EFFECT OF FATIGUE ON KNEE PROPRIOCEPTION IN FEMALE SUBJECTS WITH AND WITHOUT SYMPTOMATIC KNEE OSTEOARTHRITIS

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This study investigated the effect of muscle fatigue on knee proprioception in subjects with and without symptomatic knee osteoarthritis whose age, weight and height similar. Each group consisted of 15 subjects. Mean ages of with and without symptomatic knee osteoarthritis were 53.60±4.90 and 50±5.95 year respectively. The study was divided into 3 parts. The first part was to compare peak torque of knee flexor and extensor muscles at angular velocity of 180 degrees/second between female subjects with and without symptomatic knee osteoarthritis. The second part was to compare proprioception before fatiguing isokinetic contraction of quadriceps and hamstring muscles between subjects with and without symptomatic knee osteoarthritis. The third part was to compare knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee. All data were collected by using the Biodex System II.

In this study, the result demonstrated that peak torque in subjects with symptomatic knee osteoarthritis was significantly less than in subjects without symptomatic knee osteoarthritis. Comparison of mean absolute angular error between subjects with and without symptomatic knee osteoarthritis also showed statistically significant difference. Finally, subjects with symptomatic knee osteoarthritis had a statistically significant increment in mean absolute angular error after receiving fatigue program. However, there was no significant difference in mean absolute angular error in subjects without symptomatic knee osteoarthritis.

Finally, this study found a significant decrease in knee proprioception in subject with symptomatic knee osteoarthritis after they received fatigue program.. Therefore, clinical rehabilitation protocols should emphasize increasing muscular strength and endurance to increase fatigue-resistant to the muscle.

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พีรวุฒิ พิสุทธิ์วิมล: ผลของการล้าของกล้ามเนื้อต่อการรับรู้องศาการเคลื่อนไหวของข้อเข่าในผู้หญิงที่มีและไม่มีอาการข้อเข่าเสื่อม (EFFECT OF FATIGUE ON KNEE PROPRIOCEPTION IN FEMALE SUBJECTS WITH AND WITHOUT SYMPTOMATIC KNEE OSTEOARTHRITIS). คณะกรรมการควบคุมวิทยานิพนธ์: อนันต์พัฒน์ อิ่มพูลทรัพย์, M.D, รุ่งทิวา วัจฉละฐิติ, Ph.D. (PHYSIOTHERAPY). 94 หน้า. ISBN 974-665-017-3

การศึกษาครั้งนี้มุดประสงค์เพื่อทำการศึกษาผลของการล้าของกล้ามเนื้อต่อการรับรู้องศาการเคลื่อนไหวของข้อเข่าในผู้หญิงที่มีและไม่มีอาการข้อเข่าเสื่อม ที่มีอายุ น้ำหนัก และส่วนสูงใกล้เคียงกัน จำนวนกลุ่มละ 15 ราย โดยกลุ่มที่มีและไม่มีอาการข้อเข่าเสื่อม มีอายุเฉลี่ย 53.60$\pm$48.89 และ 50.00$\pm$5.95 ปี ตามลำดับ การศึกษาครั้งนี้จะแบ่งการทดสอบออกเป็นสามช่วง โดยช่วงแรกจะทำการเปรียบเทียบค่า peak torque ของกล้ามเนื้อ quadriceps และกล้ามเนื้อ hamstring ในผู้หญิงที่มีและไม่มีอาการข้อเข่าเสื่อม ช่วงที่สอง จะทำการเปรียบเทียบการรับรู้องศาการเคลื่อนไหวของข้อเข่าก่อนเข้าสู่โปรแกรมการล้าของกล้ามเนื้อระหว่างกลุ่มทดสอบทั้งสองกลุ่ม และช่วงที่สาม จะทำการเปรียบเทียบการรับรู้องศาการเคลื่อนไหวของข้อเข่า ระหว่างก่อนและหลังเข้าสู่โปรแกรมการล้าของกล้ามเนื้อ ในกลุ่มทดสอบทั้งสองกลุ่ม

ผลการศึกษาครั้งนี้พบว่าค่า peak torque ในผู้หญิงที่มีอาการข้อเข่าเสื่อมมีค่าน้อยกว่าในกลุ่มที่ไม่มีอาการข้อเข่าเสื่อมอย่างมีนัยสำคัญทางสถิติ ส่วนค่าการรับรู้องศาการเคลื่อนไหวของข้อเข่า ก่อนเข้าสู่โปรแกรมการล้าของกล้ามเนื้อ พบว่าในกลุ่มที่มีอาการข้อเข่าเสื่อมมีค่าคลาดเคลื่อนในการวัดค่าการรับรู้องศาการเคลื่อนไหวอย่างมีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบกับกลุ่มที่ไม่มีอาการข้อเข่าเสื่อม ส่วนค่าการรับรู้องศาการเคลื่อนไหวหลังจากเข้าสู่โปรแกรมการล้าของกล้ามเนื้อ พบความแตกต่างอย่างมีนัยสำคัญทางสถิติในกลุ่มที่มีอาการข้อเข่าเสื่อม ในขณะที่กลุ่มที่ไม่มีอาการข้อเข่าเสื่อมนั้นไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ

สรุปผลจากการศึกษาครั้งนี้ พบว่าการรับรู้องศาการเคลื่อนไหวของข้อเข่าจะมีค่าคลาดเคลื่อนมากขึ้นภายหลังเข้าสู่โปรแกรมการล้าของกล้ามเนื้อในกลุ่มที่มีอาการข้อเข่าเสื่อม ดังนั้นในรูปแบบการออกกำลังเพื่อฟื้นฟูสมรรถภาพในผู้ป่วยที่มีอาการข้อเข่าเสื่อมในทางคลินิกควรจะให้ความสำคัญในการเพิ่มความแข็งแรงและความทนทานของกล้ามเนื้อ เพื่อทำให้มีความทนทานต่อการล้ามากขึ้น

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LIST OF ABBREVIATIONS

°/sec	degrees/second
et al	et alii
yrs	years
cm.	centimeter(s)
kg.	kilogram(s)
Kg/m^2	kilogram per square metre
BMI	body mass index
ROM	range of motion
OA	osteoarthritis

CHAPTER I

INTRODUCTION

Limb proprioception is the sense of position and movement of the limb (1). There are divided into 2 categories: the sense of static position and the sense of limb movement. It is important to control stability, maintaining balance, and controlling limb movement (2). Especially in the knee joint, this joint is important in performance and prone to injury than other joints. Limb position deficit may lead to a transformation in joint stability and control of joint motion (3).

The receptors for knee proprioception originate within the knee joint ligaments, tendons, capsule and muscles and generally occur as a consequence of reflex movement. The reflex called "Ligamento muscular protective reflex" which provides stability and stiffness to the knee joint (2). The reflex was presented when the force was applied to the anterior cruciate ligament over the physiological strain limit, the receptors in anterior cruciate ligament were activated, and led to the contraction of hamstring muscle in order to reduce anterior displacement of the tibia. The coactivation of the hamstring muscle was necessary to help the ligament to maintain joint stability (4).

Signals for position sense and movement of the joint presumably generated from receptors in the skin, muscle, joint capsule and ligament but how each of these groups of receptors contributes to proprioception remain unclear. In the past, many investigators had thought that sensory inputs for joint position sense arose only from receptors located in joint capsule and ligament (5,6). However, recent studies have cast doubt on the ability of articular receptors to signal position over most of the normal range of joint angles. Most articular receptors in the knee response only at extreme joint angles, few receptors response over intermediate position (7). Anesthesia of knee joints, which believed absence of the input from articular receptors, has little effects on gait pattern and proprioception (8). Moreover, in patient who received total knee or hip replacement, which was removed the most of receptors at the joints, did not have different position sense when compared with non-operated patients (9,10).

The intramuscular receptor may play an important role in perception of the position and movement of the joint. Many studies demonstrated that vibration of the muscle could cause errors of limb movement and altered limb position (11). These studies provided enforceable dispute that signal from intramuscular receptor not only attain conscious level but also elicit kinesthetic sensation as well. Thus, these results can summarize that in the case of small joints, such as fingers, where skin and joint receptors are more important. On the other hand, most of the large joints of the body, such as hip and knee joints, intramuscular receptors may play an important role for determining proprioception in midrange than cutaneous and joint afferent. However, at the end range of motion, joint and muscle may play an equal role for detection of joint motion (6-17).

Proprioception may decrease in many reasons such as injury of ligament, capsule, nerve and muscle by injury or many diseases (13-17). Arthritis is one disease that affects proprioception of the knee (9,10,18,19).

Osteoarthritis is the most common form of arthritis in older adult. The prevalence of knee osteoarthritis increases with increasing age (20). Several factors appear to be related to the variable rate of the progression in knee osteoarthritis. Pathogenic factors in knee osteoarthritis development are effected by increasing the load distribution across the articular cartilage and/or affecting the material properties, the remodeling process of the cartilage and its ability to withstand load (21). The breakdown of protective and stabilizing mechanisms may introduce or contribute to arthritic changes in a joint. The sensory inputs from articular nerves delayed the rate at which osteoarthritis developed in unstable joints, but in stable joint, this input was not important in the protection of a stable joint from breakdown. Furthermore, the interruption of sensory nerves to an unstable joint and the development of osteoarthritis can be accelerated (22).

Osteoarthritis in the elderly was increased exponentially after the age of 40 (23). Another study found that knee osteoarthritis increased both frequency and severity in 60 years population and older (24). Moreover, knee osteoarthritis in women was found to have severe changes than men and only 50 percentage of population that developed signs and symptoms (23). Clinically, knee osteoarthritis is associated with joint pain, decrease range of motion and disability (25).

Quadriceps and hamstring strength are essential for activities of daily living such as sitting, raising from a chair, squatting, walking and climbing step. Both muscle groups stabilize the knee joint and protect the joint from stress. Weakness of the thigh muscles is common and important sequence of arthritis. At early stage of osteoarthritis, arthrogenous muscle inhibition showed to present in clinical effusion and degenerative joint damage. Arthrogenous muscle inhibition was probably evoked by aberrant afferent information from the damage joint, which resulted in decrease motor drive to muscle groups acting across the joint (26,27). Patient with osteoarthritic knee had strength deficits in both quadriceps and hamstring muscle groups particularly quadriceps muscle (26-31). The feasibility that quadriceps weakness is the primary risk factor for knee pain, disability and progression of joint damage in person with osteoarthritic knee.

There are many studies regarding proprioception and osteoarthritic knee. Generally, proprioception showed to decrease with increasing age (9,10,18,19), but patient with knee osteoarthritis had worse knee position sense than normal knee population (10,18). However, normal proprioception required sensory input from the muscle (9,10). Some reports revealed that proprioception was diminished in patients with present of muscle fatigue (32,33,34). Skinner et al in 1986 (34) studied the effect of fatigue in men by using passive reproduction of knee angle protocol in sitting position to measure knee proprioception. They found a significant difference in subject's ability to produce angle after fatigue. Marks et al in 1993 (32) studied the effect of fatigue by maximal isokinetic fatigue protocol to quadriceps muscle and measured active reproduction of knee angles in sitting position. The result showed non-significant decrease in the ability to reproduce knee angle after fatigue. However, the study of Skinner et al used passive reproductive angle, which produced a more precise sensation of the limb position. Lattanzio et al in 1997 (33) used three different fatigue protocols: ramp test, interval test and continuous test. All tests used cycle ergometer and measured proprioception by using active reproductive knee angles in standing position. Knee proprioception was statistically reduced for men in all three tests but in the women proprioception reduced only in continuous and interval tests.

From previous studies, the effect of muscle fatigue on knee proprioception was investigated only in normal subjects. The result from Lattanzio et al showed significant difference in statistic analysis but not different in clinic. On the other hand, osteoarthritic knee patients have worse knee proprioception sense from degenerative change of the joint, muscle weakness, easier to fatigue and trend to fall compare with normal subjects. It is interesting to study the effect of hamstring and quadriceps muscle fatigue on knee proprioception in patients with symptomatic knee osteoarthritis compare with asymptomatic knee osteoarthritis. Thus, the aim of this study was to compare knee joint positioning before and after fatiguing isokinetic contractions of quadriceps and hamstring muscle in female subjects with and without symptomatic knee osteoarthritis.

Purposes of the Study

General Objective

The purpose of this study was to compare knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee osteoarthritis.

Specific Objectives

1.To compare peak torque of knee flexor and extensor muscles at angular velocity of 180 degrees/second between female subjects with and without symptomatic knee osteoarthritis.

2.To compare knee proprioception before fatiguing isokinetic contractions of quadriceps and hamstring muscles between female subjects with and without symptomatic knee osteoarthritis.

3.To compare knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee osteoarthritis.

Parameters of the Study

1. Peak torque in Newton-meters (Nm)
2. Absolute angular error (AAE) in degrees (AAE = the different angle between criterion angle and the angle that performed by subject)

Scope of the Study

This study investigated changing in knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee osteoarthritis (age ranged from 40-60 years) at angular velocity of 180 degrees/second.

Hypotheses of the Study

1.There were significant differences in peak torque of quadriceps and hamstring muscles at angular velocity of 180 degrees/second between female subjects with and without symptomatic knee osteoarthritis.

2.There were significant differences in knee proprioception before fatiguing isokinetic contractions of quadriceps and hamstring muscles between female subjects with and without symptomatic knee osteoarthritis.

3.There were significant differences in knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee osteoarthritis.

Advantages of the Study

1. To be baseline data for knee proprioception, and knee flexor and extensor isokinetic strength in female subjects with and without symptomatic knee osteoarthritis.

