การเปรียบเทียบผลของการออกกำลังกายแบบสั่นกับการออกกำลังกายแบบมีแรงต้านต่อความแข็งแรงของกล้ามเนื้อขาและการรับรู้ตำแหน่งของข้อเท้าในผู้หญิงสูงอายุชาวไทย

นางสาว อัจฉราวดี ศรีจรูญ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาเวชศาสตร์การกีฬา

คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2552

EFFECTS OF VIBRATION EXERCISE IN COMPARISON TO RESISTANCE EXERCISE ON LEG MUSCLE STRENGTH AND ANKLE JOINT PROPRIOCEPTION IN ELDERLY THAI WOMEN

Miss Archrawadee Srijaroon

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Sports Medicine
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Thesis Title	EFFECTS OF VIBRATION EXERCISE IN COMPARISON TO RESISTANCE EXERCISE ON LEG MUSCLE STRENGTH AND ANKLE JOINT PROPRIOCEPTION IN ELDERLY THAI WOMEN
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Field of Study	Sports Medicine
Thesis Advisor	Associate Professor Sompol Sa-nguanrungsirikul, M.D., MSc.
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อัจฉราวดี ศรีจรูญ : การเปรียบเทียบผลของการออกกำลังกายแบบสั่นกับการออกกำลังกายแบบมีแรงต้านต่อความแข็งแรงของกล้ามเนื้อขาและการรับรู้ตำแหน่งของข้อเท้าในผู้หญิงสูงอายุชาวไทย. (EFFECTS OF VIBRATION EXERCISE IN COMPARISON TO RESISTANCE EXERCISE ON LEG MUSCLE STRENGTH AND ANKLE JOINT PROPRIOCEPTION IN ELDERLY THAI WOMEN) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.นพ.สมพล สงวนรังศิริกุล, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ.ดร.นพ.ภาสกร วัธนธาดา 99 หน้า.

วัตถุประสงค์: เพื่อศึกษาผลของการออกกำลังกายแบบสั่นต่อความแข็งแรงของกล้ามเนื้อขาและการรับรู้ตำแหน่งของข้อเท้าในผู้หญิงสูงอายุชาวไทย

วิธีดำเนินการ: อาสาสมัครผู้หญิงสูงอายุที่มีสุขภาพดี อายุระหว่าง 55-65 ปี จำนวน 45 คน แบ่งเป็น 3 กลุ่ม กลุ่มที่ออกกำลังกายแบบสั่น 17 คน กลุ่มที่ออกกำลังกายแบบมีแรงต้าน 16 และกลุ่มควบคุม 12 คน ทำการฝึกออกกำลังกล้ามเนื้อขา 3 วันต่อสัปดาห์ เป็นเวลา 3 เดือน โดยกลุ่มที่ออกกำลังกายแบบสั่นจะออกกำลังกายโดยยืนงอเข่า 160° อยู่บนเครื่องสั่น กลุ่มที่ออกกำลังกายแบบมีแรงต้านจะใช้เครื่องเหยียดขาและเครื่องงอขาในการออกกำลังกาย และกลุ่มควบคุมจะออกกำลังกายโดยยืนงอเข่า 160° อยู่บนพื้นราบแข็ง ทั้ง 3 กลุ่มจะได้รับการทดสอบ ก่อนการฝึกและหลังการฝึกสัปดาห์ที่ 12 โดยจะทดสอบความแข็งแรงของกล้ามเนื้อขาแบบ isometric ด้วยเครื่อง Biodex System 3 รวมถึงทดสอบการรับรู้ตำแหน่งของข้อเท้าแบบ passive reproduction ในแต่ละลักษณะการเคลื่อนไหวของข้อเท้า รวมทั้งสิ้น 2 แบบ (inversion และ plantarflexion) ด้วยเครื่อง Ankle Movement Extent Discrimination Apparatus (AMEDA) และทดสอบการทรงตัวด้วยเครื่อง BalanceCheck โดยให้ยืนบนแผ่นรับแรง แล้วทดสอบดังนี้ A-P CoP excursion และ Lateral CoP excursion ทั้งแบบลืมตาและหลับตา บนพื้นแข็งและพื้นนุ่ม

ผลการทดสอบ: กลุ่มที่ออกกำลังกายแบบสั่นและกลุ่มที่ออกกำลังกายแบบมีแรงต้านมีความแข็งแรงของกล้ามเนื้อเหยียดขาและกล้ามเนื้องอขาเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) ภายหลังการฝึก เมื่อทำการเปรียบเทียบระหว่าง 3 กลุ่ม พบว่ากลุ่มที่ออกกำลังกายแบบมีแรงต้านมีความแข็งแรงของกล้ามเนื้อเหยียดขาเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติมากกว่ากลุ่มออกกำลังกายแบบสั่นและกลุ่มควบคุม ในการทดสอบการรับรู้ตำแหน่งของข้อเท้าและการทดสอบการทรงตัว ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่าง 3 กลุ่ม

สรุปผลการทดสอบ: ภายหลังการฝึก 12 สัปดาห์ การออกกำลังกายแบบสั่นสามารถเพิ่มความแข็งแรงของกล้ามเนื้อขาได้ อย่างไรก็ตาม การออกกำลังกายแบบมีแรงต้านเป็นการออกกำลังกายที่ให้ประสิทธิภาพมากกว่าการออกกำลังกายแบบสั่น เมื่อเปรียบเทียบระหว่างการออกกำลังกายทั้ง 3 กลุ่ม

สาขาวิชา ....เวชศาสตร์การกีฬา................ ลายมือชื่อนิสิต..

ปีการศึกษา ....2552........................ ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก..

ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์ร่วม..

4974804430 : MAJOR SPORTS MEDICINE
KEYWORDS : ELDERLY/ RESISTANCE EXERCISE / VIBRATION EXERCISE / STRENGTH / PROPRIOCEPTION

ARCHRAWADEE SRIJAROON: EFFECTS OF VIBRATION EXERCISE IN COMPARISON TO RESISTANCE EXERCISE ON LEG MUSCLE STRENGTH AND ANKLE JOINT PROPRIOCEPTION IN ELDERLY THAI WOMEN. THESIS ADVISOR: ASSOC. PROF. SOMPOL SA-NGUANRUNGSIRIKUL, M.D.,MSc. THESIS CO-ADVISOR: ASST. PROF. PASAKORN WATANATADA, M.D., Ph.D., 99 pp.

Objectives: To study effects of vibration exercise on leg muscle strength and ankle joint proprioception in elderly Thai women.

Methods: The subjects were healthy elderly Thai women aged between 55-65 years. 45 subjects were assigned into 3 groups: a vibration exercise or VE group (n = 17), a resistance exercise or RE group (n = 16), and a control or C group (n = 12). All 3 groups were trained on leg muscle 3 times/week for 3 months. The VE group performed leg muscle exercise by performing high squat stance with knee-flexed 160° on vibration platform. The RE group trained their leg muscle by performing leg extension and leg curl while the C group trained their leg muscle by performing high squat stance with knee-flexed 160° on smooth and stable floor. At the beginning and the end of the 12-week program, all subjects were involved in 3 measurements: quadriceps and hamstrings muscle strength test in Isometric test by Biodex System 3, ankle joint proprioception (inversion and plantarflextion) test by Ankle Movement Extent Discrimination Apparatus (AMEDA) and balance assessment of A-P CoP excursion and Lateral CoP excursion with eyes-opened and –closed on hard and soft surface by standing on a force platform (BalanceCheck®).

Results: The vibration exercise and resistance exercise groups significantly increased their quadriceps and hamstrings muscle strength ($p < 0.05$) after training. It revealed that the resistance exercise group significantly increased in quadriceps muscle strength comparing among 3 groups. In addition, no significant differences among 3 groups were found in ankle joint proprioception test and balance assessments.

Conclusion: Vibration exercise increases leg muscle strength after the 12-week training. However, resistance exercise has more effectiveness than vibration exercise in comparison with the 3 groups.

Field of Study: ....Sports Medicine……………. Student's Signature ....

Academic year: ……………2009……………………. Advisor's Signature ....

Co-Advisor's Signature ....

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CHAPTER I

INTRODUCTION

Background and Rationales

In 2007, the proportion of older adults over 60 years of age in Thailand increased about 7%; that is, growth rate of the older population was higher than one of overall Thai population. From 1990 to 2020, the proportion of overall Thai population will increase 51.9% as the proportion of elderly population will increase 326% or 6 times; and such age projection is expected to be increasing in the future (สมนึก กุลสถิตพร, 2549) regarding the advancement of medical care and public health (สถาบันเวชศาสตร์ผู้สูงอายุ กรมการแพทย์ กระทรวงสาธารณสุข, 2548).

According to the high proportion of elderly Thai population, it contributes substantially to prevalence of health problems, especially chronic diseases (สถาบันเวชศาสตร์ผู้สูงอายุ กรมการแพทย์ กระทรวงสาธารณสุข, 2548) and degenerative joint diseases (DJD), such as osteoarthritis of knee found in the elderly, which causes difficulty in distance walk, stair stepping, or daily life activities. Such diseases are caused by muscle weakness due to lack of exercise or strength training; and most elderly people even have knee pains and aches. If the knee joint is stable, it can prevent stagger and falls (พงศ์ศักดิ์ ยุกตะนันทน์, 2550). Therefore muscle weakness is one of the most potential health problems in skeletal muscle that plays an important role of maintaining musculoskeletal stability including balance and postural control. Moreover, fall is one of the most recurrent incidents found in elderly people. It causes loss of body movement and affects mental health. Consequences of falls cause loss of confidence in daily life activities in elderly people and make their quality of lives even worse (สมนึก กุลสถิตพร, 2549). Major risk factors contributing to falls are significantly found 1.5 to 10.3 times in muscle weakness, 1.3 to 5.6 times in gait deficit, and 1.3 to 5.4 times in balance deficit, etc. (American Geriatrics Society, 2001).

Older adulthood is accompanied by changes in nervous system and balance, which can impair coordination of the nervous system, slow down the nerve impulse, and decrease 20% of nerve reaction time. It reveals that older adults suffer fall, which accounts for 35-40% (พงศ์ศักดิ์ ยุกตะนันทน์, 2550). They have deterioration of the nervous system and proprioception in joint knees and ankles which causes a long term degenerative joint disease (DJD) (Riberiro and Oliveira, 2007). In addition to changes in nervous system, muscular system changes indicate that not only the loss of muscle mass accounts for 50% but muscular system also decreases, which finally causes muscle power declines. Such changes affect elderly adults on less body movement and agility; and they are at risk of falls and bone fracture (พงศ์ศักดิ์ ยุกตะนันทน์, 2550).

Maximum muscle strength of adults ranges between the ages of 20 and 30 years; and it begins to decline at the age of 65 years and older, which accounts for 75% as well as the incline in muscle atrophy. Muscle mass begins to decrease at the age of 70 years and older, which accounts for 40%; and it links to the loss of muscle strength, which accounts for 30%. Such loss apparently impacts on lower extremity other than upper extremity (สถาบันเวชศาสตร์ผู้สูงอายุ กรมการแพทย์ กระทรวงสาธารณสุข, 2549).

Therefore strength training with resistance exercise is very essential to older adults because it can prolong the loss of muscle and bone mass efficiently; and it also prevents them from falls as their muscle strength reaches normal level. Moreover, alternative exercises such as Chi Kong, Yoga, and Long Stick exercise (LSE) help elderly people improve their muscle strength as well (สมนึก กุลสถิตพร, 2549).

A new exercise program is called "Vibration Exercise" which is now widely introduced to sports medicine training, rehabitation centers, and health care centers, and is the first exercise intervention conducted by a Russian scientist who used it for muscle strength training in well-trained subjects. The result showed that these subjects gained their muscle strength (Cardinale and Bosco, 2003). Some research studies claim that vibration board with low amplitude and frequency of wave is safe for strength exercise (Cardinale and Wakeling, 2005).

Although many previous research studies examined effects of vibration exercise on muscle strength, few of them examined the effects of vibration exercise on ankle joint proprioception. Therefore, the purpose of this study was to investigate the effects of vibration exercise in comparison to resistance exercise on leg muscle strength and ankle joint proprioception in elderly Thai women in order to implement an effective training program that prevents muscle deterioration, reduces risk of falls, and to be considered as an alternative exercise for older adults.

Research questions

1. Is there a difference in leg muscle strength between elderly Thai women with vibration exercise and resistance exercise?

2. Is there a difference in ankle joint proprioception between elderly Thai women with vibration exercise and resistance exercise?

Objectives

1. To study effects of vibration exercise on leg muscle strength and ankle joint proprioception in elderly Thai women.
2. To compare effects of vibration exercise in comparison to resistance exercise on leg muscle strength and ankle joint proprioception in elderly Thai women.

Hypothesis

Elderly Thai women with vibration exercise have greater or equal leg muscle strength than/to those with resistance exercise.

Conceptual Framework

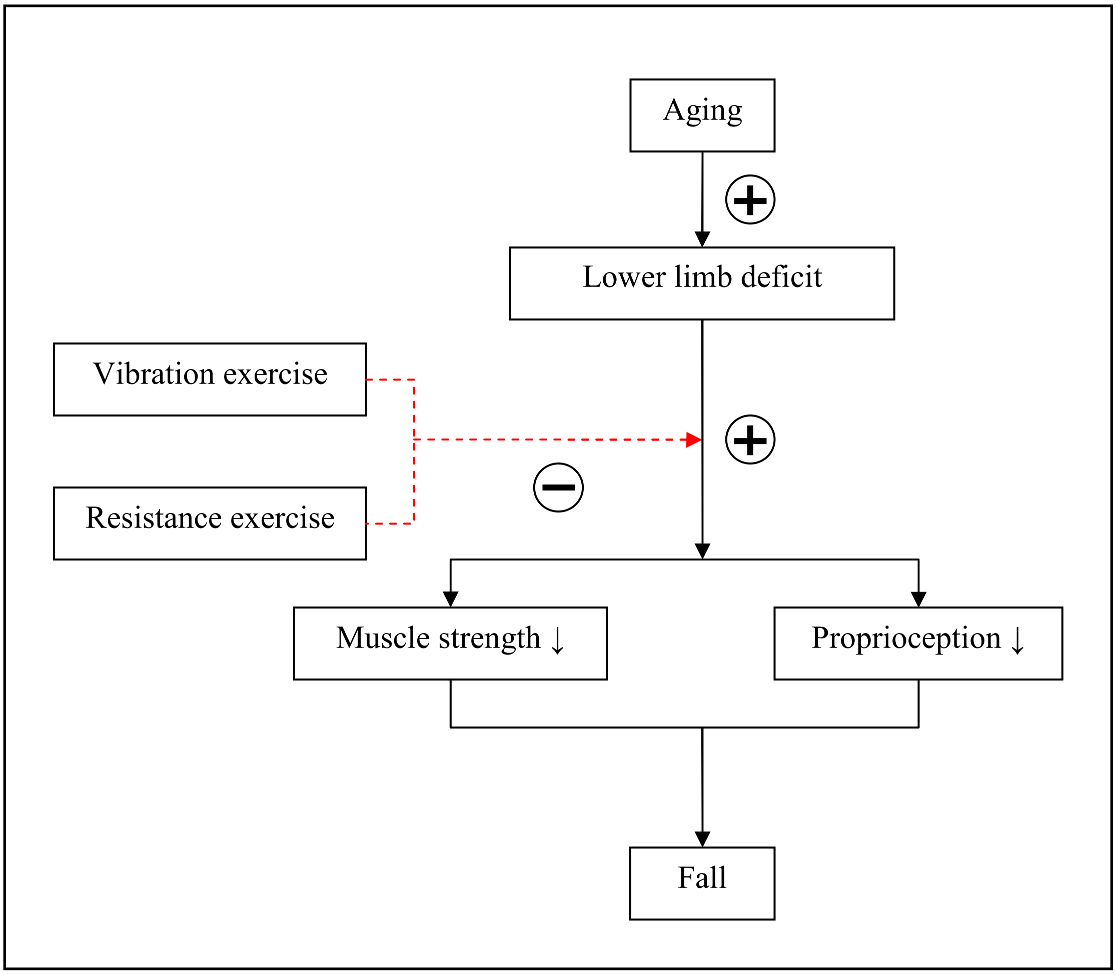

Fig 1.1 Conceptual framework

Scope of research

This study is a human experimental research in which elderly persons with sedentary life participated as the subjects.

The study approval was obtained from the Institutional Review Board of Faculty of Medicine, Chulalongkorn University. Written informed consent was obtained from each subject before the experiment started. On attendance, subjects were given the details of the research procedure and risk involved, and reminded of their right to withdraw at any stage of the study.

