University of Alberta

HIP STRENGTH IN PEOPLE WITH AND WITHOUT PATELLOFEMORAL PAIN

by

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ABSTRACT

It has been suggested that weakness of hip abductors and external rotators contributes to patellofemoral pain. However, no study has examined dynamic strength of the hip muscles. Also, it is unknown whether people with patellofemoral pain have selective weakness of hip abductors and adductors or whether other hip muscles are also weak. The purpose of this study was to evaluate isokinetic (concentric and eccentric) and isometric strength of hip abductors, adductors, external rotators and internal rotators between people with and without patellofemoral pain. The results of this study showed that people with patellofemoral pain had significantly reduced strength of hip abduction (isometric and concentric), hip external rotation (isometric, concentric, eccentric). Weakness of hip adductors and internal rotators was also observed in people with patellofemoral pain. The results of the present study found that people with patellofemoral pain may have global weakness of the hip muscles.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION AND PROBLEM STATEMENT

Patellofemoral pain is one of the most common disorders in orthopedic practice. It frequently occurs in adolescents, women, and athletes (DeHaven & Lintner, 1986). There seems to be no clear consensus in the literature on terminology for the patellofemoral pain. This is because the pain is difficult to define, as patients experience a variety of symptoms related to location and pain levels, resulting in different degrees of physical impairment (Thomeé, Renström, & Karlsson, 1999). According to Witvrouw, Werner, Mikkelsen, Van Tiggelen, & Cerulli (2005), patellofemoral pain is a descriptive term that simply means pain coming from the area of the patellofemoral joint. It is suggested that the anterior or retropatellar pain without other pathology could be diagnosed as patellofemoral pain (Thomeé et al., 1999, Witvrouw et al., 2005).

Despite its prevalence, the etiology of patellofemoral pain is still unclear. Patellar malalignment and/or abnormal patellar tracking is thought to be primary factor (Goodfellow, Hungerford & Woods, 1976; Grana & Kriegshauser, 1985). This is the factor related directly to the patellofemoral joint, and includes vastus medialis obliquus (VMO) insufficiency (Souza & Gross, 1991; Boucher, King, Lefebvre, & Pepin, 1992; Powers, Landel, & Perry, 1996; Morrish & Woledge, 1997), tight hamstrings, quadriceps or iliotibial band (Smith, Stroud, & McQueen, 1991; Doucette & Child, 1996; Piva, Goodnite, & Childs, 2005), and abnormal patellar shape or tilt (McConnell, 1996). These abnormal muscular control and patellar alignments alter the tracking of the patella within the femoral trochlear notch and contribute to increased patellofemoral contact pressure that results in pain and dysfunction (McConnell, 1986). Based on this theory, most rehabilitation programs currently focus on the patellofemoral joint itself, such as strengthening of VMO, patellar taping, stretching, and soft tissue mobilization (Brody & Thein, 1998; Fredericson & Powers, 2002; Post, 2005).

It also has been recognized that alignment and rotation of the lower extremity may influence the patellofemoral joint (Lee, Morris, & Csintalan, 2003; Powers, 2003). Since the patellofemoral joint is influenced by motion of the tibia and femur, it is essential to treat the pain by looking at not only the patellofemoral joint itself but the lower extremity as a whole. Proximal factors such as weakness of the hip muscles, particularly in the frontal and transverse planes of motion, have been proposed as contributing factors to abnormal lower extremity mechanics (Powers, 2003). Theoretically, weakness of the hip abductors and external rotators cause adduction and internal rotation of femur, which produce excessive lateral patellar pressure (Powers, 2003).

Although this approach might have a great possibility in the treatment of patellofemoral pain, limited information is available. There are only a few studies investigating hip strength in a patellofemoral pain population (Ireland, Willson, Ballantyne, & Davis, 2003; Brindle, Mattacola, & McCrory, 2003; Piva et al., 2005). Therefore, this study examined whether there were differences in the muscle strength around hip between subjects with and without patellofemoral pain.

1.2 DEFINITION OF TERMS

Patellofemoral pain (PFP):

Patellofemoral pain is described as pain coming from patellofemoral joint, excluding intra-articular pathology, peripatellar tendonitis or bursitis, plica syndromes, Sinding-Larsen-Johansson syndrome, Osgood-Schlatter syndrome, neuromas and other rarely occurring pathologies (Lieb & Perry, 1968). The term 'anterior knee pain' is used interchangeably with patellofemoral pain, and refers to all pain-related problems within the anterior aspect of the knee (Thomeé et al., 1999). Patients experience pain during stair climbing, prolonged sitting, squatting, and kneeling. Some authors refer to this pain as patellofemoral pain syndrome (PFPS). In this study, the term patellofemoral pain (PFP) is used.

Isokinetic Exercise:

Dynamic exercise with an accommodating resistance and a fixed speed. It is different from isotonic exercise, another type of dynamic exercise which is an exercise with a fixed resistance through all or part of joint's range of motion and a variable speed (Davies, Heiderscheit, & Brinks, 2000). During isokinetic exercise, a muscle group may be exercised to its maximum potential throughout a joint's entire range of motion, whereas the amount of resistance is limited to the weakest point in the range of motion during isotonic exercise. Isokinetic exercise can be used to quantify a muscle group's ability to generate torque, work, and power. However, isokinetic exercise occurs primarily from non-weight-bearing open-kinetic-chain positions (Perrin, 1993).

Concentric contraction:

Development of muscle tension while the origin and insertion of the muscle approach each other (Davies et al., 2000).

Eccentric contraction:

Development of muscle tension while the origin and insertion of the muscle move away from each other (Davies et al., 2000).

Isometric Exercise:

Exercise in which there is no change in muscle length or skeletal movement (Davies et al., 2000).

Strength:

In this study, strength was defined as peak torque (Nm) - the single highest torque output produced by a muscular contraction as the hip and limb move through the range of motion (Kannus, 1994).

1.3 OBJECTIVE OF THE STUDY

The objective of this study was to compare the isokinetic and isometric strength of hip abductors, adductors, internal rotators, and external rotators between subjects with patellofemoral pain and healthy subjects.

1.4 RESEARCH HYPOTHSES

The following hypotheses were investigated in this study:

1. Subjects with patellofemoral pain will have reduced isokinetic and isometric strength (peak torque to body weight) of hip abductors and external rotators when compared to healthy subjects.

2. Subjects with patellofemoral pain will have lower strength ratio of isokinetic and isometric hip abductors to adductors, and external rotators to internal rotators when compared to healthy subjects.

1.5 LIMITATION OF THE STUDY

A limitation of the cross-sectional nature of this study lies in an ability to discern cause and effect. It could not be determined that weakness of hip muscles was the cause of patellofemoral pain or the result from the pain. Also, since a convenience sample was used, the generalizability of this study was thus limited.

1.6 DELIMITATION OF THE STUDY

This study was delimited to:

1) Patellofemoral pain patients between 18-40 years old.

2) Measurement of isokinetic and isometric muscle strength.

1.7 ETHICAL CONSIDERATIONS

This study was performed maintaining total privacy and confidentiality of the subjects. The name or other identifying data was not attached to the data that subjects generate by their test. All data was kept confidential in a safe area (i.e. a locked filing cabinet) except when codes of ethics or the law requires. The names of subjects will never be used in any presentation or publication related of the study results. This project was approved by the Health Research Ethics Board of The University of Alberta (Appendix A) and informed consent was obtained from the subjects before the individuals were enrolled in the study. All procedures were non-invasive and there was minimal risk of injury or harm with the isokinetic or isometric measurement when using a standardized protocol. Subjects were told to inform the researcher if they had any experience muscle soreness after the isokinetic strength measurement. No subjects reported any problems. The benefits of this study were to provide better understanding of patellofemoral pain to clinicians.

CHAPTER 2: LITERATURE REVIEW

2.1. EPIDEMIOLOGY OF PATELLOFEMORAL PAIN

Among physically active people, adolescents, young adults, and females, patellofemoral pain is one of the most frequent complaints. Patellofemoral pain is reported to be the most common injuries in sports injury clinic, representing 34% of knee injuries and 10 % of all injuries (Murray, Murray, MacKenzie, & Coleman, 2005). Hörding (1983) reported that anterior knee pain was the most frequent complaint in young population. It was seen in 3.3% of subjects between 10 and 19 years old and 10% among 15 year olds. Witvrouw et al. (2000) reported that the incidence of patellofemoral pain was 9% in young athletes. In this group, 10% of females developed patellofemoral pain, whereas 7% of males did. Almeida et al. (1999) reported that female had a higher incidence at 12.1% compared to men at 1.1%. Patellofemoral pain accounts for 19.6% of all injuries in female athletes, whereas 7.4% of all injuries in male athletes (DeHaven & Lintner, 1986).

Unfortunately, this pain often becomes a chronic condition and it is a frustrating problem for both patients and clinicians (L. Almekinders & S. Almekinders, 1994; Brody & Thein, 1998). Patellofemoral pain is problematic especially for adolescents. Harrison (2005) pointed out that patellofemoral pain forces adolescents to stop or restrict regular physical activity, which is an important component in maintaining positive health behaviors during childhood and adolescence. In addition, Utting, Davies, & Newman (2005) reported that patellofemoral pain in adolescence and early adult years might be one of the contributing factors to patellofemoral osteoarthritis in later years.

2.2. MECHANISMS OF PATELLOFEMORAL PAIN

The most commonly accepted mechanism for pain development at the patellofemoral joint is that the joint is subjected to increased stress (force per contact area) due to abnormal patellofemoral alignment. Increased patellofemoral joint reaction force and/or reduced patellofemoral contact area is thought to cause irritation of retropatellar tissues.

2.2.1. KINETICS OF PATELLOFEMORAL JOINT

In the sagittal plane, there are three forces affecting the patellofemoral joint. Quadriceps tendon force that pulls the patella superiorly and patellar tendon force that pulls the patella inferiorly produce a patellofemoral joint compression force (Weber & Ware, 1994). In the frontal plane, quadriceps tendon force and patellar tendon force create a lateral force on the patella, since these tendons create an angle (quadriceps angle) (Weber & Ware, 1994). If these patellofemoral joint compression and lateral forces on the patella are excessive, damage in the patellofemoral joint could occur.

2.2.2. SOURCE OF PATELLOFEMORAL PAIN

Patellofemoral pain can be experienced by the patients as sharp, acute, or chronic pain. It can be aggravated by prolonged activity with increased patellofemoral compressive forces, such as stair climbing, squatting, and kneeling. When the structures are overloaded, exceeding the safe load acceptance capacity, with abnormal stress, normal stress in abnormal directions, or normal stress over an abnormal period of time, patellofemoal pain occurs (Dye, Staubli, Biedert, & Vaupel, 1999).

