The Correlation Between Visual Observations and Inclinometric Measurements for Special Tests Related to Patellofemoral Pain Syndrome

Erin Quada
Old Dominion University

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THE CORRELATION BETWEEN VISUAL OBSERVATIONS AND
INCLINOMETRIC MEASUREMENTS FOR SPECIAL TESTS RELATED TO
PATELLOFEMORAL PAIN SYNDROME

By

Erin Quada
B.S. April 2008, Alma College

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Approved by:

Bonnie Van Lunen (Director)

James Ofiate (member)

Martha Walker (member)
ABSTRACT

THE CORRELATION BETWEEN VISUAL OBSERVATIONS AND INCLINOMETRIC MEASUREMENTS FOR SPECIAL TESTS RELATED TO PATELLOFEMORAL PAIN SYNDROME

Erin Quada
Old Dominion University
Director: Bonnie Van Lunen

Patellofemoral pain syndrome (PFPS) is generally described as an insidious onset with pain increasing during running, jumping, ascending and descending stairs as well as sitting with the knees flexed for an extended period of time. Clinicians often use special tests in injury evaluations and range of motion assessments, usually making a visual observation of that status of the patient. The purpose of this study was to examine how interval measurements utilized in flexibility and range of motion assessments correlate with visual observations of special tests (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility, and Craig’s test). The secondary purpose was to examine the intra-examiner, inter-examiner and inter-session reliability of these special tests.

Twenty healthy college-aged students (7 males, 13 females; age = 22.75 ± 1.59 yrs; ht = 171.45 ± 11.59 cm; mass = 73.32 ± 16.34 kg) participated. Subjects were included in the study if they had no musculoskeletal pathologies in the last three months and had been cleared for all other pathologies. Five assessment measures were performed by novice athletic trainers on each subject during each of two sessions. The examiners made a visual observation of the various ranges of motion and classified each subject as flexible, neutral, or inflexible for each test. The examiners then took three measurements of each test using a digital inclinometer. This data was used to calculate the intra-examiner, inter-examiner, and inter-session reliability. The visual estimates and numeric measurements were then compared to obtain the correlation data between them. We
found slight to moderate correlation results between the numeric measurements and visual estimates for all the tests. Because we used a three-category system versus a pass/fail method, the data had a larger disbursement, decreasing the correlation value we could obtain. Also, we chose to allow the examiners to use their own criteria for categorizing the subjects, providing no guidelines to normative values. Considering these factors, visual estimates could be a reasonable method of assessment, though further studies should be conducted to confirm this.
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CHAPTER I

Introduction

Patellofemoral pain syndrome (PFPS) is the cause of 25% of knee injuries seen in sports medicine clinics and affects 15% of military infantry recruits (Devereaux, Lachmann 1984; Milgrom, Finestone, Eldad, Shlamkovitch 1991), however no known data currently exists for the general population (Callaghan, Selfe 2007). PFPS is often also referred to as anterior knee pain, chondromalacia patellae, patellar malalignment, and patellofemoral arthralgia, and is not well understood (Callaghan et al 2007; Crossley, Bennell, Green, Cowen, McConnell 2002; Devereaux et al 1984). PFPS is a term used to describe knee pain in the absence of other pathologies (Dye, Vaupel 1994; Milgrom et al 1991) and generally presents with an insidious onset and increased knee pain during stair ambulation, running, squatting, jumping, or sitting for long periods with the knees flexed (Crossley et al 2002; Dye et al 1994; Fulkerson 2002; Insall 1982; Kannus, Niittymaki 1994; Milgrom et al 1991; Thomee, Augustsson, Karlsson 1999; Witvrouw, Lysens, Ballemans, Cambier, Vanderstraeten 2000). The cause of PFPS is unknown and little research has been published explaining a predisposition to or diagnosis of this pathology, despite the moderately high incidence (Kannus et al 1994; Powers 1998; Thomee et al 1999; Witvrouw et al 2000; Zappala, Taffel, Scuderi 1992).

Health care professionals often use range of motion and alignment measurements during the assessment of injuries as well as for a mark of progress throughout the rehabilitation of injuries such as PFPS. Most of these ranges of motion are measured using a standard goniometer, the occasional inclinometer, or simple visual estimates by the health care professional. Common range of motion and alignment measurements
about the knee joint include hamstring, hip flexor, iliotibial band/tensor fascia latae, rectus femoris length/flexibility, and femoral anteversion. Though these tests and measurements were designed to be taken with a goniometer or inclinometer, clinicians often estimate the results visually to be more efficient in the evaluation process. Clinicians generally use a pass/fail method, assessing whether there is restriction of motion or malalignment present that may be causing pain or leading to an injury. Some researchers have examined other special tests and range of motion assessments by comparing interval measurements and visual observations. These studies have examined finger range of motion (Rose, Nduka, Pereira, Pickford, Belcher 2002) and hip range of motion associated with other conditions (Holm, Bolstad, Lutken, Ervik, Rokkum, Steen 2000) as well as knee range of motion (Watkins, Riddle, Lamb, Personius 1991). Interval measurements and visual estimates using the active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test have not been compared. Knowing that these are commonly used assessments, reliability of these measurements, both interval and visual estimates, must be known for the results to be meaningful to the health care professional in order to generate accurate clinical outcomes assessments as well as to track progress throughout treatment.

**Statement of the Problem**

The purpose of this study was to examine how interval measurements utilized in flexibility and range of motion assessments correlate with visual observations of special tests (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility, and Craig’s test). The secondary purpose was to examine the intra-examiner, inter-examiner
Null and Research Hypotheses

Null 1: There will be no correlation between inclinometric measurements (degrees) and the visual observations between examiners for any of the special tests (active knee extension test, Thomas test, Ober's test, rectus femoris flexibility test, and Craig's test).

Research 1: There will be a statistically significant positive correlation between inclinometric measurements and visual observations between examiners for each of the special tests (active knee extension test, Thomas test, Ober's test, rectus femoris flexibility test, and Craig's test).

Null 2: There will be no correlation between inclinometric measurements (degrees) and the visual observations for each examiner for any of the special tests (active knee extension test, Thomas test, Ober's test, rectus femoris flexibility test, and Craig's test).

Research 2: There will be a statistically significant positive correlation between inclinometric measurements and visual observations for each examiner for each of the special tests (active knee extension test, Thomas test, Ober's test, rectus femoris flexibility test, and Craig's test).

Null 3: There will be no correlation between inclinometric measurements (degrees) and the visual observations between sessions for any of the special tests (active knee extension test, Thomas test, Ober's test, rectus femoris flexibility test, and Craig's test).

Research 3: There will be a statistically significant positive correlation between inclinometric measurements and visual observations between sessions for each of the
special tests (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test).

Null 4: There will be no correlation for inter-examiner, intra-examiner, or inter-session reliability for any of the special tests (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test).

Research 4: There will be a positive correlation for inter-examiner, intra-examiner, and inter-session reliability for each of the special tests (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test).

**Independent Variables**

1. Intra-examiner reliability: three trials of each test (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test) during one session for each of two examiners.

2. Inter-examiner reliability: three trials of each test (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test) during one session between examiners.

3. Inter-session reliability: three trials of each test (active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test) for one examiner for session one and session two.
Dependent Variables

1. Interval measurement (degrees) and categorization (1, 2, or 3) of the active knee extension test, Thomas test, Ober test, rectus femoris flexibility test, and Craig’s test.

Operational Definitions

1. **Dominant leg:** the leg that a person would use to kick a ball the furthest.

2. **Range of motion for the hamstrings:** the amount of knee flexion as measured using the active knee extension test. During the test the subject was supine with the opposite lower extremity fully extended. The subject was assisted in placing their test hip into 90° of flexion, and then maintained this position as they extended their test knee. An inclinometer was used to measure the amount of knee extension, thus measuring hamstring length (Corkery et al 2007; Gajdosik 1983; Lesher et al 2006).

3. **Hip range of motion for the iliopsoas:** the amount of hip extension as measured using the Thomas test. For the test, the subject sat at the end of the table and then rolled back and brought both knees tight to their chest, the test leg was slowly lowered towards the floor in a relaxed position to the point of initial stretch. The measurement was taken using an inclinometer at the distal anterior thigh, measuring iliopsoas flexibility, thus measuring the amount of hip extension (Corkery et al 2007; Harvey 1998; Lesher et al 2006; Smith et al 1991).

4. **Hip range of motion for the iliotibial band/tensor fascia lata:** the amount of hip adduction measured with Ober’s test. The subject was side-lying with the lower
leg flexed for stability. The upper leg was flexed and then abducted and extended and then allowed to fall towards the ground. The amount of hip abduction was measured by placing an inclinometer on the distal lateral portion of the thigh, thus measuring the amount of hip adduction (Ober 1936; Piva et al 2005; Piva et al 2006; Post 1999; Reese et al 2003; Smith et al 1991).

5. *Hip range of motion for anteversion:* the amount of internal or external rotation with the greater trochanter in neutral as measured using Craig’s test. The subject was prone for this test, with the contralateral leg extended. The test knee was bent to 90° while the examiner internally and externally rotated the hip while palpating the greater trochanter until it was most prominent laterally. The angle of the lower leg from vertical was then measured using an inclinometer, indicating the amount of anteversion in the femoral neck (Gross 1995; Piva et al 2006; Post 1999).

6. *Knee range of motion for the rectus femoris:* the amount of knee flexion measured with the rectus femoris flexibility test. The subject was prone with the both legs extended; the examiner passively flexed the knee and the angle of the knee was measured by an inclinometer once an end feel was reached, measuring the amount of knee flexion (Creighton et al 2007; Piva et al 2005; Piva et al 2006; Post 1999).

7. *Examiners:* novice athletic trainers (certified for less than one year), each currently working at a NCAA Division I institution.

**Assumptions**

1. Inclinometers were reliable and valid for use in the assessment measures.
2. Goniometers were reliable and valid for use in the assessment measures.

3. Examiners followed the standardized protocol for each measurement, each subject and each session.

4. Subjects gave maximal effort when the examiner instructed it.

5. Subjects gave equal effort for all the examiners during both sessions.

6. Both examiners determined the same end feel during the passive knee flexion of the rectus femoris flexibility test.

7. Skin movement over bony landmarks was the same for all trials and sessions.

Limitations

1. Specific category criteria ranges for the observational measures were not provided to the examiners prior to data collection.