Assumption

1. The equipments were calibrated for standard accuracy and reliability.

2. All subjects should be healthy with no physical problem that impedes the research.

3. All subjects voluntarily participated in this study.

Limitations

1. This study requires cooperation of all qualified elderly women.

2. This study requires cooperation of various institutes which all equipments are used for test or exercise.

3. The result of research cannot be extended to women who are not in the study age range.

Key words

Elderly, Resistance exercise, Vibration exercise, Strength, Proprioception

Operational definitions

1. Elderly is defined as women aged 55 to 65 years old.

2. Resistance exercise, a type of active exercise, is defined as a dynamic muscular contraction of lower limb, which applied by external loaded from the machine i.e. leg curl, leg extension.

3. Vibration exercise is an exercise that subjects stand in shoes, knee flex at 20° (high squat stance with knee ankle of 160°) for 1 minute on a vibration platform (Welness I Slimm) which translates the rotating motion of the electromotor into a vertical displacement, inducing a seesaw vibration with frequency 22 Hz, peak-to-peak 8 mm.

After that, the subjects stand upright for rest 1 minute. Subjects alternate these exercises for 20 minutes (standing on platform 10 minutes and rest 10 minutes).

4. Strength is the ability of a muscle or muscle group to develop maximal contractile force against a resistance in single contraction (Heyward, 1998).

5. Proprioception is a sense or perception of the movements and position of the body and especially its limbs, independent of vision (For details see Chapter II, page 11).

Expected benefits and applications

1. To understand the result of vibration exercise that affects the strength of leg muscles and the ankle proprioception in elderly Thai women.

2. To determine the difference between vibration exercise and resistant exercise that affects the strength of leg muscles and the ankle proprioception in elderly Thai women.

3. To gain insight on the design and implementation of effective exercise program for the older adults.

4. To be an optional exercise that helps improve the strength of leg muscles that leads to prevention of falls.

5. To provide preliminary data for further studies.

CHAPTER II

REVIEW LITERATURES

Aging is the process of growing old. Biologic aging results in part from a failure of body cells to function normally or to produce new cell to replace those that are dead or malfunctioning. Normal cell function may be lost through infectious disease, disease, malnutrition, exposure to environmental hazards, or genetic influences. Among body cells that exhibit early signs of aging are those that normally cease dividing after reaching maturity. Sociologic and psychologic theories of aging seek to explain the other influences on aging caused by the environment, engagement, personality, and nonbiologic influences (Mosby's Medical Dictionary, 2009). Moreover, physiologic changes in body's structure can lead to changes in appearance and functional capacity that occurs with increased age (สมนึก กุลสถิตพร, 2549).

The physiologic changes of aging of muscular system

The maximum strength of skeletal muscle is in the range of 20 to 30 years old; but will begin to decrease into middle-aged. The decrease in rates relatively stable compared with increasing age and depending on each muscle type; for example, quadriceps muscle strength will decrease when the age increased; but, diaphragm muscle will remain its strength throughout life. The muscle strength contributes significantly to the quality of life during aging because it can indicate the integrity of other systems such as cardiovascular system and nervous system. The loss of muscle strength appears to be a limitation of physical activities in elderly adults such as sitting, standing, walking, getting up from a chair, and stairs climbing. In addition, changes in muscle mass will cause the change of muscle strength that also affects levels of physical activities and fitness of elderly people (สมนึก กุลสถิตพร, 2549).

Muscle mass

Decrease in muscles mass with increased age involves changes in both muscle fiber area and a number of muscle fibers. Type I (slow fiber) muscle fibers are resistant to age-associated atrophy, at least until the age of 60 to 70 years, while the relative area of type II (fast-twist) muscle fiber appear to decline with decreased age. The loss of muscle fibers has been reported for both male and female and corresponds to the critical age period of 50 years when muscle atrophy becomes most noticeable (Bemben, 2001). Lexell (1997) found that the progressive loss of motor neurons in elderly causing muscle fibers becomes denervated; but many fibers are re-innervated by other motor neurons thereby minimizing the loss of functional muscle fibers. However, the process is insufficient to fully compensate for denervation resulting in atrophy and progressive loss of muscle fibers. In addition, Welle et al. (1993) reported that one of the factors causing muscle atrophy comes from the reduction in protein synthesis rate that is the most essential component of muscle fiber. Older men who age more than 60 years old had the rate of protein synthesis lower than young men who age from 21 to 31 years old 28%; and had the rate of fiber creation lower than young men 44%.

Muscle strength

Since muscle strength also appeares to be a critical component in maintaining physical function, mobility, and vitality in old age, it is paramount to identify factors that contribute to the loss of strength in elderly persons. Sarcopenia, the age-associated loss of skeletal muscle mass (Doherty, 2003), has been postulated to be a major factor in the strength decline with aging (Roubenoff and Hughes, 2000). A cross-sectional study of muscle strength and mass in 45 to 78 years old men and women showed that isokinetic strength of the elbow and knee extensors and flexors was lower (range 15.5 to 26.7%) in the 65 to 78 than in the 45 to 54 years old men and women (Frontera et al., 1991). Goodpaster et al. (2006) said that the loss of muscle mass was associated with the decline in strength in older men and women adults, with men losing strength almost twice as much as women. Rates of leg strength decline were about three times greater than the rates of loss of leg lean mass. Similarly, the finding of Hughes et al. (2001) showed that the rates of decline in isokinetic strength averaged 14% per decade for knee extensors and 16% per decade for knee flexors in men and women. Women demonstrated slower rates of decline in elbow extensors and flexors (2% per decade) than men (12% per decade). Thus the change in leg strength was directly related to the change in muscle mass in both men and women.

In addition the loss of muscle strength in lower extremity is a result of change in aging physiology, which is one of the most potential factors of falls. Extensor muscle strength can prevent older persons from falls after they perform gait perturbation; and a measurement of maximum muscle strength may be used as a protocol to distinguish risks of falls in aged individuals. (Pijanappels, 2008)

Anatomy of the knee

The knee is commonly considered a hinged joint because its two principal movements are flexion and extension. However, because rotation of the tibia is an essential component of knee movement, the knee is not a true hinge joint. The stability of the knee joint depends primarily on the ligament, the joint capsule, and the muscle that surrounds the joint. The knee is designed primarily to provide stability in weight bearing and mobility in locomotion; however, it is especially unstable laterally and medially. (Prentice, 2006)

Knee musculature

For the knee to function properly, a number of muscle must work together in a highly complexion fashion. The following is a list of knee actions and muscle that initiate them (Prentice, 2006; Clemente, 1997):

• Knee extension is executed by the quadriceps femoris muscle consisting of the rectus femoris and three vastus muscle (lateralis, intermedius and medialis) as it converges inferiorly to form a power tendon which encases the patella and inserts onto the tuberosity of the tibia.

• Knee flexion is executed by the hamstrings muscle (These include three muscles: the biceps femoris, semitendinous, semimembranous), gracilus, satorius, gastrocnemius, popliteus and plantaris muscle.

• External rotation of the tibia is controlled by the biceps femoris.

• Internal rotation is accomplished by the poplitial, semitendinous, semimembranous, satorius and gracilis muscle.

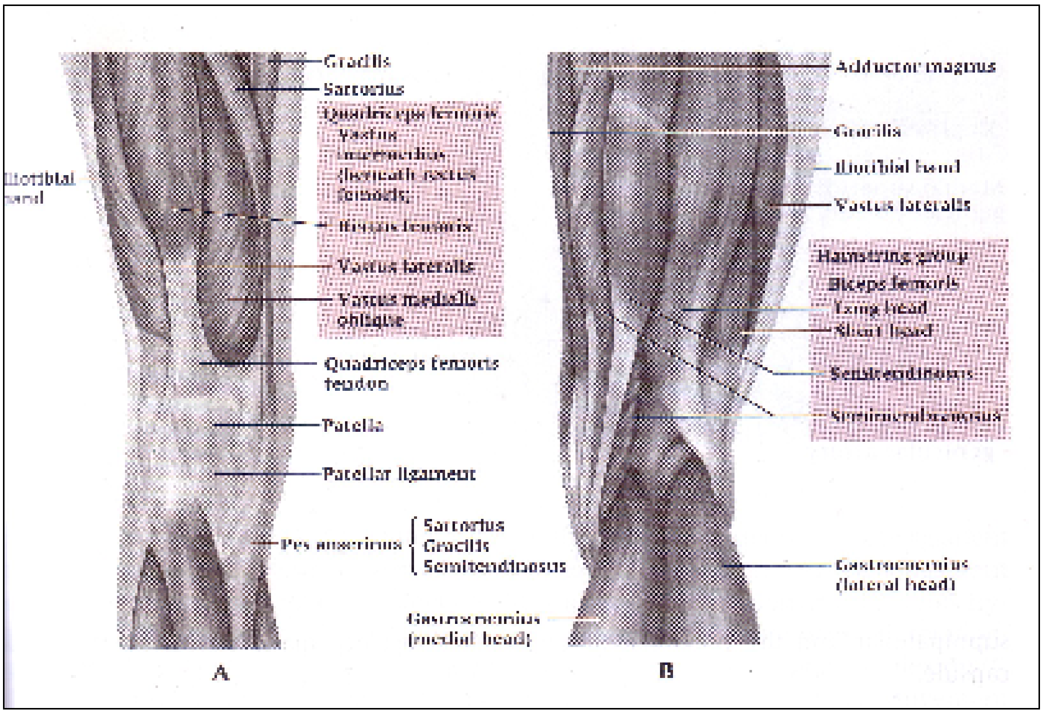

Fig 2.1 A) The quadriceps femoris muscle, B) The hamstrings muscle (Prentice, 2006)

Effect of quadriceps muscle deterioration

Lawrence et al. (1998) found that more than 15% of Americans have some from arthritis. The prevalence of the arthritis increases with age, affecting 50% of persons age 65 years or older. Osteoarthritis (OA) is the most common and has the highest annual incidence. The following are affected by the disease and contribute to functional limitation in individuals with arthritis such as flexibility, biomechanical efficiency, muscle strength, endurance, speed and proprioception. These impairments are usually more pronounced for women. Muscle weakness is the longest recognized and best established correlate of lower limb function with limitation in individuals with knee OA. (Baker, 2000) People with lower limb arthritis commonly experience reduced levels of muscular strength. Quadriceps strength deficits of between 20% and 70% have been reported for people with arthritis affecting the knees (Fisher and Pendergast, 1997; Hassan et al., 2001; Hurley et al., 1997; Nordesjo et al., 1983,; Slemenda et al., 1997). Proprioceptive deficits have also been described in arthritic populations (Hurley et al., 1997; Barrett et at., 1991; Marks et al., 1993; and Pai et al., 1997). Altered sensory information from the articular surfaces, capsule, and ligaments of arthritic joints may result in impaired perception of limb positions that is necessary for safe movement (Sharma and Pai, 1997). In addition, quadriceps femoris weakness has profound functional consequences especially in older individuals resulting in disability including limitations in activities of daily living and an increased risk of falls (Chandler, 1998).

Proprioception

Throughout the human life span the functions of several physiological systems dramatically change, including proprioception. Impaired proprioception leads to less accurate detection of body position changes increasing the risk of fall, and to abnormal joint biomechanics during functional activities, so over a period of time, degenerative joint disease may result. (Riberio and Oliveira, 2007)

Definition of proprioception

Sherrington’s classical definition of proprioception is all neural inputs (afferent information) originating from joints, muscles, tendons, and associated deep tissue proprioceptors or mechanoreceptors. These proprioceptive signals are projected to the CNS for processing, which ultimately regulates reflexes and motor control (Sherrington, 1906). Other studies said that proprioception can be defined as the cumulative neural input to the central nervous system from specialized nerve ending called mechanoreceptors. The mechanoreceptors are located in the joint, capsules, ligament, muscles, tendon, and skin (Carpenter et al., 1998; Volight et al., 1996). According to Stedman’s Medical Dictionary (2006), proprioception refers to the sense or perception of the position and movement of the body, especially its limbs, and is independent of vision (Janwantanakul 2001). Consequently, the term “proprioception” is suitable for the purpose of this study, used in order to refer the perception of joint position.

Sources of somatosensation

An organism receives sensory information about its environment through a number of different sensory channels. Information arises through activity of both the peripheral mechanoreceptor as well as visual and vestibular receptors (Lephart et al., 1996; Lephart et al., 1997). The sensory receptors of proprioception are located in skin, joints, ligaments, tendons and muscles (Biedert et al., 1992, Lephart et al., 1997) (see Fig. 2.2). They are activated by changes in pressure and movement of soft tissue structures. Their afferent inputs are integrated at all levels of the CNS to generate appropriate motor responses.

Each tactile and proprioceptive sense of the somatosensory system can be divided into two functional groups (slow adaptating and fast adaptating) with respect to the manner in which they respond to temporal (constant or enduring) characteristics of stimuli (Martin and Jessel, 1991). Possessing both types of receptors is essential for the postural control system to operate during static, dynamic, and functional activities. Mechanoreceptors located within musculotensinous tissue include the muscle spindles and golgi tendon organs (GTOs) (Guyton, 1991; Lepart et al., 1997).The GTOs, located near their musculotendinous junction (Guyton, 1991; Vander et al., 1990).

The sensation of touch, pressure, and vibration are conveys to CNS via the tactile sense organs. Each somatosensory organ is triggered by a unique stimulus. Hair follicle cells are the principal mechanoreceptors in area of hairy skin while glabrous (hairless) skin contains Meissner corpuscles (fast adapting) and Merkel receptors (slow recepting). Deep to both hairy and glabrous skin in the subcutaneous tissue are Ruffini corpuscles (slow adapting) and Pacinian corpuscles (fast adapting), each of which has a large receptor field. Based on their slow adaptation characteristic, Ruffini corpuscles can signal continuous states of deformation of the skin and deep tissues. Parcinian corpuscles, the most widely studied tactile sensory organ, are stimulated by high frequency vibration stimuli and very rapid movements of tissue, adapting within a few hundredths of second. Acting simultaneously, the population of mechanoreceptors located in the plantar surface of the foot can detect the site, force, velocity, and acceleration of transient force exerted during dynamic activity (Riemann and Guskiewicz, 2000).

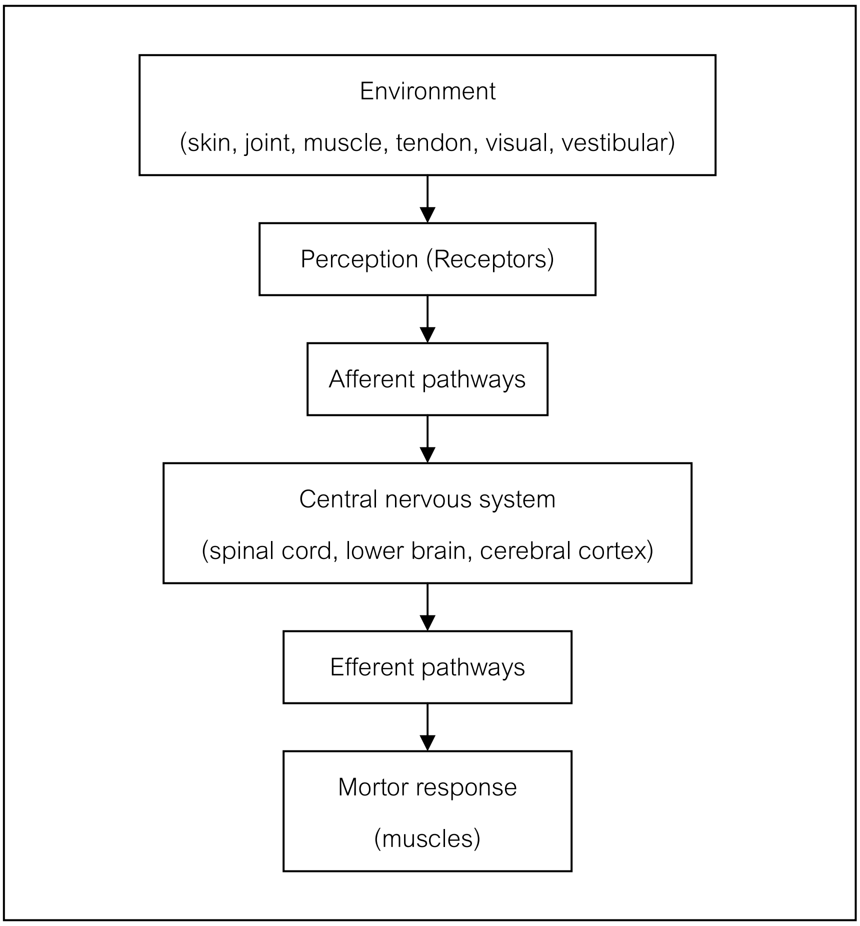

Fig. 2.2 Sensory mortor system (Biedert et al., 1992; Lephart et al., 1997)

Classification of the senses

Propriocption is subdivided into two categories: sense of static position (position sense) and sense of movement (kinesthesia or dynamic proprioception). These senses are primarily attributable to joint and muscle mechanoreceptors, with the tactile senses playing contributory roles. Joint receptors include Pacinian corpuscles, Meissner corpuscles, Ruffini endings, and free nerve ending distributed throughout the articular structures (Boyd, 1954; Freeman and Wyke, 1967; Grigg and Hoffman, 1982; Schultz et al., 1984 and Zimmy, 1888).