2. To be guideline for planing the appropriate management for female subjects with and without symptomatic knee osteoarthritis.

CHAPTER II

LITERATURE REVIEW

2.1 Osteoarthritis of the Knee

2.1.1 Definition of Osteoarthritis

Osteoarthritis is a disease of unknown cause and known as hyperthropic arthritis, arthritis deformans, senescent arthritis and degenerative joint disease. There are many clinical and research studies interested to find causative factors and developed the definition of osteoarthritis (25,35-37,38).

Gresham et al in 1975 (25) defined that the clinical characteristics of knee osteoarthritis are joint pain, joint stiffness, crepitus, bony enlargement, decrease range of motion and instability.

Alman in 1986 (36) explained that osteoarthritis is defined as a heterogeneous group of condition that leads to joint symptoms and signs. These result from defective integrity of articular cartilage, in addition to related change in the underlying bone and at the joint margins.

Moskowitz et al in 1989 (37) defined that osteoarthritis is uncommon symptoms. It is presented before age 40. Most of it arises due to secondary cause, present with pain on motion at the early state and present with rest at the advance stage. Pain may increase with prolong activity and relieve by rest. Stiffness commonly shows at the morning or after period of inactivity during the day. Joint effusion is rarely seen or may present in the secondary cause. Signs of this disease include localized tenderness, crepitus and cracking on motion, and mild joint enlargement with firm consistency from proliferation of bone and cartilage which may be caused by secondary synovitis. Late stages of the disease are associated with gross deformity and joint subluxation.

Kuettner and Goldberg in 1995 cited in Creamor et al in 1997 (38) gave the following consequence definition: "Osteoarthritic diseases are a result of both mechanical and biological events that destabilize the normal coupling of degradation and synthesis of articular cartilage chondrocytes and extracellular matrix, and subchondral bone. Although they may be initiated by multiple factors including genetic, developmental, metabolic and traumatic, osteoarthritic diseases involve all of the tissue of the diarthrodial joint. Ultimately, osteoarthritic diseases are manifested by morphologic, biochemical, molecular and biomechanical change of both cells and matrix which led to a softening, fibrillation, ulceration, loss of articular cartilage, sclerosis and eburnation of subchondral bone, osteophytes, and subchondral bone cysts. When clinical evident, osteoarthritic diseases are characterized by joint pain, tenderness, limitation of movement, crepitus, occasional effusion, and variable degrees of inflammation without systematic effects."

There are several published classifications of osteoarthritis and separate its into 2 categories (37,39):

1) Primary (Idiopathic) osteoarthritis: no presently known prior event or disease related to the osteoarthritis.

2) Secondary (Acquired) osteoarthritis: known event or disease associated with osteoarthritis.

2.1.2 Factors Influencing Knee Osteoarthritis

2.1.2.1 Age and Gender

Age is the most important factor associated with osteoarthritis. More and more evidence is accumulating to suggest that osteoarthritis is frequently represented in the middle age. Many studies suggested that osteoarthritic knee was increased dramatically after age of 40 years (20,23,35,40).

Lowman in 1955 (35) explained that aging was the most significant factor in development of tissue degradation. Degenerative change in joints began to appear in the age of 40.

Andersen in 1978 (40) investigated knee osteoarthritis in both men and women in Greenland. Two hundred and ninety five Greenlanders, aged 40 years or more were recruited in the survey. Roentgenograph in anterior-posterior direction was used for diagnosis of primary osteoarthritis. Severity from the roentgenograph were divided into mild, moderate and severe, respectively. Eighty-six (29 percents) of all subjects were found to have osteoarthritis. Seventy-two percents of these subjects represented moderate severity whereas only one percent found to be severe.

Chomechan in 1984 (23) studied the distribution of two hundred patients in Prince of Songkla University who had osteoarthritis of the knees. The results showed that the prevalence of knee osteoarthritis was most common between aged 41 and 60 years, respectively. Eighty percents of the patients were females whereas twenty percents were males.

Felson et at in 1987 (20) investigated the prevalence of osteoarthrtis of the knee in elderly subjects. The study surveyed by using physical examination, medical history and anteroposterior radiograph of the knees. Osteoarthritis was defined as grade 2 described by Kellgran and Lawrence (98). Radiographic evidence of osteoarthritis of the knee increases with age, from 27 percents in subjects younger than 70 to 44 percents in subjects age 80 or older.

Oliveria in 1995 (41) investigated the incidence of symptomatic hand, hip, and knee osteoarthritis. Approximately one hundred and thirty thousand people were participated in the study. Radiographic and clinical examination were used to elucidate the severity of the disease. In the knee, the survey showed that the number of knee osteoarthritis was first represented in 30-39 ranged of age, incidence rate was 20/100,000 in women and 39/100,000 in men, and increased rapidly in 40-49 years old, 117/100,000 in women and 121/100,000 in men. Data showed that incidence was increased with increasing age. The highest values were seen in 70-79 years, 1,082/100,000 in women and 839/100,000 in men. Finally, when compared incidence between women and men, men had more incidences between 0-39 years, because these ages had risk to injury and trauma to the knee. But in the later of ages, women showed high hazard to present the disease. Most of them were caused by mechanical factors and hormonal changes.

2.1.2.2 Obesity

Obesity has been strongly linked to osteoarthritis. Many reports reviewed that obesity may act by increasing mechanical stress in loading joints (42,43).

Litch et al in 1973 (42) studied the incidence of obesity and osteoarthritic knee. They compared 2 groups of patients; control and experimental groups. Control group was patients who did not have symptom of knee osteoarthritis. The experiment group was patients who had the clinical and radiographic diagnosis of osteoarthritis of the knee. The weight and height of all patients were recorded. In case of osteoarthritis of the knee, eighty-three percents of women and thirty-five percents of men were adjudged as obese.

Hart et al in 1999 (43) studied the natural history, role of risk factor and incidence of knee osteoarthritis. Seven hundred and fifteen women participated in the study. All subjects had an anteroposterior radiograph of the knees in weight-bearing position. Height, weight and other risk factors were also recorded. After 48 months, all women were followed with weight-bearing radiographs. Women who had incidence of knee osteophytes were heavier than other group, which was no osteophytes by mean 4.8 kilograms, but there was no significant difference in joint space narrowing between two groups of subjects.

2.1.2.3 Muscle Strength

Quadriceps and hamstring strength are necessary for activity of daily living. Weakness of both muscles groups particularly in quadriceps muscle was a common and important consequence of knee trauma, surgery and arthritis (30,31). Muscle weakness contributed significantly to disability and probably also renders the joint vulnerable to further damage (26,27).

Hurley et al in 1993 (27) investigated the influence of arthrogenous muscle inhibition on quadriceps muscle strength. Ten patients who had unilateral knee osteoarthritis were participated in the study. All subjects had quadriceps weakness and were referred to physiotherapy to increase quadriceps strength. Isometric strength measurement was performed on Cybex II dynamometer. Hurley used both static isometric muscle force and dynamic isokinetic muscle force to evaluate muscle strength. The highest value was recorded. Muscle inhibition was determined by superimposition of maximum voluntary contraction in each subject with electrical stimulation. Percent of inhibition determined by percent of electrical stimulation gained more strength. Arthrogenous muscle inhibition was presented in all patients. Hurley concluded that arthrogenous muscle inhibition was presented in early knee osteoarthritis and may be evoked by altered afferent input to central nervous system, resulting in decreased motor drive to quadriceps muscle.

Slemenda et al in 1997 (28) elucidated the role of muscle weakness in osteoarthritis. Four hundred and sixty-two persons who had aged over sixty-five years were accepted to participation. Anteroposterior and lateral radiographs were used to elicit symptoms and defined severity of the patients. The criteria of Kellgren and Lawrence (98) were also used to define severity of knee osteoarthritis. Patients with severity more than grade two were selected in osteoarthritis group. Other subjects with severity less than grade two were selected in normal group. Flexor and extensor muscles of the knee were evaluated by using an isokinetic dynamometer. Peak torque of each muscle group was recorded. The result presented significant decrement of quadriceps muscle strength in the patients who had knee osteoarthritis whereas hamstring muscle did not show significant weakness.

2.1.2.4 Trauma

O'Connor et al in 1992 (22) determined whether partial loss of the afferent fibers from the knee joints of dogs, accomplished by neurectomy of the primary articular nerves before transection of the ligament, also accelerated the development of osteoarthrosis. The results showed that osteoarthritis was developed in all dogs that had had transection of the anterior cruciate ligament, but osteoarthritis did not develop in dogs that had had transections of medial, posterior and lateral articular nerves. However, the osteoarthrotic lesions were seen more frequent and severe in dogs that had had neurectomy than normal dogs.

2.2 Knee Proprioception

2.2.1 Definition of Limb Proprioception

Proprioception is defined as the conscious perception of limb position in space (1). These sensations are necessary for maintaining balance, control limb movement and for determining the shape of a grasped object (3,45).

Many researchers defined that proprioceptive sensation are those having to do with the physical stage of the body including position sensation, tendon, skin and muscle sensation. The position sense also used as proprioceptive sensation and divided into 2 components (45);

1) Static position sense, which means conscious orientation of the different parts of the body with respect to each other.

2) Sense of limb movement, also called kinesthesia or dynamic proprioception, which means the detection of movement and acceleration.

2.2.2 Proprioceptors of the Knee

Proprioceptors of the knee originate from many connective tissues around the knee including knee joint ligament, menisci, tendon, capsule and muscle (2,3,46-49).

Joint receptors are divided into four different types: Type I endings or Ruffini receptors, Type II endings or Pacinian corpuscles, Type III endings or Golgi tendon organ and Type IV endings or bare nerve endings (5,50).

1) Type I endings or Ruffini receptors are globular or ovoid encapsulated corpuscles, averaging 100 micrometers in maximum diameter and 40 micrometers in minimum diameter. These endings are found mainly in fibrous capsule of the joint particularly in peripheral layers and found in small clusters of three to six in the fibrous capsule. Their receptors are few on extrinsic ligaments and in

paraarticular periosteum and related tendon. Ruffini endings are more densely aggregated on the anterior and posterior aspects of the joint than on its medial and lateral sides. Their afferent nerve fibers are myelinated. The diameters are small range from 6 to 9 micrometers. They are low-threshold slow adapting receptors that responsible for detecting static and dynamic factors such as joint angle, velocity and intraarticular pressure. Their functions are acted by displacement of collagenous fibrils and surrounding connective tissues, and are inactive in immobile joints. They are becoming active only at the start or stop joint movement and in the moment at which rapid changes of stress occur in its regions.

2) Type II endings or Pacinian corpuscles are elongated, conical corpuscles averaging 280 micrometers in length and 120 micrometers in diameter. Each ending is enclosed in a multilaminated connective capsule. They are found mainly in deeper layer of fibrous capsule of the knee joint. Type II endings are low-threshold rapid adapting mechanoreceptors. Their functions are response to mechanical displacement resulting from pressure and signal dynamic changes in the deformation of the tissues, the initiation, acceleration and deceleration.

3) Type III endings or Golgi tendon organ is a large fusiform body averaging 600 micrometers in length and 100 micrometers in maximum diameter, enclosed in a fine connective tissue capsule containing one to three layers. Each ending is innervated from large myelinated afferent nerve fiber about 14 to 16 micrometers in diameter. They are located mainly in all ligaments of the knee and absent from the capsular tissues of the joint. They are high thresholds and slow

adapting mechanoreceptors that are inactive in immobile joints. They become active only when joint are stimulated at extreme angles or stress that are generated in joint ligament.

4) Type IV endings or bare nerve endings consist of fine terminal nerves that do not have a myelin sheath. Their afferent p 7 nerve fibers are very small averaging 2 to 5 micrometers in diameter. They are located mostly in the ligament both extrinsic and intrinsic and found in fibrous capsule, articular fat pads and wall of blood vessels. These endings are high-threshold and non-adaptive pain receptors.

Skeletal muscles have many receptors. Muscle spindle and golgi tendon organ are the receptors which are particularly important for motor control. Muscle spindles are located within freshy portion whereas golgi tendon organs are located at the junction between freshy fibers and tendon (12,50).

Muscle spindles are innervated by group Ia, large myelinated and group II, small myelinated, afferent fibers. Primary sensory endings are connected to the group Ia axon. These groups are fast conducting axons. They are sensitive to the rate of length change and the length change in the muscles. Secondary endings are terminated from group II afferent. Secondary endings are sensitive to length change in the static phase.

Golgi tendon organs are slender encapsulated structures about 1 millimeter long and 0.1 millimeter in diameter. Each of which innervated by group Ib afferent fiber. The firing rate of tendon organs is very sensitive to change the tension of the muscle. Each of tendon organs detects muscle tension in 2 or 3 muscle fibers.

2.2.4 Joint and Muscle Proprioception

Many researchers have concentrated on proprioception since 1950s. Most of them measured proprioception in small joints, for example in fingers and toes. The result found that half of position was detected through skin receptors.

Gandevia et al in 1975 (6) studied a decrement in the ability to detect passive movement in the distal interphalyngeal joint of the middle finger when cutaneous and articular nerve afferent were blocked by local anesthesia.

Ferrell et al in 1986 (5) investigated kinesthetic acuity at the distal interphalangeal joint of the middle finger. In the first experiment, they divided subjects into 3 groups. The first group received intraarticular injection of dextran. The second group received local anesthesia and the third group was served as a control group. In the second experiment, acuity was measured under control condition and when anesthetized an area of skin on the dorsum of the joint. Position of the hand and finger was adjusted in special situation that was effectively disengaged from its muscular attachments. Subjects were required to detect 5 degrees of movement. This test was performed in different velocities between 1 and 30 degrees per second. Intraarticular injections of dextran were associated with increment of kinesthetic acuity while injections of local anaesthetic were associated with an impairment of performance.

