THE EFFECTS OF 12-WEEK BADUANJIN INTERVENTION ON BALANCE, ISOMETRIC KNEE STRENGTH, GAIT BIOMECHANICS AND RISKS OF FALLS AMONG ELDERLY

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UNIVERSITI SAINS MALAYSIA

2025

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by

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Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

April 2025

ACKNOWLEDGEMENT

First of all, I sincerely thank my supervisor Assoc. Prof. Ts. Dr. Shazlin Shaharudin and my co-supervisor Dr. Mohamad Ikhwan Zaini bin Ridzwan for providing me with the opportunity to conduct this research and gain important insights into journal selection and paper preparation. They taught me how to conduct research and write English papers and played a vital role in improving my English. Every time I encounter difficulties, they always give me great help. Regardless of the guidance and suggestions when developing the thesis, or the revision opinions during the pre-defense, they are a strong guarantee for the successful completion of this article. Therefore, I am very grateful for their help and patience throughout my research work and life, which opened up more international academic horizons for me.

Secondly, I would also like to thank my field supervisor Professor Meng Hesheng whose company provided me with the scientific research and working environment of Shanxi Normal University. It effectively guaranteed the successful completion of my thesis experiments.

In addition, I am very grateful to my heartfelt thanks for the love and tolerance given to me by my family! Thanks to my parents who are far away in my hometown. You have supported my study, work and life with the most simple actions. You have given me selfless support and encouragement when I was frustrated and hesitant, so that I can always feel the comfort and nourishment from my relatives. In addition, I would also like to express my deepest gratitude to my classmate Dr. Li Shuoqi for his help in my life and research.

Finally, I would like to express my sincere gratitude to all those who helped me in any way throughout the research work. During the period of studying for my doctorate, the edification of the school, the teachings of teachers, the hard work of my classmates, and the support of my family all condensed into stories of time and integrated them into my life to accompany me as I move forward!

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF ABBREVIATIONS

ACL	Anterior cruciate ligament
ASIS	Anterior superior iliac spine
BBS	Berg Balance Scale
BIA	Bioelectrical impedance analysis
BMI	Body mass index
COP	Center of pressure
EMG	Electromyography
FTSST	Five Times Sit to Stand Test
HR	Heart rate
LOB	Loss of balance
MFES	Modified falls efficiency scale
MFS	Morse Fall Scale
MMSE	Mini-mental State Examination
OLST	One Legs Stance test
PAR-Q+	Physical Activity Readiness Questionnaire for everyone
PD	Parkinson's disease
RPE	Rating of Perceived Exertion
SAAC	Sway average amplitude - coronal plane
SAAS	Sway average amplitude - sagittal plane
SC	Sway area - coronal plane
SI	Symmetry index
SMAC	Sway maximal amplitude - coronal plane
SMAS	Sway maximal amplitude - sagittal plane

SPC	Sway path - coronal plane
SPPB	Short Physical Performance Battery
SPS	Sway path - sagittal plane
SPT	Sway path – total
SS	Sway area - sagittal plane
ST	Sway area – total
SVC	Sway velocity - coronal plane
SVS	Sway velocity - sagittal plane
SVT	Sway velocity – total
TUG	Time up and go
WHO	The World Health Organization
6 WT	6 minute walk test
10MWS	10 meter maximum walk speed

LIST OF APPENDICES

KESAN INTERVENSI BADUANJIN SELAMA 12 MINGGU TERHADAP KESEIMBANGAN, KEKUATAN ISOMETRIK LUTUT, BIOMEKANIK GAIT DAN RISIKO JATUH DALAM KALANGAN WARGA TUA

ABSTRAK

Fungsi fizikal merosot pada warge tua apabila mereka berumur, dan kegagalan untuk mengesan postur badan yang salah atau memulihkan keseimbangan meningkatkan kemungkinan untuk jatuh. Oleh itu, meningkatkan fungsi keseimbangan warga tua telah menjadi matlamat penting dalam pemulihan geriatrik. Baduanjin adalah salah satu kaedah rawatan qigong tradisional Cina. Berbanding dengan bentuk senaman lain, ia lebih memfokuskan kepada integrasi badan dan minda, dan meningkatkan fungsi fizikal warga emas dan pelbagai populasi klinikal. Walau bagaimanapun, kajian terdahulu mengenai Baduanjin hanya menggunakan skala subjektif yang secara tidak langsung menilai risiko jatuh. Kesan Baduanjin pada biomekanik berjalan dan keseimbangan pada warga tua adalah tidak diketahui. Oleh itu, kajian ini menilai kesan 12 minggu Baduanjin terhadap risiko jatuh dari semua aspek, termasuk keseimbangan, kekuatan sendi lutut isometrik, dan parameter gaya berjalan. Selepas saringan, 42 peserta dibahagikan kepada kumpulan dengan membuat undian melalui kotak buta dengan dua jenis jalur kertas: B dan C. Mereka dibahagikan secara rawak kepada salah satu kumpulan berikut: 1. Kumpulan Baduanjin (n=22), 2. kumpulan kawalan (n=20). Tempoh intervensi adalah 12 minggu, dengan ujian keseimbangan, kekuatan sendi lutut isometrik, dan gaya berjalan yang dilakukan pada minggu pertama, keenam dan kedua belas, masing-masing. Selepas intervensi, parameter biomekanik lapan bahagian Baduanjin juga telah dinilai. Berdasarkan keputusan kajian, kami menyimpulkan bahawa berbanding