Proprioception deterioration with aging

Physiological age-related change in somatosensory system

Muscle spindle

Muscle spindles are stretch-sensitive mechanoreceptors that provide the nervous system with information about the muscle’s length and velocity of contraction, thus contributing to an individual’s ability to concern joint movement (kinesthesia) and joint position sense (JPS) (Prochazka, 1981; Miwa et al., 1995).

Swash and Fox (1972) reported that aged human muscle spindles exhibited increased spindle capsule thickness and loss of total intrafusal fiber per spindle. Likewise, Kararizou et al. (2005) investigated muscle spindles obtained from individuals (26-93 years) and found that spindles from the deltoid muscle and extensor digitorum brevis muscle had significant reduction in spindle diameter as a function of age. In addition, Miwa et al. (1995) examined the afferent response of muscle spindles to varying levels of stretch applied to the medial gastrocnemius muscle of middle-aged and older rats. Older rats had significantly lower discharge rates than middle-aged rats when compared at the same muscle length, implying a decline in spindle static sensitivity. The dynamic index was significantly lower for aged rats.

Golgi tendon organ and articular receptors

The golgi tendon organ (GTO) and articular receptors provide additional proprioceptive information that is important for accurated assessment of joint movement (Landy-Eckman, 2002).

Morisawa (1998) examined the mechanoreceptors (Ruffini’s, pacinian, golgi tendon-like ligament receptors, and free nerve endings) from coracoacromial ligaments of patients shoulder surgery. The examiner reported a general decline in number of all receptor types as increased in age from 20 to 78 years. Similarly, Aydog et al. (2006) conducted histological analysis of anterior cruciate ligament from young, adult and old rabbits. They identified a significant step-wise decrease in the number of Ruffini's, pacinian, and golgi tendon-like ligament receptors across age groups. Pacinian and Ruffini's receptors that were visualized in older rabbits also demonstrated irregular and flattened margins.

Cutaneous receptors

Cutaneous mechanoreceptors that innervate glabrous or hairless skin are the rapidly adapting Meissener's corpuscle, the slowly adapting Merkel disk, rapidly adapting Pacinian, and the slowly adapting Ruffini's ending. These four receptors, in combination with hair cells, deliver important feedback about the environment. Cutaneous receptors are not typically thought of as proprioceptors, but the information they provide supplements the JPS and movement (Landy-Eckman, 2002).

Verrillo (1979) showed that vibrotactile sensitivity involving Pacinian pathways becomes impaired with age. Moreover, Bolton et al. (1966) studied punch skin biopsies from little finger and plantar aspect of the great toe individuals ranging age from 11 to 89 years. Analysis revealed a progressive age-related decrease in both the great toe and little finger Meissener's corpuscle mean concentration (MCs/mm^2). Similarly, Bruce (1980) combined histological and sensation testing and determined the older adults not only had decreased Meissener's corpuscle in index finger, but also exhibited impaired touch threshold that were 2 ½ times over those of young control subjects.

The relation between proprioception and postural control

The postural control system utilizes complex process involving both sensory and motor components. Maintenance of postural equilibrium requires sensory detection of body motion, integration of sensory motor information within CNS and execution of appropriate musculoskeletal responses. The position of the body in relation to gravity and its surroundings is determined by combining visual, vestibular, and somatosensory inputs. Balance movements involve controlled, coordinated actions along close kinetic chain.

The relationship between balance and postural equilibrium are often used interchangeably. Balance is process of maintaining the center of gravity (COG) within the body's base of support (Nashner, 1993). Postural equilibrium is a broader term that describes the balanced state of force and moments action on body's center of mass. When postural equilibrium is achieved, the body's center of mass moves uniformly and minimally (postural sway) around the body equilibrium point (Nashner, 1993, Nashner, 1989).

The role of proprioception involving postural control is divided into 3 levels:

- **Spinal cord**: Proprioceptive afferent connections on to Aα and especially Aγ motor neurons for producing reflexes designed to protect joints against potentially harmful stresses.

- **Cerebellar**: It is important for regulation of postures, balance and movement in general (Stillman, 2002).

- **Cortex**: Proprioceptive afferent connections on to dorsal column-medial lemical tract which results the perception of body movement with independence of vision; for example, as the perception of joint position, especially when moving to restricted movement, it will help us avoid any movement beyond the point as a result of an injury (ประวิตร เจนวรรธนะกุล, 2551).

Evaluation of Proprioception

Assessment of joint proprioception is divided into 2 components: kinaesthesia and joint position sensibility. Kinaesthesia is assessed by measuring the threshold to detection of passive motion, while joint position sense is assessed by measuring the reproduction of passive positioning and the reproduction of active positioning (Lephart, 1996; Skinner, 1996; Smith, 1989). In order to minimize the contribution of musculotendinous mechanoreceptors (muscle spindles and Golgi tendon organs) in providing the CNS with information regarding limb position and movement, the threshold to detection of passive movement and reproduction of passive positioning are conducted at a slow angular velocity (0.5° to 2° per second) (Lephart, 1996). The passive nature of this assessment procedure is thought to selectively stimulate Ruffini or Golgi type mechanoreceptors in the joint. Nevertheless, there is currently very little information available regarding the measurement of ankle joint position sense. No left-right comparisons or test-retest measurements have been reported (Konradsen et al., 2000).

Assessment of the ability to perceive joint position

The assessment of the ability to perceive joint position is a test that quantitatively examines the ability of an individual to replicate a predetermined (target) joint position that has been previously demonstrated, termed the "repositioning test". The repositioning test is generally used to evaluate position sense at various joints, such as the shoulder, elbow, wrist, hip, knee and ankle joints (Beynnon et al., 2000; Borsa et al., 1994; Friden et al., 1996; Gandevia, 1996; Hogervorst and Brand, 1998; Jerosch and Prymka, 1996; Lephart et al., 1997; McCloskey, 1978).

Active/passive movement

Active/passive movement refers to the manner by which the limb or body part is moved to the target and perceived joint positions. For "passive positioning" to a target position, a limb is usually secured and supported by an apparatus. The relaxed limb is moved passively from a starting position to a target position either by an examiner or apparatus at a constant speed. For "active positioning" to a target position, a subject, instead of an examiner or apparatus, actively moves their limb or body part from a starting position to a target position at either a controlled or uncontrolled speed. A subject moves the limb until either told to stop or a mechanical stop is reached.

In "passive repositioning" technique, after reaching the target position, a subject is asked to remember the position while the limb is sustained in the position for a period of time. After that, the limb is moved away either actively or passively from the target position to the either starting position or a random position. To indicate a perceive position, the limb is passively moved towards the target position. A subject is then instrumented to inform an examiner or manipulate a switch to stop a mechanical arm when they feel the limb has regained the target position. For “active repositioning” technique, a subject actively moves the limb back to the target position (Janwantanakul, 2001).

Jerosch et al., 2003 claimed that active repositioning is theorized to test proprioception by stimulation of the muscle receptors (muscle spindle and GTOs), passive repositioning is theorized to stimulate mechanoreceptors in the joint versus muscles. In addition, Lephart et al. (1997) claimed that the repositioning test with passive movement maximally evaluates the contribution of joint mechanoreceptors to proprioceptive acuity while the repositioning test with active movement provides a more functional assessment of proprioceptive acuity. Functional activities are normally performed with active movement or muscle contraction. Therefore, testing with active movement may be more functionally relevant. However, the statement that testing with passive movement would maximally evaluate the proprioceptive contribution of joint receptors should be viewed with caution (Janwantanakul, 2001).

Falling

Altered neuromuscular control of the lower limb and consequently poor balance resulting from changes in proprioceptive function could be related to high incidence of harmful falls that occur in older age (Riberio and Oliveira, 2007). Falls are among the most common and serious problems facing elderly persons. Falling is associated with considerable mortality, morbidity, reduced functioning, and premature nursing home admissions (Brown, 1999; Nevitt, 1997; Robbins et al., 1989; Rubenstein et al., 1994; Tinetti et al., 1986). Falls generally result from an interaction of multiple and diverse risk factors and situations, many of which can be corrected. This interaction is modified by age, diseases, and the presence of hazards environment. Impairments in sensation, strength (force-generating capacity of a muscle), reaction time, vestibular function contribute to the increased likelihood of falling (Lord et al., 1999; Lord and Sturnieks, 2005; Lord and Ward, 1994).

Risk factors for falling

1. Intrinsic factors including lower extremity weakness, poor grip strength, balance disorders, functional and cognitive impairment, and visual deficits.

2. Extrinsic factors including polypharmacy (i.e., four or more prescription medications) and environmental factors such as poor lighting, loose carpets, and lack of bathroom safety equipment.

Although investigators have not used consistent classifications, The American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention studies ranked the risk factors and summarized the relative risk of falls for persons with each risk factor (Table 2.1). From this table, it can be seen that there are primary risk factors that cause falling are in the range 1.5 to 10.3 in muscle weakness, 1.7 to 7.0 in history of fall, 1.3 to 5.6 in gait deficit, and 1.3 to 5.4 in balance deficit (American Geriatrics Society, 2001).

Table 2.1 Result of Univariate Analysis of Most Common Risk Factors for Falls Identified in 16 Studies that Examined Risk Factors

Risk Factor	Mean RR-OR*	Range
Muscle weakness	4.4	1.5-10.3
History of falls	3.0	1.7-7.0
Gait deficit	2.9	1.3-5.6
Balance deficit	2.9	1.6-5.4
Use assistive device	2.6	1.2-4.6
Visual deficit	2.5	1.6-3.5
Arthritis	2.4	1.9-2.9
Impaired activities of daily living	2.3	1.5-3.1
Depression	2.2	1.7-2.5
Cognitive impairment	1.8	1.0-2.3
Age > 80 years	1.7	1.1-2.5

* RR = Relative risk ratios, OR = Odds ratios

Besides that, Sturnieks (2004) found that older people with lower limb arthritis are at increased risk of falling due to deficits in neuromuscular systems specifically, impairments in knee and ankle strength, lower limb proprioception, and balance. The arthritis group suffered significantly more falls (RR= 1.22) and injurious falls (RR =1.27) in the previous 12 months than the nonarthritis group.

The role of strength exercise in preservation during aging

Muscle weakness is associated with reduced walking speed (Buchner et al., 1996) and increased risk of disability in older people (Guralnik et al., 1995). However, muscle strength can be improved in these individuals, particularly if their muscles are significantly overloaded by training exercises (Chareette et al., 1991). Moreover, extensor muscle strength can prevent older persons from falls after they perform gait perturbation; and a measurement of maximum muscle strength may be used as a protocol to distinguish risks of falls in aged individuals (Pijnappels et al., 2008).

Resistance exercise

The long-range implication of lack of strength is limited independence. Appropriate resistance training may enhance over all well-being in older adults. Resistance training may assist in effective management of osteoarthritis (Ettinger et al., 1997). Functional ability can be improved if surrounding muscles and unaffected joints share stress with affected joints. Stronger muscles absorb more of the attendant stress on a joint, thereby reducing stress on affected joint surfaces.

Evidence indicates that resistance training slows bone loss and can increase bone density (ACSM, 2000; Hakkinen, 1985). Osteoporosis is characterized by decrease bone mineral content (decreased density) and may be improved by resistance training. Furthermore, training-induced improvements in muscular strength and balance may prevent falls that cause many fractures among elderly women with osteoporosis.

Resistance preserves muscle tissue during aging and may contribute to weight control by maintaining an increased metabolic rate. In addition, most daily activities require some muscular fitness. With appropriate resistance training, older adult improve the likelihood that they can maintain appropriate levels of muscular fitness and improved daily function (ACSM's resources for the personal training, 2005).

The effects of resistance exercise in older adults

Resistance exercise increases muscle strength; however, its effect on joint proprioception is unknown. Thomson et al. (2003) studied effects of resistance exercise on ankle joint proprioception in older women divided into 2 groups. The first group was an experimental group of 19 older women who were assigned to do resistance exercise at 80% of 1RM on both upper and lower extremity for 3 times a week. The second group was a control group of 19 older women who were assigned to do the same exercise routines as the first group without resistance training for twice a week. After 12 weeks of training period, the evaluation of muscle strength and knee joint proprioception revealed that the group of older women with resistance training significantly increased their muscle strength more than the one without resistance training. And both groups significantly increased their knee joint proprioception from doing these exercises in the first 6 weeks.

Similarly, Vincent et al. (2002) compared effects of high intensity resistance exercise at 80% of 1RM for 8 repetitions with low intensity resistance exercise at 50% of 1RM for 13 repetitions in healthy older persons. After training 3 times a week for 24 weeks, the assessment of muscle strength at 1RM and muscle endurance at 60% of 1RM showed not only that high and low intensity resistance exercise enhanced muscle strength 17.8% and 17.2% respectively but they also improved endurance. According to the above studies, they prove that older individuals benefit from high and low intensity resistance exercises.

Fielding et al. (2002) also studied effects of high-velocity (HI) exercise in comparison with low-velocity (LO) exercise in elderly women with functional limitation.

They performed 3 sets and 8-10 repetitions of leg press and knee extension exercises at 70% of 1RM 3 times a week for 16 weeks. The difference of both exercises was that older women in the group of HI exercise were assigned to do concentric phase in each repetition as fast as they could. The measurement of muscle strength and high peak power of lower extremity by performing leg press and knee extension at 1RM indicated that both HI and LO exercises significantly improved muscle strength; however, the HI exercise enhanced high peak power more than the LO.

Beneka et al. (2005) investigated that 64 healthy inactive elderly men and women were assigned to one of four groups: control group, low-intensity or LI (50% of 1RM), moderate-intensity or MI (70% of 1RM), and high-intensity or HI (90% of 1RM). Participants exercised on resistance machine: leg extension, leg curl and leg press. Regarding the different testing velocities, the HI group showed the most strength improvement at low velocity testing from 7.3% to 11.2% for men and from 2.3% to 15.2% for women while the other training groups exhibited similar strength increase at all tested speeds.

Bottaro et al. (2007) conducted research in 20 inactive older men and divided into 2 groups. The first group performed power training at 60% of 1RM for 8-10 repetitions in 3 sets as fast as they could. On the other hand, the second group performed traditional resistance training at 60% of 1RM holding contraction for 2-3 seconds for 8-10 repetitions in 3 sets. These 2 groups trained 2 times a week for 10 weeks on both upper and lower extremity. After that, older men were tested their muscle strength and peak power and found that both 2 training programs increased muscle strength; however, the power training can be performed safety and appears to be more effective in improving muscular power and functional performance compared with the traditional resistance training.

According to review literatures, exercise machines such as leg extension, leg press, and leg curl, which are mainly used for resistance training, offer several advantages (ACSM's resources for the personal training, 2005):

• They require less skill to use.

• They generally provide more support for the back by stabilizing body position.

• They enable participants to start with lower levels of resistance (depending on specific type of equipment).

• They allow greater control of exercise range of motion.

• They generally provide a more time-efficient workout.

Vibration exercise

A new exercise program called “**vibration exercise**” is introduced. As a therapy, **whole body vibration** (sometimes abbreviated as **WBV**) was explored by Russian scientist Vladimir Nazarov, who tested vibration on astronauts in an effort to decrease the loss of muscle and bone mass in space. As there is minimal gravitational force in space, muscles and bones are not loaded as they normally are on earth. Astronauts in space lose their muscular strength very quickly, which is why they are not able to easily walk when they come back to earth. The decrease of bone density increases the risk of bone fractures, so it's not safe to stay in space for extended periods. The aerospace industry in the former Soviet Union worked with vibration training. Before their departure, astronauts were subjected to special training sessions so that the density of their bones would increase and their muscular strength would rise (Felsenberg, 2004; Bleeker et al., 2005).