Previous studies provided evidence that skin receptors and joint receptors were primary determinant of proprioception (5,6). However, most studies investigated in finger, but knee joint is different in anatomy and function from those joints. Other studies investigated in the knee and found that the knee used deep receptors more than smaller joints.

Clark et al in 1979 (12) determined the role of joint and skin around the joint, which were important for detecting knee position sense. Subjects were divided into 3 experiments: injection of local anesthesia into the joint, skin-anesthesia, and combined both methods. Left leg of each subject was set at criterion angles. Subjects were tested for their ability to detect 5-degree changes of the right knee by starting at the same angle compared to the left knee. Directions of movement and angle error were recorded. The result showed that mean value of the angle difference was significant for joint injection, but not for the skin and joint anesthesia. Clark et al concluded that the awareness of static knee joint position did not depend on signal from the joint or skin around the joint. In addition, both receptors were minor influence on perceived joint angle.

Barrack et al in 1983 (8) investigated the effect of intraarticular anesthesia and possibility of functional changes. Ten subjects were evaluated joint position sense by two methods. The first method was reproduction of passive positioning. The second was threshold for detecting passive motion. Thereafter, each subject continued with gait analysis after finishing proprioceptive tests. All data were recorded both pre-injection and post-injection of local anesthesia. There were no significant differences in gait analysis and proprioceptive data b etween two methods.

Goodwin et al in 1972 (11) studied effect of vibration on biceps tendon and proprioception. They found a significant decrement in threshold to detect passive movement only when applied vibration on biceps tendon. The angle in vibrating arm was misaligned as much as 40 degrees compared to non-vibrating arm.

2.2.5 Measurement of Knee Proprioception

There are two techniques to measure knee joint position; threshold for detection of passive motion and reproduction of knee angle (9,10,12-19,21,51). The threshold for detection of passive motion was mostly conducted in a seated position. The subjects were blindfolded and eliminated any external cues to limb motion except those originating from the knee joint and surrounding structures. The legs were hanged freely over the edge of the seat. A leg air splint was placed on the foot and lower half of the leg being tested. The splint was inflated to 20 mmHg and held the pressure throughout the tests to naturalize skin sensation. A wire was attached to pulleys suspended the lower splint and driven by a slow-speed motor. The test was started at random times from 1 to 30 seconds. Subjects were asked to identify or to press the control box when they perceived movement of the extremity being tested to determine joint position sense. The primary variable was the error angle from starting position.

Reproduction of knee angles was tested in both open kinematic chain, in sitting and lying positions and closed kinematic chain, in standing position (8-10,14,15,17,19,29,51). Both techniques involved evaluating the subject's ability to reproduce specific knee angle, which was determined by examiner. From starting position, the lower leg of the subject was moved to the criterion angle and held for a few seconds. After that, the leg was returned to the starting position and rested for a few seconds. Then examiner asked the subject to reproduce the angle. The absolute angular error was used as a tested variable. Movement of the lower leg being tested to the criterion angle was done passively by the examiner or through active muscle contractions by the subject.

In closed kinematic chain, the test was usually performed in standing position. A study done by Petrella in 1997 (19) measured proprioception in both normal and knee osteoarthritis. Measurement of proprioception used electrogoniometer to determine the angle. The starting position of the subject was 35 degrees of knee flexion. The test was started by asking the subject standing on both legs. The subject was asked to flex the knee to the criterion angle and concentrate on this position and then returned to the standing position. The subject was given five seconds to reproduce the test angle. This test used absolute angular error to determine ability of the subject.

2.2.6 Factors Influencing Knee Proprioception

2.2.6.1 Vision

Martin in 1990 (1) suggested that vision gave feed forward and backward information for control limbs movement and could compensate for losing proprioception. If the subject is allowed to see the limb before making the movement, the error of the movement angle is reduced.

2.2.6.2 Age

Proprioception decreased with increasing age. Barrack et al in 1983 (9) evaluated knee proprioception in young, elderly and total knee replacement patients. Their experiment used both threshold to the sensation of motion and reproductive knee angle to test knee proprioception. After finishing the test, the data showed that young subjects demonstrated significantly better joint-position sense than elderly did, 3.8±1.0 vs. 5.9±1.6 in threshold and 3.6±1.0 and 4.6±2.2 in reproductive knee angle, respectively.

Barrett in 1991 (10) used new method to test knee joint position sense. A Thomas splint with a Pearson knee-flexion piece was used to support the whole leg. The protractor was attached to the splint to measure the angle. The passive reproductive knee angle was used as a standard protocol. The leg was passively moved to ten different predominating positions of knee flexion. The study compared knee joint proprioception in young subjects, elderly subjects with and without knee osteoarthritis. The joint-position showed greater decrease in accuracy in the elderly subjects without knee osteoarthritis compared to the young subjects. While elderly subjects with knee osteoathritis showed less accuracy in position sense compared to subjects without knee osteoarthritis.

Petrella et al in 1997 (19) investigated knee proprioception among young volunteers, active and sedentary elderly subjects. The active reproductive angle in standing position was used to determine proprioception. The result showed significant difference in absolute angular error between young subjects (2.01±0.46 degrees) and active elderly subjects (3.12±1.12 degrees; $p<0.001$), and between young and sedentary elderly subjects (4.58±1.93 degrees; $p<0.001$).

Pai et al in 1997 (18) tested 2 hypotheses. First, knee position sense decreased with increasing age. Second, patients who had knee osteoarthritis had less accuracy in knee joint position sense than subjects in the same age. The experiment used threshold for detection of passive motion to distinguish knee proprioception. The correlation coefficients between age and subject's threshold were 0.598 ($p<0.001$) in the right knee and 0.501 ($p<0.001$) in the left knee. The result showed that position sense decreased with increasing age. There were significant differences between knee osteoarthritis and elderly control (5.5±4.9 vs. 2.6±1.2 in the right side and 4.5±3.9 vs. 2.4±1.6 in the left side, presented in absolute angular errors in degrees). The results indicated that proprioceptive accuracy declined with age and osteoarthritis patients had worse knee proprioception than elderly controls.

2.2.6.3 Effusion

McNair et al in 1995 (52) tested the effect of an effusion on knee proprioception. They compared 10 men whom were injected 90 milliliters of saline and dextrose solution in intraarticular space and 10 control men. The result showed no significant difference between two groups of the subjects. However, the study investigated an increasing pressure in the knee joint. It was not the effect of chronic effusion, which was presented in the inflammatory process and capsular compliance. McNair et al stated that chronic effects may affect knee proprioception.

Guido et al in 1997 (53) studied the effect of chronic effusion on knee proprioception. The test used a subject who had sustained a 15 percent tear of medial meniscus. Guido et al measured knee proprioception using both active and passive repositioning. The result showed that knee joint proprioception was demolished in this subject.

2.3 Fatigue

2.3.1 Definition of Fatigue

Fatigue is defined as the decline in muscle tension capacity with repeated stimulation (54).

2.3.2 Muscle Fatigue and Exercise

Isokinetic exercise is the mode of resisted exercises that frequently used in both clinical and research experiment. Many researchers used isokinetic exercise to determine characteristic of muscle fatigue in various conditions.

Douris in 1993 (55) tried to measure the effects of velocity-specific isokinetic exercise on blood lactate, muscle fatigue index and rating perceived exertion and to examine the relationship between blood lactate and muscle fatigue index. Ten healthy men were participated in the study. The experiment used a Cybex II system for resisted exercise tests. The experiment divided into 1-day introductory training and 3 separate treatment sessions at different days. The independent variable of this study was the training velocity, which was 30, 120, 300 degrees per second. Each session used only one velocity. In the test session, the subject was asked to perform maximum effort exercise for 1 minute. After finished all the process, there were no significant differences between exercise sessions on the ratings perceived exertion scores. This variable reflected that all sessions had the same "very strong" level in the Borg's scale. Other variables showed that there were significant differences among the three sessions on increasing muscle fatigue and blood lactate. These findings suggested that increasing isokinetic exercise velocity would produce greater lactate accumulation and increase in muscle fatigue.

2.3.3 Fatigue and Proprioception

Skinner et al in 1986 (34) studied the effect of muscle fatigue on knee proprioception in men. Proprioceptive testing protocol was passive reproductive angles in sitting position. The authors suggested that muscle fatigue might reduce knee proprioception.

Mark et al in 1993 (32) compared the accuracy of knee position sense between control group and experiment group that received fatigue maximal isokinetic exercise. The study used male subjects age ranged between 18 and 25 years. Knee position sense was measured using potentiometer with a computer of a KinCom isokinetic dynamometer. The experiment tested subject's proprioception by using active reproductive knee angles technique in sitting position. In fatigue protocol, the subject in experiment group was performed 20 maximum concentric and eccentric contraction of the quadriceps femoris muscle. The angular velocity was set at 180 degrees per second. After finish the fatigue protocol, the experiment group was repeated testing knee proprioception immediately. The analysis of variance indicated that there was significant difference between experiment and control groups. The result suggested that fatigue exercise did not effect knee proprioception.

Voight et al in 1996 (56) studied the effect of muscle fatigue and relationship of dominance and non-dominance arm to shoulder proprioception. The experiment used Biodex isokinetic dynamometer as an instrument to test proprioception and performed fatigue exercise. The arm of the subject was tested both passive and active reproductive angle. Following proprioceptive testing, the arm was exercised through fatigue protocol, which consisted of active isokinetic internal and external rotation at 180 degrees per second. When the peak torque dropped to 50 percents of the initial peak torque, the tester stopped the test and then repeated proprioceptive testing. The result showed no significant difference between the dominance and non-dominance arms in any test condition, but there were significant differences in shoulder proprioception between pre and post fatigue exercise.

Lattanzio et al in 1997 (33) recently investigated the effect of fatigue on knee proprioception. They used three different fatigue protocols that consisted of lower limb cycling on computer driven cycle ergometer. The first protocol was ramp test (20/25 watts/minute) to exhaustion. The purpose of ramp test was to determine subject's VO_{2max}, which was used to calculate the work rate for the latter two tests. The second protocol was continuous test. In continuous test, the subject required to continue cycling at 80 percent of their VO_{2max} to exhaustion. The third protocol was interval tests, which consisted of certain percentage alternating workloads equal to 120 percent of their VO_{2max} to exhaustion. A Penny and Giles electrogoniometer was used to test static knee position sense in standing position. This proprioceptive testing was done both pre and post fatigue exercises. Knee position sense was statistically reduced for men in all three tests and for women only in continuous and interval tests.

2.4 Factors Influencing Isokinetic Strength

2.4.1 Subject Understanding

Isokinetic exercise instrument is the machine that used to measure muscle performance. It produces novel sensation to the subject, so the researcher should give a standard instruction about purpose of the test, procedure of isokinetic test, the feeling of exercise and the requirements of the subjects. All information above produces not only familiarization but also reliability and validity to all the subjects (57).

2.4.2 Test Position

Before assessing muscular strength, consideration should be given to the test position of the subject. Test position including stabilization, axis of rotation and joint alignment are important factors that can alter quantitative measurement of muscular strength. Optimum positioning and stabilization can eliminate accessory movement from upper extremity and trunk during strength measurement of lower extremity muscle. Test position for isokinetic strength measurement of the knee almost performed in sitting position. Several studies have suggested that knee muscle groups produced greater torque in upright position than in semireclined sitting position or supine position. Stabilization in the seated position was performed in many ways.

Hart et al in 1984 (60) demonstrated that adding thoracic strapping improved quadriceps strength significantly than stabilized only pelvis and thigh. On the other hand, Hanten and Ramberg in 1988 (61) were not accomplished to find differences between maximal and minimal stabilization. Maximal stabilization comprised of thoracic, pelvic and thigh straps whereas minimal stabilization comprised of thigh and pelvic straps only. Dvir et al in 1995 (58) suggested that optimum set-up of knee strength testing was normally achieved using pelvic and thigh straps. The axis of rotation of the joint being tested should be aligned with axis of rotation of dynamometer in order to allow maximum functional range of motion and smooth comfortable movement for the subject.

2.4.3 Gravity Correction

Gravity correction is important in the valid assessment of knee muscles. Gravitational force induces torque production overestimate in muscle assisted by gravity and underestimate in muscle resisted by gravity. The researcher should use gravity correction procedure to account for the weight of the dynamometer's lever arm and the limb being tested. Regardless of the muscle groups, acceleration of the limb due to gravity erroneously added to torque (57). Moreover, in the test, if dependent gravity correction procedure is used in a test and retest situation, any differences could be related to the magnitude of the different gravity correction (64,67).

2.4.4 Test Protocol

2.4.4.1 Warm Up

A warm up aids the performer in preparing either physiologically or psychologically for an event and may reduce the changes of joint and muscle injury. In physiological effects, warm up can increase in blood flow in specific muscles and core temperature. It can increase speed of contraction and relaxation of the muscles. Warm up improves greater muscle efficiency because of lower viscous resistance with the muscle, facilitated oxygen utilization and nerve transmission. In psychological effects, a warm up prepares subject mentally for the event. Especially, specific warm up related to the activity itself improves the necessary skill and coordination (68). The warm up is necessary to familiarize the subject before test. In isokinetic test, before the test at each velocity, each subject will begin with specific warm up including submaximal and/or maximal repetitions. Many studies used three submaximal and three maximal warm up repetitions before strength test occurred (58,79).