2. No outside activities were controlled during testing.

3. Attire for both testing sessions was not standardized between sessions.

Delimitations

1. Subjects included healthy individuals enrolled at Old Dominion University.

2. Subjects had no history of lower extremity surgery.

3. Subjects had no current musculoskeletal injuries.
CHAPTER II
REVIEW OF LITERATURE

The purpose of this review is to examine the various aspects of assessment for patellofemoral pain syndrome to establish the best method of testing and a visual observation of each test to determine possible causes of pain. The review will include the epidemiology of patellofemoral pain syndrome, a quick review of patellofemoral anatomy and related hip anatomy, various methods of measurements for range of motion and flexibility including visual observations, a brief overview of treatment options, and reliability background information.

Epidemiology

Patellofemoral pain syndrome (PFPS), often used synonymously with anterior knee pain (Callaghan, Selfe 2007), chondromalacia patellae, patellar malalignment, and patellofemoral arthralgia (Crossley, Bennell, Green, Cowen, McConnell 2002; Devereaux, Lachmann 1984), is an ailment seen across active populations and is not well understood (Crossley et al 2002; DeHaven, Lintner 1986; Devereaux et al 1984; Fulkerson 2002; Kannus, Aho, Jarvinen, Niittymaki 1987; Kannus, Niittymaki 1994; Milgrom, Finestone, Eldad, Shlamkovitch 1991; Thomee, Augustsson, Karlsson 1999 Witvrouw, Lysens, Bellemans, Cambier, Vanderstraeten 2000). There are many discrepancies in the incidence and prevalence data related to PFPS (Callahan et al 2007). Incidence has been reported using retrospective data from sports injury clinics (DeHaven et al 1986; Devereaux et al 1984; Kannus et al 1987) and military recruits (Milgrom et al 1991), however no data has been reported for the general population. DeHaven et al
reported that 7.4% and 19.6% of all male and female injuries, respectively, were diagnosed as PFPS. The age group with the highest prevalence was 16-19 years of age at 3.3% of all injury diagnoses (DeHaven et al 1986). Devereaux et al (1984) found PFPS in 25% of all athletes with knee injuries, which were 5.4% of all reported injuries. Kannus et al reported knee injuries were 33% of all injuries seen in the clinic but no distinction was made for PFPS. In the military recruits, 15% of the population was diagnosed with PFPS during basic training (Milgrom et al 1991). As stated before, no data is available for the general population and no data on cost for lost man-hours or money spent on rehabilitation has been published.

PFPS is used to describe knee pain in the absence of other knee pathologies: patellar dislocation, tendonitis, meniscal abnormalities, instability or laxity (Dye, Vaupel 1994; Milgrom et al 1991). Most medical histories of patients with PFPS show an insidious onset with pain occurring with increased stress on the joint (Crossley et al 2002; Dye et al 1994; Milgrom et al 1991) during activities such as the following: ascending and descending stairs, running, squatting, jumping, or sitting for long periods of time with the knees flexed (Crossley et al 2002; Dye et al 1994; Fulkerson 2002; Insall 1982; Kannus et al 1994; Milgrom 1991; Thomee et al 1999; Witvrouw et al 2000). Other symptoms reported with PFPS include clicking, locking or giving way in the knee (Devereaux et al 1984).

The cause of PFPS is unknown and many theories have been developed to try to explain the cause of pain (Naslund; Naslund, Odenbring; Lundeberg 2006). The associated anatomical factors attributed to the occurrence of PFPS include an increased Q-angle, genu valgum, femoral anteversion, vastus medialis oblique/vastus lateralis
strength and firing ratio, illiotibial band tightness, hip flexibility, foot alignment, patellar alignment, patellar subluxation, instability, tibial torsion, and quadriceps and hamstring tightness (Thomee et al 1999; Zappala, Taffe, Scuderi 1992; Witvrouw et al 2000; Kannus et al 1994). Witvrouw et al (2000) found that decreased flexibility in the quadriceps and a decrease in functional test performance, such as vertical jump, are also associated with the occurrence of PFPS. It has been suggested that this is because of the pain; however it is unclear if this is the cause of pain or the result of it. Increased loading on the patellofemoral joint during exercise has been claimed to cause the malalignment or could be caused by muscle imbalances (Fulkerson 2002). Tissue homeostasis, the most stable condition for tissues, has also been theorized as a cause for PFPS (Dye et al 1994). With a greater load applied than the patellar tissue can support, the disruption to homeostasis can cause an increase in the sensitivity of the patella resulting in pain (Dye et al 1994). The multiple theories and lack of substantial evidence about the cause of PFPS make diagnosis difficult.

Despite the moderately high incidence of PFPS, minimal research has been published showing a predisposition to this pathology through clinical measures (Kannus et al 1994; Powers 1998; Witvrouw et al 2000; Thomee et al 1999; Zappala et al 1992). More evidence is needed on the reliability of clinical measures used to assess a patient for possible pre-disposition towards PFPS. This research is needed to establish possible prevention of the condition as well as treatment when it does occur.
Overview of Anatomy

Knee

The anatomy of the knee joint is a large factor in the discussion of PFPS because of the effects of malalignment of the patella as well as the effects that the musculature can have if it is weak or inflexible. The knee is made up of two joints, the tibiofemoral joint and the patellofemoral joint. The patellofemoral joint consists of the femur, tibia and the patella, the largest sesamoid bone in the body (Blackburn, Craig 1980). The patella rests in the anterior portion of the knee and tracks through the femoral sulcus throughout knee extension (Blackburn et al 1980).

The patella acts to protect the anterior portion of the knee as well as acts an as extensor mechanism for the quadriceps increasing the mechanical advantage and allowing for greater force generation with knee extension (Blackburn et al 1980). The quadriceps connects with the patella through the quadriceps tendon, superiorly, which continues around the patella and becomes the patellar ligament, which inserts on the tibial tuberosity (Blackburn et al 1980). The muscular insertions on the patella include the rectus femoris, vastus intermedius, vastus lateralis, vastus medialis longus, and the vastus medialis obliquus. These muscles aid in the stabilization of the patella as well as in the tracking of the patella through the femoral sulcus (Blackburn et al 1980).

Other structures present in the knee include the infrapatellar fat pad, prepatellar bursa, infrapatellar bursa and other various bursae throughout the medial, lateral and anterior portions of the knee (Blackburn et al 1980). The fat pad acts to protect the knee during kneeling while the bursae lubricate the joint throughout its range of motion (Blackburn et al 1980). The synovial membrane surrounds the knee and develops from
three separate pouches. The seams of the membrane are known as plicae and tend to be inconsistent in nature (Blackburn et al 1980). The synovial membrane is the largest in the body and gains needed support from the articularis genu during knee movements (Blackburn et al 1980). The anatomy of the knee generates its function and could possibly lead to its pathologies.

Hip

Hip anatomy as it relates to the knee is important to the discussion of patellofemoral pain syndrome because abnormal structures at the hip change the forces and alignments at the knee. Many muscles that act at the knee also cross the hip joint, making the two joints very closely linked (Blackburn et al 1980). On the anterior side, the rectus femoris flexes the hip as well as extends the knee (Blackburn et al 1980; Stone, Stone 2009) while the sartorius flexes, abducts, and laterally rotates the thigh and medially rotates the lower leg after knee flexion (Stone et al 2009). The quadriceps as a group also acts to decelerate the forward motion of the femur on the tibia during movement (McLeod, Hunter 1980). The iliopsoas muscle group acts to flex the hip. Though it does not have any direct action with the knee, it can lead to pathologies more distally (Stone et al 2009).

The hamstring muscles, biceps femoris, semitendinosus, and semimembranosus also cross the hip and knee joints (Stone et al 2009). Together these muscles flex the knee and extend the thigh, while the semitendinosus and semimembranosus also act to medially rotate the leg (Stone et al 2009). Laterally, the tensor fascia latae and iliotibial band flex the hip and abduct the thigh (Stone et al 2009). The iliotibial band and the
biceps femoris insert at Gerdy's tubercle, stabilizing the lateral portion of the knee joint (Blackburn et al 1980).

The medial structure of the hip that affects the knee joint directly is the gracilis. It inserts on the pes anserine and acts to adduct the thigh and flex the knee. Other medial structures at the hip include pectineus, adductor longus, adductor brevis, and adductor magnus, which all adduct the thigh while also performing other minor actions to produce fluid hip movement (Stone et al 2009). While these structures don’t directly affect the knee, their forces on the femur can change the mechanics at the knee, leading to pathologies such as patellofemoral pain syndrome. It is important to understand the anatomy of the hip and the effects that alterations to that anatomy can have on the more distal joints, such as the patellofemoral joint. The anatomy of the knee and hip can be key in discovering the cause behind pathologies in these joints, especially PFPS.

**Hip Range of Motion**

It is necessary to consider range of motion at the hip when evaluating knee pain because of the link in the kinetic chain. In many articles discussing PFPS the authors discuss the importance in assessing range of motion or muscle tightness (Corkery, Briscoe, Ciccone, Foglia, Johnson, Kinsman, Legere, Lum, Canavan 2007; de Weijer, Gorniak, Shamus 2003; Gajdosik, Lusin 1983; Marshall, Johanson, Wickiewicz, Tischler, Koslin, Zeno, Meyers 1980; Molloy, Robertson 2008; Piva, Goodnite, Childs 2005; Piva, Fitzgerald, Irrgang, Jones, Hando, Browder, Childs 2006; Post 1999; Rakos, Shaw, Fedor, LaManna, Yocum, Lawrence 2001; Smith, Stroud, McQueen 1991; Witvrouw, Lysens, Bellemans, Cambier, Vanderstraeten 2000). Some researchers mention the
importance of hip range of motion in passing while others look in depth at the various ranges of motion and the reliability of the methods used. The ranges of motion and alignments at the hip observed most frequently related to PFPS include hamstring length (Lesher, Sutlive, Miller, Chine, Garber, Wainner 2006; Piva et al 2005; Piva et al 2006; Post 1999; Smith et al 1991; Thomee, Renstrom, Karlsson, Grimby 1995a; Thomee 1997), iliopsoas length (Lesher et al 2006; Smith et al 1991; Thomee et al 1995a; Thomee 1997), iliotibial band/tensor fascia latae length (ITB/TFL) (Lesher et al 2006; Piva et al 2005; Piva et al 2006; Post 1999; Smith et al 1991), and hip anteversion (Lesher et al 2006; Piva et al 2006; Post 1999).