The vibration is a mechanical stimulus characterized by oscillatory motion. The biomechanical variables that determine its intensity are the frequency (Hz) and amplitude (mm). The exercise devices currently available on the market deliver vibration to whole body by mean of oscillating plates using 2 different systems: a) reciprocating vertical displacements on the left and right side of a fulcrum; b) the whole plate oscillating uniformly up and down (Cardinale and Wakeling, 2005). The vibration generated by the motors underneath the platform is transmitted to the person standing on the machine with squat position.

There are 2 methods of applying vibration to the human body during exercise:

1.) Direct oscillating vibration to muscle belly or tendon of the muscle being trained, by vibration unit that may either be held by hand or be fixed to an external support.

2.) Indirect oscillating vibration to muscle belly is when the vibration wave is transferred from its source through some parts of body to target muscle. For example, during training of the quadriceps, the subject may stand on a vibrating platform that oscillates up and down in the vertical direction and perform various exercises (such as squatting). The vibration is transmitted from the platform through the lower extremities to the quadriceps. This method has been termed whole body vibration training (Luo et al., 2005).

Regarding a literature review of Luo et al. (2005), to activate the muscle most effectively, vibration frequency should be in range of 30–50 Hz; and the frequency that is lower than 20 Hz is avoidable due to it causes resonance of human body which may induce injury effect (Mester et al., 2002). Similarly, a literature review of Reln et al. (2007) suggests that the frequency 12-45 Hz and the amplitude 1.7-5 mm are compatible with long term exercise in leg muscle. Furthermore, regular vibration exercise 2 to 5 times per weeks seems to be good exercise arrangement for muscular effect for older and untrained people. Although oscillating vibration exercise has many benefits to many types of patients, the wrong combination of vibration parameters can cause damage to cardiovarcular system; and it impairs nervous system. There are quite a few side effects; however, only erythema, itching of the legs and edema are reported.

Moreover, Rittweger at al. (2003) recommends that the frequency vibration that is lower than 20 Hz can make muscle relaxation; while the frequency vibration that is higher than 50 Hz can cause muscle soreness and haematoma in muscle that usually happens to those who rarely do exercise. In addition, a literature review of Madou and Cronin (2008) suggested that with 60-second intervention and 60-second rest period, the most frequency vibratory stimulation loading parameters used were 3-6 Hz and 3 mm amplitude for multiple sclerosis and Parkinson disease patients, 30 Hz and 3-5 mm amplitude for all conditions (the elderly, postmenopausal and stroke patient) to improve physical and functional performance.

However, there are a few research studies that specify the exact suitable frequency and amplitude for vibration exercise. Yet, most studies suggest that vibration exercise with low frequency and amplitude gives safe and effective results.

The effects of vibration exercise on muscular system

Vibration exercise is one of the exercise programs that improve muscle strength. Delecluse et al. (2003) conducted a research on quadriceps muscle strength in 74 untrained female volunteers. These female volunteers were divided into 4 groups: the first group was 20 female volunteers who performed vibration exercise at frequency 35-40 Hz, amplitude 2.5-5 mm, and acceleration 2.28-5.09 g. The second group was 21 female volunteers or placebo vibration group who performed vibration exercise with so low acceleration 0.4 g that did not impact on muscle activity. Both 2 groups were standing on vibration board with different positions such as squat and deep squat. The third group was 20 female volunteers who performed resistance exercise with leg press and leg extension at moderate intensity. The fourth group was a control group with 13 female volunteers. According to the assessment of quadriceps muscle strength before and after the exercise program, it indicated that the vibration and resistance exercises significantly improve quadriceps muscle strength while the placebo vibration group and control group did not significantly improve their quadriceps muscle strength.

Later, Roelants et al. (2004) studied quadriceps muscle strength and speed of movement in 89 elderly postmenopausal women. These older women were divided into 3 groups: the first group was 30 older women who performed vibration exercise at frequency 35-40 Hz and amplitude 2.5-5 mm. The second group was 30 older women who performed resistance exercise with leg press and leg extension. The third group was a control group with 29 older women. All groups trained 3 days a week for 24 weeks. The assessment of muscle strength and speed of movement with resistance (1%, 20%, 40%, and 60% of isometric maximum) revealed that isometric knee extensor strength increased significantly over 12 weeks in resistance exercise as well as vibration exercise whereas no significant increase was found in control group. The additional increase after 24 weeks was not significant in resistance exercise or vibration exercise.

Speed of movement increased in vibration exercise and resistance exercise while there was no change in control group. However, vibration exercise group enhanced speed of muscle movement with resistance 1% and 20% of isometric maximum more than resistance exercise group.

Torvinen et al. (2002) studied 56 young, healthy, nonathletic adults divided into 2 groups. The first group performed vibration exercise at frequency 25-40 Hz and amplitude 2 mm for 4 minutes, 3-5 times a week for 16 weeks with different positions such as light squatting, standing in erect position, and standing on the heel. The second group was control group without any exercise. According to the assessment of vertical countermovement jump and quadriceps muscle strength, it showed that the height of the vertical countermovement jump increased 10.2% and quadriceps muscle strength improved 3.7% in vibration exercise group after 8 weeks; however, after 16 weeks, the height of vertical countermovement jump decreased 8.5% and quadriceps muscle strength declined 2.5% in vibration exercise group.

Mahieu et al. (2006) conducted a research on 33 skiers aged 9-15 years divided into 2 groups. The first group was 17 skiers who performed vibration training at frequency 24-28 Hz and amplitude 2-4 mm standing in different positions on vibration board such as squat, deep squat, and wide-squatting. The second group was 16 skiers who performed a land exercise which was equivalent resistance training with the above positions same exercise as vibration exercise training. Both groups trained 3 times a day for 6 weeks. The assessment of dorsiflexors and plantarflexors muscle, and the knee flexor and extensor muscles before and after training revealed that both groups significantly improved ankle and knee muscle strength. Moreover, the increase in plantarflexor strength at low speed was significantly higher in vibration exercise group than the equivalent resistance training group.

Bogaerts et al. (2007) studied muscle strength and muscle mass in older men in 1 year. These older men were divided into 3 groups: the first group performed whole body vibration exercise at frequency 30-40 Hz and amplitude 2.5 and 5 mm with standing in different positions such as squat and deep squat. The second group performed fitness training program: cardiovascular program consisted of walking, running, and cycling, resistance exercise program consisted of exercise for whole body and balance training. The third group did daily life activities. The assessment of isometric muscle strength and the measurement of muscle mass with CT showed that the first and second groups increased quadriceps muscle strength and muscle mass in comparison to the third group. There was no significant difference between training effect in the first and second groups.

Trans et al. (2009) investigated the effect of whole body vibration (WBV) exercise in 52 female patients with OA knee (mean age 60.4 $\pm$ 9.6 yrs). These subjects were divided into 3 groups: WBV-exercise on stable platform, WBV-exercise on a balance board and control group. Training intensity: frequency 24-30 Hz, duration of training program was maximum 10 ½ minutes. After 8 weeks they found that muscle strength increased significantly in WBV-exercise on stable platform compared to control group.

On the other hand, Raimundo et al. (2009) studied of low-frequency vibration (a 12.6 Hz of frequency and amplitude of 3 mm) and walk-based program in 27 postmenopausal women. After 8 months they found that none of exercise programs showed change on isokinetic measurements of knee extensors. These results indicated that both programs differ in the main achievements and could be complementary to prevent lower limbs muscle strength decrease as we age.

The effects of vibration exercise on the other system

Tissue perfusion and the peripheral vasculature

Vibration exercise has benefits to blood circulation; for example, Kerschan-Schindl et al. (2001) studied on 20 healthy adults who were assigned to stand on vibration board at frequency 26 Hz and amplitude 3 mm for 9 minutes without taking a break. Alterations in muscle blood volume of quadriceps and gastrocnemius muscles were assessed with power Doppler sonography and arterial blood flow of popliteal artery with a Doppler ultrasound machine. Power Doppler indicated that muscular blood circulation in calf and thigh significantly increased after exercise, mean blood flow velocity of the popliteal artery increased, and its resistance index decreased significantly. The result of the study indicated that vibration exercise with low frequency did not have negative effect on peripheral circulation. Similarly, Lohman et al. (2007) studied on 45 healthy adult volunteers divided into 3 groups: The first group performed vibration exercise by standing in different position such as squat on vibration board at frequency 30 Hz and amplitude 5-6 mm. The second group performed the same exercise routines as the first group without vibration board. The third group performed calves massage; that was, when the volunteers lay down on the floor and placed their calves on vibration board at frequency 30 Hz and amplitude 5-6 mm. The assessment of skin blood flow in gastrocnemius was conducted 3 times (pre-exercise, immediate post-exercise, and 10 minute post-exercise) and the results showed that the post-exercise skin blood flow of the third group compared to the pre-exercise one was 2 times; and it was higher than the immediate post-exercise of the first and second groups. Although the 10 minute post exercise blood flow of the third group dramatically decreased, it was higher than those of the first and second groups. Those 2 previous studies merely were the studies of short term blood circulation.

Bone density

The vibration exercise also effects on bone mass; for example, Gusi et al. (2006) studied the effect of vibration exercise on 28 untrained post-menopause women at frequency 12.6 Hz and amplitude 3 mm for 30 minutes in comparison to 1 hour distant walk. These 2 exercises were performed 3 times a week for 8 month. The assessment of bone mass density in lumber spine and balance revealed that the bone mass density in femoral neck of the vibration exercise group increased 4.3%; and there was no significant change in the bone mass density in lumber spine of both groups. Balance was improved 29% in vibration exercise group but not in walking group.

CHAPTER III

RESEARCH METHODOLOGY

Research design

This study was human experimental research which was designed to examine effects of vibration exercise in comparison to resistance exercise on leg muscle strength and ankle joint proprioception in elderly Thai women in accordance with a defined protocol on which all subjects were examined twice: a pre-test prior to the study and a post-test after the 12^{th} week of the study.

Population

In this study, the target population was sedentary Thai women ranging in age from 55 to 65 years. The study samples were recruited according to the following criteria. These recruited female volunteers were residents who lived in Bangkok metropolitan area and they consented to participate in the study.

Screening

Subjects were eligible for the study when they aged between 55 and 65 years and had no documented diseases or conditions listed in the exclusion criteria. All volunteers were initially contacted by telephone to determine their eligibility before being included in the study. After the screening process, 63 female volunteers were eligible and only 45 of them remained to complete the study.

Inclusion criteria

1. Thai women aged between 55 and 65 years.
2. Participants did not exercise regularly.
3. All participants were healthy and had no injuries before joining the study.

4. Participants were at risk in functional class A and B of American Heart Association (AHA).

5. Volunteers signed the consent form to become subjects.

Exclusion criteria

1. The participants were sick or injured.

2. Participants had a problem associated with neuromuscular in lower extremity from underlying such as diabetes with peripheral neuropathy, stroke, moderate or severe osteoarthritis knee during exercises, heart disease, poor control hypertension, lumbar spondylosis/listhesis with radiculopathy, and meniere's syndrome.

3. Participants were not purely voluntary.

4. Participants were absent from a training program more than 20% of training (trained less than 30 times).

Sample

Sampling technique

This study used purposive sampling technique and categorized subjects into 3 groups: vibration exercise group, resistance exercise group, and control group by using six-sized block randomization method.

Sample size determination

Sample size determination of this study was derived from sample size calculation of Roelants et al. (2004), which studied elderly women divided into 3 groups: vibration exercise group with 30 women (age 64.6 $\pm$ .7 yr), resistance exercise group with 30 women (age 63.9 $\pm$ .8 yr), and control group with 29 women (age 64.2 $\pm$ .6 yr). According to the quadriceps muscle strength test of these 3 groups, the vibration exercise group had a mean of quadriceps muscle strength in post exercise period equaled $12.4 \pm 2.1\%$ and the resistance exercise group had a mean of quadriceps muscle strength in post exercise period equaled $14.8 \pm 2.9\%$. Therefore, sample size of this study could be calculated from 2-independent group formula as shown below:

Formula $$\boxed{n / group = \frac{2(z_{\frac{\alpha}{2}} + z_{\beta})^2 \sigma^2}{(x_1 - x_2)^2}}$$

$$\alpha = 0.05 \text{ (two-sided)}, \quad z_{\frac{\alpha}{2}} = 1.96$$

$$\beta = 0.20 \text{ (two-sided)}, \quad z_{\beta} = 0.84$$

$$\sigma^2 = \text{Pooled variance}$$

$$= \frac{(n_1 - 1)s_1^2 + (n_2 - 2)s_2^2}{n_1 + n_2 - 2}$$

$$= \frac{(30-1)(2.9)^2 + (30-1)(2.1)^2}{30+30-2}$$

$$= 6.41$$

Substitute all variables

$$n / group = \frac{2(1.96 + 0.84)^2 (6.41)}{(14.8 - 12.4)^2}$$

$$= 17.42$$

n for each group will be 18 persons. To prevent drop out rate during the experiment and detect more reliability, subjects will be added for more 10%. So, total subjects are 20 persons for each group.

Instruments

1. Case record form.
2. Height measuring board.
3. Weighing apparatus (TANITA BF-700, Janpan).
4. Biodex system 3 (Biodex Medical Inc., USA).
5. North Coast Touch-Test TM Sensory Evaluator (4.31 (2.0-grams) Nylon monofilament, North Coast Medical Inc., U/K).
6. BalanceCheck force platform (BalanceCheck™ Screener and Trainer 3.2.2 by Bertec, Ohio, USA).
7. Model Ankle movement extent discrimination apparatus; AMEDA (Waddington, Adams, and Jones, 1999).
8. Level angle finder (ED-20SSMB Super Slant, Japan).
9. Magnetic torpedo level (Miley, USA).
10. Blindfold.
11. Headphones.
12. EMG electrodes (Ambu® Blue Sensor SP, Denmark).
13. A biopac MP 100 system with EMG 100C transducer module (Biopac Systems Inc., Canada).
14. An acqKnowLedge Software Version 3.7.3 (Biopac Systems Inc., Canada).
15. Vibration platform (Welness I- Slimm LF05A-26, China).
16. Nautilus Nitro leg extension and leg curl.
17. Bicycle (Cateye ergociser Model EC-3500, EC-3200, China).

18. Treadmill (Cateye ETC 220, China).

19. Stopwatch (JS-609, FBT®, China).

20. Goniometer.

Procedure

The processes of research were separated into leg strength test, balance assessment and joint position test.

3.1 Leg strength test

3.1.1 Subject preparation

Prior to the test session, all subjects were asked to refrained from vigorous physical activity was not allowed 24 hours prior to the first test session. Comfortable clothing and appropriate shoes should be worn. Then a test procedure was explained and demonstrated to subjects.

3.1.2 Leg strength test procedure

Quadriceps muscle and hamstring muscle strength of subjects were measured while they were performing maximum isometric contraction by using Biodex System 3; a unit of measurement is NmKg.

1. Subjects performed stretching exercise for quadriceps muscle, hamstring muscle and gastrocnemius muscle for 5 minutes before the test.

2. Subjects performed the test in sitting position; that is, they sat and leaned back against seatback tilt at 85° and right knee flexed at 90°. The rotation axis of dynamometer was aligned with the transverse knee joint axis and connected to the distal end of the tibia by means of a length-adjustable rigid lever arm while their shin, thighs, hip, and shoulders were fasten by seat belts. While performing the test, subjects were required to fold their arms in order to prevent compensation movement.

3. Seat height, cushion position, attachment length, and seat position were recorded. These factors were set as the same level for both pre- and post-test.

4. Subjects performed one set of leg extension and leg curl resisting force exerted by machine. For each position subjects had to performed a maximal voluntary isometric contraction during 3 seconds. Verbal encouragements were provided as stimulation for subjects to produce maximum efforts. Before the test was started, subject received instructions about procedures and was requested to perform left leg for example by manual test.

5. Subjects performed 3 sets of leg extension and leg curl alternately and rested 15 seconds during each position.

6. The machine calculated strength of quadriceps muscle and hamstring muscle in peak Torque.

Fig 3.1 Isometric Strength Test

3.2 Balance assessment and joint position test

Subject preparation

Prior to each test session, all subjects were asked to refrained from vigorous physical activity was not allowed 24 hours prior to the first test sessions. Comfortable clothing should be worn. Upon arrival to the laboratory, instruct the participant to remove the shoes and socks for all test sessions. After that, weight, height, body mass index were recorded. Then a test procedure was explained and demonstrated to subjects.