The synovium has a rich nerve supply and can be irritated producing pain (Doucette & Goble, 1992). Dye et al. (1999) reported that synovitis is the one of the most common sources of patellofemoral pain. The infrapatellar fat pad also has a rich nerve supply (Biedert, Stauffer, & Friederich, 1992). Due to the close anatomic relationship to the patellar tendon and the lateral superficial oblique retinaculum, the infrapatellar fat pad is frequently irritated (Biedert & Sanchis-Alfonso, 2002). The subchondral bone may be considered as a source of pain as well. It has a rich nerve supply and increased subchondral bone pressure is shown to produce pain (Doucette & Goble, 1992). The increased intraosseous pressure is the result of failure of energy absorption function of the articular cartilage caused by the decreased contact area

(Doucette & Goble, 1992). The retinaculum also is a possible source of patellofemoral pain (Fulkerson, 1982; Sanchis-Alfonso & Rosello′-Sastre, 2000). Fulkerson (1982) reported that the lateral retinaculum itself may be painful, although it is difficult to distinguish retinacular pain from pain coming from the underlying synovium.

2.3. ETIOLOGY OF PATELLOFEMORAL PAIN

The etiology of patellofemoral pain is still not fully understood. There are three theories that may explain the etiology of the patellofemoral pain.

2.3.1. MUSCLE INSUFFICIENCY

Vastus medialis obliquus (VMO) plays an important role in patellar tracking. Lieb and Perry (1968) reported that VMO was the primary medial stabilizer of the patella. The VMO is angled approximately 50° from the longitudinal axis of the femur, whereas vastus lateralis obliquus is angled about 38°. As a result, it is hypothesized that the VMO is capable of counterbalancing the stronger pull of vastus lateralis acting the patella (Lieb & Perry, 1968). Patients with patellofemoral pain often develop weakness or reduced control of VMO and the result is excessive lateral tracking of patella, which may cause patellofemoral pain (Hanten & Schulthies, 1990). However, controversy exists in the literature. In electromyography (EMG) studies, some authors reported that patients with patellofemoral pain had reduced activity in the VMO compared to vastus lateralis (VL) (Souza & Gross, 1991; Wise & Rullo, 1984). However, some studies have found that there was no difference between the activities of VMO and VL in people with patellofemoral pain (Boucher et al., 1992; Maclnyre & Robertson, 1992).

In addition to the magnitude of EMG activity, there might be delayed onset timing of a VMO contraction between patients and healthy subjects. In healthy people, VMO contracted prior to the VL in order to maintain patellar stability against the laterally directed forces (Voight & Wieder, 1991). However, in the patellofemoral pain group, delayed onset timing of the VMO contraction relative to VL was found (Voight & Wieder, 1991; Cowan, Bennell, Hodges, Crossley, & McConnell, 2001). In contrast, some authors argued that there was no significant difference in the onset timing of the VMO contraction between healthy subjects and patients with patellofemoral pain (Karst & Willett, 1995; Powers et al., 1996; Gilleard, McConnell, & Parsons, 1998). This controversy may be the result of different methods used, unreliable methods, or small sample size. Cowan et al. (2001) used a larger sample size, more reliable method, and a functional task to compare the EMG contraction onset timing between patients with patellofemoral pain and healthy subjects. They found a significant difference of the onset of contraction timing between the groups, however; they also found a wide variation in EMG onset of contraction timing in both groups (Cowan et al., 2001). Although VMO insufficiency is believed to be the main factor of patellofemoral pain, there is insufficient evidence in the literature to say this is a definitive cause of patellofemoral pain.

2.3.2. MALALIGNMENT OF PATELLA

Malalignment of patella might also be one of the contributing factors of patellofemoral pain (Insall, Aglietti, & Tria, 1983). Patellar malalignment includes tilting of the patella, incongruence of the patella, patella alta or infera, and patellar subluxation (Insall et al., 1983). These abnormal factors may increase the stress at the patellofemoral joint. However, some clinical studies, which investigated static patella alignment, showed that there was no alignment difference between patients with patellofemoral pain and healthy people (Post, Teitge, & Amis, 2002; Thomeé et al., 1995).

2.3.3. ABNORMAL LOWER EXTREMITY KINEMATICS

It also has been hypothesized that alignment and rotation of the lower extremity may influence the patellofemoral joint.

2.3.3.1. TIBIAL ROTATION AND FOOT PRONATION

According to Tiberio (1987), when considering the "screw-home" mechanism of the knee, the tibia must be externally rotated relative to the femur so that knee extension can be achieved. However, with prolonged or excessive foot pronation, the tibia remains internally rotated as knee begins to extend. To compensate for this internal rotation of the tibia, the femur must rotate internally and bring the tibia to the externally rotated position. This compensation creates a larger quadriceps (Q) angle. Quadriceps (Q) angle is the angle between a line drawn from anterior superior iliac spine to the midpoint of the patella and a line drawn from tibial tubercle and midpoint of the patella. It can result in increased lateral patellar pressure as the patellar is forced against lateral condyle of the femur (Huberti & Hayes, 1984). As a result, it may increase lateral patellar contact pressure and cause patellofemoral pain. Messier, Davis, Curl, Lowery, & Pack (1991), however, found no differences in maximum pronation, maximum pronation velocity, or rearfoot movement between a patellofemoral pain group and a control group. Moreover, Powers, Chen, Reichl, & Perry (2002) showed no differences in magnitude and timing of peak foot pronation and tibial rotation between a patellofemoral pain group and a control group.

2.3.3.2. FEMORAL ROTATION

The patellofemoral joint can be influenced proximally through rotation of the femur. Several studies demonstrated that femoral internal rotation can influence the patellofemoral joint (Tennant et al., 2001; Powers, Ward, Fredericson, Guillet, & Shellock, 2003). Powers et al. (2003) reported that the primary contributor to the lateral patellar tilt and displacement in a group with patellar instability was internal rotation of the femur and not patellar motion. This finding reversed the long-held assumption that lateral displacement of the patella was the result of the patellar movement on the femur. Lee, Anzel, Bennett, Pang, & Kim (1994) found that 30° of femoral internal rotation significantly increased patellofemoral stress when the knee was flexed beyond 30°. Recently, Salsich and Perman (2007) examined the relationship between tibiofemoral rotation and patellofemoral joint contact area in individuals with patellofemoral pain. They reported that internal rotation of the femur resulted in decreased patellofemoral joint contact area and increased patellofemoral joint stress. These findings suggest that femoral internal rotation might be an important contributing factor to patellofemoral pain.

2.3.3.3. GENU VALGUM

In the frontal plane, genu valgum may increase lateral patellar pressure, as the patella would be displaced medially with respect to the anterior superior iliac spine (Powers, 2003). When the patella is seated in the trochlear groove of the femur (more than 20° of knee flexion), increased quadriceps (Q) angle, can result in increased lateral patellar pressure as the patellar is forced against lateral condyle of the femur (Huberti & Hayes, 1984). It was reported that a 10° increase in Q-angle resulted in a 45% increase in patellar contact pressure when the patellar was seated in the trochlear groove (Huberti & Hayes, 1984).

Genu valgum may be the result of femoral adduction, tibial abduction, or a combination of both (Powers, 2003). Weakness of the hip abductors, such as gluteus medius, upper fibers of the gluteus maximus, and the tensor fasciae latae, may result in excessive femoral adduction during dynamic tasks, and may produce a genu valgum moment (Powers, 2003).

2.4. HIP MUSCLE FUNCTION AND PATELLOFEMORAL PAIN

Muscles around the hip play a role as stabilizers of lower extremity kinematics. The hip abductors and external rotators are especially important, since these muscles control internal rotation of the femur and the genu valgum moment could increase lateral patellar pressure and cause pain. Several studies investigated the strength of hip muscles in patients with patellofemoral pain. Ireland et al. (2003) assessed isometric strength of hip abduction and external rotation in 15 female patients with patellofemoral pain and 15 age-matched female controls using a hand-held dynamometer. They found that patients with patellofemoral pain had 26% less hip abduction strength and 36% less external rotation strength than the control subjects. Piva et al. (2005) also compared the isometric strength of hip abductors and external rotators of 30 patellofemoral pain patients and age- and gender-matched healthy subjects using a hand-held dynamometer. They did not find any significant difference between the groups.

Recently, Robinson and Nee (2007) investigated whether females seeking physical therapy treatment for unilateral patellofemoral pain exhibited deficiencies in hip isometric strength compared to a control group. Ten subjects with patellofemoral pain and 10 control subjects were evaluated. They reported that the symptomatic limbs of subjects with patellofemoral pain had 52% less hip extension strength, 27% less hip abduction strength, and 30% less hip external rotation strength when compared to the weaker limbs of control subjects. Cichanowski, Schmitt, Johnson, & Niemuth (2007) evaluated the isometric strength of six hip muscle groups in 13 collegiate female athletes with patellofemoral pain. They reported that hip abductors and external rotators were significantly weaker in the affected leg than in the unaffected leg of the injured athletes. Also, injured athletes demonstrated global hip weakness when compared to the asymptomatic controls. However, these two studies had small sample sizes. Thus, generalizability of these studies is limited.

Brindle et al. (2003) provided some potential support for the importance of hip strength in relation to patellofemoral pain patients. They examined EMG activity of VMO, VL and gluteus medius as well as kinematics in 16 subjects with anterior knee pain and 12 age-matched controls during stair ascent and descent. They reported that the anterior knee pain group demonstrated a delayed onset and a shorter duration of gluteus medius activity when compared to the control group. There were no significant differences in VMO and VL muscle activities between the two groups. This finding suggests that patients with patellofemoral pain have altered neuromuscular function in the hip abductors that may contribute to the abnormality of lower extremity kinematics.

Mascal, Landel, & Powers (2003) showed, in their case report, that 2 patients with patellofemoral pain improved the strength of the gluteus medius and maximus, pain level, and gait after a 14-week training program targeting the hip, pelvis, and trunk.

These studies suggest that there may be a relationship between weakness of the hip muscles and patellofermoral pain. Since all previous studies measured only isometric strength with hand-held dynamometer, this study will measure dynamic muscle strength with isokinetic dynamometer as well as isometric strength. Although Ireland et al. (2003) and Piva et al. (2005) emphasized that a hand-held dynamometer was the most commonly used device in clinics, it is not as reliable and accurate as isokinetic dynamometer. According to Agre et al. (1987), hand-held dynamometer relies on the tester for stabilization and consequently is subject to examiner error, especially in the measurement of lower extremity strength. Brinkman (1994) reported that testing of muscle groups capable of producing forces greater than 15 kg with a hand held dynamometer was not practical, because of the increased stabilization procedures that need to be used by the tester. Also, patients usually experience pain during dynamic activity; thus, it is meaningful to measure dynamic strength by using an isokinetic dynamometer. Moreover, most of previous studies measured hip abductors and external rotators; thus, it is uncertain whether hip abductors and external rotators are selectively weak or whether other hip muscle groups are also weak. This study was designed to measure not only hip abductors and external rotators but also hip adductors and internal rotators, so that the strength of hip abductors and external rotators can be evaluated relative to the hip adductors and internal rotators. The aim of this study was to evaluate the isokinetic and isometric strength of hip abductors, adductors, external rotators, and internal rotators between people with and without patellofemoral pain. Also, the evaluation of the isometric strength of the hip musculature enabled comparison with the previous isometric studies.