dengan intervensi berjalan dengan intensiti yang sama, intervensi Baduanjin dapat meningkatkan laluan ‘sway’ dengan berkesan (37.62±9.73% vs 10.12±0.66%, $p<0.05$), halaju ‘sway’ (19.06±10.73% vs 0.96±1.40%, $p<0.05$), kawasan ‘sway’ (31.73%±1.54% vs 1.73% $p<0.05$) dan amplitud ‘sway’ (29.16±12.44% vs 5.63±1.69%, $p<0.05$) semasa ujian imbangan pada satah koronal dalam kalangan warga emas. Di samping itu, intervensi Baduanjin boleh meningkatkan simetri berjalan dengan lebih baik semasa fasa berdiri awal (50.00±67.08% vs 20.00±84.85%, $p<0.05$) dan pertengahan (55.56±46.64% vs 11.11±82.22%, $p<0.05$) dan kekuatan maksimum ‘extensor’ lutut (7.77±1.69% vs 3.39±1.44%, $p<0.05$). Kesimpulannya, berbanding intervensi berjalan kaki konvensional, intervensi Baduanjin adalah lebih kondusif untuk meningkatkan keseimbangan dan kestabilan gaya berjalan warga tua, mungkin disebabkan oleh peningkatan kekuatan otot kaki.

THE EFFECTS OF 12-WEEK BADUANJIN INTERVENTION ON BALANCE, ISOMETRIC KNEE STRENGTH, GAIT BIOMECHANICS AND RISKS OF FALLS AMONG ELDERLY

ABSTRACT

Physical function declines in older adults as they age, and failure to detect incorrect body postures or restore balance increases the likelihood of falls. Therefore, improving the balance function of the elderly has become an important goal in geriatric rehabilitation. Baduanjin is one of the traditional Chinese qigong treatment methods. Compared with other forms of exercise, it focuses more on the integration of body and mind, and improves the physical function of the elderly and various clinical populations. However, previous studies on Baduanjin have only used subjective scales that indirectly assess fall risk. The effects of Baduanjin on gait biomechanics and balance in older adults is unknown. Therefore, this study evaluated the impact of 12 weeks of Baduanjin on the risk of falls from all aspects, including balance, isometric knee joint strength, and gait parameters. After screening, the 42 participants were divided into groups by drawing lots through the blind box with two kinds of paper strips: B and C. They were randomly divided into one of the following conditions: 1. Baduanjin group (n=22), 2. control group (n=20). The intervention period was 12 weeks, with balance, isometric knee joint strength, and gait tests conducted in the first, sixth, and twelfth weeks, respectively. Also, after the intervention, the biomechanical parameters of eight sections of the Baduanjin were evaluated. Based on the research results, we conclude that compared to walking intervention of the same intensity, the Baduanjin intervention can effectively improve the sway path (37.62±9.73% vs 10.12±0.66%, $p<0.05$), sway velocity

(19.06±10.73% vs 0.96±1.40%, $p<0.05$), sway area (31.54±11.73% vs 24.95±5.47%, $p<0.05$) and sway amplitude (29.16±12.44% vs 5.63±1.69%, $p<0.05$) during balance test in the coronal plane of the elderly. In addition, Baduanjin intervention can improve the gait symmetry during early (50.00±67.08% vs 20.00±84.85%, $p<0.05$) and mid stance phases (55.56±46.64% vs 11.11±82.22%, $p<0.05$) and maximum strength of knee extensor (7.77±1.69% vs 3.39±1.44%, $p<0.05$). In conclusion, compared to conventional walking intervention, the Baduanjin intervention is more conducive in improving the balance and gait stability of elderly, possibly due to the increase in lower limb muscle strength.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Population aging refers to an increase in the proportion of the elderly among the total population over time. In addition, the overall sociodemographic structure shows gradual aging of the population (Taylor et al., 2018). The population aging phenomenon is worldwide, and most developed countries including some developing countries, are already facing the issue of an aging population. This trend is increasing, making it difficult to control. At present, China has also reached the stage of a rapidly growing aging population (Guo et al., 2019; Zhang, Ke & Ding, 2021).

Falls are one of the leading cause of unintentional injuries and the largest cause of unintentional deaths globally for people over 60 years old (Li et al., 2022). Physical function declines in older adults as they age, and failure to detect incorrect body postures or restore balance increases the likelihood of falls (Thomas et al., 2019). Body posture or balance cannot be maintained properly during daily activities without accurate integrations of sensory input, central processing, and muscle force development (Li et al., 2022). As walking is a common daily activity, thus improving the balance function and and gait stability of the elderly has become an important goal in geriatric rehabilitation.

Exercise is the most frequent intervention for fall prevention, and previous systematic reviews have shown that exercise may assist in preventing falls through increased core strength and balance (Gillespie et al., 2012). Baduanjin is one of the traditional Chinese Qigong (e.g., Tai Chi, Wuqinxi, and Liuzijue) therapies which focuses on the integration of the body and mind (Zou et al., 2017; Jiajia Ye et al.,

2020). Baduanjin is suitable for older adults because this exercise has moderate intensity, simple movements, and is easy to learn. For deep meditation therapy, slow body movement and musculoskeletal stretching are coordinated with deep breathing, physical relaxation, and mental concentration (Zou, et al., 2018; Ye, Cheung & Tsang, 2019). Some studies have shown that Baduanjin improves physical function, including lower limb strength, balance, and grip strength, in older adults and patients with Parkinson's disease (PD), chronic disease, and knee osteoarthritis (Liu et al., 2016; Zou et al., 2017).

