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"THE DAILY VARIABILITY OF PATELLOFEMORAL PAIN RELATED TO PHYSICAL ACTIVITY"

By
Jacqueline Elliott

In Partial Fulfillment
of the Requirements for the Degree of
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THE DAILY VARIABILITY OF PATELLO-FEMORAL PAIN RELATED TO PHYSICAL ACTIVITY

BY

JACQUELINE ELLIOTT

A Thesis/Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

ABSTRACT

In recent years the prevalency of patello-femoral pain syndrome (PFPS) has been reported by several authors to be on the rise, mainly due to the increased participation in sport and leisure activities by the general public. PFPS is described as a condition that exists between the undersurface of the patella and the distal aspect of the femur which may or may not involve soft tissue support structures. Many authors have hypothesized as to the cause of PFPS but none could confirm its precise etiology. Various research studies have investigated PFPS and focused on the pain aspect of the syndrome. Many of these studies conducted a test/re-test protocol while examining efficacy of various treatment regimes and therefore they lacked information on the variability of patello-femoral pain and its interaction with physical activity. Clinically therapists have often heard from their patients that this condition changes over time and is often dependent on the type of activity they engaged in. Therefore it was the intent of this study to investigate the daily variation of patello-femoral pain and its interactions with various types of physical activity.

Twenty-eight subjects (14 females and 14 males) suffering from patello-femoral pain were selected based on a physician's diagnosis of PFPS. Each subject completed a daily pain questionnaire, using a visual analogue scale and physical activity checklist, over a three week period. Data was analyzed and the study concluded that patello-femoral pain varies from subject to subject for different reasons. Patello-femoral pain varied significantly between different times in the day and specifically demonstrated a linear trend as the day progressed. Even though each subject demonstrated a fluctuation in patello-femoral pain over the twenty-one days, a statistically significant variation was not detected between subjects or from one day to the next. However, when the data was analyzed descriptively it was found that 64.3% of the subjects experienced large fluctuations in pain day-to-day while 35.7% experienced very little or no change in pain. Females experienced

significantly more patello-femoral pain than males. The between subject interactions for daily variability, time of day and gender did not yield significant results. The type of physical activity that subjects identified as the causal factor for patello-femoral pain was significant. Subject ranked sitting, walking, vigorous physical activity, stairs and squatting respectively, as the cause of their patello-femoral pain over the twenty-one days. Standing, lying, kneeling and running were less of a factor.

Overall the study concluded that patello-femoral pain does not significantly change from one day to the next but it does have clinical relevance. Therefore, it should not be utilized to measure treatment efficacy on a day-to-day basis until a larger sample population, over an extended period of time, can be studied. Pain does significantly differ depending on the time of day and therefore time of day for testing should be constant. There are significant gender differences and therefore future studies should be restricted to one gender or the other and because females had significantly higher levels of patello-femoral pain, they should receive closer attention in future studies.

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CHAPTER I

INTRODUCTION

There has been a rise in athletic participation over the past decade (Levine, 1979; Garrick, 1989). This observation can be largely attributed to the rising popularity of fitness programs and recreational activities in the country. In conjunction with this increased participation, prevalence of injuries to the knee joint has correspondingly increased, particularly in the patello-femoral joint (Levine, 1979; Eisele, 1991). Recent sophisticated diagnostic methods and treatments may also be responsible for the increased awareness of injuries to this particular joint (Levine, 1979;+ Tiberio, 1987; Eisele, 1991). Kramer (1986) stated that patello-femoral syndromes are common problems among active individuals and according to Fox (1975), disturbance of the patello-femoral mechanism is the most commonly encountered physical abnormality involving the knee. Powers, Maffucci and Hampton (1995) reported that patello-femoral pain accounted for approximately 25% of all diagnoses at their clinic. Levine (1979) and Outerbridge (1964) concurred with the above authors by stating that patello-femoral pain is common and that its incidence in the general population is as high as one in four, with this proportion increasing in the athletic population. Reid (1992) and Taunton, Clement, Smart and McNicol (1987) also reported that across all sports and ages, it is probably the single most common cause of pain.