2.4.4.2 Test Velocity

Muscle strength can be tested at different speeds through a spectrum of slow to fast isokinetic velocities. The speeds of isokinetic dynamometer are divided into slow, intermediate and fast speeds. The slow speed testing provides an indication of the subject's ability to resist compressive force, whereas intermediate and high speeds testing provide an indication of muscular capability at functional speed (69). Dvir et al in 1995 (58) suggested a range for test velocity that would be ranged between 60 and 180 degrees per second. It also seems to meet the essential requirement of test validity. The use of very low velocities is easily to produce injury in patients with ligament and muscular disorders.

2.4.4.3 Number of Test Repetition

A test protocol consists of multiple contractions to obtain a true maximum value of force or torque at any test velocity. Few test repetition results in invalid of the data whereas numerous test repetition can produce fatigue to the muscle.

Dvir et al in 1995 (58) recommended that four to six test repetitions were suitable to yield a representative performance parameter. Many studies used specific test repetition from three to six repetitions (70,71).

2.4.4.4 Rest

Rest period between tests at different angular velocities is a source of variability in isokinetic testing. The time of rest period depends on the nature of the test (72,73). A thirty-second to one minute rest period is sufficient for recovery after four maximum repetitions at any test velocity whereas twenty to thirty repetitions require at least one minute of rest and perhaps longer (57).

2.4.4.5 Motivation

The present or absence of verbal encouragement could cause dramatically effect on ability to produce maximal effort (57). The subject should receive consistency of format and execution of verbal instruction to standardize all subjects (59).

Visual feedback is the knowledge that the subject receives during test session. This information may improve a maximal voluntary contraction (73). Most importantly, isokinetic assessment of muscular strength should be consistent with respect to the present or absence of visual feedback.

From the literature review, the effect of fatigue on knee proprioception was investigated only in normal subjects but no study investigates in knee osteoarthritis patients. Knee osteoarthritis patients had worse knee proprioception sense, muscle weakness and easier to fatigue than normal subjects. Therefore, it is interesting to study the effect of quadriceps and hamstring muscles fatigue on knee proprioception in these patients and keep this information to apply in clinic.

CHAPTER III

MATERIALS AND METHODS

3.1 Subjects

Subjects in this study were female subjects with and without symptomatic knee osteoarthritis aged ranges from 40 to 60 years.

All subjects had the following criteria:-

- right or left leg dominance in these tests with assessed by kicking a ball, picking up a rubber, draw number 8 on the floor.

- no neurological disease such as cerebrovascular accidence, Parkinson disease or dementia.

- no metabolic or vascular disease with neurological component such as diabetes millitus.

- no history of knee operation or fracture of the lower extremity.

- no inflammatory arthritis, or steroid injection within 2 months.

- not receiving any medical or physical treatment within 24 hours before the testing.

- no other problems related to rheumatoid arthritis, psychological, cardiovascular, visual or hearing system that effects the ability to communication.

Inclusion criteria for subjects with asymptomatic knee osteoarthritis were as follows:-

- no effusion or warmth of the knee.
- no ligamentous laxity of knee joint
- no symptoms or history of arthritis.
- no pain at rest or motion.
- scores of Index of Severity for Knee Osteoarthritis (99) (ISOA) = 0

Inclusion criteria for subjects with symptomatic knee osteoarthritis were as follows:-

- subjects have one or both knees osteoarthritis (screening by orthopedists).
- right or left leg dominance with symptomatic knee osteoarthritis.
- mild to moderate knee pain (visual analog scale not more than 7.5 out of 10).
- crepitus of knee joint.
- scores of ISOA between 1 and 10.

The severity of knee osteoarthritis, laxity of knee joint, passive range of knee motion, mental stage and recognition, and threshold of vibration were recorded for each subject.

All subjects who met the inclusion criteria signed an informed consent before participation in this study.

3.2 Instrumentation

1. The Biodex system II (Biodex Corporation, Shirley, NY) was used in this study.

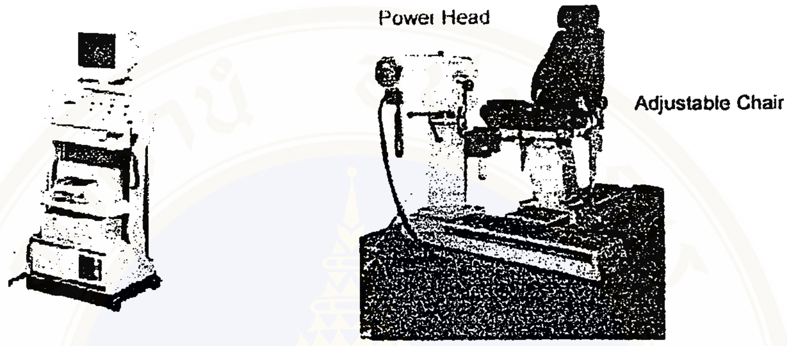

Figure 3.1 Biodex system II.

The Biodex system consists of:

- an adjustable chair
- powerhead
- controller
- stabilization system
- extremity system accessory
- base assemble
- dynamometer
- keyboard and monitor
- printer

2. Standard goniometer

3. Vernia caliper (accuracy ± 0.1mm)

4. A tape measure with 1 mm. increment

5. A ball and a rubber

6. Self-administered of Index of Severity for Knee Osteoarthritis

7. A Biothesiometer (Biomedical Instrument Co., Newbury, Ohio)

3.3 Position of Testing

Each subject sat in an adjustable chair with the back fully support and the knee hanging over the edge of the seat about 1 inch proximal to the popliteal fossa. In proprioceptive testing position, a pelvic strap, a pair of shoulder strap and a thigh strap were used to stabilize the subject. The axis of rotation of the dynamometer was visually aligned with the prominent point of the lateral condyle of femur. The researcher instructed the subject to flex and extend her knee joint through the range of motion to check the alignment of axis of rotation and accessory arm length.

The chair position (chair height and chair rotation), seat position (seat rest back/front, seat tilt), power head position (powerhead left/right, powerhead height, power head rotation, powerhead tilt, attachment length left or right), lever arm length, limb weight, and hip angle were recorded and stored in the computer. The tested knee was placed in 90-degree flexion and the hips in 85-degree flexion (see figure 3.2). In concentric isokinetic strength testing, the subject was asked to cross her arms over the chest to minimize extraneous body motion and effect of accessory muscle group contraction. In proprioceptive testing, each subject sat in suitable and relaxed position. Environment around the subject was silent. The researcher asked the subject to close her eyes during proprioceptive tests. Gravity correction was calculated automatically by the system for the effect of limb weight.

3.4 Procedure

Each subject was given an explanation of the purpose of this study. Physical examinations for each subject were performed by the researcher. The testing protocol was divided into 4 sequences of tests: proprioceptive testing, concentric isokinetic strength testing, fatiguing isokinetic contraction program and proprioceptive re-testing. Only dominant leg of each subject was tested.

3.4.1 Proprioceptive Testing

The test angle was performed at 45 degrees of knee flexion. Before testing, the researcher set the subject position in proprioceptive testing position. Each subject was given standard instruction and undergone three practice trials at 45 degrees of knee flexion or until they were accustomed to the method in this protocol. The researcher asked subjects to close their eyes during the test. Throughout the testing protocol, the starting angle for the subjects was 90 degrees of knee flexion. Next, leg was passively positioned by the researcher at the speed approximately 10 degrees per second and held for 5 seconds at the criterion angle (at 45 degrees of knee flexion). Then the researcher asked the subject to concentrate in this position. After holding for 5 seconds, the leg was passively returned to the starting position and rest for 3 seconds. In active repositioning, the subject was asked to extend the knee to the criterion angle and held for 3 seconds and the researcher recorded the knee angle performed by the subject. After finishing the first test angle, the subject repeated the same angle two more times. The difference between performed angle and criterion angle was calculated as absolute angular error.

3.4.2 Concentric Isokinetic Strength Testing

The position of each subject was shown in figure 3.2. The subject performed a warm-up session at 180 degrees/second. Warm-up was performed prior to each test to familiarize the subjects with the velocity and resistance. It consisted of 3 submaximal and 3 maximal repetitions. After 60 seconds rest period, the subject was instructed to perform 5 maximal repetitions of knee extension and flexion at 180 degrees/second. During the test, the subject was verbally encouraged to extend and flex knee as hard and as fast as possible against the dynamometer resistance. The subject was also encouraged to see the monitor for visual feedback on her ability.

Figure 3.2 Concentric isokinetic testing position.

3.4.3 Fatigue Isokinetic Contraction Program

The dominant leg was exercised in the concentric isokinetic testing position. Each subject performed isokinetic extension and flexion of knee joint at 180 degrees/second until peak torque of knee extensor muscles dropped below 50 percentage of maximal peak torque.

When finishing the fatigue isokinetic contraction program, the subject was immediately reassessed for proprioceptive testing as previously described.

3.5 Data Analysis

All data were analyzed by using SPSS for windows release 9.0. Kolmogorov-Smirnov Goodness of Fit test was used to test the distribution of data.

Unpaired t-test was used to test the difference in age, weight, height, peak torque and mean absolute angular errors before the fatigue program between subjects with and without symptomatic knee osteoarthritis.

Paired t-test was used to compare the absolute angular errors before and after the fatigue program in subjects with and without symptomatic knee osteoarthritis.

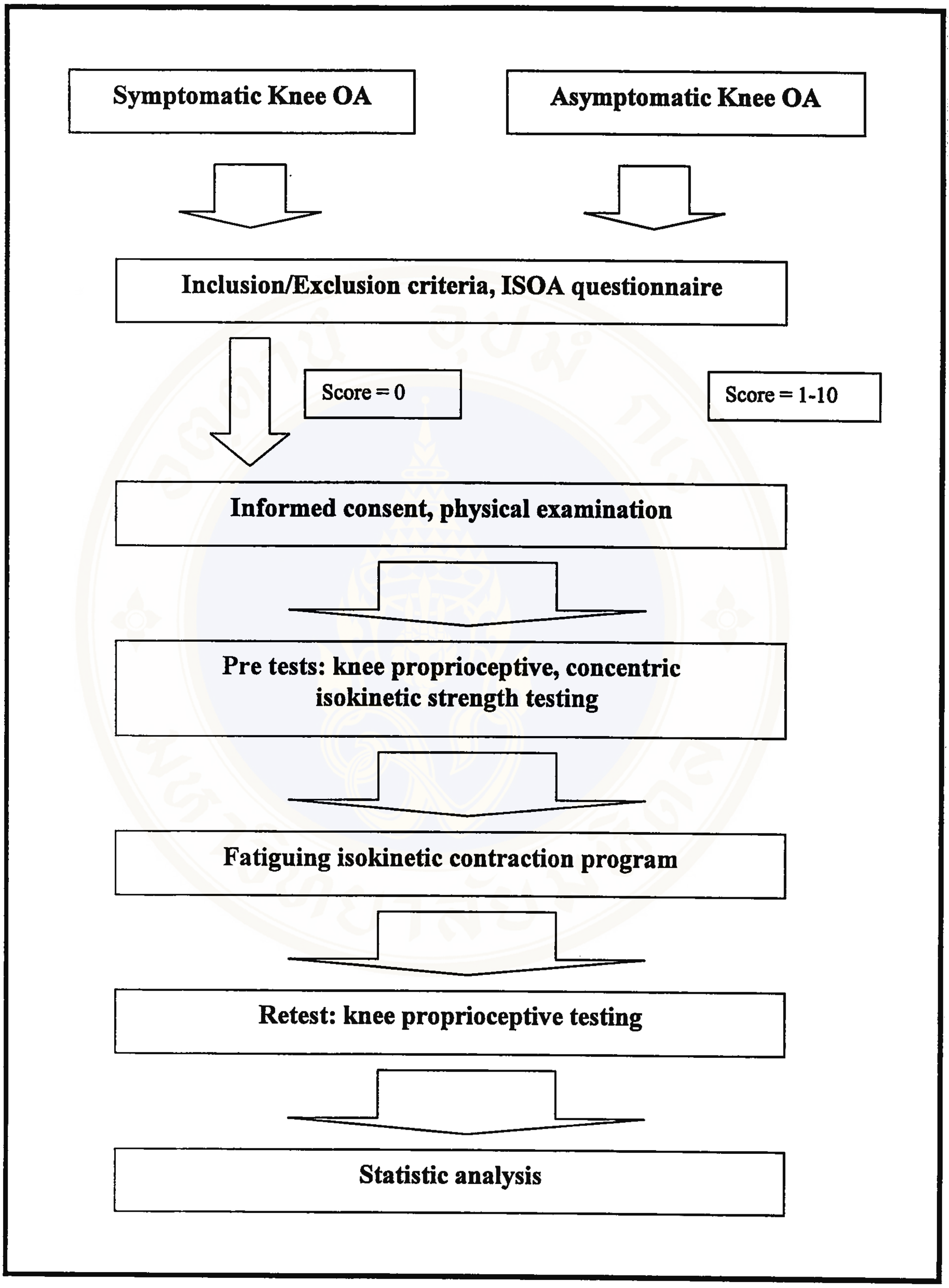

Figure 3.3 Testing procedure.

CHAPTER IV

RESULTS

4.1 Characteristics of Subjects

Thirty female subjects were recruited in this study. Subjects were divided into 2 groups, with and without symptomatic knee osteoarthritis, by similar age, weight, height, and body mass index (BMI). Mean values and standard deviations of age, weight, height and body mass index are presented in table 4.1. There were no significant differences in age, weight, height and body mass index between two groups of subjects ($p > 0.05$).