However, previous studies (Santos et al., 2011; Hohtari et al., 2013) only used the Berg Balance Scale (BBS) to assess the risk of falls, instead of quantitatively measuring the mechanics of risks of falls. At present, the impact of Baduanjin on balance function and gait biomechanics in elderly people is still unclear. Moreover, no previous research has included a control group, so it is unclear whether the form of exercise influences its effectiveness. Therefore, this study investigated the impact of 12 weeks of Baduanjin exercise on balance, isometric knee strength, gait, and risks of falls among the elderly.

1.2 Problem statement

Physical function declines in older adults as they age, and failure to detect incorrect body postures or restore balance increases the likelihood of falls (Thomas et al., 2019). Therefore, improving the balance function of the elderly has become an important goal in geriatric rehabilitation. Exercise may prevent fall by increasing muscular strength, improving posture and stability during walking. Several studies (Liu et al., 2016; Zou et al., 2017) have shown that Baduanjin improves physical function in the elderly and various clinical populations. However, the mechanism of

how Baduanjin improves balance mechanics especially during walking remain unclear. This is crucial to understand how exercise improves balance in elderly so that customised exercise can be prescribed to prevent falls. Therefore, the current study evaluated the impact of Baduanjin on the risk of falls from multiple aspects, including balance, isometric knee joint strength, and gait parameters. We also compared the effects of Baduanjin intervention to a control group (walking intervention). Walking was incorporated in the control group as it is advisable for the elderly to remain physically active (American College of Sports Medicine, 2021).

1.3 Research questions

a) How 12-week Baduanjin intervention affects elderly's balance ability?

b) How 12-week Baduanjin intervention affects elderly's isometric knee strength?

c) How 12-week Baduanjin intervention affects elderly's gait biomechanics parameters?

d) How 12-week Baduanjin intervention affects elderly's risk of falls?

1.4 Research objectives

a) To evaluate the effects of Baduanjin intervention on the balance among elderly.

b) To evaluate the effects of Baduanjin intervention on the isometric knee strength among elderly.

c) To evaluate the effects of Baduanjin intervention on the gait biomechanics among elderly.

d) To evaluate the effects of Baduanjin intervention on the risks of falls among elderly.

1.5 Research Hypotheses

a) H_O: After 12 weeks of intervention, the Baduanjin had no significant effect on the balance among elderly.

H_A: After 12 weeks of intervention, the Baduanjin had significant effect on the balance among elderly.

b) H_O: After 12 weeks of intervention, the Baduanjin had no significant effect on the isometric knee strength among elderly.

H_A: After 12 weeks of intervention, the Baduanjin had significant effect on the isometric knee strength among elderly.

c) H_O: After 12 weeks of intervention, the Baduanjin had no significant effect on the gait biomechanics among elderly.

H_A: After 12 weeks of intervention, the Baduanjin had significant effect on the gait biomechanics among elderly.

d) H_O: After 12 weeks of intervention, the Baduanjin had no significant effect on the risks of falls among elderly.

H_A: After 12 weeks of intervention, the Baduanjin had significant effect on the risks of falls among elderly.

1.6 Novelty

Previous studies (Santos et al., 2011; Hohtari et al., 2013) on Baduanjin have only used subjective scales that assess fall risks despite that the biomechanics and balance of gait can provide objective quantification regarding the risks of falls. Therefore, this study evaluated the impact of Baduanjin on the risks of falls from quantitative aspects, including balance, isometric knee joint strength, and gait parameters. In addition, a previous study (Alhammad et al., 2020) only subjectively

described the effects of each movement when explaining the mechanism of the Baduanjin, without actually measuring the activity of each joint and the changes in the center of the eight movements. In this study, for the first time, the biomechanical analysis of each section of Baduanjin were described.

1.7 Significance of the study

The focus of this study is to apply the traditional Chinese exercise "Baduanjin" to the elderly. The study investigated the effects of 12 weeks of Baduanjin exercise on balance, isometric knee strength, gait, and risks of falls among the elderly. These research findings enable us to understand the effects of Baduanjin intervention on balance, strength, and gait in the elderly. Additionally, the biomechanics of each Baduanjin motion are also evaluated to understand how these motions affect gait, balance function and risks of falls among elderly. The results of this study provided rehabilitation physicians with an effective exercise prescriptions which can be performed safely by the elderly even at home.

1.8 Operational definition

Table 1.1 Operational definition

Terms	Operational definition
Elderly	The World Health Organization (WHO) defines elderly people as those aged 60 and above. In addition, according to this standard, individuals aged 60-74 are defined as young and elderly, individuals aged 75-89 are defined as generally elderly, and individuals aged 90 and above are defined as long-lived elderly. These definitions not only reflect the physiological changes of humans at different age stages, but also emphasize the importance of health management for the elderly (Amuthavalli Thiyagarajan et al., 2022).
Baduanjin	Baduanjin is an ancient Chinese qigong technique that originated in the Northern Song Dynasty and has a history of over 800 years. Eight section brocade can be divided into sitting posture eight section brocade and standing posture eight section brocade. This study mainly focuses on standing posture eight section brocade (Koh, 1982).
Balance	Balance refers to the ability of the body to maintain good posture control and center of gravity adjustment while being still or in motion, as well as reduce the risk of falls and falls, thereby ensuring the stability and safety of the body (Yim-Chiplis & Talbot, 2000).
Falling	Falling refers to a sudden, involuntary, and unintentional change in position, resulting in falling to the ground or a lower plane (Berková & Berka, 2018). The high incidence and serious consequences of falls among elderly people are one of the important causes of disability and death among the elderly.