Variant terms have been used to describe patello-femoral pain. Different authors described it in different ways. For example, this pain has been termed patellalgia (Percy & Strother, 1985), patello-femoral arthralgia (Pickett & Radin, 1983), retropatellar pain or anterior knee pain (Jacobson & Flandry, 1989), patellar malalignment syndrome (Kramer, 1986), extensor mechanism disorder (Grana & Kriegshauser, 1985), lateral facet syndrome (Johnson, 1989), excessive lateral pressure syndrome (Fulkerson & Hungerford, 1990) and patello-femoral pain syndrome (Wise, Feibert &Kates, 1984; Taunton, Clement, Smart & McNicol, 1987). The term chondromalacia patellae has also been utilized. This term, however, precludes the consideration of other possible sources of pain and therefore, most authors agree that it should be reserved for describing actual morphological softening of the articular cartilage (Fulkerson & Hungerford, 1990; Pickett & Radin, 1983). Today, the most commonly accepted term for this condition is patello-femoral pain syndrome (PFPS). For the purposes of this thesis, pain about the patello-femoral joint will be referred to as PFPS.

The principle symptom or complaint of PFPS is pain (Fulkerson & Hungerford, 1990). The pain is usually located in the retropatellar and peripatellar regions of the knee. It is usually elicited and/or exacerbated by activities such as running, descending and ascending stairs, squatting, kneeling and sitting for long periods of time with the knee flexed (Reid, 1992; Levine, 1979; Eisele, 1991; Garrick, 1989). Pain elicited through the latter activity has been referred to as movie theatre sign (Reid, 1992; Galea & Albers, 1994). Individuals with PFPS relate the degree of pain, at least in part, to the type and intensity of physical activity. Reid (1992) wrote that the symptom of pain is often proportional to the activity the individual engaged in.

The literature abounds with information relating to the etiology and treatment of patello-femoral pain syndrome. Despite this abundance of information, the precise etiology of patello-femoral pain is poorly understood. Currently there exists no convincing proof as to the exact etiology of this condition (Reid, 1992). It is however accepted that the syndrome may involve the patella itself or the peripatellar structures; subchondral bone, synovium, retinaculum or patellar venous system (Fulkerson & Hungerford, 1990; Pickett & Radin, 1983; Arnoldi, 1990; Waisbrod & Noam, 1980; Reid 1992). Other factors have also been linked to PFPS. For example, symptoms may be either related to changes in the patellar articular surface or occur as a result of tracking problems which place abnormal stresses on the joint surface or surrounding soft tissues. According to Micheli and Stanski (1981), malalignment and improper tracking can be caused by abnormalities in the patello-femoral joint configuration and/or soft tissue support structures of the lower extremity.

Patello-femoral pain can be measured through a variety of methods; pain charts, rating scales and questionnaires. In the past, the effect of treatment on patello-femoral pain was a test-retest design (Bergeron, 1992; Chesworth, Culham, Tata & Peat, 1989; Scott & Huskisson, 1976; Carlsson, 1983; Keale, 1948; Ohnhaus & Adler, 1975; Huskisson, 1974; Price & Harkins, 1987; Joyce, Zutshi, Hrubes & Mason, 1975). Pain measurements were not recorded for the time period in-between pre and post tests. These studies therefore, did not measure the daily variability of pain during the treatment program. When pain measurements are taken only before and after a treatment program, there is a chance that pain on those particular days is not representative of the pain the subjects usually experienced. In other words, the subjects could have had either a "good pain day" or a "bad pain day" on the two days their pain was assessed. This would therefore affect the results of those studies obtained. The majority of the studies also did not take into account the affect of physical activity on the subject's level of pain. Again, if the subject was particularly active on the day prior to testing, his or her pain levels may be higher than normal.

At the conclusion of his study, Bergeron (1992) recommended that patello-femoral pain be measured on a daily basis using a visual analogue scale (VAS). The author felt that because the pain appeared to vary day-to-day, depending of the individual's level of physical activity, daily recording of pain and the analysis of its change over time would provide a more accurate picture of patello-femoral pain. The day-to-day variability of patello-femoral pain may not be accurately reflected with the previously mentioned designs.

Statement of Problem

The purpose of this proposal is to evaluate the daily variability of patello-femoral pain in relation to the type of daily physical activity.