CHAPTER 3: METHODS AND PROCEDURE

3.1. SUBJECTS

Twenty six subjects with patellofemoral pain were recruited from the local Edmonton physical therapy clinics and people who attend the University of Alberta or live in the surrounding area, using advertising (Appendix B) in Faculty of Rehabilitation Medicine, Physical Education, Education, and Medicine, the University of Alberta International Student Network (UAIS), Graduate Student Association (GSA) newsletter, and the Students' Union Building. An introductory letter was given to the potential subjects (Appendix C). Twenty six age-, gender-, and physical activity level-matched healthy subjects were recruited from university population using advertising (Appendix B). Sample size calculation may be seen in Appendix D. Age was matched within ± 2 years. Based on the study by Piva et al. (2005), physical activity level was measured by the self-reported rating of activity of the International Knee Documentation Committee (Hefti, Muller, Jakob, & Staubli, 1993). The subjects rated their level of activity by using 4 activity levels: (1) jumping, pivoting, hard cutting, football, soccer; (2) heavy manual work, skiing, tennis; (3) light manual work, jogging, running; (4) activities of daily living, sedentary work. Once it was determined that the subjects met the inclusion and were not excluded by the exclusion criteria (Appendix E), they were informed about the nature of the study, and were asked if they would like to participate. All subjects were required to give written consent to be part in the study in accordance with University of Alberta's policies on research using human subjects. The information sheet and consent form are seen in Appendix F and G.

3.2. INCLUSION AND EXCLUSION CRITERIA

In this study, the definition of patellofemoral pain introduced by Lieb & Perry (1968) was used to identify individuals with patellofemoral pain. Therefore, people who had pain in patellofemoral joint without other knee pathologies were considered as having patellofemoral pain. In order to reduce the likelihood of osteoarthritic changes in the patellofemoral joint, subjects 40 years old or less were chosen (Cowan et al., 2002).

Based on previous studies (Cowan et al., 2002; Piva et al., 2005), the inclusion criteria for the patellofemoral pain group was:

1) Males or females between 18 and 40 years old

2) Subjects having had patellofemoral pain for longer than 4 weeks

3) Subjects who had a non-traumatic onset

4) Subjects who experienced pain with at least 3 of the following: (a) manual compression of the patella against the femur, (b) palpation of posterior border of the patella, (c) squatting, (d) stair climbing, (e) kneeling, (f) prolonged sitting

The exclusion criteria for the patellofemoral pain group was:

1) Subjects with history of patellar dislocation

2) Subjects with knee surgery in the past 2 years

3) Subjects with other knee pathologies (e.g. bursitis, arthritis, ligamentous injury or laxity, peripatellar tendonitis, plica syndrome, Sinding-Larsen-Johansson syndrome, Osgood-Schlatter syndrome)

4) Subjects with a lower limb injury or pathology

5) Subjects with neurological pathology

6) Subjects with cardiac pathology

7) Subjects who were pregnant

The inclusion criteria for healthy subjects was:

1) Healthy subjects

2) Males or females between 18 and 40 years old

3) Healthy subjects were matched for age, gender, and physical activity level with subjects with patellofemoral pain

The exclusion criteria for the healthy subjects was:

1) Subjects with a lower limb injury or pathology

2) Subjects with neurological pathology

3) Subjects with cardiac pathology

4) Subjects who were pregnant

3.3. STUDY DESIGN

This study was a case-control design, measuring hip isokinetic and isometric strength in subjects with and without patellofemoral pain. This design allowed the researcher to examine whether there was a relationship between PFP and hip strength, although this was not a prospective study and did not allow one to draw any cause and effect relationship.

3.4. MEASUREMENT

Measurements were taken in Corbett Hall at the University of Alberta. The measurements took approximately one hour. Subjects were asked to wear shorts and a T-shirt for the testing.

Isokinetic concentric, eccentric, and isometric strength of hip abductors, adductors, external rotators and internal rotators were measured in both groups using a Kin-Com 3 isokinetic dynamometer (Chattex Corp.). The Kin-Com dynamometer was calibrated according to the manufacturer's manual.

In order to strictly define the group with patellofemoral pain, only the affected leg was tested in patellofemoral pain group. In the group without patellofemoral pain, the leg to be tested was randomly chosen by "drawing from the hat".

Peak torque (Nm) was measured because it has been shown to be an accurate and highly reproducible variable to measure (Kannus, 1994). Peak torque has become a gold standard and reference point in all isokinetic measurements against which accuracy, precision, and clinical relevance of all other parameters should be compared (Kannus, 1994).

3.5. RELIABILITY OF ISOKINETIC AND ISOMETRIC TESTING

Instrument reliability of the Kin-Com dynamometer has been found to be excellent for speed and force (ICC=0.990) and tension (ICC=0.948) (Farrell & Richards, 1986).

Intra-subject reliability (test-retest) of isokinetic hip abduction and adduction at 60°/s using a Cybex 2 dynamometer has been reported as an ICC of 0.87 and 0.80 (Markhede & Grimby, 1980). Similarly, the intra-subject reliability (test-retest) of isokinetic concentric hip abduction, eccentric hip abduction, concentric hip adduction, and eccentric hip adduction at 60°/s using a Kin-Com 500-H dynamometer was ICC=0.74, 0.85, 0.84, and 0.84, respectively (Kea, Kramer, Forwell, & Birmingham, 2001). The intra-subject reliability (test-retest) of isokinetic concentric hip abduction and adduction at 60°/s using a Cybex 340 dynamometer was ICC of 0.68 and 0.88, respectively (Daugailly, Pirotte, Mouraux, Feipel, & Klein, 2005). Except for the hip abductors in Dugailly's study, it has been reported that there is adequate intra-subject reliability. As Dugailly et al. suggested, it is essential to assure the stabilization of the pelvis during the measurement of hip abductors to increase the reliability. In our study, the pelvis was secured by using a technique based on previous studies (Kae et al., 2001; Dugailly et al., 2005), which includes the use of straps on the pelvis and non-tested thigh, the use of a pillow under subject's head to keep the horizontal alignment of the head and trunk, and verbal instructions to maintain proper position.

The intra-subject reliability (test-retest) of isokinetic hip external rotation and internal rotation in a seated position at 60°/s using a Cybex 340 dynamometer was ICC=0.97 and 0.95 (Lindsay, Maitland, Lowe, & Kane, 1992). The intra-subject reliability (test-retest) of isokinetic concentric hip external rotation and internal rotation at 60°/s in the seated position using a Cybex 340 dynamometer was ICC of 0.80 and 0.80, respectively (Dugailly et al., 2005). These results show that the measurement of hip external and internal rotation had a good intra-subject reliability.

Intra-subject reliability (test-retest) of isometric hip abduction, adduction, external rotation, and internal rotation was ICC of 0.96 (Cahalan, Johnson, & Chao, 1988), suggesting substantial intra-subject (test-retest) reliability.

3.6. PROCEDURE

1. If the subject satisfied the inclusion criteria and was not excluded because of the exclusion criteria, an information sheet and consent form were given to the subject. The experimental procedure was explained using the information sheet. If the subject agreed to participate, the consent form was signed by the subject and any issues were clarified before testing began.
2. Demographic data on age, height, weight and physical activity level, and duration of the pain for subjects with patellofemoral pain were recorded before testing began to help better characterize the sample being examined.
3. The order of the testing was randomized. There were eight isokinetic measurements: concentric hip abduction/adduction, eccentric hip abduction/adduction, concentric hip external/internal rotation, and eccentric hip external/internal rotation and four isometric measurements: hip abduction, adduction, external rotation, and internal rotation. In order to minimize the testing time and fatigue, the order of muscle group (abductor/adductors or external/internal

rotators) was first randomized, and then the order of muscle contraction (concentric, eccentric, or isometric) was randomized within the muscle group chosen, so that each subject did not need to be continually changing position prior to testing. This randomization was performed by "drawing from the hat".

4. A 5-minute warm-up was performed using a stationary bike at light resistance in order to maximize the testing performance and minimize the risk of injuries (Resimen, Walsh & Proske, 2005).

5. The following positioning methods based on previous studies (Kae et al., 2001; Dugailly et al., 2005) were used to obtain the best stability and increase the reliability of the measurement. Subjects were observed by a tester across all repetitions and given verbal feedback as needed to maintain proper positioning.

   a) Hip abduction/adduction

   Figure 3-1 shows subject's positioning for the hip abduction/adduction measurement. The subjects were positioned lying on the side. They faced the dynamometer head with the test leg positioned uppermost. The pelvis and non-tested lower thigh were fixed using straps. A pillow was provided under the subject's head to maintain horizontal line of the head and trunk. A hip pad was placed in front of the subject. The examiner instructed subjects to keep the contact between pelvis and the hip pad during the testing in order to prevent trunk rotation and maintain vertical orientation of the subject's coronal plane. Based on the studies that evaluated the hip joint centre (Seidel, Marchinda, Dijkers, & Soutas-Little, 1995; Ritter & Campbell, 1988), the axis was aligned 3 cm medial and 7 cm below to the anterior superior iliac spine of the tested limb. The lever arm of the dynamometer was attached with a strap, just above the knee. To provide additional stabilization, the subject held onto the plinth with the uppermost arm during testing.

b) Hip external/internal rotation

Figure 3-2 shows the subject's positioning for the hip external/internal rotation measurement. Hip rotation muscles were tested in a seated position with the hip and knee flexed to 90°, because Lindsay et al. (1992) found that this position was the most reliable among three test positions: supine with the knee extended, supine with the knee flexed to 90°, and seated with the hip and knee flexed to 90°. The tested hip was stabilized with a strap fixed over the thigh and a strap around the lower leg, just above the ankle. The axis of the dynamometer was aligned with the apex of the patella.

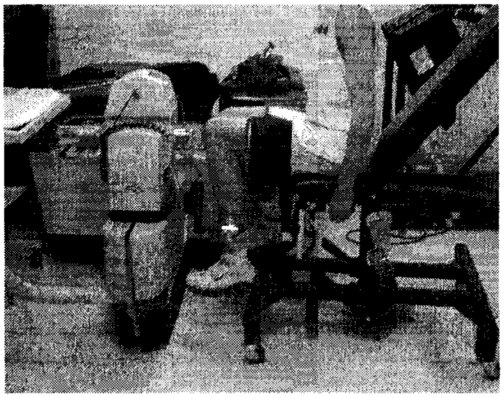


Figure 3-1. Abduction/adduction testing position

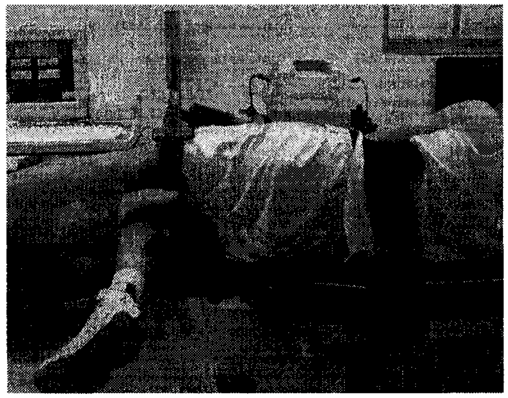


Figure 3-2. External/internal rotation testing position

6. Testing angles were set on the Kin-Com. Based on a previous study, isokinetic concentric and eccentric hip abduction/adduction were performed through a range of motion of 5°adduction to 30°abduction (Kea et al., 2001). Isokinetic concentric and eccentric hip external/internal rotation were performed from 5°of internal rotation to 25°of external rotation (Dvir, 2004). Isometric hip abduction/adduction and external/internal rotation measurements were performed in the neutral positions of the hip joint.
7. Gravity correction was performed before the testing. The gravity correction option on the Kin-Com allowed the researcher to correct for the subject's limb weight during a test. By identifying the subject's limb weight at a specific unrestricted range and identifying the true horizontal position of the Kin-Com lever arm, the gravitational effects of the subject's limb were accounted for throughout the testing range by a way of a cosine mathematical formula.