Hamstring length must be considered when assessing a subject for PFPS. A study by Piva et al (2005) showed significantly less hamstring range of motion flexibility in subjects with PFPS when compared to healthy controls. Similarly, Smith et al (1991) found that elite adolescent figure skaters with PFPS had decreased hamstring range of motion. No difference was seen among similar groups of an athletic population in a study by Witvrouw et al (2000). Piva et al (2005) found no significant difference between subjects with PFPS and healthy controls for ITB/TFL length, however Hudson et al (2003) found that painful knees with PFPS have a decreased range of motion when compared with healthy controls. Ober's test should be used in assessment of PFPS because of its dynamic and passive role in the patellofemoral joint (Hudson, Darthuy 2008). No other hip range of motion measures have been compared between cohorts of PFPS subjects and healthy controls. Multiple methods have been used in assessing each range of motion about the hip; this review of literature is necessary to determine which method is most valid and reliable.
Hamstring Length

Several procedures have been published for the measurements of hamstring length. These include methods for a standing toe touch (Marshall et al 1980), passive straight leg raise (Piva et al 2005; Piva et al 2006; Smith et al 1991; Witvrouw et al 2000), and two very similar tests: popliteal angle (Post et al 1999; Smith et al 1991) and active knee extension (Corkery et al 2007; de Weijer et al 2003; Gajdosik et al 1983; Rakos et al 2001).

The standing toe touch described by Marshall et al (1980) uses two methods of hamstring length measurement. The first is called palms to the floor in which the subject gets as close to placing their hands on the floor as possible with their knees in full extension (Marshall et al 1980). The second method, termed hamstring flexibility, measures the angle of knee flexion with the subject’s palms flat on the floor (Marshall et al 1980). The author used a unique scoring system that gave points based on flexibility (Marshall et al 1980). These methods were used in the assessment of joint looseness as it related to the function of the subjects (Marshall et al 1980). No reliability of this method was provided and this is the only study in which it was used. The standing toe touch was found to be an invalid measure of hamstring length due to the lack of control for hip flexion and vertebral flexion, allowing movement in components not being assessed (Rakos et al 2001).

The passive straight leg raise, performed with the subject supine with the contralateral leg fully extended, was used as a measure of hamstring length in several studies (Piva et al 2005; Piva et al 2006; Smith et al 1991; Witvrouw et al 2000). Using this method, a study showed that there were significant differences between healthy
controls and subjects with PFPS (Piva et al 2005). Good reliability has been reported for this method of assessment (ICC = 0.82-.96, CI 95%) (Piva et al 2006). Although this method is reliable, a study using cinematographic analysis of the passive straight leg raise showed that it is not valid (Bohannon 1982). The study showed that passive straight leg raise was not a valid measure because of the pelvic rotation that occurs during hip flexion, which increases the apparent range of motion for the hamstring. Due to this finding another method of determining hamstring range of motion needed to be developed.

The method of assessment for hamstring length that developed after the passive straight leg raise was shown to be invalid was the active knee extension (AKE) test, created by Gajdosik and Lusin in 1983. A similar test, the popliteal angle, uses the same subject position (Post 1999) but does not standardize the method to help insure reliability. For the AKE the subject is supine with the contralateral lower extremity fully extended and secured to the table. Placing a strap over the both anterior superior iliac spines stabilizes the hips. The subject is assisted in placing their test hip into 90° of flexion, confirmed by a goniometer. A bar is then placed against the distal anterior thigh to aid in maintaining hip position. The test knee is relaxed in flexion with the ankle in plantar flexion. From this position the subject actively extends the knee until the hamstrings prevent further movement while maintaining contact between the subject’s thigh and the bar. The subject is instructed not to force the leg past the point of initial resistance. When initial resistance is felt the angle at the knee is measured using a goniometer (Gajdosik 1983). To date reliability of this method is an ICC of 0.99 (Gajdosik 1983). Lesher et al (2006) used this method in the development of a clinical prediction rule
related to a predisposition of subjects with PFPS that would react well to patellar taping. This same technique has not been used in other studies directly related to PFPS, but has been used to gather normative values for college-age individuals (Corkery et al 2007), inter-rater reliability studies of school-aged children (Rakos et al 2001), and in looking at the effects of static stretch on hamstring flexibility (de Weijer et al 2003). In the latter study a digital inclinometer was used; however no reliability was tested. The digital inclinometer gave exact readings so discrepancies between raters using goniometers would be reduced (de Weijer et al 2003).

**Iliopsoas Length**

Only one method has been used in the literature to measure iliopsoas length, the Thomas test or the modified Thomas test, the names of which have been used synonymously in the literature (Clapis, Mercik, Davis 2008; Corkery et al 2007; Harvey 1998; Lesher et al 2006; Peeler, Anderson 2008; Smith et al 1991). In the original Thomas test, the subject lays supine on a table and holds the uninvolved knee to their chest with their hands (Clapis et al 2008). The involved leg is relaxed at the knee and ankle joints (Corkery et al 2007). A positive test is when the involved thigh cannot rest on the table (Clapis et al 2008). The modified Thomas test has similar positioning, however the subject’s involved leg hangs on the end of the table (Clapis et al 2008, Corkery et al 2007, Peeler et al 2008). If there is an inability for the involved hip to extend past neutral it is indicative of positive test citing iliopsoas tightness (Clapis et al 2008).

Other range of motion measurements can be taken using the Thomas test, also called the Kendall test, including the quadriceps and ITB/TFL (Clapis et al 2008; Harvey
1998; Peeler et al 2008). Reliability for this test has been reported as ICC values of 0.91-
0.94 for intra-rater reliability. Inter-rater reliability has been reported as 0.86-0.92
(Clapis et al 2008). Lesher et al (2006) used the Thomas test for iliopsoas length in
creating a clinical prediction rule for PFPS patients that would respond to patellar taping.
No other literature has utilized this measure in the assessment of PFPS.

*Iliotibial Band/Tensor Fascia Latae*

Assessment of the flexibility in the ITB/TFL has been seen frequently in the
literature relating to PFPS, using Ober’s test or modified Ober’s test (Fulkerson 2002;
Hudson et al 2008; Lesher et al 2006; Piva et al 2005; Piva et al 2006; Post 1999;
Puniello 1993). In Ober’s test, the subject is side-lying with the lower leg flexed at the
hip and knee to aid in stability and eliminate lumbar lordosis (Hudson et al 2008; Ober
1936; Puniello 1993). The upper leg is flexed to 90° at the knee with the examiner
lightly holding the ankle with one hand and stabilizing the pelvis with the other. The
upper leg is abducted and extended so the leg remains in line with the body (Hudson et al
2008; Puniello 1993). The leg is then allowed to fall towards the ground (Hudson et al
2008; Ober 1936; Puniello 1993). The range of motion can be assessed visually by
estimating if the leg is above or below horizontal (Hudson et al 2008; Ober 1936; Post
1999) or by an inclinometer (Hudson et al 2008; Piva et al 2005; Piva et al 2006; Reese,
Bandy 2003). The use of the inclinometer provides more objective data and could affect
the reliability of the test but no values are currently available using this method.

The modified Ober’s test uses the same technique but keeps the test leg knee
extended (Gajdosik, Sandler, Marr 2003; Reese et al 2003). The knee being extended
places the IT band in a stretched position, changing the range of motion at the hip
Reliability of the original Ober’s test has been reported with ICC values of 0.93-0.98 (Piva et al 2006) and 0.90 (Reese et al 2003). Reliability for modified Ober’s test has been reported with ICC values of 0.91 (Reese et al 2003). While no reliability data is available for Ober’s test with respect to patellofemoral pain syndrome, one study found that 70% of subjects with PFPS had inflexible ITBs on their symptomatic legs (Puniello 1993). Literature relating Ober’s test to PFPS looks at the flexibility abnormalities at the hip (Fulkerson 2002; Hudson et al 2008; Lesher et al 2006; Piva et al 2005; Piva et al 2006; Post 1999; Puniello 1993).

Anteversion

Anteversion of the hip is most often measured using Craig’s test (Gross 1995; Lesher et al 2006; Jonson, Gross 1997; Nguyen, Shultz 2009; Piva et al 2006; Post 1999; Souza, Powers 2008). Anteversion measures the amount of rotation in the femoral neck, which can also be classified as retroversion (Gross 1995). The rotation of the femur can lead to a change in the patellofemoral alignment and increase the pressure of the patella during knee extension (Cheung, Ng 2007; Souza et al 2008). The subject is prone for Craig’s test, with the uninvolved leg extended and the test knee bent to 90°. The tester internally and externally rotates the hip while palpating the greater trochanter until it becomes most prominent laterally. The angle of the lower leg from true vertical is then measured using an inclinometer or standard goniometer (Nguyen et al 2009; Post 1999). Anteversion is normally recognized in the presence of an apparent internal rotation at the hip or an increased angle using Craig’s test and is generally more prominent in females than in males (Gross 1995; Nguyen et al 2009). Normative values for males have been reported as 9.2° for the right leg and 8.6° for the left leg (Nguyen et al 2009). Right and
left values for females are $15.4^\circ$ and $14.7^\circ$, respectively (Nguyen et al 2009). ICC values of .01-0.7 have been reported for hip anteversion using Craig’s test (Piva et al 2006). The researchers speculated that the low reliability could be due to difficulty in palpation of the most prominent position of greater trochanter (Piva et al 2006). Jonson et al (1997) also reported reliability of Craig’s test with ICC values of 0.85 for inter-rater and 0.94 for intra-rater reliability.

Piva et al (2006) examined Craig’s test due to its frequent use in the assessment of PFPS and because of the lack of information on reliability and measurement error in the literature. Post et al (1999) used Craig’s test in his study of the clinical evaluation of patients with PFPS because its abnormal values are often associated with PFPS, though no studies have proven this. However, Souza et al (2008) found no difference between subjects with PFPS and healthy controls with respect to hip anteversion when evaluating a predisposition for hip internal rotation while running. Lesher et al (2006) used Craig’s test in the development of a clinical prediction rule to assess patients that would respond best to patellar taping. Other articles that discuss Craig’s test use it for an overall lower quarter screening and are not specific to PFPS (Gross 1995; Jonson et al 1997).