Null Hypotheses

In this proposal, three null hypotheses will be studied:

1. That patello-femoral pain will not vary day-to-day.
2. That patello-femoral pain will not vary between different times in a day.
3. That there is no relationship between patello-femoral pain and physical activity.

Rationale

The results of this study will contribute to the understanding of patello-femoral pain by changing the way in which it has been measured in the past. Patello-femoral pain was previously measured prior to and after treatment, with no pain measurements taken between tests. Therefore, patello-femoral pain may have been inaccurately portrayed or depicted. Many factors can alter pain; the intervention of a particular drug or rehabilitation program, the types of activities or sports engaged in and/or the individual's perception of pain. If these factors have a daily influence and if pain is to be accurately assessed, it may need to be measured on a daily basis.

Limitations and Assumptions

The sample population for this study is limited to male and female subjects between the ages of 16 and 35 years who are suffering from patello-femoral pain. The subjects will be included in the study only if they meet the inclusion and exclusion criteria. This study will not include a comparison group of normal subjects. The duration of the study was limited to 3 weeks. It was assumed that subjects would answer truthfully when they filled out the visual analogue scales and therefore limited to the reliance on the respondents to accurately report their patello-femoral pain and related activity.

CHAPTER 2

REVIEW OF LITERATURE

This chapter will review the recent literature pertaining to patello-femoral disorders. Anatomy of the patello-femoral joint will be described with particular attention on the articulating bones of the joint, its ligaments, muscles and neurovascular structures. This anatomical review will assist in understanding the normal configuration and biomechanics of the patello-femoral joint. Emphasis will be placed on patello-femoral contact areas and joint reaction forces during different positions of the knee joint as it relates to various types physcial activities. Insight and understanding into the probable causes and etiology of PFPS will be gained by discussing the abnormalities of the patello-femoral joint, the lower extremity and surrounding soft tissue structures. The signs, symptoms and etiology of PFPS as described by various authors and patients will be discussed. A section will briefly explain how PFPS ispresently treated.

The review of literature revealed various procedures/methods in which pain and physical activity could be measured; two authors in particular worked specfically on PF pain (Bergeron, 1992; Chesworth, Culham, Tata & Peat, 1989). This study will describe the methods used in the literature and will discuss their pros and cons.

NORMAL ANATOMY OF THE PATELLO-FEMORAL JOINT

Osseous Structures

The patello-femoral joint is formed by the articulation between the femoral trochlea at the distal end of the femur and the articular surface on the posterior aspect of the patella. This joint is structurally and functionally classified as a modified plane, synovial joint. It is a diarthrodial joint because it is comprised of articular cartilage, subchondral bone and synovium and is held together by a capsule and ligaments (Moore, 1985; Woodburne & Burkel, 1988).

Patella

The patella is a sesamoid bone located in the common tendon of the quadriceps muscle group. It is a triangular-shaped bone with a characteristically roughened anterior surface and a smooth posterior articular surface. The anterior surface is convex and vertically striated by the insertion of the quadricep tendon fibers. The base is located at the superior border of the patella. It is thick and gives attachment to the tendonous fibers of the rectus femoris muscle anteriorly and vasti intermedius muscle posteriorly. The lateral and medial borders are thinner than the base and they receive the tendonous fibers of vasti lateralis and medialis muscles respectively. The two borders converge below into a pointed apex (Figure 1). The apex gives attachment to the patellar tendon (Moore, 1985; Woodburne & Burkel, 1988).

The topographical profile of the posterior aspect of the patella is complex, reflecting its functional significance in the patello-femoral joint. The posterior surface is divided into two parts vertically. The superior three quarters is articular and the distal one quarter is non-articular (Ficat & Hungerford, 1977). The distal part is rough and has a porous appearance because of its vascular foramina (Figure 1). The articular surface is oval-shaped, smooth and is covered by hyaline articular cartilage (Moore, 1985; Woodburne & Burkel, 1988). According to Ficat and Hungerford (1977) and Cailliet (1983), the hyaline cartilage of the patella, in particular at the median ridge, is the thickest in the human body, measuring up to 4 or 5 millimeters.