Table 4.1 Mean values and standard deviations of age, weight, height and body mass index of subjects

Characteristics	With symptomatic knee osteoarthritis (n = 15)	Without symptomatic knee osteoarthritis (n = 15)	p-value
Age (years)	53.60±4.90	50.00±5.95	0.810
Weight (kg)	65.02±13.36	59.67±9.55	0.217
Height (cm)	153.46±4.99	155.27±7.19	0.432
BMI (kg/m^2)	27.54±4.83	24.66±3.03	0.610

p-value from unpaired t-test

4.2 Comparison of Isokinetic Strength of Quadriceps and Hamstring Muscles at 180°/sec between Subjects with and without Symptomatic Knee Osteoarthritis

Mean values and standard deviations for peak torque of quadriceps and hamstring muscles in subjects with and without knee osteoarthritis are presented in Table 4.2 and Figures 4.1

Table 4.2 Comparison of means values and standard deviations of peak torque of quadriceps and hamstring muscles at 180°/sec in subjects with and without symptomatic knee osteoarthritis

Peak torque (Nm)	Subjects		p-value
	With symptomatic knee osteoarthritis (n = 15)	Without symptomatic knee osteoarthritis (n= 15)	
Quadriceps muscle	53.62±16.33	69.47±8.49	0.003*
Hamstring muscle	27.80±6.57	34.61±7.37	0.012*

p-value from unpaired t-test
* = statistically significant at $p < 0.05$

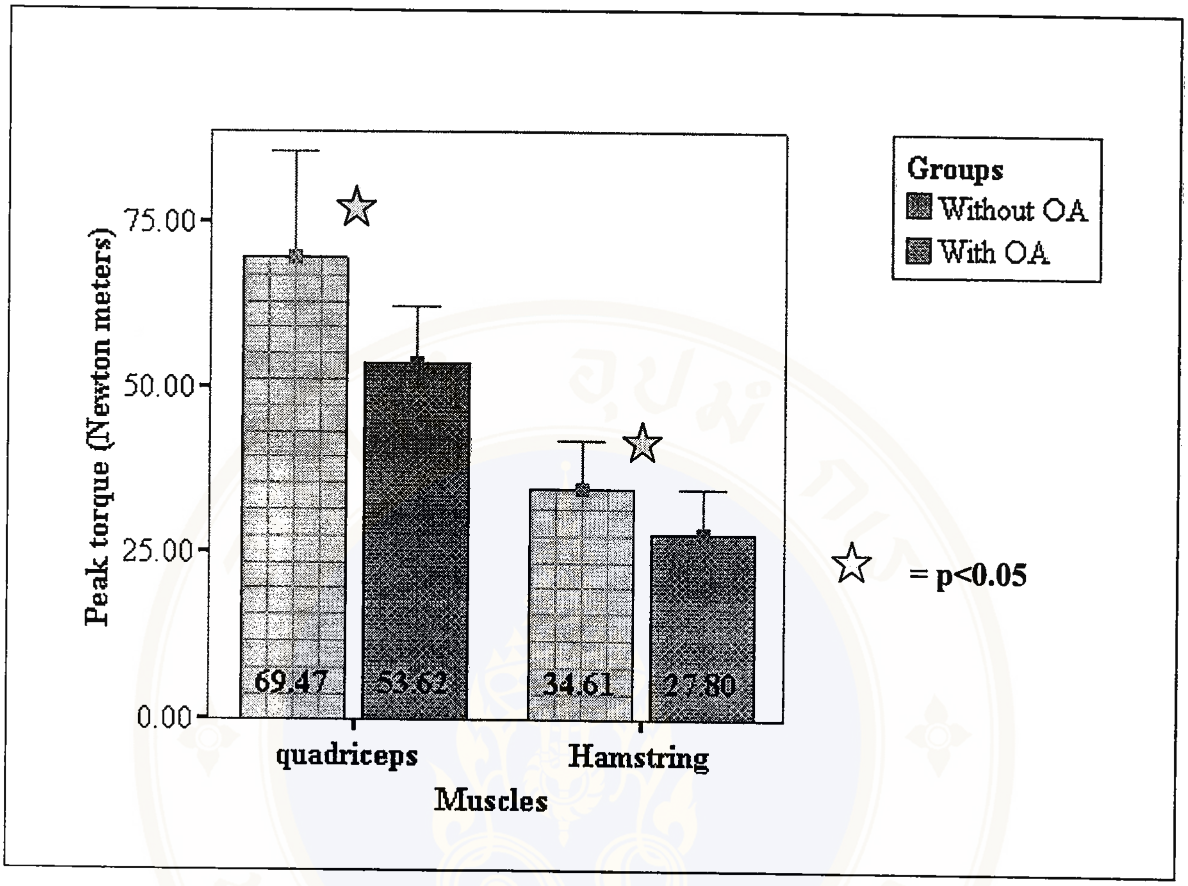

Figure 4.1 Peak torque of quadriceps and hamstring muscles in subjects with and without symptomatic knee osteoarthritis (error bar represents 1 standard deviation).

The results demonstrated that there were significant differences in peak torque of quadriceps and hamstring muscles at 180°/sec between subjects with and without symptomatic knee osteoarthritis ($p < 0.05$). Mean values of peak torque of quadriceps and hamstring muscles in subjects without symptomatic knee osteoarthritis were greater than those in subjects with symptomatic knee osteoarthritis ($p= 0.003$ and $p= 0.012$ respectively).

4.3 Comparison of Mean Absolute Angular Errors before Fatiguing Isokinetic Contractions of Quadriceps and Hamstring Muscles between Subjects with and without Symptomatic Knee Osteoarthritis

Mean values and standard deviations of absolute angular errors at 45° before receiving fatiguing isokinetic contractions of quadriceps and hamstring muscles between subjects with and without symptomatic knee osteoarthritis are presented in Table 4.3 and Figure 4.2

Table 4.3 Comparison of absolute angular error at 45° before fatiguing isokinetic contractions of quadriceps and hamstring muscles between subjects with and without symptomatic knee osteoarthritis

Test angle (45 degrees)	Subjects		p-value
	With symptomatic knee osteoarthritis (n = 15)	Without symptomatic knee osteoarthritis (n= 15)	
Absolute angular errors (degrees)	**3.80±2.56**	**2.18±1.22**	**0.035***

p-value from unpaired t-test
* = statistically significant at $p < 0.05$

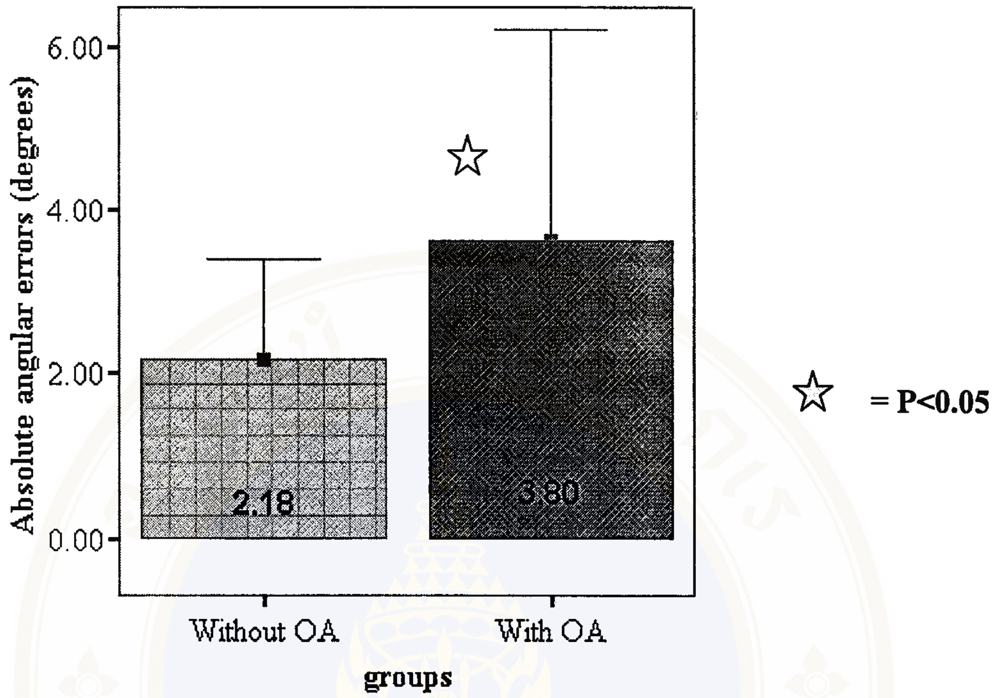

Figure 4.2 Mean absolute angular errors in subjects with and without symptomatic knee osteoarthritis (error bar represents 1 standard deviation).

There was statistically significant difference in mean absolute angular errors at 45° of knee flexion before receiving fatigue isokinetic contraction between subjects with and without symptomatic knee osteoarthritis (p-value < 0.05). Mean absolute angular error in subjects with symptomatic knee osteoarthritis was greater than that in subjects without symptomatic knee osteoarthritis ($p = 0.035$).

4.4 Comparison of Mean Absolute Angular Errors before and after Fatiguing Isokinetic Contractions of Quadriceps and Hamstring Muscles in Subjects with and without Symptomatic Knee Osteoarthritis

Mean values and standard deviations of absolute angular errors at 45° of knee flexion before and after fatiguing isokinetic contraction of quadriceps and hamstring muscles in subjects with and without symptomatic knee osteoarthritis are presented in Table 4.4 and Figure 4.3

Table 4.4 Mean values and standard deviations of absolute angular errors before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in subjects with and without symptomatic knee osteoarthritis

Subjects	Absolute angular errors at 45°		Mean difference (degrees)	p-value
	Before (degrees)	After (degrees)		
Without symptomatic knee osteoarthritis (N=15)	2.18±1.22	3.13±2.04	0.95	0.100
With symptomatic knee osteoarthritis (N=15)	3.80±2.56	10.33±5.55	6.53	0.001*

p-value from paired t-test
* = statistically significant at $p < 0.05$

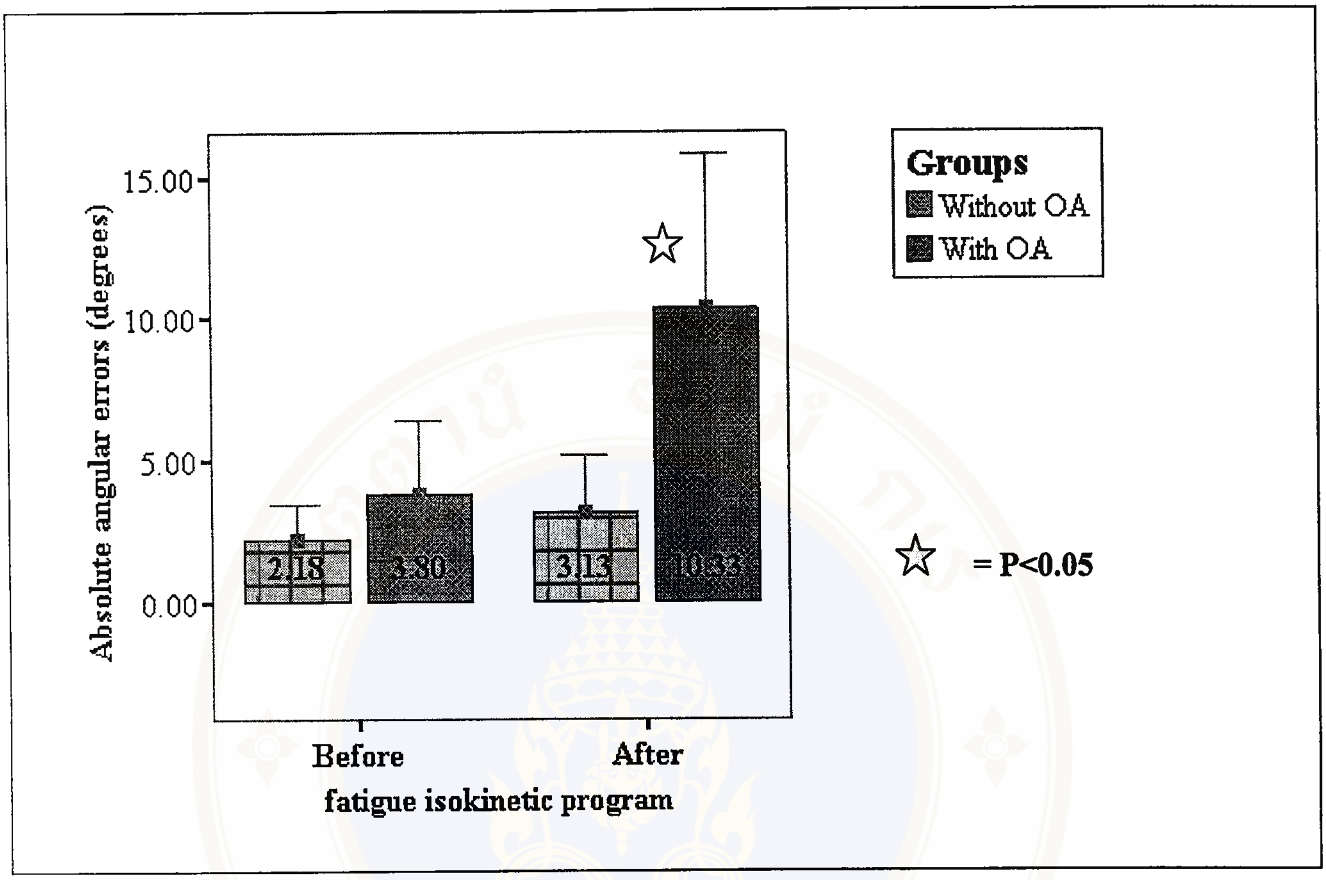

Figure 4.3 Mean absolute angular errors before and after fatiguing isokinetic contraction of quadriceps and hamstring muscles in subjects without and with symptomatic knee osteoarthritis (error bar represents 1 standard deviation).