**Knee Range of Motion**

It is important to look at the range of motion at the knee, more specifically knee flexion due to the association of inflexible quadriceps and PFPS (Creighton, Krauss, Kondratek, Huijbregts, Will 2007; Fulkerson 2002; Peeler, Anderson 2008; Piva et al 2005; Piva et al 2006; Smith et al 1991; Thomee et al 1995; Witvrouw et al 2000).
Additionally, when assessing knee flexion it is important to note whether the range of motion is limited by a stretch in the quadriceps or by knee pain (Post 1999).

**Quadriceps Length**

Much of the literature evaluating quadriceps length looks at knee flexion with the subject lying in a prone position (Creighton et al 2007; Fulkerson 2002; Lesher et al 2006; Piva et al 2005; Piva et al 2006; Post 1999; Witvrouw et al 2000). Three studies use different techniques; the first utilized the modified Thomas test (Corkery et al 2007), the second calculated the quadriceps-inhibited flexion angle (QFA) (Smith et al 1991), the third video-recorded the subjects in various positions and took measurements later using identified anatomical points (Thomee et al 1995). In the modified Thomas test, the subject is positioned as usual, however when he or she relax the involved leg he or she actively and maximally flexes the knee (Corkery et al 2007). The angle at the knee is then measured using a goniometer (Corkery et al 2007). The QFA is the difference between the angle of maximal knee flexion with the involved hip flexed to 80° and the angle of maximal knee flexion with the involved hip fully extended. A QFA greater than or equal to 10° indicates rectus femoris tightness (Smith et al 1991). Normative values for subjects with patellofemoral pain were 24 for females and 35 for males (Smith et al 1991). No details of the procedure are given and no references are used in the description of the test. Thomee et al (1995) made black spots on various anatomical landmarks to make them visible in the video recording. The subject was then recorded in several positions for later assessments. The methods in this article are difficult to understand and are not ideal for a clinical exam.
In prone quadriceps length measurements, sometimes referred to as Ely's Test, subject lays with both legs extended (Peeler et al 2008). The tester passively flexes the knee to a firm end feel watching for lumbar extension and anterior pelvic tilt. However in Ely's test, the subject actively flexes the knee (Peeler et al 2008). The angle of the knee is then measured by placing an inclinometer at the distal tibia (Piva et al 2005; Piva et al 2006) or by a goniometer (Creighton et al 2007). Witvrouw et al (2000) used the same basic position with the subject still prone, but recommends that the uninvolved foot be placed on the floor with the hip in 90° of flexion to stabilize the pelvis. In the literature with the subjects prone, most authors assess passive knee flexion by measuring the angle at the knee (Creighton et al 2007; Piva et al 2005; Piva et al 2006; Witvrouw et al 2000). Normative values of knee angle were 145.4° and values for subjects with PFPS had a mean of 134° (Piva et al 2005). Witvrouw et al (2000) found numbers slightly lower; 132.21° for control and 124.62° for PFPS subjects. Post (1999) measured the distance from the heel to the buttocks due to the convenience, however he found that the angle of knee flexion is a more valid measure when assessing quadriceps length.

Fulkerson (2002) recommends measuring knee range of motion in the assessment of patients with PFPS but gives no details of the methods a clinician should utilize to measure it. Reliability for prone quadriceps length measures have been reported with ICC values of 0.8-0.96 (Piva et al 2006). As stated earlier, most literature describing evaluation of quadriceps length does so because of the association of decreased flexibility in patients with PFPS.
Visual Observation

Research has been conducted comparing visual observations to goniometric or inclinometric measurement of various ranges of motion including rectus femoris flexibility, finger range of motion, hip ranges of motion, and ranges of motion at the knee (Holm, Bolstad, Lutken, Ervik, Rokkum, Steen 2000; Peeler et al 2008a; Peeler et al 2008b; Rose, Nduka, Pereira, Pickford, Belcher 2002; Watkins, Riddle, Lamb, Personius 1991). Often times, clinicians will use a visual estimate instead of using a goniometer or inclinometer for a measurement because it saves times and is simple to do. In these cases, the clinician is looking for a major change in range or motion, not a change of a few degrees (Peeler et al 2008; Rose et al 2002; Watkins et al 1991). Unfortunately, reliability of all the ranges of motion has not been established for visual estimates, so more research is needed to determine if this is a reasonable method of measurement (Rose et al 2002). Rose et al (2002) compared goniometric measurements to visual observations made by 71 volunteers ranging from orthopedic surgeons to consultants; the volunteers visually estimated the metacarpophalangeal and interphalangeal joints post surgery. A computer-based goniometer was then used to determine the true joint positions. The statistics were reported in percent error with a mean of 25% for all fingers and raters (Rose et al 2002). Holm et al (2000) used four teams to gather reliability information on hip range of motion measurements; three of the teams measured range of motion using goniometers while team four made visual estimates. The Pearson's correlation between the goniometric measurement and visual observation was 0.8 for hip flexion and 0.88 for total hip motion (Holm et al 2000). The passive knee flexion and extension observations were made at the examiners' own discretion and had no criteria
for scoring (Watkins et al 1991). Intraclass correlation coefficient (1,1) analysis was performed and found that for visual observations using the same position 0.85 and 0.83 reliability was achieved while 0.8 and 0.82 reliability was achieved using different methods of assessment for flexion and extension, respectively (Watkins et al 1991).

Other research uses a pass/fail method for visual observations in comparison with goniometric or inclinometric measurements (Peeler et al 2008a; Peeler et al 2008b). Knee range of motion was evaluated in each of the studies using various methods: Ely’s test and modified Thomas test. Ely’s test had the subject perform active knee flexion from a prone position; a pass was if the hip remained stationary against the exam table and a fail was if the hip flexed, raising the anterior hip off the table (Peeler et al 2008a). For the modified Thomas test, a pass was if the test knee remained at 90° and a fail was if the test knee moved into extension beyond 90° while the hips remained in a stationary position with the opposite thigh to the chest (Peeler et al 2008b). Similar statistics were utilized for both studies including interclass correlation coefficients and Kappa statistics. When comparing the goniometric measurements to visual observations the study for Ely’s test found a mean Kappa score of 0.46 for visual observations and ICC (2,1) value of 0.66 for goniometric measurements (Peeler et al 2008a). The study looking at modified Thomas test found results of mean visual observation Kappa statistic of 0.33 and mean goniometric results ICC (2,1) value of 0.50 (Peeler et al 2008b).

Though all of the aforementioned research uses different methods and has different criteria for their visual observations, they all agree that they are less time-consuming than goniometric measurements and can be very useful to clinicians (Holm et al 2000; Peeler et al 2008a; Peeler et al 2008b; Rose et al 2002; Watkins et al 1991). If
visual observations are to be used in place of true measurements then it is important that they be reliable and have results similar to those measurements.

Treatment

Treatment for PFPS includes a broad range of methods including conservative non-surgical treatments such as taping/bracing and rehabilitation and more aggressive surgical treatments like lateral release. There is no consensus on the best method of rehabilitation or treatment for PFPS; results in the literature are conflicting and more evidence is needed.

Taping/Bracing

Taping/bracing is often used in the treatment of patients with PFPS in an attempt to relieve pain by correcting malalignments (Crossley et al 2002; Herrington 2006; Molloy et al 2008; Powers 1998; Thomee et al 1999). The taping is often used in conjunction with rehabilitation but can be used during activities of daily living for pain reduction (Powers 1998; Thomee et al 1999). Herrington (2006) used MRI to evaluate the change in patellar positioning at multiple knee flexion angles when a medial glide taping was applied and found that there was a significant reduction in lateral patella displacement at all joint angles. There are mixed results of the effects of patellar taping in the literature, though more positive articles have been found (Powers 1998; Thomee et al 1999). There is no data in the current literature detailing the predictors in patients with PFPS that will respond well to patellar taping and a trial and error approach is recommended (Crossley et al 2002).
Rehabilitation

Conservative therapy for PFPS generally includes strengthening of the musculature around the knee, balance and proprioceptive training, stretching of the structures around the knee, endurance and a progression to functional activity with gradual increases in load (Creighton et al. 2007; Crossley et al. 2002; Fulkerson 2002; Powers 1998; Thomee 1997; Thomee et al. 1999; Zappala et al. 1992). More specifically, strengthening of the knee extensor mechanism is the most used treatment because it is thought to decrease the load on the patella throughout extension of the knee (Creighton et al. 2007; Insall 1982; Powers 1998; Thomee 1997; Thomee et al. 1999; Zappala et al. 1992). Special emphasis on strengthening the VMO has been recommended due to the theory of patella malalignment due to weak musculature (Crossley et al. 2002; Molloy et al. 2008; Powers 1998; Zappala et al. 1992). Stretching and mobilization of all structures surrounding the knee have been suggested to help increase flexibility and decrease pain (Creighton et al. 2007; Fulkerson 2002; Molloy et al. 2008). Since tightness around the hip and knee are considered to be possible causes of PFPS, stretching the musculature could be a reasonable treatment (Witvrouw et al. 2000). There is no standard treatment for PFPS and rehabilitation should be individualized for each patient for better results (Fulkerson 2002).

Surgical Treatment

Non-surgical treatment is always preferred over surgical treatment. However in the case of failed conservative treatment, a more aggressive approach is warranted (Insall 1982; Thomee et al. 1999). The most frequently used procedures include patella realignment, most commonly resulting in lateral retinacular release (Fulkerson 2002;
Insall 1982; Kolowich et al 1990; Thomee et al 1999). Other surgical techniques include proximal realignment, distal realignment, alteration to the tibial tubercle (elevation or transfer), cartilage alterations, and as a last resort, patellectomy (Fulkerson 2002; Insall 1982; Thomee et al 1999). Patients with lateral patellar compression syndrome with a negative patellar tilt, a medial or lateral patellar glide of two quadrants or less, and a normal tubercle-sulcus angle have been recommended for surgery due to positive post-surgical results (Kolowich et al 1990). Surgical treatment is not always successful in the management of PFPS and aggressive rehabilitation should be attempted (Kolowich et al 1990).