The articular surface is divided into medial and lateral facets by a vertical ridge called the median ridge. The median ridge runs proximal to distal and forms the apex of the patella. The ridge also occupies the groove on the patellar surface of the femur (Moore, 1985, Ficat & Hungerford, 1977; Fulkerson & Hungerford, 1990). The size and the shape of the patellar facets can vary. Usually the lateral facet is larger than the medial. Ficat and Hungerford (1977) stated a ratio of lateral to medial facet size of approximately 2:1, while Minkoff and Fien (1989) reported a 1.4:1 ratio. The lateral facet is broad, deep and concave. The medial is thinner, shallower and slightly convex or flattened. The shape of the lateral facet, according to Grana and Kriegshauser (1985), is conducive to joint stability, while the convex shape of the medial facet is not. The concavity of the lateral facet leads to greater contact between the lateral femoral groove and the lateral patellar facet. The medial facet of the patella is further subdivided by a secondary ridge, creating the medial facet proper and the odd facet (Moore, 1985).

The Femur

The femur is broadened distally and articulates with the tibia to form the tibio-femoral joint. The femoral articular surfaces are two large oblong condyles which project posteriorly separated by a deep U-shaped intercondylar notch. The lateral femoral condyle is short and wide while the medial condyle is long and narrow. Theses condyles blend with each other anteriorly and with the body of the femur superiorly. Anteriorly, the femur presents an articulating surface called the trochlear surface (Figure 2). The trochlear surface has also been referred to as the patellar articular surface located above the femoral condyles (Moore, 1985; Woodburne & Burkel, 1988). This surface articulates with the posterior articular surface of the patella to form the patello-femoral joint. This trochlear surface has two well defined medial and lateral facets. The lateral facet extends further proximally and its ridge projects further anteriorly than the medial facet. The lateral ridge provides a bony buttress against lateral displacement of the patella. The shape created by the two femoral facets is referred to as the femoral groove or sulcus.

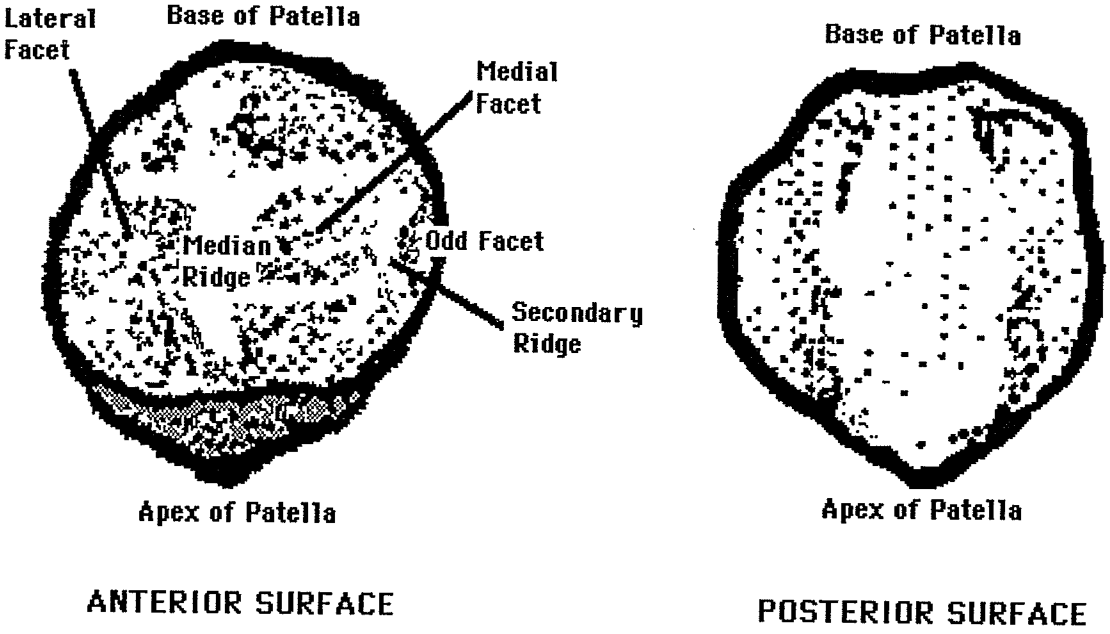

Figure 1. The patella; anterior surface on the left and the posterior surface on the right. Redrawn according to Moore (1985).