Standard measurements

Measurements of height, weight provide baseline characteristics of the subjects. The following procedures were performed and baseline characteristics of the subjects were recorded.

Standing height: The participants were standing bare feet with the heels together, and then stretching upward to the fullest extent. Heels, buttocks, and upper back were touching a wall. The chin was not lifted. Measurement was recorded in centimeters.

Weight: Weight was recorded with the individual wearing comfortable clothing and no shoes. Weight was recorded in kilograms.

Body mass index: The BMI, is used to assess weight relative to height and is calculated by dividing body weight in kilograms by height in meters squared ($kg \bullet m^{-2}$). BMI is predicted according to ACSM (2006).

3.2.1 Sensation test for the foot

Semmes-Weinstein monofilament test

1. Subjects sitting supine in the examination chair with both feet level no socks and shoes while they were being tested in a quiet and relaxing place.

2. Subjects should then have their eyes closed for the actual conduct of the examination and to say “yes” each time that they perceive the application of the monofilament.

3. The monofilament was being hold and its wire was pressed in C shape against subject's test site for one to two seconds (the wire was not allowed to drag along the skin during the test). The monofilament wire had to be placed outside of wound, scar and callus area.

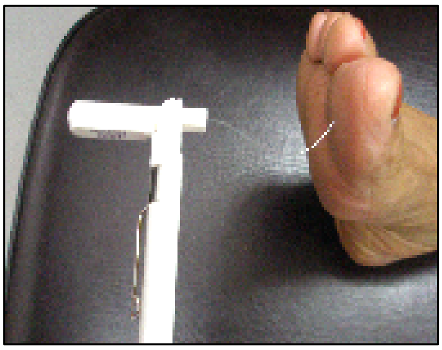

Fig 3.2 Semmes-Weinstein monofilament test

4. The measurements should be taken at each of the 10 sites on the foot:

- Dorsal midfoot
- Plantar aspect of foot including pulp of the first, third, and fifth digits
- The first, third, and fifth metatarsal heads
- The medial and lateral midfoot
- The calcaneus

Each position of the test was randomized in order to prevent subject's presumption of the right position.

5. The monofilament test was repeated twice for test site where the subjects could not indicate the feeling.

6. The results of the test were recorded. If a subject did not perceive the monofilament at more than 4 out of 10 sites, that subject was reported as neuropathy or sensory loss (Lee et al., 2003).

3.2.2 Balance assessment

Subject preparation

1. Inform subjects of the test.

▪ This test evaluated subjects' standing stability and consisted of 4 individual tests: Normal Stability-Eyes Open, Normal Stability-Eyes Closed, Perturbed Stability-Eyes Open, and Perturbed Stability-Eyes Closed.

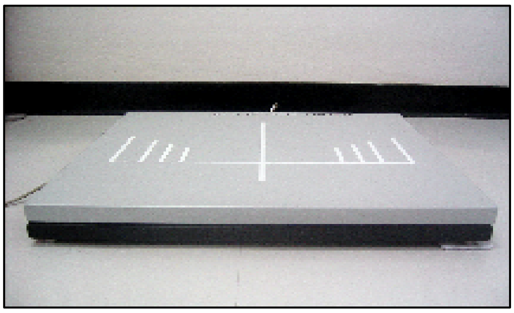

Fig 3.3 Normal stability surface

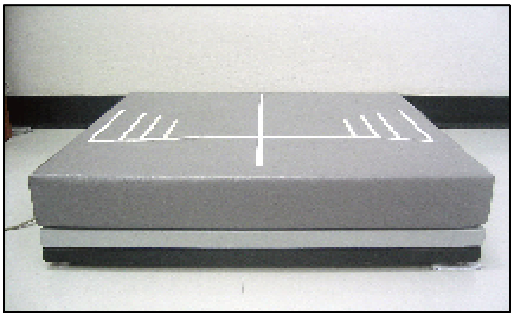

Fig 3.4 Perturbed stability surface

2. The position of subjects' feet was in details below (There are white vinyl markings on the balance platform lines as a guide):

▪ The medial malleolus of both feet should be aligned with the malleolus line on the platform.

▪ Subjects' feet should be symmetric around the midline and their outside borders should be formed an imaginary square.

▪ The angular alignment of subjects' feet should be such that the subjects did not feel uncomfortable.

3. Subjects stood still in a comfortable position with weight centered and arms to the sides.

Balance assessment procedure

Normal Stability-Eyes Open and Normal Stability-Eyes Closed

1. The BalanceCheck™ is calibrating itself by BalanceCheck™ software before the test.

2. Subjects were required to stand in the position of subjects' feet was according to subject preparation with eyes open and avoid any unnecessary movement such as talking, gesturing, or turning.

3. The test acquisition lasted for 10 seconds.

4. Then subjects were required to stand in the same position according to subject preparation with eyes closed and repeat the test procedure 2-3.

5. The test results were calculated by BalanceCheck™ software.

6. After finishing both tests, subjects were allowed to rest for a moment prior to Perturbed Stability-Eyes Open, and Perturbed Stability-Eyes Closed tests.

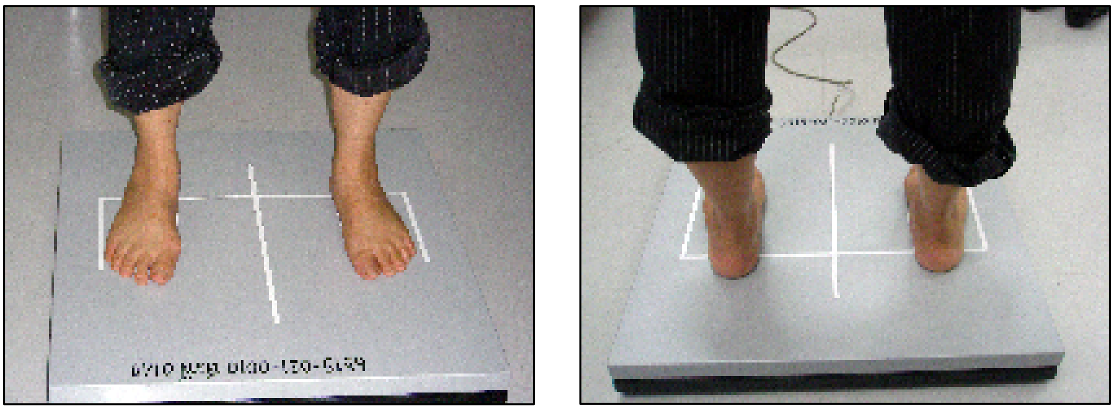

Fig 3.5 Normal stability test

Perturbed Stability-Eyes Open, and Perturbed Stability-Eyes Closed

1. Placed the BalanceCheck™ foam on top of the BalaceCheck™ platform with the reference lines facing up.

2. Subjects were allowed to wait 3 seconds to make sure that the system calibrates itself.

3. Helped subjects to step onto the BalanceCheck™ platform.

4. Subjects were required to stand in the position of subjects' feet was according to subject preparation with eyes open and avoid any unnecessary movement such as talking, gesturing, or turning.

5. The test acquisition lasted for 10 seconds.

6. Then subjects were required to stand in the same position according to subject preparation with eyes closed and repeat the test procedure 4-5.

7. The test results were calculated by BalanceCheck™ software.

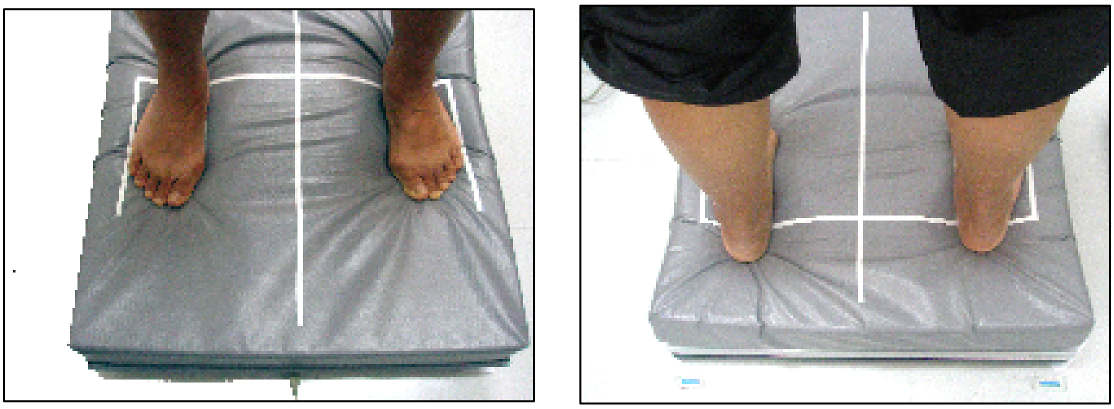

Fig 3.6 Perturbed stability test

3.2.3 Passive to Passive Reproduction of Joint Position

This test used a model of ankle movement extent discrimination apparatus (AMEDA) for joint position sense assessment which was developed similar to the one that was used in discrimination of movement into inversion. (Waddington, Adams, and Jones, 1999) (Fig 3.7) AMEDA consists of single shaft driven pass the sensor based on the work of electric motor, which connects to computer via a sensor converter of the LabView 8.0 data acquisition system in computer, with expose capability of 0.01°. The single shaft rotates at angular displacement 0.25°/s. It allows hinged platform move from horizontal to inversion/plantarflexion direction from the ankle. Under computer-determined positioning of motor, the single shaft can be set to allow different range of motion (0°-22°) for the hinged platform from horizontal.

A model of ankle movement extent discrimination apparatus is calibrated by an angle finder (ES-20SSMB Super Slant, Japan) (recording capability of 0.5°) and a magnetic torpedo level (Miley, USA)

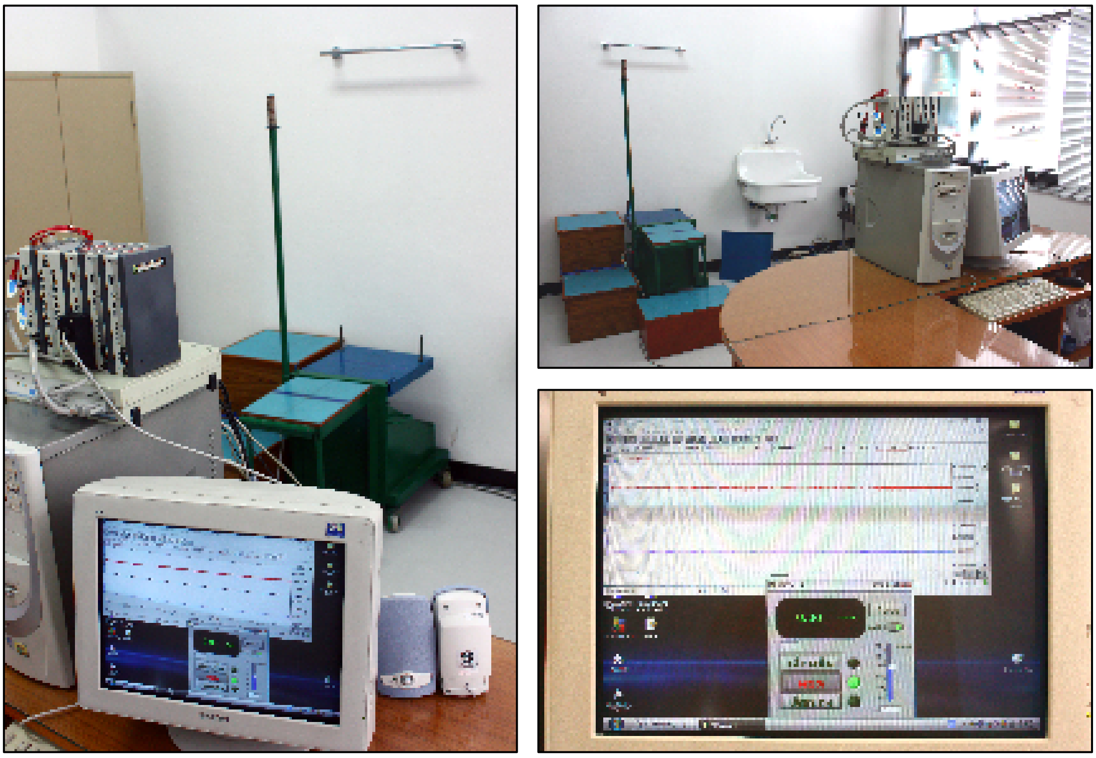

Fig 3.7 A model of ankle movement extent discrimination apparatus (AMEDA)

Validity

Validity was determined by comparing the joint angular position data that was recorded by Angle finder and a computer with Labview 8.0 software. The angular positions were measured in 10 different positions (range 0°- 20°) by randomly chosen.

Test-retest reliability

Test- retest reliability was established by determining an instrument's capability of measuring a variable with consistency. It was determined when the subjects began in starting position (0°) and passively moved ankle through the functional range, stopped at target position (15° Inversion, 12° Plantarflexion) and returned to starting position. The subjects were then instructed to passively reproduce target position. The data collected from the two test sessions. Test conditions were kept as consistently as possible including the same tester, procedure and time. Reliability data were collected from 15 subjects (mean age of 40.6 $\pm$ 12.98 yr). Testing in present study revealed test-retest reliability ICC = 0.5 at 15° inversion and ICC = 0.9 at 12° plantar.

Subject preparation

1. Subjects stood bare feet, extended their trunk, hip, knees straight and maintained symmetrical weight bearing while standing and placed their right foot on hinged platform and the other on fixed platform.

2. Subjects wore a blindfold to eliminate visual feedback and a headphone with soft music to eliminate auditory cues from motor.

3. Subjects' right ankle was not tied up with the machine. For safety, they should hold a hand bar firmly.

4. EMG was used to determine muscle activities by using a biopac MP 100 system with EMG 100C transducer module (Biopac System Inc. Canada). EMG data were recorded by an acqKnowLedged software version 3.7.3 (Biopac System Inc, Canada).

5. The surface of EMG electrodes was adhesive tape. In order to reduce skin impedance, the recording sites were applying electrode gel on. The electrodes were fixed with adhesive tape again on the skin over the muscle. The muscle was palpated during contraction before electrodes were attached.

- For inversion ankle movement, electrodes were placed on tibialis anterior (TA) and extensor hallucis longus (EHL).

- For plantar flexion ankle movement, electrodes were placed on soleous and gastrocnemius.

6. Hinged platform moved the right ankle at a velocity of 0.25°/s towards target joint position: 15° inversion and 12° plantarflextion.

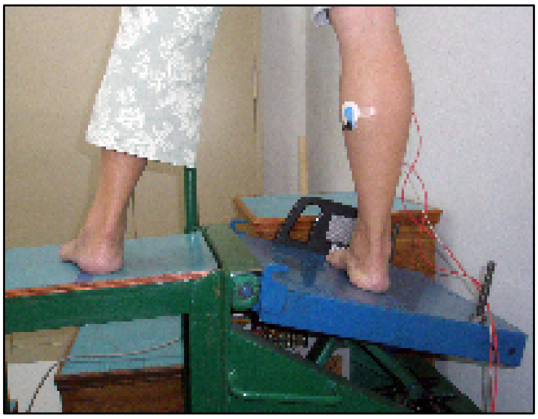

Fig 3.8 Inversion ankle movement

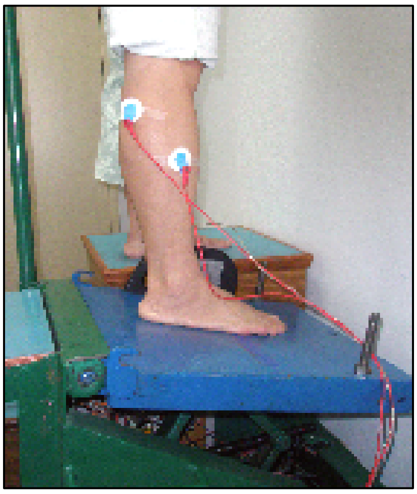

Fig 3.9 Plantarflexion ankle movement

Joint position test procedure

1. AMEDA was calibrated every time prior to the test.

2. Inversion or plantarflexion ankle movement tests were randomized.

3. Subjects placed their right foot on hinge platform at the starting position (0°) and passively move their ankle according to the target position (15° inversion and 12° plantarflextion). Then they were asked to remember the target position while the ankle was held for 15 seconds; and after that the hinged platform moved their right foot back to the starting position (0°).

4. The ankle was then passively moved towards the target position again and subjects were asked to press a stop button once they perceived the target position had been reproduced. Each test was performed a total of 2 times with each target position.