Reliability

Reliability is the ability of a test, in this case a physical examination, to be reproduced under the same conditions multiple times (Domholdt 2005). Reliability can be divided between one rater (intra-examiner), more than one rater (inter-examiner), one session (intra-session) or more than one session (inter-session). Consequences of unreliable data related to physical exams can include ineffective treatments, inaccurate diagnoses, and false impressions about pain and symptoms (Fitzgerald, McClure 1995). Reliability can be determined using a variety of statistics, usually variations of intraclass correlation coefficients (ICC), used for interval data. Generally, when looking at interrater reliability, a sample of \( n \) subjects are each rated by \( k \) raters (Shrout, Fleiss 1979). Different types of studies need a different mathematical model to generate the required statistics; there are many parameters that determine which formula to use, such as number of raters, number of subjects, and generalizability of a study (Shrout et al
1979). A given data set can generate many ICC results so it is important that the proper formula is used in order to analyze the data correctly (Shrout et al 1979).

Kappa statistics are also used in reliability studies but deal with categorical data instead of interval data, though continuous data can be categorized into ordinal data in order for this statistic to be used (Sim, Wright 2005). The Kappa statistic looks at percent agreement between two examiners, inter-rater reliability, or for one examiner using two different measurements, intra-rater reliability, and takes chance into account; in other words it is a true agreement (Sim et al 2005). Though Kappa statistics do account for chance, they do not determine the cause of disagreement between examiners’ ratings; the data should be analyzed to determine the causes of disagreement (Sim et al 2005).

There are different types of methods to gathering information about reliability: in-person measurements (Denegar et al 2006) or measurements off photos, video recordings or diagnostic imaging (Thomee et al 1995; Thomee 1997). In-person measurements are more commonly used in the literature, especially in regards to clinical tests (Fitzgerald et al 1995; Harvey 1998; Jonson et al 1997; Piva et al 2006; Rakos et al 2001; Reese et al 2003; Sim et al 2005; Watson et al 2001). Reliability is an important part of clinical research and running the right statistic to determine the reliability is key to successful research.

Summary

PFPS is a common condition that is not well understood. Many factors are associated with PFPS including inflexible musculature and patella malalignment. Range of motion at the hip, hamstring length, iliopsoas length, ITB/TFL length, and anteversion,
are important factors that could predispose an individual to PFPS. Knee flexion, looking at quadriceps length, is also a necessary evaluation in the assessment of PFPS for possible pathologies of the extensor mechanisms. Visual observation of the tests associated with PFPS are common among clinicians, so correlation values on how they compare to established measurements needs to be determined. The reliability of these visual observations also needs to be assessed. Reliability of each of these assessments is important in order to gather information on validity for diagnosis of PFPS and possible treatments.

In order to gather this information, it is necessary to establish the reliability of the active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility test, and Craig’s test for with the examiners for this study. It is also necessary to concurrently assess the reliability of the visual observations of each of these tests between examiners. Once these values have been established, the correlation between the interval measurements, gathered using an inclinometer, and the visual observation can be obtained thus deciding if a visual estimate of range of motion is enough during the assessment of PFPS. This knowledge could be used to decrease the time for an evaluation as well as aid in the construction of a rehabilitation protocol.
CHAPTER III

METHODOLOGY

Design

We required the subjects to come in for two sessions of 25 assessment measures related to function and anatomical alignment and be assessed each session by two examiners. We examined inter-examiner, intra-examiner and inter-session interval data reliability for five of the 25 measures and compared observational measures and interval measurements of each test for intra-examiner and inter-examiner correlation.

Subjects

The subjects were twenty healthy college-aged volunteers (7 males, 13 females; age = 22.75 ± 1.59 years; ht = 171.45 ± 11.59 cm; wt = 73.32 ± 16.34 kg) recruited through undergraduate exercise science classes at a university. Participants were included in the study if they were healthy individuals over the age of 18 with no musculoskeletal pathologies in the last three months and who had been cleared for all other pathologies. Exclusion criteria included abnormal neurological status (i.e. numbness, tingling, etc.), prior lower extremity or back surgery, systemic disease, or neurological disease. Only the dominant leg was tested with leg dominance established by asking subjects with which leg they would kick a ball furthest. Each subject was instructed about the procedures and was given the option to participate. No activities outside the research study were controlled. Each subject signed an informed consent document that was approved by the institutional review board.
Instrumentation

The instruments used in this study included a standard 60" flexible tape measure, digital inclinometer (Philips Podiatric Medical Center, Great Falls, MT), goniometer (standard 6 inch goniometer), a bubble level attached to a piece of cork board, a washable marker, and a stabilization apparatus to ensure hip angles. The stabilization apparatus was constructed from 2” PVC with two cross bars for stabilization.

Examiners

Two novice (certified within the year before testing) certified athletic trainers (ATC) in a postgraduate masters athletic training program served as examiners for this research. The examiners graduated in the same year from two different CAATE accredited undergraduate athletic training programs. Prior to this study, the examiners had minimal knowledge of the tests, any exposure during the examiners’ education as well as during clinical experience. Each examiner went through a training procedure consisting of reading a manual and practicing each assessment measure. Practice sessions for examiners included two hours on each of five days for a total of 10 hours with different sets of volunteers each day. The tests were practiced in the ordered that was used during testing.

Procedures

The subject’s height, weight, age, gender, and activity level were taken and recorded on the subject demographic form. The dominant leg length was measured and
recorded by the first examiner using three methods: anterior superior iliac spine to medial malleolus, greater trochanter of the femur to lateral malleolus, and medial joint line of the knee to medial malleolus. The first examiner then drew four lines on their extremity with washable marker at the following points: 2” proximal to the talar dome, 2” proximal to the superior pole of the patella, 2” proximal to the lateral joint line of the knee on the lateral thigh, and 4” proximal from the inferior border of the lateral malleolus. The subject then proceeded through the measurements with each examiner in a random rotation. The included assessments in the order of measurement, based on patient positioning, were active knee extension test, Thomas test, Ober’s test, rectus femoris flexibility, and Craig’s test. The visual observation was taken once, prior to the interval measurements, which were each taken three times. For the visual observation of each test, the tester would place the subject in the test position and then decide if the subject was flexible, neutral, or inflexible using existing knowledge perception and no specific value guidelines.

Hamstring Range of Motion

The hamstring range of motion was measured using the active knee extension test (ICC = 0.99) (Figure 1 and Figure 2) (Corkery et al 2007; Gajdosik 1983; Lesher et al 2006). During the test the subject was supine with the contralateral lower extremity fully extended. The subject was assisted in placing the hip of their test limb into 90° of flexion (confirmed by a goniometer) against the stabilizing device. The subject was instructed to keep their thigh against the device during each trial of this test. The test knee was relaxed in flexion with the ankle in plantar flexion. From this position the subject actively extended the knee until the hamstrings prevented further movement while maintaining
contact with the table with the contralateral thigh. The subject was instructed not to force the leg past the point of initial resistance. The examiner then visually observed the angle at the knee and classified hamstring flexibility as positive (inflexible), neutral (normal), or negative (flexible). At this point the inclinometer was placed on the line two inches proximal to the talar dome and the angle at the knee was measured from horizontal (Gajdosik 1983). This measure was then repeated two more times.

*Iliopsoas Range of Motion*

Iliopsoas range of motion was measured using the Thomas test (Figure 3 and Figure 4) (Corkery et al 2007; Harvey 1998; Lesher et al 2006; Smith et al 1991). For this test the subject sat at the end of the table and then rolled back, bringing both knees tight to their chest, held by their arms, to ensure that the lumbar spine was flat and the pelvis was tilted posteriorly. The contralateral leg was maintained against the chest, held by both arms with no elbow flexion, while the test leg was slowly lowered towards the floor in a relaxed position to the point of initial stretch. The subject was instructed to not force more motion at the hip. The examiner then visually observed the angle of the thigh from horizontal and classified iliopsoas flexibility as positive (inflexible), neutral (normal), or negative (flexible). At that time the angle of hip from horizontal was measured by placing the inclinometer on the line two inches proximal to the superior pole of the patella (Harvey 1998). Positive numbers were considered above horizontal and negative numbers were considered below horizontal. Reliability of the Thomas test has previously been reported with ICC values from 0.91-0.94 (Harvey 1998).

*Iliotibial Band/Tensor Fascia Latae*
Ober’s test was used to assess the range of motion in the iliotibial band and tensor fascia lata (ITB/TFL) (Figure 5, Figure 6, and Figure 7) (Ober 1936; Piva et al 2005; Piva et al 2006; Post 1999; Reese et al 2003; Smith et al 1991). The subject was side-lying with the uninvolved leg against the table and flexed at the hip and knee to aid in stability and eliminate lumbar lordosis. A bubble inclinometer was placed on the line four inches proximal to the lateral malleolus with double-sided tape to ensure the lower leg was level for the starting point of the test. The test leg was flexed to 90° at the knee with the examiner lightly holding the ankle with one hand and stabilizing the pelvis with the other. The upper leg was then abducted and extended so the thigh was in line with the body. The leg was then allowed to fall towards the ground. The examiner visually observed the angle of the thigh from horizontal and classified iliotibial band/tensor fascia lata flexibility as positive (inflexible), neutral (normal), or negative (flexible). The inclinometer was then placed on the line two inches proximal to the lateral joint line of the knee and the amount of hip abduction was measured from horizontal (Ober 1936). Positive numbers were considered above horizontal (abducted) and negative numbers were considered below horizontal (adducted). Piva et al (2006) reported ICC values of 0.93-0.98 for Ober’s test.

*Knee Range of Motion*

The range of motion of the knee was measured by prone passive knee flexion (Figure 8 and Figure 9) (Creighton et al 2007; Piva et al 2005; Piva et al 2006; Post 1999). The subject was prone with both legs extended. The examiner then passively flexed the knee by placing a hand at the ankle and pushed to a firm end feel as she observed lumbar extension and anterior pelvic tilt. If any lumbar extension or anterior...
pelvic tilt was observed, the examiner reduced the angle at the knee until the pelvis was in a neutral position again. The examiner visually observed the angle at the knee and classified rectus femoris flexibility as positive (inflexible), neutral (normal), or negative (flexible). The angle of the knee was then measured by placing an inclinometer on the line two inches proximal to the talar dome (Piva et al 2005; Piva et al 2006). The angle was measured from horizontal. Reliability for knee angle measure with prone passive knee flexion has been reported with ICC values of 0.80-0.96 (Piva et al 2006).