Articular cartilage covers the articulating surfaces of the femoral condyles and trochlear facets. The articular cartilage on the medial trochlear facet is thinner than that found on the lateral trochlear facet (Moore, 1985). The articular cartilage on the femoral trochlea is thinner than that found on the patella. Ficat and Hungerford (1977) reported that the thickness of the cartilage on the femoral facets measures approximately 2 to 3 millimeters as compared to the 4 to 5 millimeters on the patella.

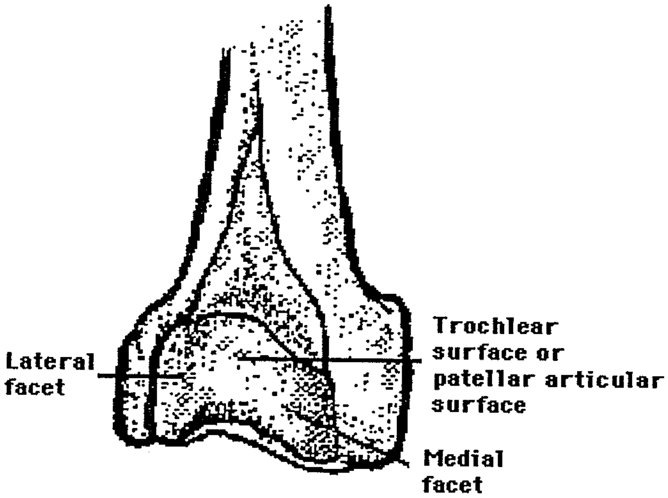

Figure 2. The anterior surface of the right femur, redrawn according to Woodburne and Burkel (1988).

Patello-femoral Joint Stabilizers

The stability, alignment and function of the patella is dependent on surrounding muscles, ligaments, retinaculum and aponeuroses. Terry (1989) described this stabilizing system as a "tent pole effect" where the patella is the center pole and the supporting structures are the guide ropes radiating out from the pole. The patella is stabilized by the quadriceps tendon proximally and the patellar tendon distally. Medially the patella is stabilized by the vastus medialis and vastus medialis oblique muscles, the medial retinaculum and the medial patello-femoral ligament. Laterally it is supported by the vastus lateralis muscle, lateral retinaculum and the lateral patello-femoral ligaments. The lateral condylar facet of the femur also stabilizes the patella by providing a boney buttress against lateral displacement. The proper tracking of the patella through the femoral groove is dependent upon these dynamic and static stabilizers (Paulos, Ruschek, Johnson & Noyes, 1980).

Dynamic Stabilizers

The dynamic stabilizers of the patello-femoral joint consist primarily of the quadriceps muscle group which is made up of four parts; rectus femoris (RF), vastus intermedius (VI), vastus medialis (VM) and vastus lateralis (VL) (Figure 3 & 4). Medial and lateral vastii muscles are further divided into vastus medialis oblique (VMO) and vastus lateralis oblique (VLO), respectively (Fulkerson, Hallisay & Schutzer, 1985; Bose & Kanagasuntheram & Osman, 1980). The primary function of the quadriceps group is to extend the leg at the knee joint and to stabilize the patella in the trochlear groove (Woodburne & Burkel, 1988, Terry 1989).

The quadriceps muscle group stabilizes the patella with three primary pull vectors; the pull of the RF and VI along the shaft of the femur and the medial and lateral pull of VM and VL, respectively (Fulkerson, 1989). According to Lieb and Perry (1968) the angle of pull for each muscle is calculated to be: RF is 7-10 ° medially; VI is zero because its angle of pull is parallel to that of the femur; VL is 12-15 ° laterally; VLO is approximately 45 ° for males and 39 ° for females, VM is 15-18 ° medially; VMO is 50-55 ° medially (Figure 3). These angles reflect the direction that the muscles insert into the patella and therefore the angle of pull they exert on the patello-femoral joint (Brunet & Stewart, 1989).