8. Angular velocity of 60°/s for the isokinetic testing was set on the Kin-Com. Only one angular velocity was used, since, in view of the very limited range of motion (35° for hip abductors/adductors and 30° for hip external/internal rotation), it has been suggested that one velocity might suffice for demonstrating frontal strength values (Dvir, 2004). Also, according to Cahalan et al. (1988), testing at a slower angular velocity was appropriate for the measurement of hip strength, since torque overshoot was exhibited inconsistently at greater than 150°/s. In addition, previous studies measured the strength of the hip abductors/adductors and external/internal rotators using an angular velocity of 60°/s (Lindsay et al., 1992; Kea et al., 2001; Jacobs & Mattacola, 2005; Daugailly et al., 2005), so by using this velocity, the researcher could compare the data with that of previous studies.

9. A standardized instruction was given to the subjects (Appendix H). The subjects were instructed to push and pull the testing pad as hard as possible for the isokinetic concentric and eccentric testing. For the isometric testing, the subjects were instructed to push the testing pad as hard as possible and hold for 5 seconds.

10. Prior to the each test, subjects had an opportunity to practice the movement. Four practice repetitions at 50 % effort and four at maximal effort were performed for the isokinetic concentric and eccentric measurements. According to Johnson & Siegel (1978), three submaximal and three maximal warm-up repetitions are

necessary before stability of measurement can be obtained during isokinetic assessment of knee extensor peak torque. One practice was performed for the isometric measurement based on a previous study (Ireland et al., 2003). One practice seemed sufficient to perform a proper movement for the isometric testing. The researcher monitored the torque curve on the screen to ensure if the subjects were performing correct and smooth contractions. If subjects were not performing the movement being tested correctly, subjects were asked to continue practicing until they could perform the movement correctly.

11. After completing the practice session, four concentric and eccentric repetitions were performed at maximal effort. This number was chosen, since multiple contractions are necessary to obtain a true maximal value of force or torque (Baltzopoulos & Brodie, 1989). Maximum torque is typically evaluated from the first two to six contractions (Baltzopoulos & Brodie, 1989). Four test repetitions were chosen for each condition. For the isometric testing, three trials were performed based on a previous study (Ireland et al., 2003). The examiner monitored the torque curve on the screen, and if subjects were not performing correct and smooth contractions, the testing was repeated. During the test, subjects were not informed of their results, nor allowed to see the computer screen, nor they be encouraged verbally during testing to avoid any types of feedback that may

affect their performance (Hald & Bottjen, 1987; Baltzopoulos, Williams, & Brodie, 1991).

12. One minute rest was given between each test. Research has shown that an interval of rest enables the production of greater amounts of isokinetic strength with higher reliability of measurement than when no rest is provided between trials (Stratford, Bruulsema, Maxwell, Black, & Harding, 1990). A rest interval of 15 seconds appears to be too short to allow optimal recovery between sets, but no difference has been observed between 60, 180, and 300 seconds rest intervals (Parcell, Sawyer, Tricoli, & Chinever, 2002). At least forty to ninety seconds between sets has been recommended (Davies et al., 2000; Parcell et al., 2002; Wrigley & Strauss, 2000). Also, Dawson et al. (1997) reported that approximately 70% repletion of phosphocreatine was achieved with 30 seconds rest after a 6 second sprint and complete repletion was achieved after 3 minutes rest. Each test lasted approximately 6-8 seconds in this study; thus, a recovery time of greater than 30 seconds would be optimal. Based on these findings, 1-minute rest was allowed between each test.

3.7. DATA COLLECTION

The highest peak torque (Nm) of the four (concentric and eccentric)/three (isometric) contractions was recorded. Since the subjects' body weight affects the strength output, peak torque to body weight (Nm/Kg) was recorded to normalize the strength data (Lexell, Taylor, & Sjostrom, 1988). The ratios of hip abductors/adductors and external/internal rotators were recorded. The data was registered using a data collection sheet for each subject (Appendix I).

3.8. STATISTICAL ANALYSIS

The mean, standard deviation, and 95% confidence intervals of peak torque to body weight, and ratios in each group were calculated. A three-way ANOVA mixed design with repeated measure (3 independent variables: group (patellofemoral pain, healthy), contraction type (concentric, eccentric, isometric), muscle group (hip abductors, hip adductors, hip external rotators, hip internal rotators) was used to evaluate the differences in peak torque to body weight. A MANOVA was used to compare the strength ratio between subjects with and without patellofemoral pain. Alpha level was set at .05. SPSS software 16 was used to perform the statistical analysis.

CHAPTER 4: RESULTS

The present study examined isokinetic and isometric strength of hip abductors, adductors, external rotators, and internal rotators in subjects with and without patellofemoral pain. All participants were between 18 and 40 years of age. All subjects completed the test program. No one reported pain or discomfort during the testing.

4.1. SUBJECT CHARACTERISTICS

Fifty two subjects were included in this study: twenty six subjects with patellofemoral pain and twenty six subjects without patellofemoral pain. Table 4-1 presents the mean and standard deviation of age (measured in years), height (measured in centimeters), weight (measured in kilograms) and physical activity level (1= jumping, pivoting, hard cutting, football, soccer; 2= heavy manual work, skiing, tennis; 3= light manual work, jogging, running; 4= activities of daily living, sedentary work), and affected/tested side (right or left) for all subjects and by group. No significant differences were found in demographics between groups (MANOVA test $p<0.05$) (Table 4-1).

Table 4-1. Descriptive statistics (mean ± standard deviation) for age, height, weight, activity level, and affected/tested side in patellofemoral pain (PFP) and healthy groups

	PFP group	Healthy group	Significance
Age (years)	27.46 ± 6.04	27.12 ± 5.83	0.83
Height (cm)	169.5 ± 10.14	167.35 ± 10.19	0.45
Weight (kg)	72.18 ± 15.62	64.8 ± 11.39	0.06
Activity Level	2.5 ± 1.07	2.5 ± 1.07	1.00
Affected/Tested Side	Right: 13/Left: 13	Right: 11/Left: 15	

4.2. COMPARISON HIP MUSCLE STRENGTH DURING CONCENTRIC, ECCENTRIC AND ISOMETRIC CONTRACTION

A mixed three-way ANOVA with repeated measures analysis was used to compare concentric, eccentric and isometric strength (peak torque/body weight) of hip abduction, adduction, internal rotation and external rotation between the two groups.

Tests of within-subjects effects (Table 4-2) found significant main effects in movement type (p=0.00; ES=0.86; observed power=1.00) and contraction type (p=0.00; ES=0.73; observed power=1.00) when the hip was tested. This suggests that there are differences in strength (peak torque/body weight) among movement types (hip abduction, adduction, external and internal rotation) and also among contraction types (concentric, eccentric and isometric). Significant interaction was seen between movement type and contraction type (p=0.00; ES=0.39; observed power=1.00). This implies that hip strength changed depending on the movement type and contraction type tested. The observed powers in movement, contraction, and movement/contraction were 1.0, showing that there was no chance of beta error.

Table 4-2. Test of within-subjects effects for movement type, contraction type and group when combining patellofemoral pain (PFP) and healthy groups

Effect	Sum of squares	df	F	Sig.	Effect size	Observed power
Movement	92.66	2.82	316.30	0.00*	0.86	1.00
Movement/Group	0.27	2.82	0.91	0.43	0.02	0.24
Contraction	14.23	2.00	133.67	0.00*	0.73	1.00
Contraction/Group	0.20	2.00	1.88	0.16	0.04	0.38
Movement/Contraction	4.03	4.84	32.20	0.00*	0.39	1.00
Movement/Contraction/Group	0.23	4.84	1.86	0.10	0.04	0.62

* Significant ($p<0.05$)

The between-subjects analysis showed that there were significant differences in hip strength between individuals with patellofemoral pain and healthy subjects ($p<0.03$; ES=0.09; observed power=0.61; Table 4-3).

Table 4-3. Tests of between-group effects for hip strength (peak torque/body weight) for patellofemoral pain (PFP) and healthy groups

Source	Sum of Squares	df	Mean Square	F	Sig.	Effect size	Observed Power
Intercept	739.02	1	739.02	1091.03	0.00*	0.96	1.00
Group	3.49	1	3.49	5.15	0.03*	0.09	0.61
Error	33.87	50	0.68				

* Significant ($p<0.05$)

Descriptive statistics for hip strength measurements according to the type of movement (hip abduction, adduction, external rotation, and internal rotation) and type of contraction (concentric, eccentric, and isometric) are presented in Table 4-4.

Table 4-4. Descriptive statistics for concentric, eccentric, and isometric strength (peak torque/body weight) in hip abduction, adduction, external rotation, and internal rotation in patellofemoral pain (PFP) and healthy groups

Type of Movement	Type of Contraction	Group	Mean	Standard Deviation
Abduction	Concentric	PFP	1.26	0.42
		Healthy	1.51	0.34
	Eccentric	PFP	1.85	0.38
		Healthy	1.92	0.39
	Isometric	PFP	1.34	0.35
		Healthy	1.54	0.31
Adduction	Concentric	PFP	1.07	0.45
		Healthy	1.28	0.47
	Eccentric	PFP	1.64	0.41
		Healthy	1.74	0.37
	Isometric	PFP	1.09	0.36
		Healthy	1.36	0.42
External Rotation	Concentric	PFP	0.55	0.21
		Healthy	0.68	0.19
	Eccentric	PFP	0.66	0.22
		Healthy	0.80	0.19
	Isometric	PFP	0.61	0.19
		Healthy	0.75	0.21
Internal Rotation	Concentric	PFP	0.58	0.23
		Healthy	0.69	0.17
	Eccentric	PFP	0.86	0.23
		Healthy	0.94	0.20
	Isometric	PFP	0.67	0.25
		Healthy	0.74	0.26

Pairwise comparisons using the Bonferroni Post Hoc test demonstrated that individuals with patellofemoral pain had significantly less hip strength for concentric abduction (p=0.02) and isometric abduction (p=0.03), isometric adduction (p=0.02), concentric external rotation (p=0.03), eccentric external rotation (p=0.02) and isometric external rotation (p=0.01), compared to healthy subjects (Table 4-5; Figure 4-1, 4-2).