**Hip Anteversion**

Hip anteversion was measured using Craig’s test (Figure 10 and Figure 11) (Gross 1995; Piva et al 2006; Post 1999). The subject was prone with the contralateral leg extended. The examiner gently pulled on both ankles and positioned both legs on the table to achieve a natural hip angle. The test knee was bent to 90 degrees and the examiner internally and externally rotated the hip while palpating the greater trochanter until it was most prominent laterally. The examiner visually observed the angle of the lower leg from vertical and classified anteversion as positive (medial), neutral (normal), or negative (lateral). The angle of the lower leg from vertical was then measured using the inclinometer placed on the line four inches proximal to the lateral malleolus (Post 1999). Positive values were considered lateral and negative values were considered medial from vertical. ICC values of 0.10-0.70 have been reported for hip anteversion using Craig’s test (Piva et al 2006).

The subjects returned for a second session of assessment following the same procedures as the first session with a minimum of 24 hours between the sessions. The order of examiners during testing was randomized for each session.
Statistical Analysis

Statistical Package for the Social Sciences (SPSS) Version 16.0 for Mac was used for reliability analysis of the interval measurement data and determined the intra-examiner reliability using intraclass correlation coefficient (ICC) analysis (3,1) for consistency. Inter-examiner reliability was determined using ICC analysis (2,k). Inter-examiner reliability of the observational data was determined using Kappa analysis. After reliability was established, Kappa values were used to determine the consistency between observational values and interval measurements for each test. If a Kappa statistic could not be determined, percent agreement was used.
Figure 1: Hip flexion for Active Knee Extension Test
Figure 2: Measurement of Active Knee Extension Test
Figure 3: Start position for Thomas Test
Figure 4: Measurement position for Thomas Test
Figure 5: Start position for Ober’s Test with level placement
Figure 6: Neutral position before Ober's Test
Figure 7: Measurement position for Ober's Test
Figure 8: Starting position for Rectus Femoris Flexibility Test
Figure 9: Measurement position for Rectus Femoris Flexibility Test
Figure 10: Starting position for Craig's Test
Figure 11: Measurement of Craig’s Test
CHAPTER IV
RESULTS

Kappa correlations and ICC values were calculated for all tests, however percent agreement had to be calculated when not all the categories had subjects placed in them in either the visual observation or interval measurement.

Active Knee Extension Test

Intra-examiner ICCs (3,1) for AKE for examiners one and two were 0.943 and 0.838, respectively. An ICC (2,k) value of 0.921 was found for inter-examiner reliability, while inter-session reliability resulted in an ICC (2,k) value of 0.909. Kappa, percent agreement and average scores for the AKE are located in Table 1.

Thomas Test

Intra-examiner ICCs (3,1) for the Thomas test for examiners one and two were 0.763 and 0.887, respectively. The inter-examiner ICCs (2,k) was 0.911, while an ICC (2,k) value of 0.916 was found for inter-session reliability. Other results for the Thomas test, including Kappa, percent agreement and average scores, can be found in Table 2.

Ober’s Test

Intra-examiner ICCs (3,1) for Ober’s test for examiners one and two were 0.481 and 0.670, respectively. Inter-examiner and inter-session reliability using ICC (2,k) resulted in values of 0.225 and 0.621, respectively. Kappa, percent agreement and average scores can be found in Table 3 for Ober’s test.

Rectus Femoris Flexibility Test

Intra-examiner ICCs (3,1) for the rectus femoris flexibility test for examiners one and two were 0.743 and 0.815, respectively. The inter-examiner ICC (2,k) was 0.657,
while an ICC (2, k) value of 0.902 was found for inter-session reliability. Rectus femoris flexibility test Kappa, percent agreement and average score results can be found in Table 4.

Craig’s Test

Intra-examiner ICCs (3,1) for Craig’s test for examiners one and two were 0.758 and 0.533, respectively. The inter-examiner ICC (2, k) was -0.909, while an ICC (2, k) value of 0.694 was found for inter-session reliability. Other results for Craig’s test, including Kappa, percent agreement and average scores, can be found in Table 5.
Table 1: Correlation Results for the Active Knee Extension Test

<table>
<thead>
<tr>
<th></th>
<th>Inflexible</th>
<th>Neutral</th>
<th>Flexible</th>
<th>% Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examiner 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>13</td>
<td>6</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Examiner 2&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>1</td>
<td>19</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Interexaminer&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td>-</td>
<td></td>
<td>0.341</td>
<td>-</td>
</tr>
<tr>
<td>Range of Motion Categories&lt;sup&gt;e&lt;/sup&gt;</td>
<td>&lt;15</td>
<td>15-45</td>
<td>&gt;45</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Raw Data: Mean (SD)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>-</td>
<td>42.5(±0)</td>
<td>66.98(±10.36)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a</sup> Number of subjects placed in each classification based on visual estimate by Examiner 1.

<sup>b</sup> Number of subjects placed in each classification based on the interval values and the determined categories.

<sup>c</sup> Number of subjects placed in each classification based on visual estimate by Examiner 2.

<sup>d</sup> Kappa correlation value between visual observations of the two examiners.

<sup>e</sup> Classification categories by degrees of range of motion.

<sup>f</sup> Means of interval results of the two examiners.

<sup>g</sup> Percent agreement between categorical classifications of interval data and classifications of visual observations for each examiner.
Table 2: Correlation Results for the Thomas Test

<table>
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<th>Inflexible</th>
<th>Neutral</th>
<th>Flexible</th>
<th>% Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examiner 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4</td>
<td>15</td>
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<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>-</td>
<td>19</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Examiner 2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2</td>
<td>12</td>
<td>6</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td>-</td>
<td>19</td>
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<td>-</td>
</tr>
<tr>
<td>Interexaminer&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-</td>
<td></td>
<td></td>
<td>-</td>
<td>0.126</td>
</tr>
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</table>

| Range of Motion Categories<sup>e</sup> | >5 | 1-5 | <1 | - | - |
| Raw Data: Mean (SD)<sup>f</sup>      | -2.5 (±0) | - | -26.55 (±8.65) | - | - |

<sup>a</sup> Number of subjects placed in each classification based on visual estimate by Examiner 1.

<sup>b</sup> Number of subjects placed in each classification based on the interval values and the determined categories.

<sup>c</sup> Number of subjects placed in each classification based on visual estimate by Examiner 2.

<sup>d</sup> Kappa correlation value between visual observations of the two examiners.

<sup>e</sup> Classification categories by degrees of range of motion.

<sup>f</sup> Means of interval results of the two examiners.

<sup>g</sup> Percent agreement between categorical classifications of interval data and classifications of visual observations for each examiner.
Table 3: Correlation Results for Ober's Test

<table>
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<tr>
<th></th>
<th>Inflexible</th>
<th>Neutral</th>
<th>Flexible</th>
<th>% Agreement&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Kappa</th>
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<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>8</td>
<td>12</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Examiner 2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5</td>
<td>14</td>
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<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>9</td>
<td>11</td>
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<td></td>
</tr>
<tr>
<td>Interexaminer&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>-</td>
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<td>0.127</td>
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<th>&gt;25</th>
<th>10-25</th>
<th>&lt;10</th>
<th>-</th>
<th>-</th>
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</thead>
<tbody>
<tr>
<td>Raw Data: Mean (SD)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>-</td>
<td>10.61(±2.08)</td>
<td>0.933(±6.13)</td>
<td>-</td>
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</table>

<sup>a</sup> Number of subjects placed in each classification based on visual estimate by Examiner 1.

<sup>b</sup> Number of subjects placed in each classification based on the interval values and the determined categories.

<sup>c</sup> Number of subjects placed in each classification based on visual estimate by Examiner 2.

<sup>d</sup> Kappa correlation value between visual observations of the two examiners.

<sup>e</sup> Classification categories by degrees of range of motion.

<sup>f</sup> Means of interval results of the two examiners.

<sup>g</sup> Percent agreement between categorical classifications of interval data and classifications of visual observations for each examiner.
Table 4: Correlation Results for the Rectus Femoris Flexibility Test

<table>
<thead>
<tr>
<th></th>
<th>Inflexible</th>
<th>Neutral</th>
<th>Flexible</th>
<th>% Agreement</th>
<th>Kappa</th>
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<td>Examiner 1&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
</tr>
<tr>
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<td>9</td>
<td>7</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>8</td>
<td>12</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Interexaminer&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td></td>
<td>50</td>
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<td>&lt;25</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Raw Data: Mean (SD)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>54.51(±6.91)</td>
<td>42.03(±1.80)</td>
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</table>

<sup>a</sup> Number of subjects placed in each classification based on visual estimate by Examiner 1.

<sup>b</sup> Number of subjects placed in each classification based on the interval values and the determined categories.

<sup>c</sup> Number of subjects placed in each classification based on visual estimate by Examiner 2.

<sup>d</sup> Kappa correlation value between visual observations of the two examiners.

<sup>e</sup> Classification categories by degrees of range of motion.

<sup>f</sup> Means of interval results of the two examiners.

<sup>g</sup> Percent agreement between categorical classifications of interval data and classifications of visual observations for each examiner.
<table>
<thead>
<tr>
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<th>Medial</th>
<th>% Agreement&lt;sup&gt;b&lt;/sup&gt;</th>
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<tr>
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<td>11</td>
<td>9</td>
<td>-</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Examiner 2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2</td>
<td>17</td>
<td>1</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Categorical&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4</td>
<td>15</td>
<td>1</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Interexaminer&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-</td>
<td></td>
<td></td>
<td>80</td>
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</tr>
</tbody>
</table>

**Range of Motion Categories<sup>e</sup>**

<table>
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<tr>
<th></th>
<th>&lt;5</th>
<th>5-25</th>
<th>&gt;20</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Data: Mean (SD)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>-0.458±1.53</td>
<td>9.02±2.56</td>
<td>-</td>
<td>-</td>
<td></td>
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</tbody>
</table>

<sup>a</sup> Number of subjects placed in each classification based on visual estimate by Examiner 1.

<sup>b</sup> Number of subjects placed in each classification based on the interval values and the determined categories.