The RF muscle inserts on the proximal base of patella and its fibers extend distally over the patellar surface to the tibial tuberosity. The VI blends with the deep surface of RF and the other vasti muscles and inserts posteriorly onto the base of the patella (Ficat &

Hungerford, 1977; Moore, 1985). The VL inserts into the superolateral border of the patella, lateral tibial condyle and the lateral retinaculum. It is divided into two parts by a layer of connective tissue. The proximal two thirds inserts into the common quadriceps tendon while the distal third has its own laterally oriented attachment into the patella

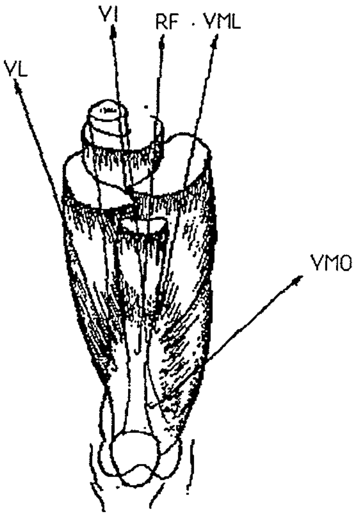

Figure 3. Cable muscle attachments were fastened to the tendons. Arrows indicate cable aligned along fiber-axes of different heads of the quadriceps (Lieb, et al 1968). VL=vastus lateralis, VM=vastus medialis, VI=vastus intermedius, VMO=vastus medialis oblique.

(Fulkerson et al, 1985; Johnson, 1989). The VM inserts into the tendon of RF, the superomedial patellar border, medial tibial condyle and the medial retinaculum. The VMO originates from the distal portion of the adductor magnus tendon, close to its insertion and inserts onto the medial margin of the patella. Its fibers are mostly horizontal and therefore they are in a unique position to stabilize the patella against lateral displacement in the later stages of knee extension (Bose et al, 1980; Bose, 1985). During flexion, the patella is buttressed by the lateral femoral condyle. In extension, however, the patella sits above the trochlear groove and is in an unstable position. The patella then relies on the VMO for stability. Lieb and Perry (1968) and Butterwick (1982) stated that the exclusive function of VMO is to maintain patellar alignment. As the quadriceps muscle contracts, the tendency is to laterally deviate the patella. The horizontal oriented fibers of VMO counteract this laterally displacement which, according to Paulos et al (1980), is the chief medial dynamic stabilizer of the patella. Bose (1985) stated that the VMO's origin was unique to humans and that it is likely a developmental adaptation to bipedal gait This idea was also described by Lieb and Perry (1968).

Static Stabilizers

Patello-femoral alignment is also maintained by static stabilizers. Static stabilization comes from the interrelationship between the bony and the connective tissue support structures. The connective tissues include the joint capsule, retinaculum and ligaments.

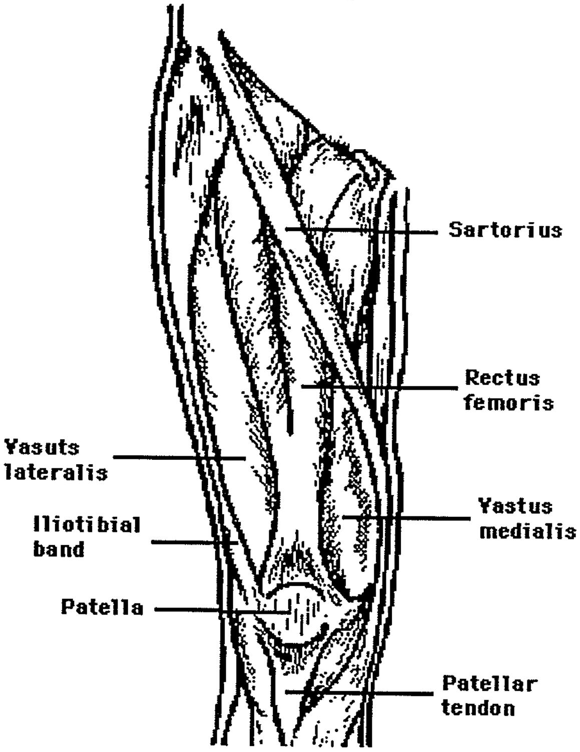

Figure 4. The muscles of the anterior thigh; quadriceps, sartorius and iliotibial band. Redrawn according to Woodburne and Burkel (1988).

Bony support of the patello-femoral joint comes from two areas. The lateral trochlear facet acts as a buttress against lateral patellar displacement because it is projected further anteriorly than the medial trochlear facet (Fox, 1975). The congruent fit of the patella within the femoral groove also provides support. Incongruent fit of the patella in the groove has been implicated as a probable cause of articular cartilage damage and subsequent cause of patello-femoral pain (Fulkerson & Hungerford, 1990; Ficat & Hungerford, 1977).