Table 1.1 Continued

Terms	Operational definition
Risks of Fall	The risk of falling refers to the possibility of sudden, involuntary, and unintentional changes in body position in daily life, such as falling to the ground or a lower plane. In this study, the assessment of fall risk was mainly measured using a Morse Fall Scale (Parati *et al.*, 1989).
Lower Limb Strength	Lower limb strength refers to the ability of the lower limb muscles to overcome resistance during motions (Aguiar et al., 2019). In this study, the focus was on the isometric strength of the knee extensor muscle.
Gait Biomechanics	Gait refers to the posture and behavioral characteristics of the human body during walking (Russo et al., 2024). In this study, the biomechanical aspects of gait that we measured include tha ground reaction force (GRF) and spatiotemporal variables during walking.

CHAPTER 2

LITERATURE REVIEW

The purpose of this chapter is to summarize the concept of Baduanjin and its impact on strength and balance. This chapter will first introduce the relationship between age, balance, and strength. Next, we will summarize the impact of exercise on balance and strength, and then focus on introducing the concept of Baduanjin and its influence on balance and strength of different groups of people. Finally, key studies on the correlation between gait variables and risks of falls were discussed, which contributed to the main theme of this study.

2.1 Effects of aging on balance and strength

The balance ability of the elderly has unique characteristics. As one ages, the functions of various organs decline yearly (Xie, Han & Hu, 2022). The comprehensive ability of an individual's central nervous system to analyze external stimulus information decreases with aging. The duration for nerve impulses from the nerve center to reach each a motor unit also increases, and the activities of each motor unit become slighlty slow, sometimes resulting in wrong actions (Gouveia et al., 2020). The reason may be that the function of the cardiovascular system of the elderly is degraded, leading to vascular sclerosis, which reduces blood flow velocity, resulting in insufficient support of the nervous system. Long-term hypoxia leads to the decline of various functions of the sensory organs, and aging also causes functional decline (Proudlock, Shekhar & Gottlob, 2004; Song et al., 2023). For example, the deterioration of the functions of various eye tissues in the older adults leads to a decline in the their vision, which causes inaccurate response to their

surroundings including inaccurate judgment of distance, object color, and shape of objects (Amoo et al., 2023). Similarly, the function of vestibular organs degenerates in old age resulting in the loss of spatial sense and orientation sense (Proudlock, Shekhar & Gottlob, 2004). Proprioceptive function also gradually declines due to long-term insufficient blood supply, which makes the elderly prone to falls. Muscle strength gradually decreases with aging (Wiszomirska et al., 2015). In addition, long-term physical inactivity or insufficient exercise leads to decreased joint flexibility and reduced range of motion. Elderly people who begin exercising at a later age are at risk of an increased rate of muscle deterioration, which may lead to reduced exercise ability, reduced flexibility, and poor coordination (Park et al., 2020). As motor function weakens, the limbs experience difficulty in maintaining balance, and the accuracy of the central nervous system in controlling the limbs are affected. In the elderly, when there is external perturbation, the lower limbs cannot adjust to the change, as their balance ability decreases significantly (Pu et al., 2015).

Balance is necessary for individuals to maintain posture, respond to random movements, and respond to external disturbances. To maintain balance, an individual's center of gravity (COG) must remain within a constantly changing base of support (Osoba et al., 2019). This "stability limit" depends on the individual's biomechanics, task requirements, and the type of surface they stand on. Animal studies have shown that posture is controlled through mechanisms on the spinal cord (Hogg et al., 2022). Specifically, the vestibular system and cerebellum are considered to play a major role in posture control, while the cerebellum is important for altering the muscle strength required for limb and trunk movements and balancing tasks (Viswanathan & Sudarsky, 2012).

The decline of balance ability is positively correlated with aging (Battilana et al., 2020). In the study by Choy, Brauer & Nitz, (2003), stability tests were conducted on 453 women aged 20-80, including stable and unstable planes, as well as open and closed eyes. The results showed that as age increased, especially between the ages of 60 and 70, the sway speed of the participants' COG was significantly higher than that of younger participants in various situations. When standing on a hard surface with their eyes open, the elderly subjects have a sway speed of about 2.5 times that of the young subjects, while the elderly subjects have a sway speed of about 4 times that of the young subjects when their eyes are closed. Based on the study, it is important to screen women before the age of 60 and introduce effective prevention strategies to minimize the potential decline in balance with age.

The physical functions of the elderly gradually decline and their vision and muscle strength decreases, while their vestibular and central and peripheral nervous system functions decline (Xavier et al., 2023). Vision, proprioception, and vestibular perception are the main factors that affect balance ability, and the decline in muscle strength is among the main risk factors for falls in the elderly (Lauretani et al., 2003). The decrease in muscle strength can impair the balance ability of elderly people (Coletti et al., 2022). A study (Judge et al., 1995) shows that for every Nm/kg increase in lower limb muscle strength, the chance of losing balance after adjustment decreases by 20%. Judge et al., (1995) also investigated the contributions of visual and proprioceptive inputs, muscle strength, and age to balance performance in 110 elderly individuals without neurological disorders. They evaluated the displacement of loss of balance (LOB) and anterior-posterior center of force (COF) through a force

measurement platform. Their results showed that muscle strength and age were independent predictors of LOB.