Table 4-5. Pairwise comparison for concentric, eccentric, and isometric strength (peak torque/body weight) in hip abduction, adduction, external rotation, and internal rotation between patellofemoral pain (PFP) and healthy groups

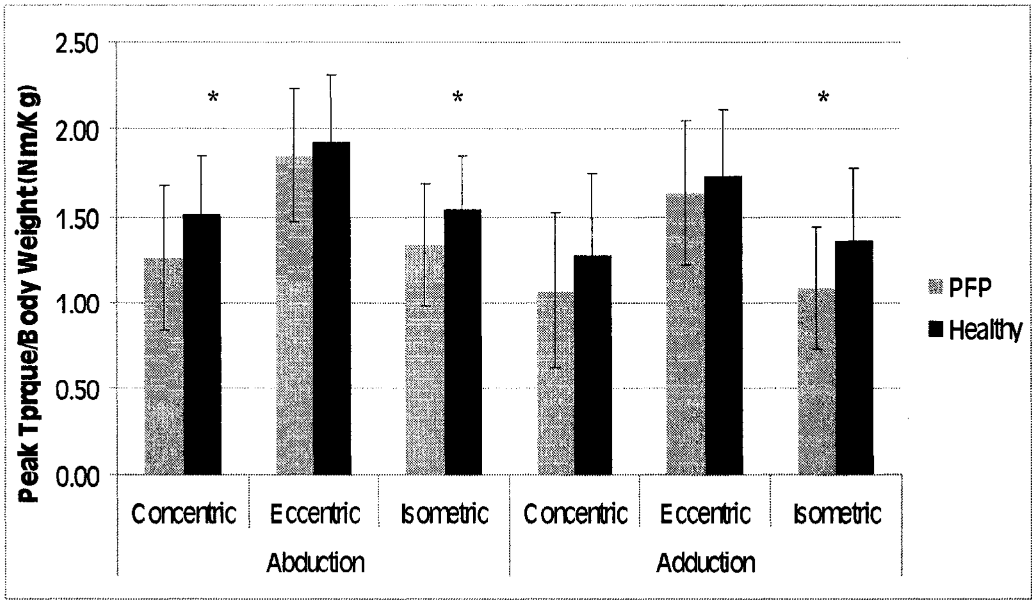
		Groups	Mean Difference	Standard Error	Sig.†	95% Confidence Interval†	
						Lower	Upper
Abduction	Concentric	PFP vs.Healthy	0.25	0.11	0.02*	0.37	0.47
	Eccentric	PFP vs.Healthy	0.08	0.11	0.49	-0.14	0.29
	Isometric	PFP vs.Healthy	0.21	0.09	0.03*	0.02	0.40
Adduction	Concentric	PFP vs.Healthy	0.21	0.13	0.11	-0.05	0.46
	Eccentric	PFP vs.Healthy	0.10	0.11	0.36	-0.12	0.32
	Isometric	PFP vs.Healthy	0.27	0.11	0.02*	0.06	0.49
External Rotation	Concentric	PFP vs.Healthy	0.13	0.06	0.03*	0.02	0.24
	Eccentric	PFP vs.Healthy	0.14	0.06	0.02*	0.03	0.26
	Isometric	PFP vs.Healthy	0.14	0.06	0.01*	0.03	0.26
Internal Rotation	Concentric	PFP vs.Healthy	0.11	0.06	0.05**	0.00	0.22
	Eccentric	PFP vs.Healthy	0.08	0.06	0.20	-0.04	0.20
	Isometric	PFP vs.Healthy	0.08	0.07	0.30	-0.07	0.22

†Adjustments for multiple comparison: Bonferroni

* Significant (p<0.05)

** Although this value appears to be significant, in reality it was not because the value was 0.054

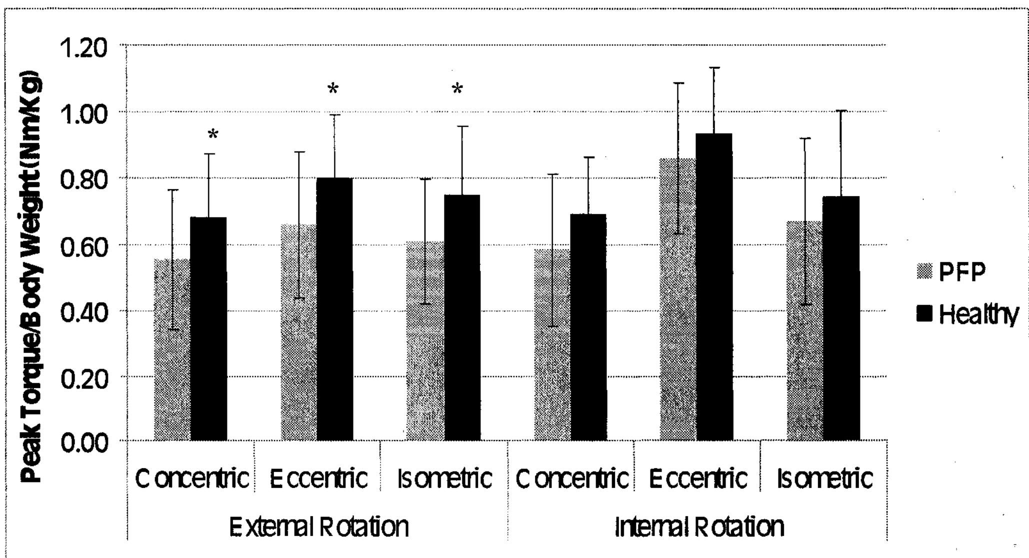
Figure 4-1. Bar graph of concentric, eccentric, and isometric strength (peak torque/body weight) in hip abduction and adduction in patellofemoral pain (PFP) and healthy groups



* Significant ($p<0.05$)

** Error bar demonstrates standard deviation

Figure 4-2. Bar graph of concentric, eccentric, and isometric strength (peak torque/body weight) of hip external and internal rotation in patellofemoral pain (PFP) and healthy groups



* Significant ($p<0.05$)

** Error bar demonstrates standard deviation

4.3. COMPARISON OF HIP STRENGTH RATIOS

A MANOVA was used to compare hip strength ratios (abduction/adduction and external/internal rotation) between subjects with patellofemoral pain and healthy subjects. There was no significant difference of strength ratios between the two groups ($p>0.05$; Table 4-6, 4-7; Figure 4-3).

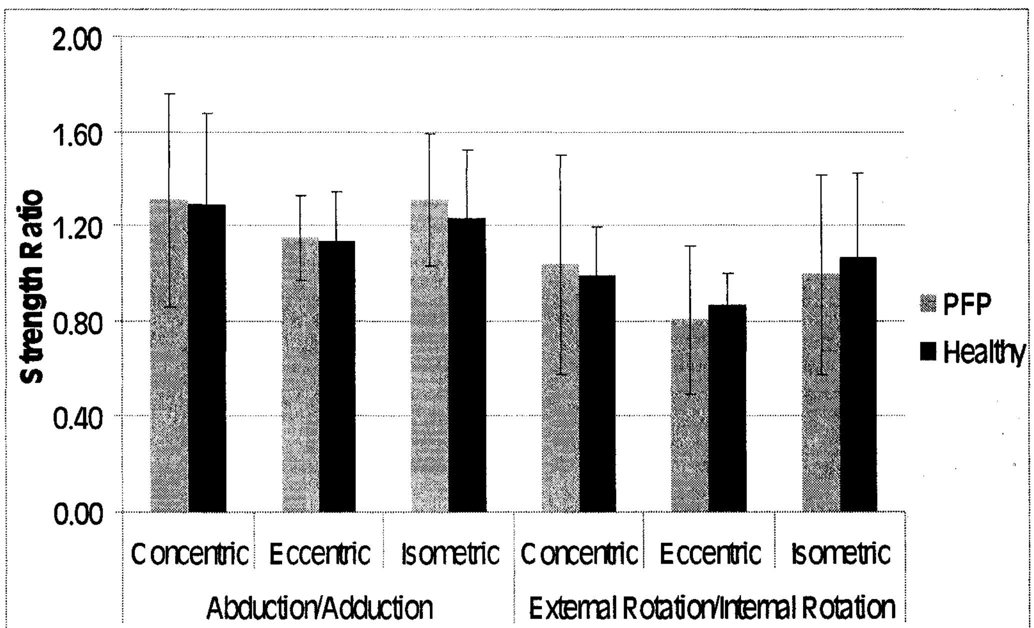
Table 4-6. Descriptive statistics for hip strength ratios (abduction/adduction and external/internal rotation) of concentric, eccentric, and isometric contractions in patellofemoral pain (PFP) and healthy groups

		Group	Mean	Standard Deviation
AB/AD	Concentric	PFP	1.31	0.45
		Healthy	1.29	0.39
AB/AD	Eccentric	PFP	1.15	0.18
		Healthy	1.13	0.21
AB/AD	Isometric	PFP	1.31	0.28
		Healthy	1.23	0.29
ER/IR	Concentric	PFP	1.04	0.46
		Healthy	0.99	0.20
ER/IR	Eccentric	PFP	0.80	0.31
		Healthy	0.86	0.14
ER/IR	Isometric	PFP	1.00	0.42
		Healthy	1.06	0.30

Table 4-7. Tests of between-group effects for hip strength ratios (abduction/adduction and external/internal rotation) of concentric, eccentric, and isometric contractions for patellofemoral pain (PFP) and healthy groups

		Sum of squares	df	F	Sig.	Effect size	Observed power
AB/AD	Concentric	0.01	1.00	0.04	0.85	0.00	0.05
	Eccentric	0.01	1.00	0.13	0.72	0.00	0.07
	Isometric	0.09	1.00	1.04	0.31	0.02	0.17
ER/IR	Concentric	0.03	1.00	0.20	0.66	0.00	0.07
	Eccentric	0.05	1.00	0.80	0.38	0.02	0.14
	Isometric	0.06	1.00	0.44	0.51	0.01	0.10

Figure 4-3. Bar graph of hip strength ratios of concentric, eccentric, and isometric contractions in patellofemoral pain (PFP) and healthy groups



* Error bar demonstrates standard deviation

According to Dvir, Eger, Halperin, & Shklar (1989), it would be more realistic to analyze inter-muscle relationship in terms of co-contraction, where the agonist contracts concentrically and the antagonist contracts eccentrically. Dividing the eccentric torque of the antagonist by the concentric torque of the agonist results in what has been termed the dynamic control ratio (Dvir et al., 1989). Aagaard, Simonsen, Magnusson, Larsson, & Dyhre-Poulsen (1998) suggested that this ratio may be more functional compared to the conventional ratio (concentric/concentric). Therefore, the strength ratios of abduction (eccentric)/ adduction (concentric), adduction (eccentric)/abduction (concentric), external rotation (eccentric)/internal rotation (concentric), and internal rotation (eccentric)/external rotation (concentric) were calculated. A MANOVA was used to compare these dynamic control ratios between groups. However, no significant differences were observed in the dynamic control ratios between groups (Table 4-8, 4-9; Figure 4-4). The analysis showed that the standard deviation of the dynamic control ratio of hip internal rotation to external rotation in PFP group was quite large (SD = 1.93). Since some of the subjects in PFP group had very weak hip external rotators, the variation of hip external rotation strength in people with PFP was large. This may have affected the standard deviation.