5. The absolute error was a difference between the target angle and the reproduced angle. Mean value of two trials in each position were used for analysis.

Exercise program

Vibration exercise

1. Subjects warmed up by cycling or walking for 15 minutes.

2. Subjects stood in training shoes, knee flexed at 20° (high squat stance with knee ankle of 160° in order to direct its mechanical impulses to the inferior limbs and to avoid the involvement of the head).

Note: Subjects wore the same training shoes through out the entire exercise program.

3. Subjects stood on vibration platform (Welness I – Slimm) with frequency 22 Hz, peak-to-peak 8 mm for 1 minute and rest 1 minute in one set. Subjects performed 10 sets per exercise for 20 minutes. They wore timing watch and recorded the number of exercises.

Fig 3.10 Vibration exercise

4. After finishing exercise, subjects rested for a while before getting off the vibration platform (Welness I – Slimm).

5. Subjects performed vibration exercise 3 times a week, with at least 1 day of rest between sessions for 12 weeks.

Resistance exercise

1. Subjects warmed up by cycling or walking for 15 minutes.

2. Leg curl machine for resistance exercise:

▪ Subjects were prone lying, grabbing the edge of the mattress or grabbing the handles located directly below, stretched their knees, and inserted both legs under the set of roller pad.

▪ Subjects exerted force to curl their legs as much as they could; and then slowly released the leg back to the starting position.

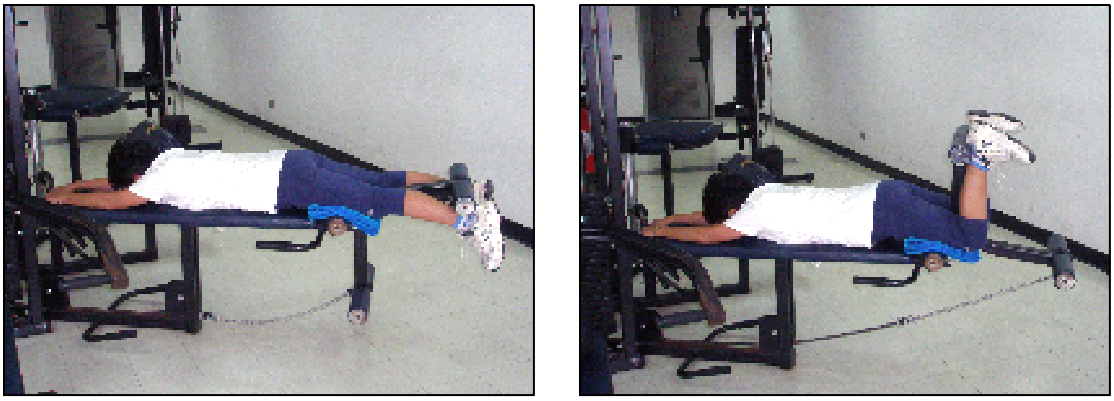

Fig 3.11 Leg curl exercise

3. Leg extension for resistance exercise:

▪ Subjects sat on the chair and adjusted axis of the machine to suitable the length of their legs, then inserted both legs under the set of roller pad. Their transverse knee joint should align with the axis.

▪ Subjects leaned back against the seatback and grabbed the handles beside the chair while they were performing the exercise.

▪ Subjects exerted force to extend their legs as much as they could; and then slowly released the leg back to the starting position.

Fig 3.12 Leg extension exercise

4. Subjects performed at 65% of 1RM for 15 repetitions in 3 sets and rested 3 minutes between set.

5. Subjects performed leg curl and leg extension exercise 3 times a week, with at least 1 day of rest between sessions for 12 weeks.

Exercise for Control group

1. Subjects warmed up by cycling or walking for 15 minutes.

2. Subjects used the model of Goniometer tied up with the side of their right knee by letting the upper axis aligned parallel with their lateral thigh and the lower axis aligned parallel with their lower leg, and stood upright, knee flexed at 20° (high squat stance with knee ankle of 160°) as written in color in the model of Goniometer on smooth and stable floor.

3. Subjects performed this exercise for 1 minute and rest 1 minute in one set. Subjects performed 10 sets per exercise for 20 minutes. They wore timing watch and recorded the number of exercises.

Fig 3.13 Exercise control group

4. Subjects performed this exercise 3 times a week, with at least 1 day of rest between sessions for 12 weeks.

Data Analysis

The results were shown as mean, mean difference and standard deviation (S.D.) by analyzing the following data:

1. Descriptive statistics were used for baseline calculation.

- Means with standard deviation were used for quantitative data.
- Numbers with percentages were used for qualitative data.

2. The paired t-test was used to detect the difference of muscle strength, ankle joint proprioception and balance between pre- and post tests within groups: vibration exercise group, resistance exercise group, and control group.

3. The comparison of mean difference of quadriceps muscle and hamstrings muscle between vibration exercise group, resistance exercise group, and control group by using 1-way ANOVA.; Post Hoc Multiple Comparisons with Scheffe.

4. The comparison of mean difference of ankle joint proprioception: 15° Inversion and 12° Plantarrflexion between vibration exercise group, resistance exercise group, and control group by using 1-way ANOVA; Post Hoc Multiple Comparisons with Scheffe.

5. The comparison of mean difference of balance assessment between vibration exercise group, resistance exercise group, and control group by using 1-way ANOVA; Post Hoc Multiple Comparisons with Scheffe.

6. Intraclass correlation coefficients (ICC) were used to determine an instrument's capability of measuring a variable with consistency between mean joint angular position data that were concomitantly recorded by the angle finder and the LabView 8.0 system.

An alpha level of .05 was used to determine statistical significance. All statistical analysis was performed by using Statistic Package for the Social Sciences (SPSS for Window version 15.0, Chicago, IL, USA).

CHAPTER IV

RESULTS

Characteristics of Subjects

Sixty three eligible female volunteers were selected according to the following criteria and categorized into 3 groups of 21: vibration exercise group (VE), resistance exercise group (RE), and control group (C). Two women dropped out of the vibration exercise group prior to the training because they could not participate in specific training schedule and the other 2 women were lost to follow-up during the training program. Therefore, 17 women were remained in this group. For the resistance exercise group, 3 women dropped out of this group prior to the training program since they could not participate in specific training schedule and the other 2 women were lost to follow-up during the training program. Thus, 16 women remained in this group. The control group also had 6 dropouts prior to the training program due that 5 women had the burden of responsibilities: taking care of their mothers and babysitting their grandchildren; 1 woman had ankle fracture; and the other 3 women were lost to follow-up during the training program. Therefore, 12 women were remained in this group. Results were analyzed from data of 45 subjects (See Fig.4.1).

Baseline characteristics of the subjects were shown in Table 4.1. The age of 45 subjects ranged from 55 to 65 years, the mean age of vibration exercise, resistance exercise and control groups were 58.41 $\pm$ 2.96 years, 60.00 $\pm$ 4.16 years and 59.75 $\pm$ 3.74 years respectively. BMI of all subjects were in a normal range. In addition, all subjects of vibration exercise, resistance and control groups had no loss of protective sensation according to Table 4.2.

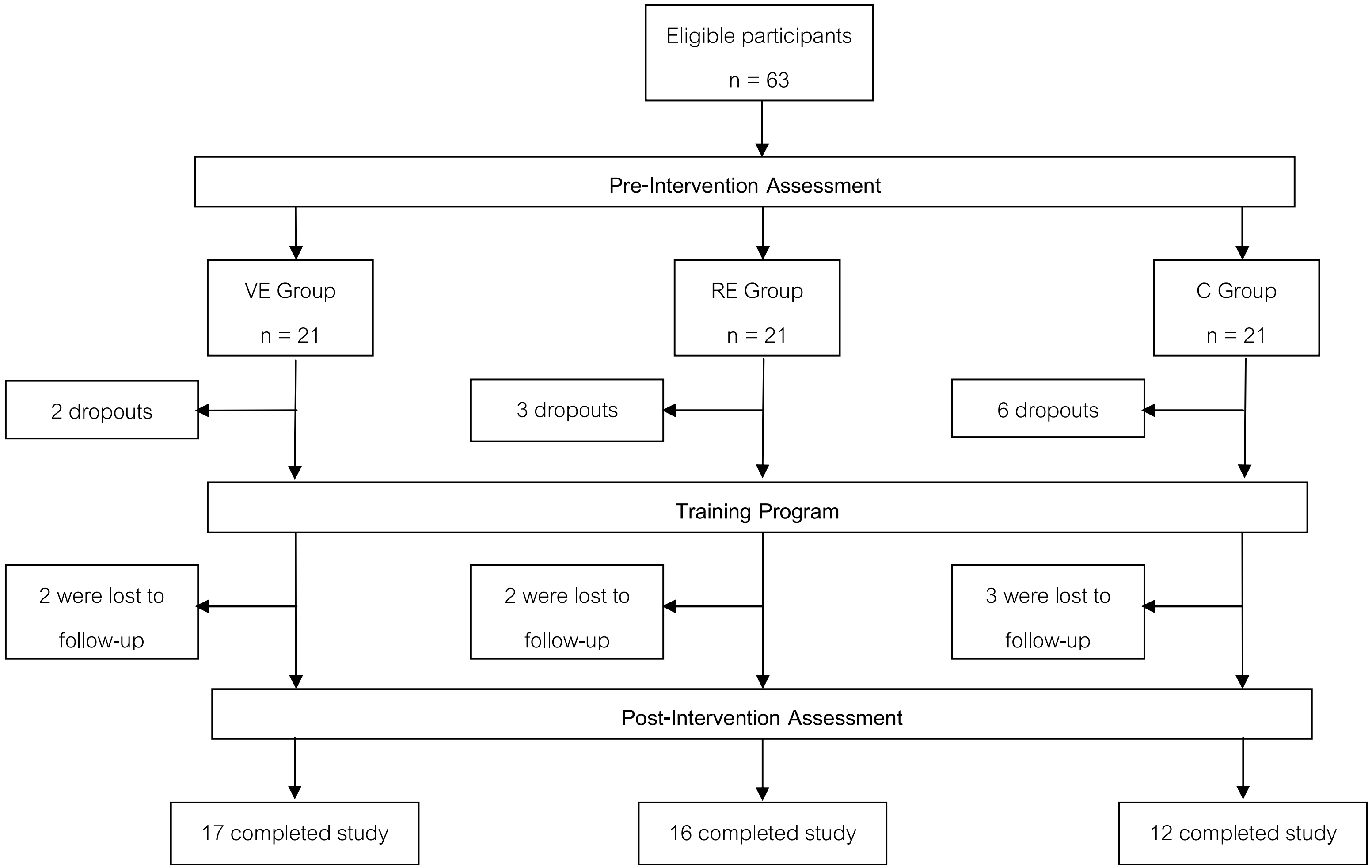

Fig 4.1 Study profile for participants in VE, RE, and C groups

Table 4.1 Baseline characteristics of subjects (n=45)

Characteristics	Group		
	Vibration (n=17)	Resistance (n=16)	Control (n=12)
Age (yr)	58.41 $\pm$ 2.96	60.00 $\pm$ 4.16	59.75 $\pm$ 3.74
Weight (kg)	51.33 $\pm$ 7.97	54.26 $\pm$ 8.49	60.98 $\pm$ 8.19
Height (cm)	153.06 $\pm$ 3.61	151.25 $\pm$ 4.61	156.50 $\pm$ 5.11
BMI (kg/m^2)	21.92 $\pm$ 2.98	23.72 $\pm$ 3.37	24.87 $\pm$ 3.41

Values are Mean $\pm$ SD.

Table 4.2 Sensation test for the foot

Diagnosis, n (%)	Group			Total
	Vibration (n=17)	Resistance (n=16)	Control (n=12)	(n=45)
<4 no loss of protective sensation	17 (100)	16 (100)	12 (100)	45 (100)
≥4 loss of protective sensation	0 (0)	0 (0)	0 (0)	0 (0)

Values are presented in Percentages.

Leg muscle strength

All subjects in 3 exercise groups experienced no adverse injury and knee pain during the training. In the VE group, subjects reported a mild degree of muscle fatigue at the end of each session throughout 12 weeks of training. No other adverse side effects were reported such as erythema, edema and itching on legs. In RE group, subjects reported a moderate degree of muscle fatigue at the end of each session for the first 2 weeks and a mild degree of muscle fatigue from the third week to the 12th week. Finally, in C group, subjects reported a mild degree of muscle fatigue at the end of each session in 12 weeks.

Table 4.3 Comparison of quadriceps muscle strength between vibration exercise group, resistance exercise group and control group

Group	n	Quadriceps muscle strength (NmKg)	
		Pre-test (mean $\pm$ SD)	Post-test (mean $\pm$ SD)
Control	12	1.88 $\pm$ .32	1.90 $\pm$ .33
Vibration	17	1.98 $\pm$ .43	2.13 $\pm$ .39†
Resistance	18	1.85 $\pm$ .39	2.17 $\pm$ .33†,*,§

† Within-group difference between pre-test and post-test ($p < 0.05$)

* Between-group differences between resistance and vibration groups ($p < 0.05$)

§ Between-group differences between resistance and control groups ($p < 0.05$)

After 12 weeks, quadriceps muscle strength were significantly increased from 1.98 $\pm$ .43 to 2.13 $\pm$ .39 NmKg in the vibration group and from 1.85 $\pm$ .39 to 2.17 $\pm$ .33 NmKg in the resistance group. Conversely, quadriceps muscle strength in the control group revealed no significant difference.

In addition, quadriceps muscle strength between the resistance and vibration group and the resistance and control group were statistically significantly different, whereas the vibration and control group did not differ significantly (For more details see Appendix E).

Table 4.4 Comparison of hamstrings muscle strength between vibration exercise group, resistance exercise group and control group

Group	n	Hamstrings muscle strength (NmKg)	
		Pre-test (mean $\pm$ SD)	Post-test (mean $\pm$ SD)
Control	12	.69 $\pm$ .12	.70 $\pm$ .08
Vibration	17	.70 $\pm$ .18	.77 $\pm$ .24†
Resistance	18	.64 $\pm$ .13	.74 $\pm$ .15†

† Within-group difference between pre-test and post-test ($p < 0.05$)

After 12 weeks, hamstrings muscle strength were increased significantly from .70 $\pm$ .18 to .77 $\pm$ .24 NmKg in the vibration group and from .64 $\pm$ .13 to .74 $\pm$ .15 NmKg in the resistance group. Conversely, hamstrings muscle strength in the control group revealed no significant difference.

However, no significant differences in hamstrings muscle strength were found among the 3 groups (For more details see Appendix E).

The mean error passive joint position sense

Table 4.5 Comparison of ankle proprioception (15° inversion) between vibration exercise group, resistance exercise group and control group

Group	n	Absolute angle error (degree)	
		Pre-test (mean ± SD)	Post-test (mean ± SD)
Control	12	2.53 ± 1.54	2.44 ± 1.38
Vibration	17	3.01 ± 1.55	2.68 ± 1.13
Resistance	16	3.15 ± 1.88	2.66 ± 1.35

The within-group differences in ankle proprioception (15° inversion) after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group. Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

Table 4.6 Comparison of ankle proprioception (12° plantarflexion) between vibration exercise group, resistance exercise group and control group

Group	n	Absolute angle error (degree)	
		Pre-test (mean ± SD)	Post-test (mean ± SD)
Control	12	2.87 ± 1.37	2.16 ± 1.33
Vibration	17	2.96 ± 0.97	2.24 ± 1.40
Resistance	16	3.00 ± 1.36	2.79 ± 1.12

The within-group differences in ankle proprioception (12° plantarflexion) after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group. Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

Center of pressure excursion

Table 4.7 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Group	n	Anerior-Posterior CoP excursion (cm)			
		Normal stability-Eye opened		Normal stability-Eye closed	
		Pre-test (mean ± SD)	Post-test (mean + SD)	Pre-test (mean + SD)	Post-test (mean + SD)
Control	12	.68 ± .21	.71 ± .24	.73 ± .20	.67 ± .25
Vibration	17	.69 ± .15	.63 ± .13	.84 ± .43	.76 ± .30
Resistance	16	.61 ± .27	.62 ± .19	.89 ± .39	1.00 ± .33

The within-group differences in balance assessment: Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened and -Eye closed after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group.

Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

Table 4.8 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Group	n	Anerior-Posterior CoP excursion (cm)			
		Perturbed stability-Eye opened		Perturbed stability-Eye closed	
		Pre-test (mean ± SD)	Post-test (mean + SD)	Pre-test (mean + SD)	Post-test (mean + SD)
Control	12	.94 ± .22	.95 ± .33	1.59 ± .41	1.43 ± .37
Vibration	17	.92 ± .24	.81 ± .29	1.18 ± .43	1.22 ± .38
Resistance	16	.94 ± .34	.95 ± .38	1.18 ± .36	1.39 ± .48

The within-group differences in balance assessment: Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group.

Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

Table 4.9 Comparison of balance assessment: Lateral CoP excursion (cm); Normal stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Group	n	Lateral CoP excursion (cm)			
		Normal stability-Eye opened		Normal stability-Eye closed	
		Pre-test (mean ± SD)	Post-test (mean + SD)	Pre-test (mean + SD)	Post-test (mean + SD)
Control	12	.33 ± .14	.30 ± .15	.24 ± .14	.24 ± .10
Vibration	17	.26 ± .09	.25 ± .12	.22 ± .06	.22 ± .10
Resistance	16	.26 ± .14	.23 ± .09	.24 ± .10	.25 ± .09

The within-group differences in balance assessment: Lateral CoP excursion (cm); Normal stability-Eye opened and -Eye closed after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group.

Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

Table 4.10 Comparison of balance assessment: Lateral CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Group	n	Lateral CoP excursion (cm)			
		Perturbed stability-Eye opened		Perturbed stability-Eye closed	
		Pre-test (mean ± SD)	Post-test (mean + SD)	Pre-test (mean + SD)	Post-test (mean + SD)
Control	12	.48 ± .19	.70 ± .39	.61 ± .46	.57 ± .20
Vibration	17	.51 ± .20	.78 ± .63	.43 ± .25	.48 ± .35
Resistance	16	.54 ± .30	.55 ± .24	.47 ± .24	.61 ± .29

The within-group differences in balance assessment: Lateral CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed after 12 weeks of training were not significant in the vibration group, the resistance group, and the control group.

Besides, the training effects revealed no significant difference among the 3 groups (For more details see Appendix E).

CHAPTER V

DISCUSSION AND CONCLUSION

Leg muscle strength

The results of this study demonstrated that 12 weeks of vibration exercise (VE) training led to a significant increase in quadriceps and hamstrings muscle strength. The primary variable of this improvement included 2 important findings. At first, VE training contributes to the vibration stimulus. The findings of a previous placebo study (Deleclause et al., 2003) indicated that younger women's strength increased after VE training due to the vibration stimulus, whereas an identical exercise program performed without vibration did not result in a significant strength gain. The findings from several other studies (Torvinen et al., 2002; Cardinale and Bosco, 2003) suggested that the major part of the gain in strength was due to the muscle activity provoked by vibration stimulus.

The second important finding related to the vibration protocol: frequency and positions of exercise. Many studies revealed that different frequencies and positions of exercise resulted in positive effects on leg muscle (Deleclause et al., 2003; Torvinent et al., 2002; Roelants et al., 2004). Only elderly subjects were recruited in Roelants et al.'s (2004) as our study. They investigated the effects of whole body vibration (WBV) training on knee extension strength in older women with frequency 35-40 Hz by performing exercise in 4 different positions: high squat (knee angle between 120° and 130°), deep squat (knee angle 90°), wide-stance squat and lunge. All positions of training increased in knee extensor muscle strength. The findings agreed with our study's result in the intervention of high squat (knee angle of 160°) on vibration platform with frequency 22 Hz. According to ReIn et al.'s (2007) suggestion, the frequency 12-45 Hz was compatible with long term exercise in leg muscle. High squat was selected in this present study because elderly Thai women could perform exercise in this position throughout the period of training. It might be speculated that subjects performing lower squat had higher shear force on the ligament and muscle in posterior direction (Hamill and Knutzen, 1995).

Based on our findings, quadriceps and hamstrings muscle strength significantly increased in VE and resistance exercise (RE) groups. However, the RE group had significant increase in quadriceps muscle strength comparing among 3 groups. No significant differences of hamstrings muscle strength were found between 3 groups. Although the single vibration frequency could increase leg muscle strength during the exercise program, the result revealed relatively inferior strength gain compared with resistance exercise. The possibility to explain why VE group had less leg muscle strength than RE group might be a single vibration frequency training program.

In RE group, subjects also increased leg muscle strength since training intensity of this study was designed according to the ACSM recommendation (ACSM, 1998). In addition, one possibility to explain why RE training increased strength is adaptation mechanism of nervous system. Motor neuron output contributes to increase strength, not muscle size in early training. Thus, neural adaptation play an important role in the dramatic muscular strength and power improvement of elderly with resistance training compared with training-induced alternations in muscular hypertrophy (McArdle et al., 2007).

Ankle joint position sense and balance

This present study revealed no significant difference in absolute angle error (AAE) between pre- and post-test on ankle proprioceptive ability at both target positions (12° inversion and 15° plantarflextion). The investigation of difference in AAE showed no significance among the 3 groups. Besides, no significant difference was found in balance assessment with anterior-posterior and lateral CoP excursion with eyes opened and closed, for both normal and perturbed stability surface between pre- and post-test of the present study. The investigation of difference in balance assessment showed no significance among the 3 groups.

Similarly, Westlake et al. (2007) also found no significance after post-test of plantarflextion testing passive joint position sense (JPS) in healthy older participants in both groups: balance exercise group and fall prevention education group in spite of focusing on the 8-week balance exercise on proprioception.

Interestingly, vibration exercise has a positive effect on proprioception in previous studies. For athletes with unilateral ACL reconstruction, active knee joint reposition assessed by the Biodex dynamometer significantly improved with whole body vibration training (WBVT) (Meozy et al., 2008).

Conclusion

Vibration exercise increases leg muscle strength after the 12-week training. However, resistance exercise has more effectiveness than vibration exercise. Based on the result of vibration exercise, it is beneficial to maintain leg muscle strength in elderly adults and also a safe exercise due to low impact on knee joint. Additionally, vibration exercise and resistance exercise have no significant improvement in ankle joint proprioception and balance in elderly Thai women.

Recommendations to further study

1. Since the present study had small sample size especially in control group, more participants should be recruited or the further study should only focus on the effect of vibration exercise. For example, vibration exercise program should be designed to compare leg muscle strength in a variety of squat positions: high squat (100°, 120°, and 160°), deep squat and wide stance squat at the same or different frequencies.

2. The study should be followed up in order to determine the existence of long-term exercise after completing the exercise program in 1 month, 3 months or 6 months.

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APPENDIX A

General information of elderly Thai women participating in the research

Vibration Exercise Group:

No.	Age	Weight	Height	BMI
1	55	73.00	160	28.52
2	55	54.30	153	23.21
3	58	47.70	149	21.49
4	58	47.20	148	21.55
5	55	53.90	152	23.33
6	57	48.60	150	21.60
7	61	47.50	150	21.11
8	65	50.50	147	23.38
9	60	46.90	153	20.40
10	58	37.90	157	15.41
11	60	47.00	153	20.09
12	59	49.10	156	20.21
13	55	44.90	152	19.44
14	59	64.30	153	27.48
15	64	53.30	155	22.21
16	57	57.30	158	22.92
17	57	49.20	156	20.25
Mean	58.41	51.33	153.06	21.92
S.D.	2.96	7.97	3.61	2.98

BMI = Body Mass Index

Resistance Exercise Group:

No.	Age	Weight	Height	BMI
1	61	60.30	156	24.81
2	55	58.10	157	23.62
3	55	69.60	155	29.00
4	65	55.30	157	22.48
5	58	53.20	152	23.03
6	61	68.80	152	29.78
7	56	57.00	156	23.46
8	55	44.20	149	19.91
9	65	47.70	145	22.71
10	65	47.50	145	22.62
11	57	48.80	142	24.40
12	65	43.10	152	18.66
13	60	63.70	147	29.49
14	65	57.60	153	24.62
15	62	49.30	150	21.91
16	55	44.00	152	19.05
Mean	60.00	54.26	151.25	23.72
S.D.	4.16	8.49	4.61	3.37

BMI = Body Mass Index

Control Group:

No.	Age	Weight	Height	BMI
1	61	68.00	156	27.98
2	56	61.40	158	24.56
3	61	59.20	146	27.79
4	55	58.90	162	22.48
5	63	51.90	160	20.27
6	56	52.60	156	21.65
7	55	61.70	164	22.94
8	64	55.50	152	24.03
9	65	53.10	155	22.13
10	64	58.30	152	24.24
11	58	75.60	155	31.50
12	59	75.60	162	28.85
Mean	59.75	60.98	156.50	24.87
S.D.	3.74	8.19	5.11	3.41

BMI = Body Mass Index

APPENDIX B

Quadriceps and hamstring muscle strength test results of elderly Thai women participating in the research

Vibration Exercise Group:

	Quadriceps muscle strength (Nm/kg)		Hamstring muscle strength (Nm/kg)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	2.32	2.47	0.93	1.07
2	1.19	1.26	0.44	0.40
3	1.89	2.07	0.65	0.68
4	1.56	1.64	0.48	0.54
5	1.79	1.87	0.50	0.43
6	1.96	2.15	0.81	0.87
7	2.63	2.60	0.70	0.82
8	2.21	2.58	0.65	0.68
9	2.80	2.68	0.99	0.92
10	1.91	2.31	0.73	0.92
11	2.34	2.26	0.99	1.18
12	2.36	2.43	0.84	1.04
13	1.99	2.12	0.49	0.52
14	1.51	1.69	0.69	0.69
15	1.55	1.77	0.54	0.51
16	2.08	2.23	0.82	0.78
17	1.56	2.04	0.67	0.98
Mean	1.98	2.13	0.70	0.77
S.D.	0.43	0.39	0.18	0.24

Resistance Exercise Group:

	Quadriceps muscle strength (Nm/kg)		Hamstring muscle strength (Nm/kg)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	1.79	2.06	0.41	0.49
2	2.40	2.44	0.67	0.85
3	1.57	1.77	0.58	0.66
4	1.03	1.84	0.52	0.58
5	1.89	2.05	0.81	0.86
6	1.31	1.53	0.48	0.57
7	1.91	2.02	0.59	0.64
8	1.85	2.47	0.63	0.97
9	1.88	2.14	0.55	0.59
10	2.00	2.28	0.58	0.64
11	1.57	2.31	0.71	0.78
12	2.09	2.29	0.68	0.94
13	1.62	1.80	0.78	0.82
14	1.89	2.28	0.80	0.93
15	2.23	2.51	0.63	0.69
16	2.58	2.86	0.89	0.84
Mean	1.85	2.17	0.64	0.74
S.D.	0.39	0.33	0.13	0.15

Control Group:

	Quadriceps muscle strength (Nm/kg)		Hamstring muscle strength (Nm/kg)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	1.62	2.05	0.75	0.58
2	2.69	2.68	0.87	0.83
3	1.60	1.45	0.60	0.63
4	1.93	1.77	0.80	0.72
5	2.03	1.88	0.66	0.72
6	2.08	2.18	0.63	0.79
7	1.88	1.86	0.77	0.78
8	1.90	1.91	0.67	0.68
9	1.85	1.81	0.81	0.74
10	1.94	2.05	0.61	0.59
11	1.51	1.53	0.61	0.66
12	1.54	1.63	0.46	0.66
Mean	1.88	1.90	0.69	0.70
S.D.	0.32	0.33	0.12	0.08

APPENDIX C

Ankle joint proprioception (15° inversion and 12° plantarflexion) test results of elderly Thai women participating in the research

Vibration Exercise Group:

	Ankle joint proprioception 15° inversion (Degree)		Ankle joint proprioception 12° plantarflexion (Degree)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	1.50	4.53	2.50	3.00
2	2.11	5.10	1.80	1.86
3	3.75	2.22	3.75	3.03
4	2.25	2.34	2.75	0.56
5	4.75	3.18	1.75	4.37
6	1.50	1.89	2.50	2.85
7	6.45	4.03	2.56	4.37
8	4.39	2.00	4.76	0.36
9	0.00	1.50	2.75	1.81
10	2.50	2.50	3.50	0.96
11	3.50	2.92	3.50	0.17
12	2.50	2.92	3.50	2.87
13	4.50	0.75	3.50	0.64
14	4.00	3.42	1.75	3.86
15	1.75	2.42	2.25	2.10
16	3.50	2.31	5.00	1.61
17	2.25	1.45	2.25	3.67
Mean	3.01	2.68	2.96	2.24
S.D.	1.55	1.13	0.97	1.40

Resistance Exercise Group:

	Ankle joint proprioception 15° inversion (Degree)		Ankle joint proprioception 12° plantarflexion (Degree)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	0.75	1.17	4.50	4.67
2	2.25	3.13	2.25	3.30
3	1.25	2.91	1.75	2.44
4	1.85	1.83	1.35	2.76
5	2.50	2.78	4.45	3.40
6	1.50	2.10	3.50	2.48
7	6.52	4.30	5.22	3.84
8	1.39	1.11	2.79	3.61
9	3.75	2.50	2.50	2.23
10	7.00	6.19	2.25	4.24
11	2.39	3.71	0.89	2.89
12	5.50	3.10	5.00	1.53
13	3.50	2.92	3.50	1.30
14	4.50	2.50	3.00	0.28
15	3.25	1.28	1.25	3.10
16	2.50	1.00	3.75	2.53
Mean	3.15	2.66	3.00	2.79
S.D.	1.88	1.35	1.36	1.12

Control Group:

	Ankle joint proprioception 15° inversion (Degree)		Ankle joint proprioception 12° plantarflexion (Degree)	
No.	Pre-test	Post-test	Pre-test	Post-test
1	2.53	1.95	2.36	0.70
2	0.56	4.22	2.97	1.77
3	3.60	2.00	2.28	2.87
4	4.59	1.75	2.99	3.50
5	2.92	2.50	2.00	1.85
6	5.50	1.67	2.85	2.34
7	1.90	0.98	1.50	0.84
8	2.36	1.64	3.06	1.57
9	0.78	2.47	6.00	3.25
10	2.50	3.20	4.50	5.17
11	0.42	1.12	0.70	1.12
12	2.75	5.78	3.25	0.97
Mean	2.53	2.44	2.87	2.16
S.D.	1.54	1.38	1.37	1.33

APPENDIX D

Balance assessment results of elderly Thai women participating in the research

Vibration Exercise Group:

	Anterior-Posterior Normal Stability				Anterior-Posterior Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.50	0.60	0.70	1.00	0.90	0.70	1.90	1.40
2	0.80	0.90	0.50	0.50	1.40	1.70	1.40	2.30
3	0.70	0.50	1.20	0.50	0.60	0.60	2.30	0.60
4	0.60	0.40	0.80	0.40	0.90	0.90	0.70	1.00
5	0.80	0.70	0.90	0.80	0.80	0.70	1.30	1.30
6	0.80	0.60	1.10	0.80	0.70	0.60	1.40	1.30
7	0.80	0.80	0.80	1.10	1.50	0.90	0.90	1.10
8	0.90	0.50	0.70	1.10	0.80	1.00	0.80	1.70
9	0.50	0.70	0.90	0.70	1.20	0.50	0.80	1.20
10	0.80	0.70	0.50	0.60	0.90	0.50	0.80	1.00
11	0.80	0.50	2.30	0.90	0.80	0.70	1.20	1.20
12	0.60	0.50	0.60	0.70	0.90	0.90	0.80	1.00
13	0.60	0.70	0.40	0.30	0.80	0.80	0.90	1.30
14	0.40	0.70	0.60	0.70	0.70	0.90	1.50	0.80
15	0.90	0.70	0.90	1.40	0.90	0.80	1.00	1.50
16	0.50	0.60	0.60	0.40	0.80	1.00	1.20	1.10
17	0.70	0.60	0.70	1.00	1.00	0.50	1.20	1.00
Mean	0.69	0.63	0.84	0.76	0.92	0.81	1.18	1.22
S.D.	0.15	0.13	0.43	0.30	0.24	0.29	0.43	0.38

Resistance Exercise Group:

	Anterior-Posterior Normal Stability				Anterior-Posterior Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.50	0.70	1.00	0.90	0.90	0.80	1.30	1.50
2	1.30	0.60	0.60	0.90	1.50	0.70	0.80	1.00
3	0.40	0.30	0.80	0.60	0.90	0.80	1.50	1.30
4	0.40	0.70	0.80	1.40	1.00	0.90	1.40	1.20
5	0.50	0.70	0.80	1.30	0.70	1.10	0.90	1.60
6	0.90	0.60	2.10	1.70	0.80	1.10	1.40	1.10
7	0.60	0.50	0.90	1.00	1.80	1.20	1.50	2.20
8	0.50	0.60	0.70	0.80	0.50	0.70	1.50	1.20
9	0.30	0.50	1.00	0.60	1.00	0.70	0.80	0.90
10	0.80	0.90	1.00	1.10	0.70	0.70	0.80	1.20
11	0.40	0.50	0.80	0.60	0.60	0.70	0.50	1.80
12	0.50	0.50	0.70	0.80	0.60	0.80	1.50	1.20
13	0.70	0.70	0.40	1.30	0.90	0.70	1.40	1.50
14	1.00	1.10	1.40	1.40	1.20	2.20	1.70	2.60
15	0.60	0.60	0.60	0.70	1.20	1.20	0.90	1.10
16	0.30	0.40	0.70	0.90	0.80	0.90	0.90	0.80
Mean	0.61	0.62	0.89	1.00	0.94	0.95	1.18	1.39
S.D.	0.27	0.19	0.39	0.33	0.34	0.38	0.36	0.48

Control Group:

	Anterior-Posterior Normal Stability				Anterior-Posterior Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.70	0.50	0.80	0.60	1.00	1.00	1.40	0.90
2	0.60	0.90	0.60	0.60	0.70	0.60	1.70	1.40
3	0.40	0.80	0.60	0.30	1.30	0.60	2.10	1.30
4	0.60	0.50	0.80	0.60	0.90	0.90	1.60	1.30
5	0.80	0.50	0.60	0.80	0.70	1.10	1.00	0.80
6	0.40	0.30	0.40	0.30	1.10	0.40	0.90	1.30
7	1.10	0.60	0.60	0.90	0.90	1.50	1.70	1.60
8	0.80	0.60	0.60	1.00	1.30	0.60	2.10	1.60
9	0.60	1.00	0.90	1.00	1.00	1.30	2.10	2.00
10	1.00	1.10	1.10	0.50	1.00	1.20	1.70	1.90
11	0.60	0.80	0.70	0.50	0.70	1.10	1.20	1.20
12	0.60	0.90	1.00	0.90	0.70	1.10	1.60	1.80
Mean	0.68	0.71	0.73	0.67	0.94	0.95	1.59	1.43
S.D.	0.21	0.24	0.20	0.25	0.22	0.33	0.41	0.37

Vibration Exercise Group:

	Lateral Normal Stability				Lateral Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.30	0.10	0.20	0.20	0.40	0.40	0.80	0.40
2	0.30	0.40	0.20	0.30	0.60	0.90	0.50	0.50
3	0.30	0.20	0.20	0.10	0.40	0.40	0.90	0.20
4	0.30	0.10	0.30	0.10	0.50	0.60	0.20	0.30
5	0.20	0.30	0.20	0.30	0.50	0.60	0.30	1.30
6	0.40	0.30	0.30	0.30	0.30	0.80	0.50	0.40
7	0.30	0.20	0.20	0.20	1.10	1.00	0.50	0.40
8	0.10	0.30	0.20	0.20	0.40	1.90	0.30	0.80
9	0.30	0.30	0.10	0.20	0.30	0.50	0.20	0.30
10	0.40	0.40	0.20	0.20	0.40	0.30	0.20	0.20
11	0.20	0.10	0.30	0.10	0.40	0.30	0.40	0.20
12	0.20	0.10	0.20	0.10	0.30	0.30	0.30	0.20
13	0.10	0.20	0.10	0.10	0.50	0.70	0.20	0.30
14	0.20	0.30	0.30	0.40	0.70	0.50	1.00	0.30
15	0.20	0.50	0.30	0.40	0.60	0.90	0.40	0.60
16	0.40	0.20	0.20	0.20	0.50	2.70	0.30	1.30
17	0.30	0.30	0.20	0.30	0.70	0.40	0.30	0.40
Mean	0.26	0.25	0.22	0.22	0.51	0.78	0.43	0.48
S.D.	0.09	0.12	0.06	0.10	0.20	0.63	0.25	0.35

Resistance Exercise Group:

	Lateral Normal Stability				Lateral Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.10	0.20	0.20	0.20	1.20	0.30	0.60	0.60
2	0.50	0.40	0.20	0.20	0.50	0.70	0.40	1.20
3	0.30	0.20	0.30	0.30	0.40	0.60	0.70	0.50
4	0.20	0.20	0.20	0.30	0.90	0.60	0.60	0.40
5	0.30	0.20	0.20	0.20	0.20	0.40	0.40	0.40
6	0.50	0.40	0.40	0.40	0.80	0.80	1.00	0.80
7	0.30	0.40	0.40	0.40	1.00	1.20	0.40	1.20
8	0.10	0.10	0.10	0.20	0.30	0.30	0.60	0.40
9	0.10	0.20	0.40	0.40	0.50	0.60	0.60	0.90
10	0.20	0.20	0.20	0.20	0.20	0.70	0.20	0.40
11	0.10	0.10	0.30	0.20	0.30	0.30	0.20	0.40
12	0.40	0.20	0.20	0.20	0.40	0.50	0.70	0.40
13	0.20	0.20	0.10	0.20	0.50	0.30	0.20	0.30
14	0.40	0.30	0.30	0.30	0.80	0.60	0.50	0.80
15	0.10	0.20	0.20	0.10	0.40	0.40	0.20	0.60
16	0.30	0.20	0.10	0.20	0.30	0.50	0.20	0.40
Mean	0.26	0.23	0.24	0.25	0.54	0.55	0.47	0.61
S.D.	0.14	0.09	0.10	0.09	0.30	0.24	0.24	0.29

Control Group:

	Lateral Normal Stability				Lateral Perturbed Stability			
	Eye Opened		Eye Closed		Eye Opened		Eye Closed	
No.	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.30	0.30	0.20	0.20	0.50	0.80	0.50	0.70
2	0.40	0.20	0.20	0.10	0.20	0.40	0.30	0.50
3	0.20	0.10	0.10	0.20	0.70	1.40	0.30	0.60
4	0.40	0.10	0.20	0.20	0.40	0.30	0.60	0.30
5	0.60	0.20	0.20	0.20	0.80	0.30	0.40	0.30
6	0.10	0.30	0.10	0.10	0.20	0.30	0.20	0.30
7	0.30	0.30	0.20	0.30	0.50	0.80	0.70	0.80
8	0.30	0.20	0.20	0.20	0.60	0.30	1.80	0.70
9	0.30	0.40	0.30	0.40	0.70	0.80	0.10	0.90
10	0.30	0.50	0.60	0.30	0.40	0.80	0.60	0.60
11	0.50	0.40	0.40	0.30	0.40	0.90	0.80	0.50
12	0.20	0.60	0.20	0.40	0.40	1.30	1.00	0.60
Mean	0.33	0.30	0.24	0.24	0.48	0.70	0.61	0.57
S.D.	0.14	0.15	0.14	0.10	0.19	0.39	0.46	0.20

APPENDIX E

STATISTIC RESULTS

Leg muscle strength measurement

Table 1 Comparison of quadriceps muscle strength between pre- and post-tests

Group	n	Quadriceps muscle strength (NmKg)		Sig.
		Pre-test (mean $\pm$ SD)	Post-test (mean $\pm$ SD)	
Control	12	1.88 $\pm$ .32	1.90 $\pm$ .33	.69
Vibration	17	1.98 $\pm$ .43	2.13 $\pm$ .39	.00†
Resistance	18	1.85 $\pm$ .39	2.17 $\pm$ .33	.00†

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 2 Comparison of quadriceps muscle strength between vibration exercise group, resistance exercise group and control group

Test	Group						Sig.
	Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Quadriceps muscle strength (NmKg)†	.02	.16	.15	.16	.32	.22	.00*

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of quadriceps muscle strength between subgroups

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.13	.19
	Resistance	-.30*	.00
Vibration	Resistance	-.17*	.04

* The mean difference is significant at the .05 level.

Table 3 Comparison of hamstrings muscle strength between pre- and post-tests

Group	n	Hamstrings muscle strength (NmKg)		Sig.
		Pre-test (mean ± SD)	Post-test (mean ± SD)	
Control	12	.69 ± .12	.70 ± .08	.70
Vibration	17	.70 ± .18	.77 ± .24	.03†
Resistance	18	.64 ± .13	.74 ± .15	.00†

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 4 Comparison of hamstrings muscle strength between vibration exercise group, resistance exercise group and control group

Test	Group						Sig.
	Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Hamstrings muscle strength (NmKg)†	.01	.10	.07	.11	.10	.09	.11

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of hamstrings muscle strength between subgroups

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.05	.39
	Resistance	-.08	.11
Vibration	Resistance	-.03	.69

* The mean difference is significant at the .05 level.

The mean error passive joint position sense

Table 5 Comparison of ankle proprioception (15° inversion) between pre- and post-tests

Group	n	Absolute angle error (degree)		Sig.
		Pre-test (mean ± SD)	Post-test (mean ± SD)	
Control	12	2.53 ± 1.54	2.44 ± 1.38	.89
Vibration	17	3.01 ± 1.55	2.68 ± 1.13	.45
Resistance	18	3.15 ± 1.88	2.66 ± 1.35	.15

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 6 Comparison of ankle proprioception (15° inversion) between vibration exercise group, resistance exercise group and control group

Test	Absolute angular error (degree)†						Sig.
	Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
15° Inversion	-.09	2.20	-.34	1.81	-.49	1.30	.84

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of ankle proprioception (15° inversion) between subgroups

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.24	.94
	Resistance	.40	.84
Vibration	Resistance	.16	.97

* The mean difference is significant at the .05 level.

Table 7 Comparison of ankle proprioception (12° plantarflexion) between pre- and post-tests

Group	n	Absolute angle error (degree)		Sig.
		Pre-test (mean $\pm$ SD)	Post-test (mean $\pm$ SD)	
Control	12	2.87 $\pm$ 1.37	2.16 $\pm$ 1.33	.06
Vibration	17	2.96 $\pm$ 0.97	2.24 $\pm$ 1.40	.18
Resistance	18	3.00 $\pm$ 1.36	2.79 $\pm$ 1.12	.64

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 8 Comparison of ankle proprioception (12° plantarflexion) between vibration exercise group, resistance exercise group and control group

Test	Absolute angular error (degree)†						Sig.
	Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
12° Plantarflexion	-.71	1.17	-.72	2.11	-.21	1.73	.66

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of ankle proprioception (12° plantarflexion) between subgroups

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.01	1.00
	Resistance	-.50	.76
Vibration	Resistance	-.51	.71

* The mean difference is significant at the .05 level.

Center of pressure excursion

Table 9 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened and -Eye closed between pre- and post-tests

Group	n	Anerior-Posterior CoP excursion (cm)					
		Normal stability-Eye opened			Normal stability-Eye closed		
		Pre-test (mean ± SD)	Post-test (mean + SD)	Sig.	Pre-test (mean + SD)	Post-test (mean + SD)	Sig.
Control	12	.68 ± .21	.71 ± .24	.78	.73 ± .20	.67 ± .25	.48
Vibration	17	.69 ± .15	.63 ± .13	.21	.84 ± .43	.76 ± .30	.50
Resistance	16	.61 ± .27	.62 ± .19	.84	.89 ± .39	1.00 ± .33	.24

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 10 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Test		Anterior-Posterior CoP excursion (cm.)†						Sig.
		Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	
Normal Stability	Eye opened	.03	.30	-.06	.19	.01	.24	.58
	Eye closed	-.06	.28	-.08	.46	.11	.35	.34

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened and -Eye closed between subgroups

Anterior-Posterior CoP excursion (cm); Normal stability-Eye opened

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.08	.65
	Resistance	.01	.99
Vibration	Resistance	-.07	.70

* The mean difference is significant at the .05 level.

Anterior-Posterior CoP excursion (cm); Normal stability-Eye closed

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.02	.99
	Resistance	-.16	.53
Vibration	Resistance	-.18	.40

* The mean difference is significant at the .05 level.

Table 11 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between pre- and post-tests

Group	n	Anerior-Posterior CoP excursion (cm)					
		Perturbed stability-Eye opened			Perturbed stability-Eye closed		
		Pre-test (mean ± SD)	Post-test (mean + SD)	Sig.	Pre-test (mean + SD)	Post-test (mean + SD)	Sig.
Control	12	.94 ± .22	.95 ± .33	.95	1.59 ± .41	1.43 ± .37	.12
Vibration	17	.92 ± .24	.81 ± .29	.13	1.18 ± .43	1.22 ± .38	.79
Resistance	16	.94 ± .34	.95 ± .38	.95	1.18 ± .36	1.39 ± .48	.10

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 12 Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Test		Anterior-Posterior CoP excursion (cm.)†						Sig.
		Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	
Perturbed Stability	Eye opened	.01	.47	-.11	.29	.01	.41	.61
	Eye closed	-.17	.34	.04	.62	.21	.48	.16

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of balance assessment: Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between subgroups

Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye opened

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.12	.72
	Resistance	.00	1.00
Vibration	Resistance	-.12	.68

* The mean difference is significant at the .05 level.

Anterior-Posterior CoP excursion (cm); Perturbed stability-Eye closed

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.21	.56
	Resistance	-.38	.16
Vibration	Resistance	-.17	.63

* The mean difference is significant at the .05 level.

Table 13 Comparison of balance assessment: Lateral CoP excursion (cm); Normal stability-Eye opened and -Eye closed between pre- and post-tests

Group	n	Lateral CoP excursion (cm)					
		Normal stability-Eye opened			Normal stability-Eye closed		
		Pre-test (mean ± SD)	Post-test (mean + SD)	Sig.	Pre-test (mean + SD)	Post-test (mean + SD)	Sig.
Control	12	.33 ± .14	.30 ± .15	.71	.24 ± .14	.24 ± .10	1.00
Vibration	17	.26 ± .09	.25 ± .12	.74	.22 ± .06	.22 ± .10	1.00
Resistance	16	.26 ± .14	.23 ± .09	.30	.24 ± .10	.25 ± .09	.43

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 14 Comparison of balance assessment: Lateral CoP excursion (cm); Normal stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Test		Lateral CoP excursion (cm.)†						Sig.
		Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	
Normal Stability	Eye opened	-.03	.23	-.01	.15	-.03	.09	.96
	Eye closed	.00	.13	.00	.10	.01	.06	.92

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of balance assessment: Lateral CoP excursion (cm); Normal stability- Eye opened and -Eye closed between subgroups

Lateral CoP excursion (cm); Normal stability-Eye opened

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.01	.98
	Resistance	.00	1.00
Vibration	Resistance	.01	.97

* The mean difference is significant at the .05 level.

Lateral CoP excursion (cm); Normal stability-Eye closed

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	.00	1.00
	Resistance	-.01	.95
Vibration	Resistance	-.01	.93

* The mean difference is significant at the .05 level.

Table 15 Comparison of balance assessment: Lateral CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between pre- and post-tests

Group	n	Lateral CoP excursion (cm)					
		Perturbed stability-Eye opened			Perturbed stability-Eye closed		
		Pre-test (mean ± SD)	Post-test (mean + SD)	Sig.	Pre-test (mean + SD)	Post-test (mean + SD)	Sig.
Control	12	.48 ± .19	.70 ± .39	.09	.61 ± .46	.57 ± .20	.76
Vibration	17	.51 ± .20	.78 ± .63	.10	.43 ± .25	.48 ± .35	.68
Resistance	16	.54 ± .30	.55 ± .24	.94	.47 ± .24	.61 ± .29	.12

† Significant difference between pre- and post-tests ($p < 0.05$)

Table 16 Comparison of balance assessment: Lateral CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between vibration exercise group, resistance exercise group and control group

Test		Lateral CoP excursion (cm.)†						Sig.
		Control (n = 12)		Vibration (n = 17)		Resistance (n = 16)		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	
Perturbed Stability	Eye opened	.22	.40	.27	.64	.01	.31	.27
	Eye closed	-.04	.46	.05	.47	.14	.34	.55

† The mean difference between the posttest after the 12th week of training program and the pretest prior to the training program.

* The mean difference is significant at the .05 level.

Comparison of balance assessment Lateral CoP excursion (cm); Perturbed stability-Eye opened and -Eye closed between subgroups

Lateral CoP excursion (cm); Perturbed stability-Eye opened

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.05	.96
	Resistance	.21	.52
Vibration	Resistance	.26	.30

* The mean difference is significant at the .05 level.

Lateral CoP excursion (cm); Perturbed stability-Eye closed

(I) Group	(J) Group	Mean difference (I-J)	Sig.
Control	Vibration	-.09	.86
	Resistance	-.18	.55
Vibration	Resistance	-.09	.83

* The mean difference is significant at the .05 level.

BIOGRAPHY

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