In summary, there was no significant difference in age, weight, height and body mass index between both subject groups. Peak torque values of quadriceps and hamstring muscles in subjects with symptomatic knee osteoarthritis were higher than those in subjects without symptomatic knee osteoarthritis (p-value < 0.05). Significant difference was demonstrated in mean absolute angular errors that compared before fatiguing isokinetic program between both subject groups (p = 0.035) and compared before and after fatiguing isokinetic program in subjects with symptomatic knee osteoarthritis ($p = 0.001$). The result showed that mean absolute angular errors after fatiguing isokinetic program was greater than before fatiguing isokinetic program. Whereas there was no significant difference in mean absolute angular error in subjects without symptomatic knee osteoarthritis ($p = 0.100$).

CHAPTER V

DISCUSSION

5.1 Characteristic of Subjects

Subjects were females and divided into two groups; with and without symptomatic knee osteoarthritis. Both groups were aged ranges from 40 to 60 years. All subjects reported their dominance leg by answering three primary items questionnaire. The questions consisted of kicking a ball, holding a rubber and writing a number on floor. Furthermore, all of subjects passed the Thai Mental State Examination questionnaire for assurance the subjects that were no effect of abnormal brain function (97). Besides, the age in years, weights in kilograms, height in centimeters and body mass index in kilograms per meter squares were similar in both subject groups. Thus, the age, weight, height, body mass index, leg dominance, memory and brain function would not be the cause of the differences in all parameters investigated in this study.

5.2 Comparison of Isokinetic Strength of Quadriceps and Hamstring Muscles between Subjects with and without Symptomatic Knee Osteoarthritis at 180 degrees/second

The present study represented decrement in peak torque of quadriceps and hamstring muscles in subjects with symptomatic knee osteoarthritis when compared to without symptoms.

From the past to the present research, there have been many different results of peak torque values of quadriceps and hamstring muscles, when compared between subjects with and without symptomatic knee osteoarthritis. Nicholas et al in 1976 (76) presented no significant differences of maximum peak torque of both quadriceps and hamstring muscles in subject with symptomatic knee osteoarthritis compared to subjects without symptomatic knee osteoarthritis. This may be explained by using unaffected leg of the patients as controls. Subjects who had pathology in both legs were excluded from control group, which was lacking the variety of the subjects.

In the studies of Jan et al in 1990 (77), Tan et al in 1995 (78) and Narongrach et al in 1998 (79), they showed significant differences in peak torque of quadriceps and hamstring muscles compared between subjects with and without symptomatic knee osteoarthritis. However, the resulted of Jan et al (77) and Tan et al (78) did not take into consideration of the effect of leg dominance, which may be effect to the muscular strength (80). Although the present study did not compare dominance and non-dominance but the present result showed significant decrement in peak torque of quadriceps and hamstring muscles in dominance leg of subjects with symptomatic knee osteoarthritis.

Decrement of quadriceps and hamstring muscles may be resulted by many reasons. In general, the quadriceps muscles are thought to contain fast twitch fiber than the hamstring muscles and to lose more fast twitch fibers than slow twitch with age (81-83) causing limited activity in older person. The patients had pain and joint pathology, which can inhibit muscle activity and so cause both weakness and wasting

(27,29,44). Nordstrom (84) demonstrated that immobilization of healthy muscle for six weeks resulted in a significant reduction of mean fiber area for all fiber types, whereas fiber type proportions were unchanged. Thus, in subjects with symptomatic knee osteoarthritis, which had pain, limit range of motion and inactivity, may be reduced in muscle cross section area compared with subjects without symptomatic knee osteoarthritis. In knee strength testing, using Biodex System II has been tested to have high test-retest reliability. Gross et al in 1991 (85) reported that intramachine reliability of Biodex was between 0.89-0.97. When compared between machine, they found intermachine reliability of Cybex II and Biodex was between 0.79 and 0.97. The test angular velocity that selected in the present study was 180 degrees/second and this velocity believed not to injure to the subjects after exercise. Douris in 1993 (55) suggested that blood lactate responses were strongly dependent on the velocity, faster velocity produced more lactate accumulation than slower velocity. Furthermore, the velocity of 180 degrees/second was met the essential requirement of test validity and gave information about muscle performance at the functional range (58). Therefore, if higher velocity than 180 degrees/second was used, it might be difficult for osteoarthritic knee patients to extend and flex the knee.

5.3 Osteoarthritis Knee and Proprioception

The aim of the present study was to identify the specific sensory deficit in subjects with symptomatic knee osteoarthritis when compared subjects without symptomatic knee osteoarthritis. The study has found that subjects with symptomatic knee osteoarthritis were significantly poorer in proprioception compared to without symptoms. The finding of worse knee proprioception in patients with symptomatic knee osteoarthritis as compared with without symptom subjects in this study was represented that mean absolute angular error which were 3.80 and 2.18 degrees, respectively. These results are consistent with the results of previous studies using threshold to detection of passive motion (18,21) and active/passive reproductive methods (10,85). These findings cannot determine with any one specific structure for proprioception deficit, however a clinically applicable and index of severity for knee osteoarthritis test has been shown to be able to identify the global sensory deficit of proprioceptive sense in subjects with symptomatic knee osteoarhtritis.

Proprioception in the knee joints depends upon both relatively static restrain such as ligaments, capsules, and articular surface geometry and dynamic neuromuscular systems. Both systems require the integration of sensory proprioceptive input and motor response. Previous studies showed that proprioception (18,19) and muscle strength decline (27,28) with increasing age. All impairments cause poor spatial and temporal coordination of limb position and muscle activity. Continued with increasing poorly distributed load across the articular surface resulted articular surface more vulnerable to physiologic load and shifting in the point of no return which is the result of osteoarthritic pathogenesis. The decline in knee joint proprioception sense in subjects with symptomatic knee osteoarthritis may be expected from structural pathology involving capsule, ligaments, and muscle that cause loss or abnormal function of mechanoreceptors producing greater impairment in proprioception.

The present study used active reproductive angle in sitting ned kinematics chain position because active muscle contractions related to functional joint position sense and neuromuscular joint protection. It has been shown by Paillared and Brachon (86) that active muscle contractions produced more precise sensation of the limb. However, many studies preferred to use active reproductive angle in standing closed kinematics chain position (18,85). Marks et al (32) studied knee proprioception in standing closed kinematics chain position and sitting opened kinematics chain position in healthy young, old, and osteoarthritic older women. (87) The results showed that the accuracy in all three groups of women in reproductive angles was greater in the closed kinematics chain position than those in opened kinematics chain position. Nevertheless, the present study preferred to use active reproductive knee angle in sitting opened kinematics chain position because this test is safer for subjects with symptomatic knee osteoarthritis. Moreover, the test position was designed for test only single joint motion and this test position is frequently used in the clinic.

Test angle that used in the present study was 45 degrees because the angle was in the middle of testing position for proprioceptive test, 0-90 degrees of knee flexion. Many studies (7-10) showed the ability of joint receptors to signal over the normal range of knee joint angles that the characteristic of joint receptor firing near the end of joint range. Moreover, patients with symptomatic knee osteoarthritis had problem with limit knee flexion and extension. Thus the present study excluded the angle near the end range of motion of knee flexion and extension and collected the middle angle for knee proprioception test. Besides, the present study measured only one angle, 45 degrees, because the measurement time for one angle testing was not enough for muscle to recovery from fatigue. Furthermore, pilot study showed that measuring more angles might decreased attention and increased error angles. Moreover, Sinacore et al in 1993 (88) studied the characteristics of recovery peak torque after a 1-minute bout of isokinetic exercise of quadriceps femoris muscle. The result showed that after fatigue program 30 and 60 seconds, peak torque recovered to 69 and 75 percents. By the third and fourth minutes of recovery, muscle torque had recovered to within 90 to 95 percents. The present study concerned about to the time of recovery. Thus, the present study selected only 45 degrees, which was the best angle in the position and would not produce error in this study.

5.4 Fatigue and Proprioception

Concentric isokinetic contraction program was applied in the present study as a fatigue protocol to determine the effect of fatigue on knee proprioception. Normally, subjects had different fatigue levels, resulting in the different of initial peak torque of each subject. Nevertheless, the study did not use fitness level measurement index as an inclusion criterion. All subjects were house-wife or worked in the office, which were not frequently exercise. This may assume that the subjects had the same fitness level. From the above mentioned reasons, the researchers believed that this protocol could decrease the same level, 50 percents decrement, in each subject. Moreover, The use of Biodex System II provides feedback for the subjects all the time. Subjects could observe the change in peak torque from the monitor immediately. On the other hand, this protocol was an intense exercise that had a limitation by which was exercise only in anaerobic system. Anyhow, the present study preferred to use Biodex System II and selected 50 percents decrement of peak torque as a fatigue protocol. It was also observed that subjects with symptomatic knee osteoarthritis had worse knee proprioception after received concentric isokinetic fatigue program whereas in subjects without symptomatic knee osteoarthritis were not reached a statistically significant difference in knee proprioception.

The result in the present study may be comparable to the investigations by Skinner et al (34), Mark and Quinney (32) and Lattanzio et al (33). Each of previous studies measured effect of fatigue in different protocols. Skinner et al (34) used passive reproductive angle to measure knee proprioception after received a series of interval running sprints for total running 3.75 miles (1.25 miles with 90 seconds rest). The result found a statistically significant increase in absolute angular errors in male subjects of $1.07 \pm 1.84°$ after received fatigue protocol. Furthermore, Mark and Quinney (32) compared the accuracy of knee proprioception in women age from 18 to 30 years before and after receiving 20 maximal concentric and eccentric contraction of quadriceps muscle at 180 degrees/second. They found only small increment in knee proprioception, which was not reached statistically significant difference. However, both previous studies did not take into consideration in fitness level of their subjects, causing the fatigue protocol was not standardized to their subjects. Moreover, in the study of Skinner did not use active muscle contraction for testing proprioception, which produced a more precise sensation of the limb than those in passive reproductive angle test (86).

Lattanzio (33) applied three types of fatigue protocol by using lower limb cycling on a computer ergometer in both men and women subjects. The first protocol consisted of ramp test to exhaustion. The second protocol consisted of continuous test and the third protocol consisted of interval test. The first protocol was presumable with the study of Mark and Quinney and the present study. The third protocol similar with Skinner's study. In the women subjects, there was statistically significant in the continuous and interval protocols but there was not significant in ramp test. The result in subjects without symptom in this present study supported the studies of Mark and Quinney and Lattanzio but in subjects with symptomatic knee osteoarthritis made a difference result. Subjects without symptomatic knee osteoarthritis in the present study and previous study did not decrease in knee proprioception because fatigue protocol may be inadequate to disturb mechanoreceptors around the knee. Thus, mean absolute angular that presented in these subjects had only small increment.

The decrement of knee proprioception in the subjects with symptomatic knee osteoarthritis may be the result of reducing muscle and joint receptor activity. After receiving fatigue program, the present study found decrement in knee proprioception in subjects with symptomatic knee osteoarthritis.

Fatigue may be affect to mechanoreceptors in tissue around the knee in two ways. The first, exercise to fatigue produces muscle acidosis causing failure of muscle spindles and golgi tendon organs functions (89,90). The second, fatigue produces ligamentous laxity to the knee joint. It could causes failure of mechanoreceptors in the ligament, capsule and tissue around the knee joint. Impairment of the mechanoreceptors causes loss in important reflexes for maintenance of knee stability (2).

Weisman et al (91) measured the effect of cyclic loading on knee ligaments in both human athletes (hockey, basketball, soccer and downhill skiing) and animals by using a specially built machine. They found that high-intensity cycling caused an increase in the laxity of the medial collateral ligament when compared before and after participation in various sports. In the animal, they repeated their work and found a reduction of strength of medial collateral ligament of isolate rats. Skinner HB (92) found an increment in ligament laxity after receiving exercise quadriceps and hamstring muscles near the point of volitional fatigue. Moreover, Barrack (93) suggested that exercise near the point of exhaustion might increase in ligament laxity, which may lead to reduction of the ligament mechanoreceptor functions. Ligament laxity may cause inadequate ligament mechanoreceptor feedback required to elicit the muscular reflexes responsible for joint stability (2). Thus, this may increase an individual's risk for injury during exercise to volitional fatigue.

Many studies showed that mechanoreceptors in both muscle and joint could be reduced after fatigue or lactic acid accumulation. Hutton and Nelson (90,94) observed alteration in golgi tendon organs stretch sensitivity in gastrocnemius muscle in cat. They induced 50-60 percent fatigue in the muscle. After that, they found a reduction of golgi tendon organ resting discharge, vibration, static and dynamic discharge. Lagier-Tessonnier et al (89) measured the effect of ischemia and hypoxia on mechanoreceptors (muscle spindle and golgi tendon organ) in tibialis anterior muscle of the cat. They injected lactic acid and observed the activation of metaboreceptors (groups III and IV fibers) and mechanoreceptors on high-frequency vibrations. The result showed the decrement of the firing rate of the mechanoreceptor after received lactic acid injection.