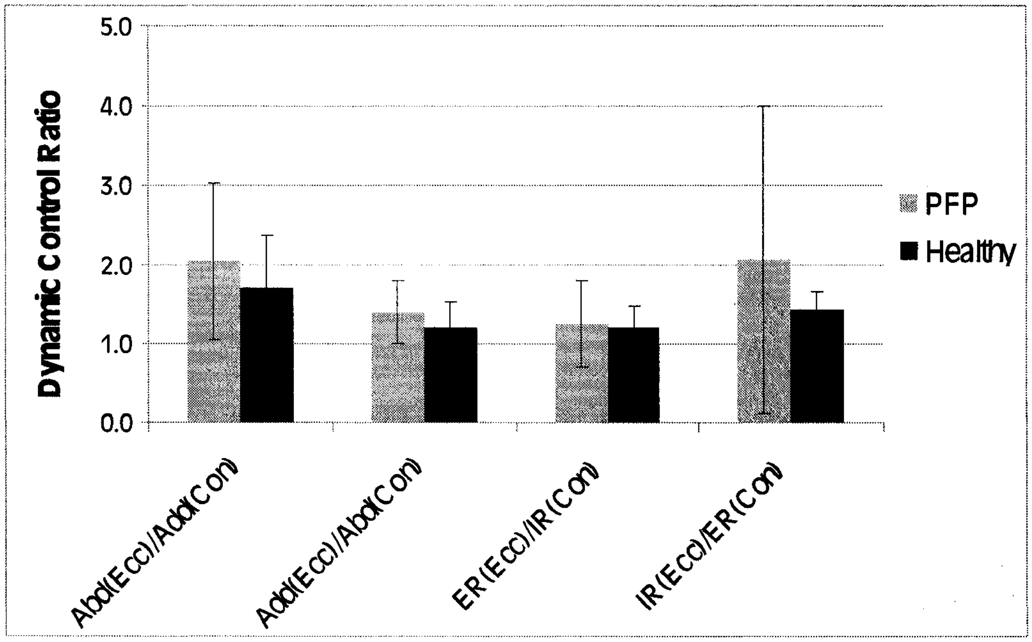
Table 4-8. Descriptive statistics for dynamic control ratios (eccentric/concentric) in patellofemoral pain (PFP) and healthy groups

	Group	Mean	Standard Deviation
Abd(Ecc)/Add(Con)	PFP	2.03	1.00
	Healthy	1.69	0.68
Add(Ecc)/Abd(Con)	PFP	1.39	0.40
	Healthy	1.19	0.32
ER(Ecc)/IR(Con)	PFP	1.25	0.55
	Healthy	1.19	0.29
IR(Ecc)/ER(Con)	PFP	2.06	1.93
	Healthy	1.42	0.25

Table 4-9. Tests of between-group effects for dynamic control ratios (eccentric/concentric) for patellofemoral pain (PFP) and healthy groups

	Sum of squares	df	F	Sig.	Effect size	Observed power
Abd(Ecc)/Add(Con)	1.53	1.00	2.10	0.15	0.04	0.30
Add(Ecc)/Abd(Con)	0.53	1.00	4.03	0.05	0.08	0.50
ER(Ecc)/IR(Con)	0.05	1.00	0.27	0.61	0.01	0.08
IR(Ecc)/ER(Con)	5.39	1.00	2.83	0.10	0.05	0.38

Figure 4-4. Bar graph of dynamic control ratios (eccentric/concentric) in patellofemoral pain (PFP) and healthy groups



** Error bar demonstrates standard deviation

CHAPTER 5: DISCUSSION

Lack of proximal control of the leg at the hip has been suggested to contribute to patellofemoral pain. Salsich and Perman (2007) reported that internal rotation of the femur decreased patellofemoral joint contact area, thereby increased patellofemoral joint stress in people with patellofemoral pain. Also, it has been reported that a knee valgus moment may increase lateral patellar pressure (Powers, 2003). Hip abductors and external rotators play an important role in controlling the internal rotation of the femur and valgus moment (Ireland et al., 2003; Robinson & Nee, 2007; Cichanowski et al., 2007). Several studies (Ireland et al., 2003; Piva et al., 2005; Robinson & Nee, 2007; Cichanowski et al., 2007) examined strength of the hip abductors and external rotators in individuals with patellofemoral pain. Some of these studies (Ireland et al., 2003; Robinson & Nee, 2007; Cichanowski et al., 2007) found weakness of the hip abductors and external rotators in people with patellofemoral pain. However, in these previous studies only isometric strength measurement using a hand-held dynamometer was tested. Since people with patellofemoral pain experience pain mostly during dynamic activities, it is important to assess dynamic strength. Use of isokinetic measurement enables assessment of dynamic strength (concentric and eccentric contraction) as well as isometric strength. Also, the previous studies evaluated only strength of hip abductors and external rotators, which did not allow the present researcher to determine whether hip abductors and external rotators are selectively weak or global weakness of the hip muscles existed. In order to determine this, the present study measured not only the strength of the hip abductors and external rotators but also the strength of the hip adductors and internal rotators.

The purpose of this study was to compare isokinetic (concentric and eccentric) and isometric strength of hip abductors, adductors, external rotators and internal rotators between individuals with and without patellofemoral pain.

5.1. ISOKINETIC AND ISOMETRIC STRENGTH OF HIP ABDUCTORS, ADDUCTORS, EXTERNAL ROTATORS AND INTERNAL ROTATORS

The first hypothesis of this research was subjects with patellofemoral pain will have reduced isokinetic and isometric strength (peak torque (Nm)/body weight (Kg)) of hip abductors and external rotators when compared to healthy subjects. The results of this study showed that hip abduction and external rotation in individuals with patellofemoral pain were significantly weaker than healthy subjects ($p<0.05$; Table 4-5; Figure 4-1, 4-2). As some of the previous studies reported (Ireland et al., 2003; Robinson & Nee, 2007; Cichanowski et al., 2007), the present results showed that individuals with patellofemoral pain had decreased isometric strength of hip abduction and external rotation compared to healthy subjects ($p<0.05$; Table 4-5; Figure 4-1, 4-2).

In addition, people with patellofemoral pain in this study had significantly weaker concentric and eccentric strength of hip external rotation and concentric strength of hip abduction when compared to healthy subjects ($p<0.05$; Table 4-5; Figure 4-1, 4-2). This suggests that people with patellofemoral pain demonstrate decreased concentric and eccentric strength as well as isometric strength of hip abductors and external rotators. There was no significant difference in eccentric strength of hip abduction, although people with patellofemoral pain presented with less strength than healthy subjects. This may be due to the difficulty of eccentric contraction testing. Some subjects had a difficult time performing the eccentric contraction, especially for the hip abduction/adduction measurement, compared to concentric and isometric contractions.

In the present study, people with patellofemoral pain also had significantly decreased isometric strength of hip adduction compared to healthy subjects ($p=0.015$; Table 4-5; Figure 4-1). One possible reason for reduced strength of the hip adductors in people with patellofemoral pain could be the relationship between hip adductors and vastus medialis obliquus (VMO). The importance of VMO in relation to patellofemoral pain has been frequently discussed in the literature. VMO is considered as a restraint to lateral displacement of the patella (Wise & Rullo, 1984; Hanten & Schulties, 1990; Souza & Gross, 1991; Voight & Wieder, 1991; Cowan et al., 2001). Several studies have suggested that activating the hip adductors could affect the VMO, since some of the fibers of VMO originate from the adductor magnus and some of the fibers originate from the adductor longus (Beck & Wildermuth, 1985; Hanten & Schulties, 1990; Cerny, 1995). According to Hanten and Schulties (1990), stronger hip adductor muscles give the VMO a stable origin from which to contract. In addition, Beck and Wildermuth (1985) reported that stretching of the VMO by the hip adductors would alter length tension properties, thus contributing to an enhanced contraction force. Hodges & Richardson (1993) reported that preferential activation of VMO was observed when hip adduction was added to closed chain quadriceps exercise. Also, several studies demonstrated that increased overall muscle activity of quadriceps (both VMO and VL) was found for quadriceps exercises done with the hip in adduction (Cerny, 1995; Earl, Schmitz & Arnold, 2001; Coqueiro et al., 2005). Some researchers did not find increased activity of VMO with hip adduction with open kinetic chain exercises (Karst & Jewett, 1993; Cerny, 1995; Laprade, Culhan, & Brouwer, 1998); however, it seems that VMO activity is enhanced when combining quadriceps exercise with hip adduction in closed kinetic chain. Although the present study measured the hip strength in an open kinetic chain position, people with patellofemoral pain might have obtained an altered recruitment pattern of the hip adductors and VMO. The weakness of hip adductors that was found in people with patellofemoral pain in this study may be explained by this relationship between VMO and hip adductors.

In addition, all of the strength values of hip adduction and internal rotation were decreased in people with patellofemoral pain when compared with subjects without patellofemoral pain (Table 4-5; Figure 4-1, 4-2). This finding suggests that individuals with patellofemoral pain may demonstrate not only weakness of the hip abductors and external rotators but also hip adductors and internal rotators. There is only one study that evaluated hip adductors and internal rotators in people with patellofemoral pain (Cichanowski et al. 2007). They reported that global hip weakness was seen in people with patellofemoral pain. However, they explained that this global weakness might result from reduced training, since the subjects were all collegiate athletes. In the present study, physical activity level in each group was matched for subjects with PFP and healthy subjects; thus, the difference between two groups in the hip strength was not due to the reduced activity.

5.2. RATIO OF ISOKINETIC AND ISOMETRIC HIP ABDUCTORS TO ADDUCTORS AND EXTERNAL ROTATORS TO INTERNAL

The second hypothesis of this study was subjects with patellofemoral pain will have lower ratio of isokinetic and isometric hip abductors to adductors, and external rotators to internal rotators when compared to healthy subjects. The results of the present study did not support this hypothesis. There were no significant differences in the strength ratios of all muscle groups and contraction types between the two groups of subjects ($p>0.05$; Table 4-7; Figure 4-3). In addition, the dynamic control ratios were evaluated in order to understand a more functional and realistic agonist-antagonist relationship. However, the analysis did not show any significant difference in the dynamic control ratios between two groups for hip abduction (eccentric)/adduction (concentric), adduction (eccentric)/abduction (concentric), external rotation (eccentric)/internal rotation (concentric), and internal rotation (eccentric)/external rotation (concentric) ($p>0.05$; Table 4-9; Figure 4-4).

The fact that there were no differences in the hip strength ratios and there were differences in peak torques of hip muscles between groups suggests that people with patellofemoral pain may have global weakness of the hip muscles. In other words, not only the strength of hip abductors and external rotators but also the strength of hip adductors and internal rotators may need to be taken into account.

Unlike hip abductors and external rotators, the importance of hip adductors and internal rotators has seldom been discussed. The functional role of hip adductors is to stabilize the pelvis during weight shifting from one limb to the other (Oatis, 2004). In addition to the important role of the hip adductors in relation to the VMO as mentioned previously, the hip adductors may play an important role as a stabilizer of the hip joint in patellofemoral pain.

The hip internal rotators may play a role in controlling an excessive external rotation of the hip joint. Lee et al. (1994) examined the effects of fixed femoral rotation on patellofemoral joint contact pressures. They found that both the external and the internal rotation of the femur resulted in non-linear increase in patellofemoral contact pressures on the contralateral facet of the patella. The external rotation of the femur increased the joint contact pressures on the medial facet of the patella, whereas the internal rotation of the femur increased the joint contact pressures on the lateral facet of the patella. A significant increase in the contact pressure was observed between 20° and 30° of the femoral rotation. Interestingly, the increase of the joint contact pressure was greater when the femur was externally rotated than when the femur was internally rotated. The hip internal rotators may be important in controlling the excessive external rotation of the femur that may ultimately increase the patellofemoral joint contact pressures.