<sup>c</sup> Number of subjects placed in each classification based on visual estimate by Examiner 2.

<sup>d</sup> Kappa correlation value between visual observations of the two examiners.

<sup>e</sup> Classification categories by degrees of range of motion.

<sup>f</sup> Means of interval results of the two examiners.

<sup>g</sup> Percent agreement between categorical classifications of interval data and classifications of visual observations for each examiner.
CHAPTER V
DISCUSSION AND CONCLUSIONS

Clinicians often utilize the categorical method of classification for range of motion to expedite evaluations and findings, therefore understanding the relationship of these findings is essential. We chose to examine the relationship between visual observation measures and clinical interval measures for five common tests that are utilized for assessment of patellofemoral conditions. We did not delve into the validity of these tests, so no conclusions may be drawn about diagnostic accuracy. We conducted this study from a clinical perspective, based solely on the knowledge that the clinicians held prior to the study concerning the involved tests. Because of this approach, no guidelines were given for the categories during the visual estimates so as not to orient the examiners to the normative values for each test. The examiners were asked to place each subject into one of three categories for each of the tests automatically decreasing the Kappa value that could be achieved because the data is spread across a larger range. Some studies use categories of pass or fail (Peeler et al 2008a; Peeler et al 2008b) while ours used a 3-step approach. Reliability interpretation values for both intraclass correlation coefficients and Kappa statistics have been suggested as less than 0.0 as poor, 0-0.2 as slight, 0.21-0.4 as fair, 0.41-0.6 as moderate, 0.61-0.8 as substantial and 0.81-1.0 as almost perfect (Landis, Koch 1977).

There are commonalities that affected the results of all of the tests, including examiner experience, body composition, choice of subjects for the study and order of testing. The examiners were novice athletic trainers with less than one year of clinical experience at the time of data collection. The examiners have limited experience
measuring range of motion and alignment and even less experience observing the assessments visually, which may have affected the results of our study for all five assessments.

The body composition of the subjects may have affected the measurement by altering the angle of the inclinometer during testing. The largest differences would be seen with subjects that have large muscles, such as quadriceps, which would come into account during the Thomas test or Ober's test. Large calf muscles could affect the angle of the inclinometer during Craig's test and a large anterior tibialis muscle could affect placement of the inclinometer during the AKE or rectus femoris flexibility test. Similar to muscle, excess fatty tissue could also change the angle of measurement of the inclinometer for all five assessments in our study.

There was limited variability in our study across each test, possibly because all of the subjects were healthy, college age individuals who were at least recreationally active. Although activity level was not a part of the inclusion criteria, all twenty subjects reported that they were active, adding to the similarities between them. Because the subjects were so much alike, it decreased the variability of the data reducing the values that we could obtain. None of the tests had subjects in every category, both placed by each examiner as well as categorized based on the measured range or motion or alignment. A larger variability between the subjects, such as though that may be seen when assessing patients with PFPS, may positively impact the result if this study were repeated.

Although the subjects were randomly assigned to the examiners for both sessions, the order of the tests was the same each time. There were three trials of each assessment,
which may have gently stretched the muscles during the first examiner’s measurements, altering the results for the second examiner during that session. This may also have had some affect between the trials for each examiner. The subjects may have been slightly tense at the beginning of testing and relaxed as the testing procedures continued, which could also affect the results. These were possibilities for all the tests, though more specific factors affected each test individually.

*Active Knee Extension Test*

We found good reliability (ICC 0.838-0.943) for the AKE. Others have reported reliability values as 0.95 (de Weijer et al 2003), 0.99 (Gajdosik et al 1983), and 0.79 (Rakos et al 2001). Comparison of the categorical visual observations to the interval values obtained with the inclinometer demonstrated that intra-examiner agreement was fair for both examiner one and examiner two, however when comparing the visual observations of the two examiners, the inter-examiner correlation was fair with a Kappa value of 0.341.

These fair results could be ascribed to a comparison between the straight leg raise (SLR), more commonly used in the clinical setting, and the AKE. Generally, the AKE is not taught within educational programs as the assessment test for hamstring length and is not found in the common textbooks used by these programs. However, the AKE has been reported as a more valid test compared to the SLR because it controls pelvic motion allowing for a more accurate assessment of hamstring flexibility (Bohannon 1982; Gajdosik et al 1983; Rakos et al 2001). Reliability for the SLR has been reported with an ICC of 0.92 (Piva et al 2006). Because the SLR is generally taught as the method to use when testing hamstring flexibility and is commonly used in the clinical setting,
examiners may have been oriented to what is normally considered to be flexible, inflexible, or average. However when using the AKE for hamstring assessment, the hip is already placed at 90°, resulting in a smaller angle of flexibility compared to the SLR. Normal values for the SLR are 79.1±11.5 degrees for subjects with PFPS and 88.6±10.5 degrees for healthy subjects (Piva et al 2005), while normative values for the AKE are 26.8±13.3 degrees (Corkery et al 2007). Holm et al (2000) examined hip range of motion, including hip flexion measured by hamstring length, in patients with osteoarthritis by comparing goniometric measurements to visual estimates. Although they only reported the correlation between the goniometric measurement and visual estimates in hip flexion (0.80) and hip range of motion (0.88) as a whole, their results were good. Percent agreement was also reported with results of 0.83 and 0.77 for hip flexion and overall hip motion, respectively.

Most of the participants were in the flexible category (95%) with the rest of the subjects falling into the neutral category (5%) (Table I). Based on the above comparison of the SLR and AKE, the mindset of the clinician for the SLR to expect larger angles for hamstring range of motion, could affect the observations of the examiners. While the results of the correlation between a visual observation and an interval measurement using the AKE are fair, the visual observation could be clinically useful in determining whether or not there is a normal amount of hamstring flexibility in a patient. If only two categories had been used during the visual observation, inflexible/flexible, the examiners might have been more successful, increasing the percent agreement/Kappa, thus showing that visual observations are a reasonable method for range of motion assessment with this technique.
Thomas Test

Our reliability for the Thomas test was similar to that reported in other research (Clapis et al 2008; Harvey 1998; Peeler et al 2008b). We found ICC values ranging from 0.763 to 0.916 whereas others report ICC values of 0.86 to 0.92 (Clapis et al 2008), 0.91 to 0.94 (Harvey 1998), and 0.55 to 0.76 (Peeler et al 2008b). Clapis et al (2008) found that the Thomas test is reliable using either a goniometer or an inclinometer as a measuring device. The percent agreement between inclinometric measurements and visual estimates in our study was slightly higher for examiner one than for examiner two. The correlation between the visual estimates of the two examiners was slight.

We found no research comparing visual estimates of the Thomas test to goniometric or inclinometric measurements testing for iliopsoas flexibility. Peeler and Anderson (2008b) used a pass/fail method of comparing visual estimates to goniometric measurements using the Thomas test to assess rectus femoris flexibility and found fair to moderate reliability (intrarater chance-corrected k statistic = 0.30-0.54). Placement of the goniometer may have an effect on the outcome values within this measurement. We used an inclinometer placed two inches above the superior pole of the patella. The assessment angle could be altered because during this test the skin may move over bony landmarks, changing the intended positioning of the inclinometer, altering the measurement. The visual appearance of the leg to the examiner wouldn’t change, however the angle of measure could be different, decreasing the correlation between the two measures.

Most of our participants were categorized as flexible (95%), with the remainder in the inflexible category (5%). The categories were only separated by a few degrees, making placement into the accurate category difficult for the examiners, potentially
resulting in low correlation. A study using similar methods, through using pass or fail categories may result in higher correlations making the visual estimates a more reliable method of assessment.

Ober’s Test

Our reliability for Ober’s test was fair to moderate, while other researchers have reported good intra-examiner reliability with ICC values of 0.92 (Gajdosik et al 2003), and 0.90 (Reese et al 2003) and with ICC inter-examiner reliability of 0.97 (Piva et al 2006). Goniometers and inclinometers were used by Reese et al (2003) to obtain these reliability results, indicating that either method is reliable. Examiner one had slightly higher agreement between visual estimate and the interval measurements for Ober’s test than examiner two. The Kappa value was found to be slight for the correlation between the two examiners for the visual estimates.

When using a goniometer or inclinometer, placement of the device is an important factor in the results. We placed the inclinometer two inches proximal to the lateral joint-line of the knee on the lateral side of the thigh. This was marked while the subject was relaxed and the alterations of the subject position could change because of skin movement over other landmarks, altering the results of Ober’s test. Movement either more proximally or distally as well as anteriorly or posteriorly could increase or decrease the measured angle, decreasing the reliability of the test. Ober’s test is used to assess excessive tightness in the iliotibial band and tensor fascia latae complex associated with many conditions of both the hip and knee (Cibere et al 2008; Fulkerson 2002; Hudson et al 2008; Khaund et al 2005; Ober 1936; Piva et al 2005; Piva et al 2006; Post 1999; Puniello et al 1993; Reese et al 2003). Because the iliotibial band/tensor fascia latae has
many functions including hip abduction and assists in hip flexion as well has involvement in knee flexion, accurately performing Ober’s test is difficult (Ober 1936; Reese et al 2003). In reference to PFPS, Ober’s is an important assessment because of the pull that the ITB exerts on the lateral patella (Hudson et al 2008).

Our categories for Ober’s test again were not vastly different, with only 15 degrees accounting for the neutral category. All of the subjects were found to be either neutral (43%) or flexible, with slightly more being classified as flexible (57%). The average measurement in the neutral category (10.61) was very close to the minimum range for the inflexible category suggesting that the difference between inflexible and neutral was very difficult for the examiners to see. As with the Thomas test, pass or fail categories in a study similar to this one may yield results showing that visual estimates are a reliable method of assessment.

Rectus Femoris Flexibility Test

Our high reliability findings are supported by other researchers who reported intra-examiner ICC values between 0.5 and 0.83 (Peeler et al 2008a) and an inter-examiner value of 0.91 (Piva et al 2006). Piva et al (2006) also used passive knee flexion, while Peeler and Anderson (2008a) used active knee flexion. Examiner one had a poor Kappa correlation when comparing the visual estimate and the inclinometric measurements. Examiner two had fair agreement between the visual estimate and interval measurements. Between the visual estimates of the two examiners moderate agreement was found.