The methodology of the present study had some differences from the study of Mark and Quinney in 1993 (32). The present study induced both quadriceps and hamstring muscle fatigues because receptors in both muscles are important to signal the proprioception of the knee. Verschueren et al in 1998 (95) used vibration to tendon of extensor muscles (extensor carpi radialis, extensor carpi ulnaris and extensor digitorum) either individual or in different combination during the performance of the motor task. Vibrations individual to each tendon resulted systematic undershoot errors in performance. Verschueren et al suggested that kinesthesia is derived from the integrated input from muscle spindles from all synergistic muscles. Ribot-Ciscar and Roll in 1998 (96) observed muscle spindle feedback in both agonist and antagonist muscles. They analyzed the activity of single muscle spindle located in the lateral peroneal nerve by using microneurographic technique. Robot-Ciscar and Roll instructed the subject performing voluntary movement (plantar/dorsi flexions of the ankle at 3, 4.5 and 6 degrees/second). The data suggested that the direction of slow movement may be specified on the basis of the spindle discharge rate and that the velocity of this movement might be correlated with the difference between the spindle activity occurring in the agonist and antagonist muscles.

To summarize, knee movement perception seems to result from the co-processing from the whole set of mechanoreceptors in the muscles, tendon, joint and ligament involved in the performance of a movement. The velocity in the present study selected at 180 degrees/second, which produced greater lactate accumulation and increased in muscle fatigue (55). After finished fatigue protocol, we avoided recovery by reassessing proprioceptive sense immediately.

5.5 Clinical Implication

This study provided the quantitative data of peak torque of quadriceps and hamstring muscles at 180 degrees/second in subjects with and without symptomatic knee osteoarthritis aged from 40 to 60 years. Generally, peak torque is one of the indicators to determine maximum muscular tension capacity. The result in this study found the decrement in peak torque value in subjects with symptomatic knee osteoarthritis compared to subjects without symptomatic knee osteoarthritis. Thus, physical therapists should pay attention to gain strength both quadriceps and hamstring muscles in subjects with symptomatic knee osteoarthritis.

Proprioceptive data in the present study represent the baseline for knee proprioception in both subject groups. Moreover, decrement in knee proprioception may lead to increase repetitive, poorly distributed load across the joint surface, which may destroy the function of capsule, ligament and mechanoreceptor around the knee resulting more severity in disease of knee osteoarthritis (18,21). This information can instruct the patient to aware the darkness place where the patients mainly use somatosensory and vestibular systems to prevent the patients fall down.

Finally, this study found significant decrease in knee proprioception after muscle fatigue. Therefore, clinical rehabilitation protocols should emphasize increasing muscular endurance to increase fatigue-resistant to the muscle.

CHAPTER VI

CONCLUSION

This study investigated the effect of fatigue on knee proprioception in female subjects with and without symptomatic knee osteoarthritis. These study was divided into three parts.

The first part was to compare peak torque of knee flexor and extensor muscles at angular velocity of 180 degrees/second between female subjects with and without symptomatic knee osteoarthritis. The results showed statistically significant decrement in peak torque of both quadriceps and hamstring muscles in subjects with symptomatic knee osteoarthritis.

The second part was to compare proprioception before fatiguing isokinetic contraction of quadriceps and hamstring muscles between subjects with and without symptomatic knee osteoarthritis. The result demonstrated significant difference greater in absolute angular errors in the subjects with symptomatic knee osteoarthritis compared to subjects without symptomatic knee osteoarthritis.

Finally, knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles in female subjects with and without symptomatic knee osteoarthritis were investigated. There was greater significant difference in absolute angular errors after receiving fatigue program in subjects with symptomatic knee osteoarthritis whereas the difference was not found in the subjects without symptomatic knee osteoarthritis.

For further study, it is interesting to determine the effect of fatigue on knee proprioception before and after receiving rehabilitation programs in patients with symptomatic knee osteoarthritis.

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APPENDIX A

CONSENT FORM

แบบฟอร์มหนังสือยินยอม

วันที่.............................

ข้าพเจ้า...อายุ................ปี อาศัยอยู่บ้านเลขที่...............ถนน.........................แขวง...จังหวัด................................ได้ทราบรายละเอียดของโครงการวิจัยเรื่อง "ผลของการล้าของกล้ามเนื้อต่อการรับรู้ตำแหน่งของเข่าในผู้หญิงที่มีและไม่มีอาการข้อเข่าเสื่อม" ดังต่อไปนี้

โดยข้าพเจ้าจะได้รับการสัมภาษณ์ และทำการตรวจร่างกายทางกายภาพบำบัด

ข้าพเจ้าเข้าใจวัตถุประสงค์ของการศึกษา และได้พิจารณาว่าการศึกษานี้ จะเป็นประโยชน์ต่อการสาธารณสุขของประเทศไทยข้าพเจ้ายินดีที่จะเข้าร่วมการศึกษาดังกล่าว

ในระหว่างการศึกษานี้ หากข้าพเจ้ามีข้อสงสัยประการใด หรือมีผลข้างเคียงจากการวิจัยขึ้นข้าพเจ้าจะติดต่อกับ นายพีรวุฒิ พิสุทธิ์วิมล ได้ที่ 10 ซอย 12(เสรี 2) ถนน รามคำแหง 24 ตำบล สวนหลวง เขต ประเวศ กรุงเทพมหานคร 10250 หรือโทรศัพท์ 7190625

หากผู้วิจัยมีข้อมูลเพิ่มเติม ทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ผู้วิจัยจะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็วและไม่ปิดบัง

ข้าพเจ้ามีสิทธิ์ที่จะบอกเลิกการร่วมในการศึกษาเวลาใดก็ได้ และการบอกเลิกการศึกษาครั้งนี้ จะไม่มีผลกระทบต่อการให้การรักษาพยาบาลแต่อย่างใด

ข้าพเจ้ารับทราบจากผู้วิจัยว่า จะไม่เปิดเผยข้อมูลหรือผลการวิจัยของข้าพเจ้าเป็นรายบุคคลต่อสาธารณชน

ข้าพเจ้ารับทราบและได้ซักถามผู้วิจัยจนหมดข้อสงสัยโดยตลอดแล้ว และยินดีเข้าร่วมในการวิจัย

ลงชื่อ.....................................ผู้ยินยอม

(..)

ลงชื่อ..............................ผู้ดำเนินงานวิจัย

(...)

APPENDIX B

ASSESSMENT FORM

Group/No. ...../.....

Date..................

Name.. **Age**............**years**

Height.......................................**cm.** **Weight**...........**kg.**

Occupation................................., **TMSE scores** (97)......................

Work activity ☐ Sitting ☐ Standing
☐ Standing-walking ☐ other...................

Knee pain Onset...........days,...........months,...........years
☐ Acute ☐ Gradual

Characteristics of pain
☐ Dull pain ☐ Deep pain
☐ Sharp pain ☐ Other...................

Duration of pain/time................. **Frequency of pain/day**...................

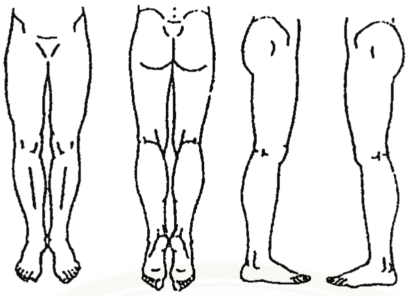
Aggravating factors
☐ Standing ☐ Walking
☐ Up-stairs ☐ Down-stairs
☐ Other......................................

Easing factors
☐ Rest ☐ Massage
☐ Others......................................

Has subject received any treatment during the period of symptomatic knee osteoarthritis?

........No treatment: normal activity of daily living ....Heat
........No treatment: rest ....Medication
........Knee support
........Exercise
........Other..

Site of pain



Visual analogue scale

Knee pain during activity of daily living

No pain Very severe pain

Knee pain when performing 10 repetitions of knee extension

No pain Very severe pain

Knee pain when performing 10 repetitions of knee flexion

No pain Very severe pain

Knee pain during isokinetic testing

No pain Very severe pain

Knee pain after testing

No pain Very severe pain

Test for knee joint stability*

Test	Right knee	Left knee
Varus stress test when knee joint at 0 degree and 30 degrees of flexion		
Valgus stress test when knee joint at 0 degree and 30 degrees of flexion		
Anterior Drawer test Internal rotation/neutral/external rotation		
Posterior Drawer test		
Pivot shift test		
McMurray's test		

* A first-degree instability: less than 0.5 cm opening of the joint surfaces
A second-degree instability: 0.5 to 1 cm opening of the joint surfaces
A third-degree instability: more than 1 cm opening of the joint surfaces

Range of motion of knee joint when active and passive movement

ROM of knee joint flexion/extension	Leg	Active	Passive
	Right	/ /	/ /
	Left	/ /	/ /

Leg length (distance from ASIS to medial malleolus on that side)

Leg length (cm.)	Right	
	Left	

Crepitus of knee joint during active movement

Crepitus of knee joint	Right	
	Left	

Alignment of knee joint when standing

Alignment of knee joint (degrees)	Right	
	Left	

(The intersection of a line from the midpoint of half thigh to the midpoint above joint line 10 cm and a line from the midpoint of half calf through the midpoint of tibial tuberosity level)

Circumference of the knee joint

Circumference of knee joint (cm.)	Right	Left
Joint line		
Above joint line 10 cm.		

Muscle strength

Strength of knee Flexor muscles	Right	
	Left	
Strength of knee Extensor muscles	Right	
	Left	

Strength scale

0 -unable to move
1 -trace contraction of muscle; little to no move
1.5 -moves part through partial range, gravity eliminated
2 -moves part through full range, gravity eliminated
2.5 -moves part to partial range against gravity
3 -moves part against gravity; take no resistance
3.5 -moves part against gravity; take minimum resistance
4 -moves part against gravity; take moderate resistance
5 -moves part against gravity; take maximal resistance

Vibroperception threshold

Location of testing	Right leg (mA)	Left leg (mA)
Deep peroneal n.		
Superficial peroneal n.		
Medial plantar n.		
Lateral plantar n.		
Medial calcanial br.		
Lateral sural n.		
Saphenous n.		
Lateral joint line		
Medial joint line		
Posterior femoral cut. n.		

APPENDIX C

PILOT STUDY

Ten female subjects from Siriraj hospital and School of Physiotherapy, Mahidol University, participated in the pilot study. These ten subjects were divided into two groups, subjects with and without symptomatic knee osteoarthritis groups

Sample Size Determination

The main purpose of this pilot study was to compare knee proprioception before and after fatiguing isokinetic contractions of quadriceps and hamstring muscles between female subjects with and without symptomatic knee osteoarthritis. Unpaired t-test was used to analyze the differences in knee proprioception in each group. Therefore, The sample size was calculated with the following formula.

$$N = \frac{2Sp^2[Z_{(1-\alpha/2)}+Z_{1-\beta}]^2}{(\mu_1-\mu_2)^2}$$

N =sample size for each group

Sp^2 =pooled variance = $\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{(n_1-1)+(n_2-1)}$ or $\frac{S_1^2+S_2^2}{2}$

If $n_1 = n_2$

n_1 = sample size of controlled group in pilot study

n_2 = sample size of studied group in pilot study

s_1^2 = variance of controlled group in pilot study

s_2^2 = variance of studied group in pilot study

$Z_{(1-\alpha/2)}$ = Z-value when set the confident level equal to 95% or significant level at 0.05(α=0.05)=1.96

$Z_{(1-\beta)}$ = Z-value when set the power of testing equal to 80%(β=0.02)=0.84

$\mu_1 - \mu_2$ = the difference of means of parameter between controlled and studied groups in pilot study

From the sample size calculation, the appropriate sample size for each group in the present study was 15 subjects.