5.3. STRENGTHS AND LIMITATIONS OF THE STUDY

5.3.1. STRENGTHS

To the researcher's knowledge, this is the first study in which isokinetic strength (concentric and eccentric contraction) of hip strength was tested in people with patellofemoral pain. Also, this study evaluated the strength of hip abductors and external rotators as well as hip adductors and internal rotators. The results of this study will contribute to the understanding of patellofemoral pain and provide a new sight on treatment of patellofemoral pain.

In this study, the subjects with patellofemoral pain and healthy subjects did not have any statistical difference in age, gender and physical activity level. This facilitated the comparison between two groups, since these factors could affect the strength measurement.

5.3.2. LIMITATIONS

One of the limitations of this study was its cross sectional nature which did not allow the researcher to determine a cause and effect relationship. Therefore, it was not possible to determine if the weakness of the hip muscles was the cause or the effect of the patellofemoral pain. However, in either case, it is important for individuals with patellofemoral pain to gain sufficient strength of the hip muscles since significant differences in strength were observed between people with and without patellofemoral pain. The results of this study suggest that strengthening of hip muscles could play an important role in rehabilitation of patients with patellofemoral pain.

The present study included both females and males, and their age ranged from 18 to 38 years old. The heterogeneous sample may have affected the muscle strength. However, an ANOVA analysis adding a gender factor (females/PFP, males/PFP, females/healthy, males/healthy) found no significant differences in the hip strength ($p=0.56$). This may be due to the small sample size and the unbalanced sample (females/PFP=18, males/PFP=8, females/healthy=18, males/healthy=8). A covariate analysis was performed in order to analyze the effects of age in analyzed variables. This analysis found that age did not significantly contribute to the values of the strength in this study.

Another limitation was the use of a convenience sample. The generalizability of the results of the present study was limited due to the use of a convenience sample. Other factors such as intensity of pain, chronicity of pain were not considered in the analysis. Intensity and chronicity of pain may be important, since pain alters the muscle strength. It is possible that depending on the characteristics of the sample (i.e. greater intensity of pain, more chronicity), results could have reached significance.

Also, in this study, blinding of examiner was not achieved although the statistician was blinded. Lack of blinding may have produced unintentional bias during the strength testing.

Although there was no significant difference in body weight (Kg) between the two groups, the average difference of 7.38 Kg between the two groups may have affected the strength values since the strength was normalized by the body weight.

5.4. CLINICAL SIGNIFICANCE

The results of the present study showed that there were statistically significant differences in the strength of hip abduction (concentric and isometric), adduction (isometric), and external rotation (concentric, eccentric, isometric) between the subjects with and without patellofemoral pain. In this study, normalized peak torque in people with patellofemoral pain was 17% lower for hip concentric abduction, 14% lower for isometric abduction, 20% lower for isometric adduction, 19% lower for concentric external rotation, 18% lower for eccentric external rotation, and 19% lower for isometric external rotation when compared to healthy subjects. These percentages were lower when compared to some of the previous studies. Ireland et al. (2003) reported that people with patellofemoral pain were 26% weaker in hip abduction and 36% weaker in hip external rotation when compared to healthy subjects. Also, Robinson & Nee (2007) reported that people with patellofemoral pain had 27% weaker hip abduction and 30% weaker hip external rotation when compared to weaker limb of control subjects. These differences between the present study and these previous studies may be due to the use of different strength measurement (isokinetic dynamometer in the present study v.s. hand-held dynamomer in the previous studies). A study by Cichanowski et al. (2007) showed similar results to the present study, in which people with patellofemoral pain were 21% weaker in hip abduction, 16% weaker in hip adduction, 15% weaker in hip internal rotation and 15% weaker in hip external rotation when compared to healthy subjects.

According to the analysis of clinical significance in the present study, calculating the minimal important difference (MID) for all statistically significant results, the researcher found that concentric abduction, isometric abduction, isometric adduction, concentric external rotation, eccentric external rotation and isometric external rotation were clinically and statistically significantly different between people with and without patellofemoral pain (Table 5-1).

However, Sepega (1990) suggested that with weakness, a difference of 10-20% is possibly abnormal, whereas a difference of 20% or more should be considered as almost certainly due to pathology. Strength differences of less than 10% could be largely attributed to factors like measurement error. The differences found in the present results ranged from 14% to 20%, which would be 'possibly abnormal' according to Sepega. Therefore, although there were statistically significant differences, the results should be interpreted carefully, considering clinical significance if Sepega's criterion was used.

Table 5-1. Clinical Significance data for hip abduction, adduction, and external rotation for patellofemoral pain (PFP) and healthy groups

		Group	Effect Size	MID	Clinical Significance
Abduction	Concentric	PFP vs. Healthy	0.66	0.19	√
	Isometric	PFP vs. Healthy	0.63	0.17	√
Adduction	Isometric	PFP vs. Healthy	0.70	0.20	√
External Rotation	Concentric	PFP vs. Healthy	0.65	0.10	√
	Eccentric	PFP vs. Healthy	0.70	0.10	√
	Isometric	PFP vs. Healthy	0.71	0.10	√

*Statistically significant data is shown

*MID=Minimal Important Difference

CHAPTER 6: SUMMARY AND CONCLUSION

6.1. SUMMARY AND CONCLUSION

The purposes of this study were 1) to compare the isokinetic (concentric and eccentric) and isometric strength of hip abductors, adductors, external rotators and internal rotators between individuals with and without patellofemoral pain and 2) to evaluate the strength ratios of hip abductors/adductors and external rotators/internal rotators in the two groups. Based on the results of this study, the following conclusions can be stated:

1. People with patellofemoral pain presented significantly weaker concentric and isometric strength of the hip abductors and concentric, eccentric and isometric strength of the hip external rotators when compared to healthy subjects.
2. People with patellofemoral pain presented significantly weaker isometric strength of the hip adductors when compared to healthy subjects.
3. Overall, people with patellofemoral pain demonstrated weaker concentric, eccentric and isometric strength of the hip abductors, adductors, external rotators and internal rotators when compared to healthy subjects.
4. Selective weakness of the hip abductors and external rotators (i.e. weakness of only these muscles) was not found in people with patellofemoral pain. The

results of this study showed that no differences were found in the strength ratios of hip abductors/adductors and external rotators/internal rotators between people with and without patellofemoral pain.

5. Selective weakness of the hip abductors and external rotators (weakness of only these muscles) was not observed in people with patellofemoral pain when evaluated using the dynamic control ratios (eccentric/concentric). This study demonstrated no differences between people with and without patellofemoral pain in the dynamic control ratios; hip eccentric abduction/concentric adduction and eccentric external rotation/concentric internal rotation.

6.2. CLINICAL RELEVANCE

As the concept of proximal joint stability is one of the key elements in rehabilitation, strengthening exercises of the hip abductors and external rotators has been frequently used for the treatment of patellofemoral pain. However, there is limited evidence to support this application for people with patellofemoral pain.

This study evaluated strength of hip abductors, adductors, external rotators and internal rotators in people with and without patellofemoral pain. The clinical implications of this study are that strengthening of hip abductors and external rotators may be beneficial for people with patellofemoral pain as this study has shown that people with patellofemoral pain have reduced strength of the hip abductors and adductors when compared to healthy subjects. In addition, strengthening of the hip adductors and internal rotators may also be important as this study has shown that the hip adductors and internal rotators are weaker in people with patellofemoral pain and no selective weakness of the hip abductors and external rotators was observed in people with patellofemoral pain.

6.3. SUGGESTIONS FOR FUTURE INVESTIGATIONS

Since this study was a cross-sectional study comparing the strength of hip muscles between people with and without patellofemoral pain, the researcher could not determine whether the weakness of hip muscles caused patellofemoral pain or the patellofemoral pain caused the weakness of hip muscles. In order to determine the cause and effect relationship between weakness of hip muscles and patellofemoral pain, prospective studies are needed.

Also, this study evaluated only muscle strength, which is one parameter of muscle integrity. In order to draw a whole image of the muscular system, it may be necessary to evaluate neuromuscular function of hip muscles using electromyography.

In addition, this study has found that people with patellofemoral pain have weakness of the hip abductors and external rotators when compared to healthy subjects. However, it is unknown if people with patellofemoral pain actually demonstrate excessive hip adduction, hip internal rotation, or knee valgus during dynamic activity. Therefore, a study that examines hip and knee kinematics is needed. Ideally, both the strength and kinematics should be evaluated simultaneously in order to understand the relationship between strength and kinematics, since it is uncertain whether the strength measured in an open kinetic chain position actually explains the dynamic movement.

This study found that people with patellofemoral pain may have global weakness of the hip muscles. As the muscles around the hip are closely related and contract together to produce an optimal movement (Oatis, 2004), a study including other muscle groups, such as hip flexors and extensors, would be of benefit.

Finally, a future study is needed to evaluate if a rehabilitation program directed to strengthen hip muscles results in improvement of pain and function in patients with patellofemoral pain.

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APPENDIX A

Ethics Approval Form

Health Research Ethics Board

213 Heritage Medical Research Centre
University of Alberta, Edmonton, Alberta T6G 2S2
p.780.492.9724 (Biomedical Panel)
p.780.492.0302 (Health Panel)
p.780.492.0459
p.780.492.0839
f.780.492.7808

HEALTH RESEARCH ETHICS APPROVAL FORM

Date of HREB Meeting: June 1, 2007

Name of Applicant: **Dr. David Magee**

Organization: **U of A**

Department: **Faculty of Rehabilitation Medicine/Department of Physical Therapy**

Project Title: **Hip Strength in Individuals with and without Patellofemoral Pain**

The Health Research Ethics Board (HREB) has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the subject information letter and consent form.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval. Written notification must be sent to the HREB when the project is complete or terminated.

Special Comments:

Dr. Jennifer Rodgers, PhD
Associate Chair, Health Research Ethics Board
(B: Health Research)

JUL 10 2007
Date of Approval Release

File Number: B-060607

UNIVERSITY OF ALBERTA

Capital Health
Edmonton and area

CARITAS HEALTH GROUP

APPENDIX B
Advertisement

Faculty of Rehabilitation Medicine

Hip Strength in Individuals with and without Patellofemoral Pain

WANTED

Are you healthy? Are you between 18 and 40 years old? We invite you to participate in our study. We are trying to evaluate the hip strength in healthy subjects and subjects with knee pain (patellofemoral pain). This study will contribute and strengthen the knowledge of treatment of knee pain. It will take about 1.5 hours. If you wish to participate or find out more information call 492-4824, or send an e-mail to Reiko Otsuki (rotsuki@ualberta.ca).

Thank you in advance.

APPENDIX C
Introductory Letter

Dear ______________________________,

Our research team at University of Alberta is investigating hip strength in people with knee pain. The records at the clinic show that you have knee pain. We would appreciate having you participated in our study.