Gait speed and standing balance on one foot are also related to LOB (Anagnostou, Karagianni & Skoularidou, 2022). Older people may use antagonists muscles more frequently and inappropriately than younger people when trying to maintain balance. In addition, to resist external perturbation information, elderly people tend to activate muscles in a sequence from proximal to distal, and may use posture stabilization strategies involving hip bending or stretching (Narici & Maganaris, 2006). However, young people often do not trigger this strategy and respond to perturbation with normal distal to proximal muscle activation sequences (Manchester et al., 1989). In order to maintain posture stability, elderly people may compensate by increasing posture sway, but it may not necessarily lead to posture instability, which means that elderly people may need more COG sway to maintain posture stability (Panzer, Bandinelli & Hallett, 1995).

Many sensory systems contribute to balance, such as foot/ankle sensory input, visual input, and vestibular input (Zalewski, 2015; Osoba et al., 2019). However, many of these systems decline with age. For example, compared to young people, elderly people have a significant decrease in foot position awareness, which can affect gait while walking, possibly due to a decrease in plantar mechanical sensation (Robbins, Waked & McClaran, 1995; Patel et al., 2009). To conclude, balance ability, which progressively declines with aging, is affected by several physical functions, significantly reducing the balance ability of the elderly. Therefore, lack of exercise greatly increase the risk of functional limitation and disability.

2.2 Effects of exercise on improving balance and stability of lower limbs

With the extension of life expectancy, elderly people must maintain physical fitness and health while living longer (World Health Organization, 2015). The health of the elderly is of great significance to individuals, families, and society. Firstly, for individuals, health means being able to enjoy greater quality of life, enjoy good times, and experience the richness and diversity of life. Secondly, for families, improving the health of the elderly can reduce the burden on the family, avoid the economic and mental pressure caused by the elderly's illness and care issues, and also allow family members to have more time and energy to focus on their own lives and work (Qu et al., 2024). Finally, for society, improving the health of the elderly can alleviate the medical burden on society. At the same time, healthy elderly people can continue to contribute to society, whether through volunteer work or through imparting experience and knowledge. Therefore, it is urgent to take effective intervention measures to promote healthy aging and minimize the economic burden of the public health system to care for the elderly.

Exercise has always been considered beneficial to improve the health and physical function of the elderly. The World Health Organization (WHO) recommends that adults aged 65 and above should take 150 minutes of moderate intensity or 75 minutes of high-intensity aerobic exercise and two days or more of muscle strengthening activities (Bull et al., 2020). However, most of the elderly are still inactive, and the proportion of elderly people who meet such criteria decreases with age, ranging from 16% of people aged 65-74 to 7% of people aged 85 and over (Thorpe & Whitfield, 2017). Because physical function usually decreases with age, exercise is more challenging for the elderly. A previous study showed that physical barriers are common to physical activity for the elderly, which makes it difficult for

many elderly people to participate in exercise (Baert et al., 2011). However, it is believed that even a low amount of exercise may be beneficial (Mitnitski et al., 2002). In view of the elderly, we should advocate personalized and interesting exercise prescription for them to sustain their participation in exercise and remain physically active (Izquierdo et al., 2021).

Exercise training can effectively improve the balance ability of the elderly and frail adults (Kim & Yim, 2020). Exercise intervention under the supervision and face-to-face environment seems to be more beneficial than exercise intervention in the family environment (Lacroix et al., 2016). In fact, it is reported that compared with unsupervised training, supervised exercise has a better effect on the improvement of balance ability (Lacroix et al., 2016). The elderly may exercise below the effective threshold without supervision due to poor compliance, which lead to slow progress of exercise intervention and fail to achieve the expected effect (Lacroix et al., 2017). In a systematic review (Lacroix et al., 2017), the effects of supervised and unsupervised exercise intervention on balance and muscle strength measurement in the elderly were compared. A total of 11 studies were included, involving 621 participants, of which 33.7% were males and 66.3% were females. The average age of the participants was 73.6 years old, ranging from 65.3 to 81.1 years old. The results showed that compared with the unsupervised exercise program, the supervised exercise program showed a greater effect in promoting balance and muscle strength (Lacroix et al., 2017). Therefore, the use of supervised training programs may be more suitable for the elderly who need to improve their balance ability.

Various movements can be classified into four categories including movement to improve muscle strength, proprioception, neuromuscular control ability,

and vestibular sensation (Pu et al., 2015). The role of any form of exercise in improving various functions of the body is extensive. For example, Taijiquan can improve lower limb muscle strength, ankle and knee joint proprioception, nerve control ability, vestibular sensation, and other functions (Xu et al., 2004). However, different kinds of exercise may have different effects on the body functions. A study by Dunsky et al., (2017) implemented two protocols. For the first protocol, an aerobic step was used, and for the second protocol a stability ball was used. Both protocols were administered for 45 min, twice a week for 8 consecutive weeks. The two protocols, aerobic step and stability ball exercise protocols, comprised 1 to 3 sets each of different speed (slow to medium pace) with 8 to 15 repetitions per exercise. Such interventions might be considered as a combination of aerobic and resistance exercises. One leg stance was used to evaluate balance performance. The results of the study indicated that aerobic step protocol could improve one leg stance performance to a greater extent compared with that observed with the stability ball protocol (aerobic step pre: 13.1 ± 10.4 s, post: 17.4 ± 11.9 s; stability ball pre: 14.6 ± 9.2 s, post: 15.9 ± 11.6 s) (Dunsky et al., 2017).