RESULTS OF PILOT STUDY

Table C.1 Characteristics of subjects with and without symptomatic knee osteoarthritis

Characteristic	Without OA (n=5)	With OA (n=5)
	Mean ± SD	Mean ± SD
Age(years)	50.00 ± 4.53	53.80 ± 4.15
Weight (kg.)	63.80 ± 7.60	60.20 ± 4.92
Height (cm.)	159.40 ± 6.54	151.40 ± 6.23
BMI (kg/m^2)	25.10 ± 2.60	26.36 ± 3.13

Table C.2 Comparison of means and standard deviations of isokinetic parameters between subjects with and without symptomatic knee osteoarthritis at 180°/ second

Characteristic		Without OA (n=5)	With OA (n=5)
Peak Torque	Flexion	38.78±7.89	24.14±7.70*
	Extension	70.28±12.82	51.12±10.62*

*significant difference at p<0.05

Table C.3 Comparison of means and standard deviations of absolute angular error before fatigue contractions among young subjects, subjects with and without symptomatic knee osteoarthritis at 45° of knee flexion

Subjects		Without OA (n=5)	With OA (n=5)
Before	Mean ± SD (deg.)	1.60±0.43	4.00±3.44
	Range (deg.)	1.00-2.00	1.66-10.00

*Significant difference at p<0.05

Table C.4 Comparison of means and standard deviations of absolute angular error before and after fatigue contractions subjects with and without symptomatic knee osteoarthritis at 45° of knee flexion

Subjects	Before	After
	Mean ± SD	Mean ± SD
Without OA (n=5)	1.60±0.43	2.06±0.55
With OA (n=5)	4.00±3.44	11.53±5.44*

*significant difference at p<0.05

RAW DATA OF PILOT STUDY

Table C.5 Characteristic of subjects without symptomatic knee osteoarthritis (n=5)

Subject number	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)
1	52	69.00	158.00	27.64
2	54	70.00	158.00	28.04
3	43	56.00	159.00	22.15
4	48	55.00	152.00	23.80
5	53	69.00	170.00	23.87

Table C.6 Characteristic of subjects with symptomatic knee osteoarthritis (n=5)

Subject number	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)
1	60	62.00	154.00	26.14
2	54	54.00	150.00	24.00
3	55	56.00	150.00	24.88
4	50	65.00	143.00	31.79
5	50	64.00	160.00	25.00

Table C.7 Absolute angular error of pre and post fatigue in subjects without symptomatic knee osteoarthritis at 45° of knee flexion in the first, second and third sessions

Subject number	Absolute angular error (deg)					
	Pre fatigue			Post fatigue		
	1st trial	2nd trial	3rd trial	1st trial	2nd trial	3rd trial
1	1.00	2.00	1.00	1.00	2.00	5.00
2	3.00	0.00	3.00	5.00	0.00	2.00
3	2.00	2.00	2.00	3.00	2.00	2.00
4	0.00	0.00	3.00	0.00	0.00	2.00
5	2.00	1.00	0.00	3.00	1.00	1.00

Table C.8 Absolute angular error of pre and post fatigue in subjects with symptomatic knee osteoarthritis at 45° of knee flexion in the first, second and third sessions

Subject number	Absolute angular error (deg)					
	Pre fatigue			Post fatigue		
	1st trial	2nd trial	3rd trial	1st trial	2nd trial	3rd trial
1	9.00	10.00	11.00	15.00	16.00	15.00
2	1.00	2.00	5.00	15.00	19.00	22.00
3	2.00	2.00	1.00	6.00	11.00	9.00
4	3.00	1.00	2.00	5.00	4.00	6.00
5	3.00	4.00	4.00	10.00	9.00	11.00

Table C.9 Peak torque of knee flexor and extensor muscles in subjects without symptomatic knee osteoarthritis at 180°/sec

Subject number	Flexor muscle (Nm)	Extensor muscle (Nm)
1	34.60	91.00
2	34.00	56.40
3	40.70	67.70
4	32.80	65.00
5	51.80	71.30

Table C.10 Peak torque of knee flexor and extensor muscles in subjects with symptomatic knee osteoarthritis at 180°/sec

Subject number	Flexor muscle (Nm)	Extensor muscle (Nm)
1	23.90	47.90
2	15.60	45.20
3	18.20	39.60
4	28.30	56.00
5	34.70	66.90

APPENDIX D

RELIABILITY TESTING

This pilot study aimed to investigate the number of trials for proprioceptive testing and the reliability of mean absolute angular error of the first and second sessions of active reproductive angles. Five female subjects with right knee dominance ranged in age from 20 to 25 years were included in this test. Each session required 3 trials and each session was 5 minutes apart. After setting subject position (see position of testing), each subject received standard instruction and performed two practice sessions at 45 degrees of knee flexion. Throughout the testing protocol, the researcher moved the subject's leg at slow angular velocity approximately 10 degrees/ second from the knee angle of 90 degrees to a criterion position which was 45 degrees. Each subject was asked to hold the tested knee at 45 degrees for 5 seconds. After that, the leg was moved to the original position by the researcher. After 3 seconds, the subject then moved the leg to the criterion angle and held the leg at that position. The researcher recorded the angle which was shown on the computer screen. The same testing procedure was repeated for three times.

The differences among three absolute angular errors for the test angle were determined by using ANOVA for repeated measures. Intraclass Correlation Coefficients (ICCs), the formula of $ICC_{(3,1)}$ was chosen to analyze intratester reliability of the three absolute angular errors. Paired t-test was used to analyze the mean absolute angular errors of the first and second sessions of active reproductive angles in subjects with and without symptomatic knee osteoarthritis. Statistical significance for this study was based on p-value less than 0.05.

RESULT OF PILOT STUDY: TEST RETEST RELIABILITY

Table D.1 Means and standard deviations of age, weight, height and body mass index of subjects

Characteristic	Subjects (n=5)
Age (years)	23.2±1.09
Weight (kg)	52.0±4.89
Height (cm)	156.4±4.09
BMI (kg/m^2)	21.6±0.65

Table D.2 The intratester reliability of the three absolute angular errors for the first and second sessions at 45° degrees of knee flexion.

Test angle (degrees)		p-value	ICC (3,1)
45°	1st session	0.1296	0.2703
	2nd session	0.5997	0.0833

p-value from ANOVA

The result of this pilot study demonstrated poor intratester reliability. However, there were no significant differences shown by ANOVA among three trials in either the first or the second session. Therefore, 3 trials for proprioceptive testing were appropriate to detect knee proprioception in this test.

RAW DATA FOR RELIABILITY TESTING

Table D.3 Characteristic of subjects for reliability testing

Subjects	Age (years)	Weight (kg)	Height (cm)	BMI(kg/m^{2})
1	25	52	155	21.64
2	23	48	157	21.33
3	22	48	152	20.78
4	23	52	155	21.64
5	23	60	163	22.58

Table D. 4 Absolute angular error in the first, second and third trials for the first and second sessions at 45 degrees of knee flexion

Subjects	Absolute angular error (deg.)					
	First session			Second session		
	1st	2nd	3rd	1st	2nd	3rd
1	1.00	2.00	1.00	0.00	0.00	0.00
2	3.00	2.00	2.00	0.00	0.00	0.00
3	0.00	1.00	0.00	1.00	1.00	0.00
4	1.00	2.00	0.00	0.00	1.00	1.00
5	0.00	4.00	2.00	1.00	0.00	4.00

APPENDIX E

RAW DATA OF THE STUDY

Table E.1 Characteristics of subjects with and without symptomatic knee osteoarthritis (n=30)

Subjects	With symptomatic OA (n=15)				Without symptomatic OA (n=15)			
No.	Age	Weight	Height	BMI	Age	Weight	Height	BMI
1	60	62	154	26.14	52	69	158	27.64
2	54	54	150	24.00	54	70	158	28.04
3	55	56	150	24.89	43	56	159	22.15
4	50	65	143	31.79	48	55	153	23.50
5	50	64	160	25.00	53	69	170	23.88
6	48	61	154	25.72	45	60	155	24.97
7	58	58.5	146	27.44	56	59	155	24.56
8	53	110	160	42.97	59	64	145	30.44
9	50	63	160	24.61	47	75	163	28.23
10	59	65	155	27.06	51	61	155	25.39
11	53	64	155	26.64	44	67	163	25.22
12	53	70	157	28.40	57	53	147	24.53
13	60	56	155	23.31	42	43	143	21.03
14	43	56.8	150	25.24	57	49	155	20.40
15	58	70	153	29.90	42	45	150	20.00
Mean	53.60	65.02	153.46	27.54	50.00	59.67	155.27	24.66
SD	4.90	13.36	4.99	4.83	5.95	9.55	7.19	3.03

Table E.2 Characteristic of peak torque of quadriceps and hamstring muscles, number of repetition of concentric isokinetic contraction at 180°/seconds in subjects with and without symptomatic knee osteoarthritis

Subjects	**With symptomatic OA (n=15)**			**Without symptomatic OA (n=15)**		
No.	**Peak Torque (Nm)**		**No. of rep.**	**Peak Torque (Nm)**		**No. of rep.**
	Quadriceps muscle	**Hamstring muscle**		**Quadriceps muscle**	**Hamstring muscle**	
1	47.9	23.9	32	91.1	34.6	25
2	45.2	15.6	22	56.4	34	28
3	39.6	18.2	49	67.7	40.7	31
4	56	28.3	22	65	32.8	29
5	66.9	34.7	20	71.3	51.8	29
6	61.4	30	26	72.4	29.3	30
7	52.9	28.2	24	85	32.3	29
8	55.2	19.7	39	45	28.5	21
9	59.5	39.9	27	102.1	42	24
10	42	29.7	22	84.9	38.9	33
11	57.8	26.4	34	70.9	36.6	33
12	48.4	32.7	24	44.9	19.1	35
13	50.7	24.8	12	71.1	35.1	32
14	69	33.2	33	57.9	34.7	28
15	51.8	31.7	27	56.3	28.7	28
Mean	53.62	27.80	27.53	69.47	34.61	29
SD	16.33	6.57	8.87	8.49	7.37	3.68

Table E.3 Absolute angular errors (and performed angle) before receiving fatigue program in subjects with and without symptomatic knee osteoarthritis at 45 degrees

Subjects	With symptomatic OA (n=15)			Without symptomatic OA (n=15)		
No.	Absolute angular errors (deg.)			Absolute angular errors (deg.)		
	1	2	3	1	2	3
1	9 (36)	10 (35)	11 (34)	1 (44)	2 (43)	1 (46)
2	1 (44)	2 (43)	0 (40)	2 (47)	1 (46)	1 (46)
3	2 (43)	2 (47)	1 (46)	2 (43)	2 (47)	2 (47)
4	3 (42)	1 (44)	2 (43)	0 (45)	2 (43)	3 (42)
5	3 (42)	4 (41)	4 (41)	2 (43)	1 (44)	0 (45)
6	3 (42)	4 (41)	4 (41)	1 (46)	1 (46)	4 (41)
7	1 (46)	2 (47)	3 (48)	1 (46)	1 (46)	1 (46)
8	6 (39)	2 (43)	5 (40)	5 (40)	4 (41)	8 (37)
9	2 (43)	2 (43)	3 (42)	1 (44)	3 (42)	1 (44)
10	4 (41)	4 (41)	5 (40)	2 (43)	3 (42)	6 (39)
11	8 (37)	8 (37)	9 (36)	4 (41)	1 (44)	2 (43)
12	0 (45)	5 (40)	10 (35)	2 (43)	2 (43)	2 (43)
13	1 (44)	4 (41)	6 (39)	0 (45)	2 (47)	2 (43)
14	0 (45)	1 (44)	1 (44)	2 (42)	3 (42)	3 (41)
15	2 (43)	6 (39)	5 (40)	2 (47)	1 (44)	6 (39)

Table E.4 Absolute angular errors (and performed angle) after receiving fatigue program in subjects with and without symptomatic knee osteoarthritis at 45 degree

Subjects	With symptomatic OA (n=15)			Without symptomatic OA (n=15)		
No.	Absolute angular errors (deg.)			Absolute angular errors (deg.)		
	1	2	3	1	2	3
1	15 (30)	16 (29)	15 (30)	1 (43)	2 (42)	5 (41)
2	15 (30)	19 (26)	22 (23)	3 (42)	0 (45)	3 (42)
3	6 (39)	11 (34)	9 (36)	3 (42)	2 (43)	2 (43)
4	5 (40)	4 (41)	6 (39)	4 (41)	4 (41)	3 (42)
5	10 (35)	9 (36)	11 (34)	9 (36)	5 (40)	7 (38)
6	5 (50)	3 (48)	3 (48)	1 (46)	2 (47)	4 (49)
7	3 (48)	1 (46)	1 (46)	1 (44)	1 (46)	2 (47)
8	7 (38)	11 (34)	19 (31)	7 (38)	7 (38)	7 (38)
9	3 (42)	0 (45)	0 (45)	4 (41)	0 (45)	2 (43)
10	15 (30)	19 (26)	17 (28)	4 (49)	3 (48)	2 (47)
11	7 (38)	10 (35)	11 (34)	4 (41)	1 (46)	5 (50)
12	14 (31)	11 (34)	10 (35)	2 (43)	0 (45)	0 (45)
13	13 (32)	17 (28)	20 (25)	4 (41)	7 (38)	8 (37)
14	15 (30)	10 (35)	14 (31)	3 (38)	0 (36)	1 (39)
15	9 (36)	13 (32)	11 (34)	1 (44)	3 (48)	2 (47)

Table E.5 Characteristic of clinical appearance in subjects without symptomatic knee osteoarthritis

Subjects	Without symptomatic knee osteoarthritis (N=15)				
No.	Pain (cm.)	Circumference (cm.)		ROM of knee flexion/extension	Score ISOA
		Joint line	Above joint line 10 cm.		
1	0	39	47	125/0	0
2	0	39	43	140/0	0
3	0	38	41	135/0	0
4	0	37	41	135/0	0
5	0	40	41.5	130/0	0
6	0	34	42	146/0	0
7	0	37	42	140/0	0
8	0	41.5	44	138/0	0
9	0	39	45	135/0	0
10	0	37	42	135/0	0
11	0	39	44.9	145/0	0
12	0	34	41	143/0	0
13	0	34.2	39.1	145/0	0
14	0	34	42	137/0	0
15	0	34	37	134/0	0

Table E.6 Characteristic of clinical appearance in subjects with symptomatic knee osteoarthritis

Subjects	With symptomatic knee osteoarthritis (N=15)				
No.	Pain (cm.)	Circumference (cm.) Joint line	Circumference (cm.) Above joint line 10 cm.	ROM of knee flexion/extension	Score ISOA
1	6	39	41	125/0	10
2	0.7	33	36.5	128/0	3
3	1.1	37.5	41	128/0	6
4	2.7	39	47	125/0	4
5	3.1	38	45	128/0	6
6	3.7	37	45	140/0	2.5
7	3.8	37.5	42.5	140/0	7
8	6	37	42	140/0	7
9	5.6	36.4	42.7	157/0	6.5
10	0.9	39	43	115/0	3
11	5.1	41	47	135/0	5
12	4.2	40.5	45	145/0	5
13	3.3	35	42.5	130/0	2
14	1	33.5	40	145/0	1
15	4.8	40	46	120/0	5

BIOGRAPHY

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