from Nanjing Normal University, China, June 2009.

Membership of Professional Bodies:

- Member, American College of Sport Medicine
- Member, Hong Kong Physical Fitness Association
- Member, Hong Kong Association of Gerontology
- Member, Society of Chinese Scholars on Exercise Physiology and Fitness

Academic Publications:

- Chung, P. K., Mui, R., **Zhao, Y. N.,** & Liu, J. D. (2015) Training Effects of Water Tai Chi on Health Indicators among Chinese Older Females in Hong Kong, *International Journal of Physical Education, Sports and Health* (accepted)
- Chung, P. K., Leung, R. W., Liu, J. D., Quach, B., **& Zhao, Y. N.** (2013). Exercise regulation during cycle ergometry using Cantonese version of the CERT and Borg's RPE. *Journal of Physical Education and Sport*, 13(2): 170-176.
- Chung, P. K, **Zhao, Y. N.**, Quach, B., & Liu, J. D. (2013). The use of a Braille version of the Cantonese RPE scale in visually impaired adolescents. *Youth, technology, and health*, 89-106.

- Chung, P. K., & Zhao, Y. N. (2011). Experimental advancement in using RPE 6-20 Scale in predicting maximal oxygen consumption. *Journal of Wuhan Institute of Physical Education, 45*(9), 36-40. (In Chinese)

Academic Activities:

- **Zhao, Y. N.** & Chung, P. K. (29 - 30th, Nov., 2014). Differences of Functional Fitness among Older Adults with and without Risk of Falls. *The 9th Pan-Pacific Conference on Rehabilitation cum 21st Annual Congress of Gerontology*. Hong Kong Polytechnic University (Oral presentation).
- Chung, P. K., **Zhao, Y. N.,** Quach, B., & Liu, J. D. (9 – 11th, Oct., 2013). The Use of the Cantonese Rating of Perceived Exertion Scale in Older People. *The 12th SCSEPF Annual Conference*. The Society of Chinese Scholars on Exercise Physiology and Fitness, Shenyang **(Win prize for "Excellent Oral Presentation"**).
- **Zhao. Y. N**. (18 - 20th, Oct., 2013) Exercise regulation during cycle ergometry using Cantonese version of the CERT and Borg's RPE. *Postgraduate Academic Forum*, Shenzhen (**Win prize for "Excellent Oral Presentation"**)
- Zhao. Y. N. (26th, April, 2013) Joints movements and Body balance in older adults: A literature review. Research Postgraduate Forum, Hong Kong (Oral presentation).
- **Zhao, Y. N.,** & Chung, P. K. (2-4th, Nov., 2012). The Effect of Dance on Balance in Older Healthy Adults: A Systematic Review. The 11th SCSEPF Annual Conference. The Society of Chinese Scholars on Exercise Physiology and Fitness, Shanghai. (Oral presentation).

- **Zhao, Y. N.,** & Chung, P.K. (20-21st, Oct., 2012). A Review on the Reliability and Validity of Using RPE 6-20 Scale to Predict VO2max. *International Conference on Youth, Technology & Health*, Hong Kong. (Oral presentation).
- **Zhao, Y. N.** (19-24th, July, 2012). Prediction of Peak Oxygen Uptake from Submaximal Ratings of Perceived Exertion in the Visually Impaired Adolescents. *International Convention on Science, Education and Medicine in Sport*, Glasgow, Scotland, UK. (Oral presentation).
- Chung, P. K., Quach, B., Leung, R. L., & **Zhao, Y. N.** (13th, July, 2011) Exercise Regulation During Cycle Ergometry Using the Translated Children's Effort Rating Table and Rating of Perceived Exertion Scale. *International Conference on Sports Science Lifestyle Management: A Long-term Wellness Education*, Hong Kong (poster).

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