Exercises can be classified as dynamic and static. Static exercises are exercises that are performed with the body in a stable posture and does not affect the body's balance (Ghasempour et al., 2017). With static exercises, the small and deep muscle groups are responsible for maintaining posture stability, and they play a key role in maintaining body stability. Therefore, static exercise is better than dynamic exercise in improving the core stability of the body, whereas dynamic exercise is more helpful in improving muscle strength and joint stability (Örgün, Kurt & Özsu, 2020).

American College of Sports Medicine (2021) recommended that 30 min of moderate- and low-intensity exercises several times a week may delay the onset of functional limitation in the elderly and improve their quality of life. Regarding research on the influence of exercise on the balance ability of the elderly, most studies in China have focused on exercise interventions such as brisk walking (Bai et al., 2021; Jinakote et al., 2023), square dancing (Yu et al., 2018; Ou et al., 2022), Qigong (Fong et al., 2018; Yang et al., 2023). Baduanjin is a type of Qigong exercise. Baduanjin is a type of qigong exercise, and the reason why this study focuses on Baduanjin is that it has the characteristics of being simple, easy to learn, and highly safe compared to other Qigong exercises, making it more suitable for middle-aged and elderly people. However, to the best of our knowledge, the biomechanics of motions related to Baduanjin are scarce, thus the biomechanical aspect of balance improvement due to Baduanjin is unknown.

2.3 Introduction to Qigong and Baduanjin

Qigong is a traditional Chinese mind-body practice that has a long standing history in Chinese culture. It encompasses a variety of techniques that focus on the regulation of the mind, breathing, and body movements (Patil et al., 2011). Qigong practice is believed to cultivate and balance the flow of “Qi”, the vital energy in traditional Chinese medicine theory. Qigong has been associated with multiple health - promoting effects, including improvements in physical and mental health. It has been used in complementary and alternative medicine settings to manage various conditions such as stress related disorders, chronic pain, and some immune related diseases (Guo, Liu & Yuan, 2022). Qigong includes a wide range of practices, each

with its own unique characteristics and methods of practice, which can be classified into different schools and styles.

Baduanjin is a well known and widely practiced form of Qigong. It consists of eight distinct movement sequences, each designed to target specific aspects of the body and promote the circulation of blood (Chen et al., 2019). Baduanjin has a history spanning centuries and is popular not only in China but also globally. As described in a study (Gong et al., 2019), Baduanjin practice can enhance physical fitness, including improving balance, flexibility, and muscle strength. It also has positive impacts on psychological well being, such as reducing anxiety and depression. The movements in Baduanjin are relatively gentle and suitable for people of different ages and fitness levels.

Similar to Tai Chi and Five Animal Exercise, Baduanjin is a subset of Qigong. It adheres to the fundamental principles of Qigong, such as the cultivation and regulation of “Qi”. While Qigong is a broad concept that encompasses numerous practices, Baduanjin is a specific and standardized form of Qigong. The practice of Baduanjin embodies the essence of Qigong, with its focus on integrating the mind, breath, and body movements (Zou, et al., 2018). Through the practice of Baduanjin, practitioners can experience the effects of qigong, such as enhanced Qi flow, improved physical function, and mental relaxation. In research on the health related outcomes of Qigong, Baduanjin is often one of the most studied forms due to its accessibility and well defined practice routines (An et al., 2008).

2.4 Effects of Baduanjin on improving the balance and strength of the lower limbs

Baduanjin, also known as eight-section brocades, dates back to the Chinese

Song Dynasty (10th–13th century A.D.) and is a traditional Chinese exercise method that combines human exercise, breathing, and psychological regulation (Fang et al., 2021). In performing the exercise, both breathing and body movements are slow, and the breathing is in rhythm and in harmony with the body movements. For hundreds of years, millions of Chinese have practiced Baduanjin to enhance and maintain health (Ma et al., 2022). In recent years, Baduanjin has become popular worldwide as a promising low-intensity, physical, and mental exercise due to its effectiveness for fitness, the ease with learning its techniques, and the short exercising time (Wang et al., 2021).

Moreover, Baduanjin is an aerobic exercise that combines body posture, breathing, and mental activities through slow body movements to stretch the whole body's musculoskeletal structure (Zhou et al., 2020). The Baduanjin movement is simple and gentle, with a characteristic combination of relaxed, soft and slow, tight and coherent, and dynamic and static movements. Due to its intensity and ease of motions, Baduanjin is suitable for all ages, especially the middle-aged and elderly (Liu et al., 2022).

Baduanjin exercise is not popular in young people, resulting in few relevant studies on young people. A study by Li et al., (2015) assessed lumbar muscle strength after a 12 weeks Baduanjin training for college students. The study found that the lumbar strength of the participants was significantly enhanced. The balance ability test scores were also significantly improved, which further confirmed a significant correlation between lumbar muscle strength and balance ability. Therefore, the study concluded that short-term practice of Baduanjin can improve the abduction strength and balance ability of the lower limbs of college students (Li et al., 2015). In another study (Jin et al., 2017), 40 healthy adults underwent a 45-min

Baduanjin training for 16 weeks, three times a week. After analyzing the lower limb muscles of the participants using surface electromyography (EMG), they concluded that Baduanjin can significantly improve muscle strength, especially that of the lateral and medial femoral muscles, which play a key role in the balance ability of the lower limbs. Existing studies on the non-elderly have shown that Baduanjin exercise can improve the lower limb muscle strength and balance ability of young and middle-aged people.