Peeler and Anderson (2008a) also compared a visual estimate, with a pass or fail categorization, to the goniometric measurement. The pass and fail criterion was based on
pelvic movement instead of knee flexion angle as we assessed. Their Kappa values for the visual estimates to other visual estimates were moderate and ranged from 0.46 to 0.62, but they did not compare the goniometric measure to the visual observation making it difficult to compare the two studies. This test is important to the clinician because an inflexible rectus femoris muscle could alter how the patella sits in the femoral groove during rest and tracks through the groove during knee extension leading to PFPS (Powers 1998).

Participants were categorized as neutral (42%), with the rest categorized as flexible (Table 4) by examiner one while examiner two had subjects categorized as neutral (43%) and the rest were inflexible (Table 4). The neutral subjects had an average of 42.03, just below the maximum range in that category. This makes it difficult for the examiners to make the distinction between the two categories, especially without any criteria to guide them.

Craig's Test

Our reliability results for Craig's test covered a wide range and were only moderate. Reliability ICC values for inter-examiner was substantial while intra-examiner averaged 0.758. These findings are consistent with previous research, as other research has shown ICC values for inter-examiner reliability of 0.45 (Piva et al 2006) to 0.85, with intra-examiner reliability of 0.94 (Jonson et al 1997). The correlation results comparing the inclinometric measurements to the visual estimates were moderate and found to be 70% and 35% for examiner one and examiner two, respectively, and was 80% for the visual observations between the two examiners. Because the reliability of Craig's test is not high, the raw data from this study may also be poor.
Researchers have not compared the use of an inclinometer to the use of a goniometer, but both methods have been used and have had similar reliability (Jonson et al 1997; Piva et al 2006). This is a difficult test to perform accurately because the leg must be moved into the measurement position while palpating the greater trochanter, however the greater trochanter cannot be palpated while the measurement is taken unless more than one examiner aids in the measurement (Gross 1995; Jonson et al 1997; Piva et al 2006). It is difficult to maintain the lower leg in the position found so it is likely that minor movements could alter the results of Craig’s test.

Our study utilized two of the three categories in all but one subject. The majority of subjects were found to be neutral, though a few were placed in the inflexible category. Based on this knowledge, it is reasonable to assume that using two categories would automatically increase the moderate results by increasing the agreement between examiners as well as between the visual estimates and the interval data. Visual observations could be a reasonable method with which to assess femoral torsion using the technique from Craig’s test. Craig’s test is an important test for clinicians because femoral anteversion changes the way the femur aligns with the tibia and how the patella tracks through the femoral groove during knee movements and could lead to PFPS. However, this may not be the most effective way to obtain this measure due to the low consistency of the assessment.

Conclusions

Overall, the correlation between the visual observations and interval measurements was poor to moderate, with the best results coming from the active knee
extension test and Craig’s test. The reliability of each test was found to reflect the reliability results reported in previous literature. These tests have all been associated with PFPS as they affect range of motion about the hip and knee, possibly altering knee kinematics either causing or caused by patellofemoral dysfunction. Previous studies comparing visual estimates to interval measurements, whether goniometric or inclinometric, have most often used a pass or fail method for visual observations and have had better results, though none related to PFPS directly. Further research should be conducted with the AKE, Thomas test, Ober’s test, rectus femoris flexibility, and Craig’s test, with a pass or fail system or giving the examiners category criterion to assess if this visual observation is a reasonable method of assessing range of motion. These tests have been associated with PFPS and knowing if a visual observation is a reliable method of measurement during evaluation is key to a successful diagnosis, since clinicians already visually assess the patients to save time. In conclusion, based on the results of this study, we do not recommend visual observations as a method of assessment of novice examiners.
References


PROJECT TITLE: Reliability of Clinical Measures Associated with Patellofemoral Pain Syndrome

INTRODUCTION:
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This research study will be conducted in the Clinical Outcomes Research Laboratory (CORL) of the Student Recreation Center, Room 2001.

RESEARCHERS:
Bonnie Van Lunen, Director, PhD, Responsible Project Investigator, Graduate Athletic Training Program, Old Dominion University, ESPER Department

Co-investigators:
Erin Hemerling, BS, Graduate Assistant, Old Dominion University, ESPER Department
Stephanie Kowell, BS, Graduate Assistant, Old Dominion University, ESPER Department
Dorice Hankemeier, BS, MS, Doctoral Student, Old Dominion University, ESPER Department
Ashley Canfield, BS, Graduate Assistant, Old Dominion University, ESPER Department
Crystal Nelson, BS, Graduate Assistant, Old Dominion University, ESPER Department

DESCRIPTION OF RESEARCH STUDY:
Several studies have been conducted looking into the reliability components of clinical measurements associated with patellofemoral pain syndrome that are performed by clinicians in the sports medicine field. There is a lack of consistency across the previous research regarding the reliability of these measures.

If you decide to participate, then you will join a study involving research of the reliability of clinical measurements associated with patellofemoral pain syndrome.
If you say YES, then your participation will last for two days over a one week period, consisting of two data collection sessions within the clinical outcomes research laboratory. No physical exam will be required prior to your participation in the study, however you will be asked for any pertinent orthopedic medical history. Basic demographic data (age, gender, mass, height) will be collected first. Secondly, you will rotate among three examiners during the testing session and several measurements will be taken. These measurements will consist of timed balance, one-legged reach, lunges, and step-downs over a 30-second time period. Additionally, various angles of the hip, knee, ankle and foot will be assessed in standing, seated and lying positions with a angle measurement device. These measurements will be taken three times. After the completion of all measurements, there will be a brief rest period. Following the rest period, the cycle of measurements will be repeated with a different tester. This process will be repeated until all three testers have performed the measurements. You will return one week later and the same measurement process will be repeated.

If you say YES, then your participation will last for a total of 4 hours over a one week period (2 hours per session). Approximately twenty healthy subjects with no current injuries will be participating in this study.

EXCLUSIONARY CRITERIA:
Although no physical exam is necessary prior to participation you are asked to report pertinent medical history. To the best of your knowledge, you should not have neurological conditions, prior lower extremity or back surgery, systemic disease, or neurological disease. If you currently have or previously have had any of the conditions listed you will be excluded from this study.

RISKS AND BENEFITS:
RISKS: Possible risks include delayed onset muscle soreness from unfamiliar activity, strain from over stretching, falling during functional activities or other activity related injuries. As in all research experiments, all possible risks have not yet been identified. The risks in this experiment are no different than one would experience at the beginning of a new exercise regimen that includes stretching.

BENEFITS: There are no benefits from your participation in this study. Clinicians will benefit from the knowledge provided from this study as to what clinical measurements are the most useful in the assessment of patellofemoral pain syndrome.

COSTS AND PAYMENTS:
The researchers want your decision about participating in this study to be absolutely voluntary. Yet they recognize that your participation may pose some inconvenience. The researchers are unable to give you any payment for participating in this study. A “research credit” can be given to subjects who
participate in the study, and those who choose not to participate will be offered an alternate form of research credit.

NEW INFORMATION:
If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY:
All information obtained about you in this study is strictly confidential unless disclosure is required by law. The results of this study may be used in reports, presentations and publications, but the researcher will not identify you.

WITHDRAWAL PRIVILEGE:
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY:
If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of harm arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in this research project, you may contact the investigators at the following phone numbers: Bonnie Van Lunen at 683-3516, or Dr. George Maihafer, the current IRB chair at 757.683.4520 at Old Dominion University, who will be glad to review the matter with you.

VOLUNTARY CONSENT:
By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Erin Hemerling 683-4995, Stephanie Kowell 683-4995, Dorice Hankemeier 683-4995, Crystal Nelson 683-4995, Ashley Canfield 683-4995, Bonnie Van Lunen 683-3516

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. George Maihafer, the
current IRB chair, at 757-683-4520, or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

<table>
<thead>
<tr>
<th>Subject's Printed Name &amp; Signature</th>
<th>Date</th>
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</table>

**INVESTIGATOR'S STATEMENT:**

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

<table>
<thead>
<tr>
<th>Investigator's Printed Name &amp; Signature</th>
<th>Date</th>
</tr>
</thead>
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APPENDIX B

DEMOGRAPHIC INFORMATION FORM
Demographic Information

Name ________________________________

Age _______ DOB ________________

Height _________________

Weight _________________

Activity Level
High (More than 10 hours/week)
Medium (2-10 hours/week)
Low (Less than 2 hours/week)

Leg Length:
ASIS to medial malleolus ________________________

Greater trochanter to lateral malleolus ________________

Joint line to medial malleolus _______________________

Inclinometer markings:
• 2” proximal to the talar dome
• 2” proximal to the superior pole of the patella
• 2” proximal to lateral joint line of the knee on the lateral side of the thigh
• 4” proximal from the inferior border of lateral malleolus
<table>
<thead>
<tr>
<th>Test Name</th>
<th>Visual Estimate</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
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<tbody>
<tr>
<td>Patellar Positioning: Med/Lat</td>
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<tr>
<td>Lateral Pull</td>
<td>+/-</td>
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<td>Craigs Test (Anteversion II)</td>
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<td>Pelvic Obliquity (deg and cm)</td>
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<td>Negative</td>
<td></td>
</tr>
</tbody>
</table>
VITA

Erin Joy Quada

Department of Study

Old Dominion University
Department of Human Movement Sciences
Student Recreation Center
Norfolk, VA 23529

Education

May 2010
Master of Science in Education
Athletic Training
Old Dominion University
Norfolk, Virginia

April 2008
Bachelor of Science
Athletic Training
Alma College
Alma, Michigan

Professional Experience

08/08-05/10
Old Dominion University; Norfolk, VA
Graduate Assistant Athletic Trainer
- Duties include prevention, recognition, care and rehabilitation of emergency, acute and chronic injuries and illnesses for the following teams specifically: Field Hockey, Men’s and Women’s Soccer, Men’s and Women’s Tennis, and Rowing.

08/09-12/09
Old Dominion University; Norfolk, VA
Co-Instructor: First Aid and CPR (HE 224, 3 credits)
- Created lesson plans, skill laboratories, assignments, examinations and practical examinations following the curriculum of the American Red Cross for the Emergency Response course; responsible for daily teaching and administration duties such as grading examinations and assignments and taking roll.