We will be examining your hip muscle strength. We will measure three different types of strength (concentric, eccentric, and isometric). The concentric test measures your ability to push and pull the testing pad. You will be asked to push and pull as hard and fast as you can. The eccentric test measures your ability to resist the movement of the testing pad. You will be unable to stop the movement of the pad; however, your maximum resistance is still required. The isometric test measures your ability to push the testing pad which is fixed. You will be unable to move the testing pad; however your maximum effort is still required.

Each strength test will be performed in two positions (side lying and sitting). Since isometric testing includes two movements (upward and downward), there will be eight strength tests.

1. Concentric, side lying
2. Eccentric, side lying
3. Isometric, side lying, upward
4. Isometric, side lying, downward
5. Concentric, sitting
6. Eccentric, sitting
7. Isometric, sitting, upward
8. Isometric, sitting, downward

In concentric and eccentric tests, you will practice 4 repetitions using a 50% effort and 4 repetitions with maximal effort. After the practice, you will perform 4 testing repetitions. In isometric test, you will practice once and test 3 times.

The measurement will take about 1.5 hours. It will take place at Corbett Hall at University of Alberta. We would like you to bring shorts and a T-shirt for the testing. Your time will be greatly appreciated, since the information you provide will contribute to better understanding of knee pain and its treatment.

The decision whether you are taking part in this study will not affect your treatment at the clinic in the future. If you are willing to take part in the study, please contact Reiko Otsuki at 780-492-4824 or send an email at rotsuki@ualberta.ca. We will arrange the time for the testing. Please feel free to contact us, should you have any questions. Thank you for considering our request.

Sincerely yours,

Reiko Otsuki, MSc Rehabilitation Science Student
Faculty of Rehabilitation Medicine
Phone number: 780-492-4824
Email: rotsuki@ualberta.ca

Dr. David Magee, PhD, Professor
Faculty of Rehabilitation Medicine
Phone number: 780-492-5765

APPENDIX D
Sample Size Calculation

The sample size calculation was based on ANOVA procedure considering: $\alpha = 0.05$, $\beta = 0.20$, Power = 0.80, Effect Size = 0.25 (medium).

		Patellofemoral pain	Healthy
Concentric contraction	Abduction		
	Adduction		
	External rotation		
	Internal rotation		
Eccentric contraction	Abduction		
	Adduction		
	External rotation		
	Internal rotation		
Isometric contraction	Abduction		
	Adduction		
	External rotation		
	Internal rotation		

From the table above, degree of freedom (df) = (row-1)(coumns-1) = (12-1)(2-1) = 11

From tables (Table 8.4.4 and 8.4.5, Cohen, 1988), with $\alpha = 0.05$, Power = 0.80, Effect Size = 0.25, df = 11, sample size needed is 24. 26 subjects in each group will be recruited.

APPENDIX E

Inclusion & Exclusion Criteria

(Subjects with Patellofemoral Pain)

Inclusion

1) Are you 18-40 years old?	Y N
2) Is the duration of symptom greater than 4 weeks?	Y N
3) Was it non-traumatic onset?	Y N
4) Do you have pain with at least 3 of the following? compression of the knee cap, palpation of the knee cap, squatting, stair climbing, kneeling, prolonged sitting	Y N

Exclusion

1) Do you have history of patellar dislocation?	Y N
2) Have you had knee surgery in the past 2 years?	Y N
3) Do you have any other knee pathologies? (bursitis, arthritis, ligamentous injury or laxity, peripatellar tendonitis, plica syndrome, Sinding-Larsen-Johansson syndrome, Osgood-Schlatter syndrome)	Y N
4) Do you have any lower limb injury or pathology?	Y N
5) Do you have neurological pathology?	Y N
6) Do you have any cardiac pathology?	Y N
7) Are you pregnant?	Y N

Comments:..

....

Inclusion & Exclusion Criteria
(Healthy Subjects)

Inclusion

1) Are you healthy?	Y	N
2) Are you 18-40 years old?	Y	N
3) Are you matched for age, gender, and physical activity level to subjects with patellofemoral pain?	Y	N

Exclusion

1) Do you have any lower limb injury or pathology?	Y	N
2) Do you have any neurological pathology?	Y	N
3) Do you have any cardiac pathology?	Y	N
4) Are you pregnant?	Y	N

Comments:...

....

APPENDIX F
Information Letter to Subjects

Title: Hip Strength in Individuals with and without Patellofemoral Pain

Researchers:

Principle Investigator: Dr. David Magee, PhD, Professor
Faculty of Rehabilitation Medicine

Co-Investigator: Reiko Otsuki, MSc Rehabilitation Science Student
Faculty of Rehabilitation Medicine

Background/Purpose

Knee pain is one of the most common disorders in our population. Recently, control of the knee joint thorough the hip muscles has been investigated, and these muscles may play an important role in knee pain. However, there is limited information regarding hip muscle strength in knee pain. The purpose of this study is to compare hip muscle strength between people with and without knee pain. This study will provide better understanding of knee pain and its treatment.

Procedure:

If you agree to participate, you will be asked questions to make sure you meet the criteria to be included in this study. If you meet the criteria, your age, physical activity level, height and weight will be recorded. Before the testing, you will be asked to warm up on a bike for 5 minutes. The affected side will be tested for subjects with anterior knee pain. For healthy subjects, the leg to be tested will be determined by the examiner.

Three different types of strength (concentric, eccentric, and isometric) will be measured. The concentric test measures your ability to push and pull the testing pad. You will be asked to push and pull as hard and fast as you can. The eccentric test measures your ability to resist the movement of the testing pad. You will be unable to stop the movement of the pad; however, your maximum resistance is still required. The isometric test measures your ability to push the testing pad which is fixed. You will be unable to move the testing pad; however your maximum effort is still required.

Each strength test will be performed in two positions (side lying and sitting). Since isometric testing includes two movements (upward and downward), there will be eight strength tests.

1. Concentric, side lying

2. Eccentric, side lying
3. Isometric, side lying, upward
4. Isometric, side lying, downward
5. Concentric, sitting
6. Eccentric, sitting
7. Isometric, sitting, upward
8. Isometric, sitting, downward

In concentric and eccentric tests, you will practice 4 repetitions using a 50% effort and 4 repetitions with maximal effort. After the practice, you will perform 4 testing repetitions. In isometric test, you will practice once and test 3 times. You will have 1-minute rest between testing conditions.

Benefits/risks:

The benefit of participating in this study is that you can help us to evaluate the hip muscle strength in people with knee pain. The results of this study will lead better understanding of knee pain and its treatment. The testing is considered safe and is done in everyday practice. Subjects may experience muscle soreness after the testing.

Privacy/confidentiality:

All data will be kept confidential, except where a code of ethics or the law requires. The data you give will be kept for at least 5 years after the study is completed. The data will be kept in a safe, secure area. Your name or any other identifying data will not be attached to the data you generate by your test. Your name will never be used in any presentation or publications related of the study results. The data gathered for this study may be looked at again in the future to help us answer other study questions. If so, an ethics board will first review the study to ensure that the data are used ethically.

Freedom to withdraw:

Your participation is completely voluntary. If, at any time, you decided to withdraw you are completely free to do so without consequences.

Contact information;

If you have any questions about the study, please call Reiko Otsuki at 780-492-4824 or Dr. David Magee at 780-492-5765.

If you have any questions, concerns or complaints regarding the study and procedures, please feel free to contact Dr. Paul Hagler, Associate Dean-Research in The Faculty of Rehabilitation Medicine at 780-492-9674. Dr. Hagler is independent from the study investigator.

APPENDIX G

Subject Consent Form

Title: Hip Strength in Individuals with and without Patellofemroal pain

Part 1: Researcher Information		
Principal Researcher and Academic Advisor: Dr. David Magee Name of Co- Investigator: Reiko Otsuki Affiliation: University of Alberta, Faculty of Rehabilitation Medicine Contact Information: 780-492-4824 Email: rotsuki@ualberta.ca		
Part 2: Consent of Subject		
	Yes	**No**
Do you understand that you have been asked to be in a research study?		
Have you read and received a copy of the attached information sheet?		
Do you understand the benefits and risks involved in taking part in this research study?		
Have you had an opportunity to ask questions and discuss the study?		
Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your care.		
Has the issue of confidentiality been explained to you?		
Do you understand who will have access to your records/information?		
Part 3: Signatures		
I have read the information sheet and this study was explained to me by: ______________________ Date: __________________________		
I agree to take part in this study. Signature of Research Participant: ____ Printed Name: ____		
Witness (if available): ____ *Printed Name:* ____		
I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate. *Researcher:* ____ *Printed Name:* ____ ** A copy of this consent form must be given to the subject.*		

APPENDIX H
Instructions

Isokinetic measurement

Concentric contraction

This strength test measures your ability to push and pull the testing pad. You must push all the way up before pulling down.

Eccentric contraction

This test measures your ability to resist the movement of the testing pad. You will be unable to stop the movement of the pad, but your maximum resistance is still required.

Practice & testing

1. Practice (50% effort)
   - You will start with 4 practice repetitions with 50% effort to familiarize you with the
     test movement. You will perform 4 repetitions continuously. Are you ready? Go.
   - Do you feel comfortable enough with the movement to attempt maximal push?
     If yes - We will try 4 practice repetitions with maximal effort after 1 minute break.
     If no - Try with 50% effort.
2. Practice (maximal effort)
   - Push up and pull down as hard as you can and keep pushing and pulling all the way
     through the movement. Are you ready? Go.
   - Do you feel confident enough to attempt the test repetitions?
     If yes -You are going to perform 4 test repetitions exactly the same as the last
     practice after1 minute break.
     If no - Try practice repetitions with maximal effort again.
3. Testing
   - Push up and pull down as hard as you can and keep pushing and pulling all the way
     through the movement. Are you ready? Go.

Isometric measurement

Isometric contraction

This test measures your ability to push the testing pad which is fixed. You will be unable to move the testing pad, but your maximum effort is required.

Practice & testing

1. Practice

- You will continue pushing the testing pad for 5 seconds. You will push as hard as possible. Are you ready? Go.
- Do you feel confident enough to attempt the test?
  If yes -You are going to perform the test after 1 minute break.
  If no - Try one more practice.

2. Testing

- You will have 3 tests with 1 minute rest between. Push as hard as possible. Are you ready? Go.

APPENDIX I

Data Collection Sheet

ID : ____________________

Gender: ____________________

Age : ____________________

Height : ____________________

Weight : ____________________

Duration of pain: ____________________

Physical Activity Level:

(1) Jumping, pivoting, hard cutting, football, soccer

(2) Heavy manual work, skiing, tennis

(3) Light manual work, jogging, running

(4) Activities of daily living, sedentary work

ABDUCTORS /ADDUCTORS

	Abductors			Adductors		
	Con	Ecc	Iso	Con	Ecc	Iso
Peak Torque						
Peak Torque BW						

ABDUCTORS/ADDUCTORS RATIO

	Concentric	Eccentric	Isometric
Peak Torque			

EXTERNAL/INTERNAL ROTATORS

	External rotators			Internal rotators		
	Con	Ecc	Iso	Con	Ecc	Iso
Peak Torque						
Peak Torque BW						

EXTERNAL/INTERNAL ROTATORS RATIO

	Concentric	Eccentric	Isometric
Peak Torque			