Importantly, several studies have shown that Baduanjin can improve the lower limb muscle strength, enhance the proprioception, and improve the balance ability of the elderly (Yuen et al., 2021; Wang et al., 2022). In the study by Yuen et al., (2021), Baduanjin training were conducted on elderly patients with chronic stroke, with the first 8 weeks of supervised training and the last 8 weeks of unsupervised training. The duration of each exercise is about 50 minutes, including 10 minutes of warm-up exercises, 30 minutes of Baduanjin exercises, and 10 minutes of relaxation exercises, for three times a week. The control group received resistance training of the same duration and frequency. The Mini-Balance Evaluation Systems Test (Mini-BESTest), Sensor Organization Test, and Five Times Sit to Stand Test (FTSST) were used to evaluate balance ability, proprioception and lower limb muscle strength, respectively. Mini-BESTest provides a unique and brief clinical rating scale for dynamic balance. It is helpful to guide the specific treatment of patients and determine the specific systems affected and the changes brought about by treatment. However, it needs equipment and professional evaluators, and it also needs 10-15 minutes of management time. As it needs more time, it is not suitable for regular large-scale screening or evaluation in the community environment (Franchignoni et al., 2010). The results showed that after 8 weeks of training, the

Baduanjin group showed significant improvement in Mini-BESTest score, proprioception score and FTSST compared to the control group (Yuen et al., 2021). After another 8 weeks of family Baduanjin practice, these results were still better than the control group.

Effective balance control involves organization and integration of sensory information. In the Baduanjin exercise, different senses are required to perform different forms of Qigong movements. For instance, in practicing the Prop up the sky by two hands to improve tri-jiao, Look back to treat five strains and seven impairments and Clench one's fist and glare to increase strength, a wide field of view is required for looking at the hands, looking backward, and looking at the fist, respectively. The vestibular system is also involved when performing the head and neck movements in the Look back to treat five strains and seven impairments and the Shake the head and wag to expel Heart-fire. Engaging in repetitive Baduanjin exercises may have enhanced balance ability in our participants by improving the integration of sensory information required for effective balance control.

In addition, similar results were also presented in the study by Yuen et al., (2021). The elderly with chronic stroke underwent a 24 week Baduanjin exercise intervention, three times a week, with each exercise lasting 60 minutes. The traditional training group used traditional strength and endurance training, also three times a week, for 60 minutes of exercise. The mixed exercise group performed two forms of exercise for 30 minutes each. The physical performance of the participants was evaluated pre and post intervention by utilizing the 10 meter maximum walk speed (10MWS), Time up and go test (TUG), grip strength, and the 6 minute walk test (6 WT). The results showed that after 24 weeks of training, all experimental groups showed some degree of improvement in strength, speed, and endurance.

Among them, the mixed exercise group showed the best improvement in physical fitness among the subjects in 10 MWS and TUG test.

Relevant studies (Wang et al., 2009; Ye et al., 2020) have also shown that short-term Baduanjin intervention training for less than 3 months can improve the balance ability, muscle strength, gait, and other indicators of the elderly, and its effect on balance ability is better than that of control group. Ye et al., (2020) showed that Baduanjin training can significantly improve the balance ability of the elderly aged 60–70 years. Participants with knee osteoarthritis were randomly assigned to either the experimental group or the control group. The participants in the experimental group received 12 weeks of Baduanjin training, three times a week for 40 minutes each time. The participants in the control group did not receive any additional physical training. All participants completed a balance assessment of opening and closing their eyes before and after intervention. It evaluates the balance ability of participants through the sway path in the sagittal and coronal planes. The results showed that the sway path of the Baduanjin group in the sagittal plane was significantly smaller than that of the control group. It attributes the improvement in balance ability to the enhancement of quadriceps strength. According to reports, impaired proprioception of the knee joint is related to quadriceps weakness (Wang et al., 2009). Previous studies (An et al., 2008; An et al., 2013) have shown that after regular Baduanjin training, the strength of the quadriceps femoris muscle is significantly improved. This positive effect on muscle strength can prevent the degradation of balance ability.

In the study of Liu et al., (2016), the elderly were divided into two groups, one group received Baduanjin intervention for 12 weeks, and the other group received moderate speed walking intervention. Timed-Up-and-Go (TUG), One Leg

Stance test (OLST) and BBS of the two groups were evaluated before and after intervention. The results show that compared to the walking group, the Baduanjin group showed better results in TUG, OLST results and BBS scores. The results indicate that the Baduanjin may be a more suitable exercise method for elderly in the communities, which can be used to improve their balance ability.

An analysis of previous reports on Baduanjin exercise shows that long-term participation can effectively delay the decline in the balance ability of the elderly and reduce the incidence of falls (Chen et al., 2022). In a study by Chen et al., (2022), middle-aged individuals with schizophrenia were subjected to 12 weeks of Baduanjin training, with 60 minutes of exercise each time, twice a week, for a total of 24 times over 12 weeks. The control group used the same the Rating of Perceived Exertion (RPE) brisk walking exercise, with 60 minutes of brisk walking activity each time, twice a week, for 12 weeks. Both groups received routine medical and psychosocial treatment. Which used TUG testing to evaluate the balance ability of participants. The results showed that both the Baduanjin exercise and brisk walking improved the physical fitness of the study participants. At the end of the 12 week intervention, the Baduanjin exercise improved overall cognitive ability. The Baduanjin group showed significant improvement in balance and dual task performance compared to the brisk walk group. However, during follow-up, the maintenance effect of Baduanjin on overall cognition was not significant. The above study show that Baduanjin exercise can improve the muscle strength and delay the declining trend in balance ability of the elderly.

2.5 Overview of risks of falls

Falls among the elderly are a significant public health concern due to their

high prevalence and the severe consequences they can entail, such as fractures, increased morbidity, and even mortality (Ortega-Bastidas et al., 2023). Understanding the risk factors associated with falls in older adults is crucial for developing effective prevention strategies.

One study highlights the incidence of falls and fall-related injuries in frail older persons with cancer, emphasizing the need for multifactorial falls risk assessment and management programs (Kenis et al., 2022). The study identifies predictive factors such as sex, falls history, depression risk, cognitive impairment, and dependency in activities of daily living as significant contributors to fall risk (Kenis et al., 2022). Another research focuses on the association between frailty and serum biomarkers in older women, suggesting that high levels of certain bone metabolism markers and low vitamin D levels are linked to increased frailty and, consequently, a higher risk of falls (Alvarez-Ríos et al., 2015).

In institutional settings, falls are particularly prevalent among older adults, with studies showing that preventive measures like bed rails and physical restraints are commonly used, although the latter may increase the risk of injuries from falls (Aranda-Gallardo et al., 2018). The effectiveness of interventions such as exergaming training using devices like the “Wii Fit” balance board has been demonstrated to significantly reduce the risk and incidence of falls in older adults with a history of falls, highlighting the potential of innovative exercise programs in fall prevention (Fu et al., 2015).

A systematic review and meta-analysis have identified social and demographic characteristics as predisposing factors for falls among the elderly, with difficulties in activities of daily living and being of Caucasian descent being notable risk factors. The study underscores the importance of targeting specific at-risk

populations for fall prevention programs (Bloch et al., 2010). Furthermore, multifactorial interventions, which include components like exercise, education, and environmental modification, have been shown to significantly reduce fall rates among community-dwelling older adults, particularly those at high risk (Lee & Yu, 2020).

These aforementioned studies collectively emphasize the multifaceted nature of fall risk in the elderly and the need for comprehensive, individualized prevention strategies that address both intrinsic and extrinsic factors. By integrating such approaches, healthcare providers can better mitigate the risk of falls and improve the quality of life for older adults.

2.6 Gait variables associated with risks of falls

Gait, a fundamental locomotor pattern in human locomotion, represents a complex, highly coordinated, and cyclic motor activity. Gait refers to the posture of the human body during walking, which is the external comprehensive reflection of physiological factors such as anatomical structure and function, human motion control and regulation system, human behavior and psychological state activities during walking (Cicirelli *et al.*, 2022). It is the result of the intricate interplay among the nervous, musculoskeletal, and cardiopulmonary systems, enabling efficient and stable human ambulation (Mirelman et al., 2018). A normal gait is characterized by distinct features such as stability, coordination, and rhythmicity, which are essential for maintaining balance and efficient forward progression (Krasovsky et al., 2012). The gait stage was divided into two phases (Missmann et al., 2022): stance phase and swing phase. The stance phase consists of three sub phases: loading response, single limb support and pre-swing.

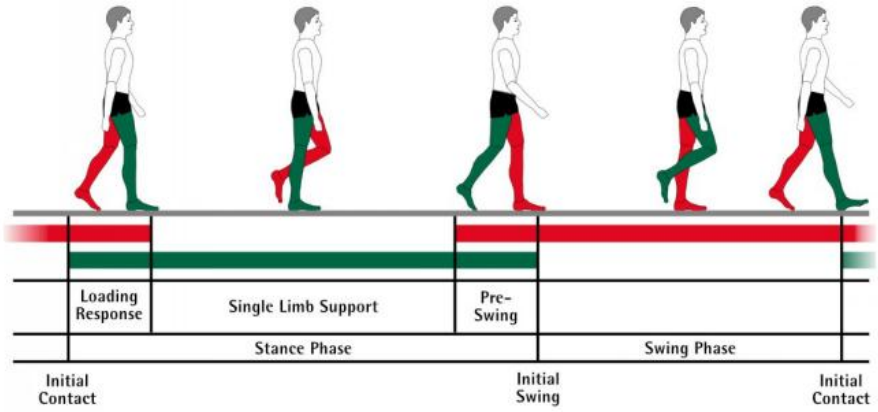

Figure 2.1 Gait phases

Gait symmetry is one of the important characteristics that characterize human gait. In related research, it is usually assumed that the gait function of the left and right sides of the human body is consistent (Sadeghi et al., 2000). The symmetry of a healthy human gait can effectively reduce energy consumption during walking, reduce the risk of falls, and provide a stable and comfortable walking mode (Gouwanda, 2014). Clinical studies have found that some neurological or motor system problems such as lower limb length differences (Kutilek et al., 2014), lower limb amputations (Devan et al., 2015), stroke (Mahon et al., 2015), cerebral palsy (Dussault-Picard et al., 2022), and Parkinson's disease (Alencar et al., 2023) can impair gait symmetry, produce gait abnormalities, and to some extent reveal the health status and pathological characteristics of the human body. Exploring the symmetry of human gait has become a key research topic in interdisciplinary fields such as gait analysis, exercise biomechanics, and rehabilitation. For example, some scholars propose that the dominant functional differences in walking between the left and right lower limbs during normal walking are reflected in gait symmetry variations, suggesting that there is gait asymmetry in normal (healthy) individuals (Sadeghi et al., 2000; Viteckova et al., 2018). In terms of devices to measure gait parameters, studies use gait analysis systems such as Simi motion capture systems