Retinacula are thickenings of the joint capsule (see Figure 5). They arise from the aponeurotic tendons of vastus medialis and lateralis muscles and attach to the medial and lateral borders of the patella. Distally and obliquely they extend down as far as the patellar tendon and the collateral ligaments. The retinacula also connect the patella to the lower part of the tibial condyles. They can be divided into medial/lateral and superior/inferior structures (Bergeron, 1992). Functionally, the retinacula restrict proximal and distal movement of the patella. They also keep the patella centered mediolaterally in the femoral groove.

Several ligaments of the patello-femoral joint were identified by Ficat and Hungerford (1977); medial and lateral patello-femoral, patello-tibial and patello-meniscal ligaments. Thickenings of the retinacula form the patello-femoral ligaments. Medial and lateral patello-femoral ligaments attach to each side of the patella and to the femoral epicondyles. The medial patello-femoral ligament is larger than the lateral. The patello-tibial ligament run from the patella to the tibial condyles and they function to counter balance the effect of the patello-femoral ligaments. According to Terry (1989) these ligaments are the main stabilizers of the patella distally (Figure 5). These ligaments act as guide wires and function to guide the patella through the femoral groove (James, 1979;

Ficat & Hungerford, 1979). The patello-meniscal ligaments arise from the anterior surface of the meniscus and insert on the distal part of the patella (Ficat & Hungerford, 1977).

The lateral retinaculum is comprised of superficial and deep fibers. The superficial fibers are oriented obliquely and they run from the iliotibial band (ITB) and blend with the quadriceps expansions over the patella (Fulkerson, 1989). According to Fulkerson (1989), these superficial fibers provide relatively little support to the patella. The deep fibers are separated into proximal and distal bands, the epicondylopatellar and deep transverse respectively. The deep fibers run from the ITB to the middle part of the patella (Figure 6). According to Fulkerson and Hungerford (1990) and Terry (1989), this particular band provides significant lateral support to the patella. This band is also known as the iliopatellar band (Terry, 1989). The fibers of this deep transverse band interdigitate with VL's insertion onto the patella. The proximal bulk of this band forms the lateral patello-femoral ligament (Fulkerson, 1989). Just distal to these deep fibers are more oblique fibers which run from the lateral patella to the tibia. These fibers make up the patellotibial component of the deep retinaculum.

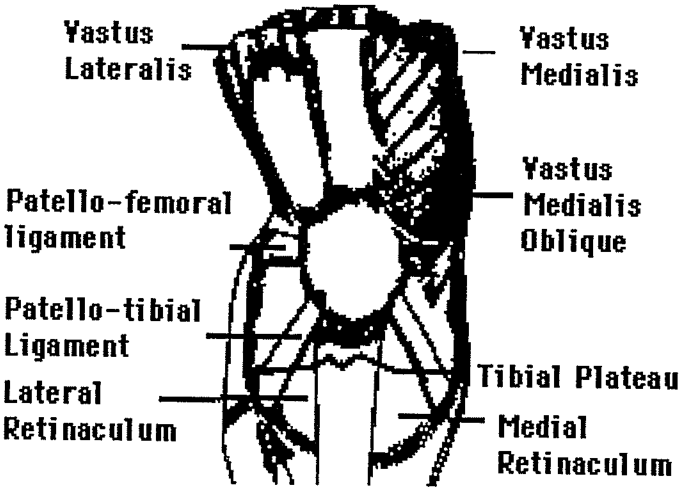

Figure 5. Static stabilizers of the patello-femoral joint. Redrawn according to Terry (1989).

The dynamic and static balance between the medial and lateral aspects of the patello-femoral joint must be maintained in order to control the movement of the patella through full range of knee motion (Brunet & Stewart, 1989). Terry (1989) summarized by saying that all structures of the patello-femoral joint are interrelated so that the forces of the lateral static stabilizers are balanced by the forces exerted by the medial dynamic stabilizers and the medial static stabilizers are balanced by lateral dynamic restraints. Percy and Strother (1985) stated that the balance between these structures is critical and that "any imbalances between these relationships and general skeletal alignment, influences patello-femoral rhythm and thus may lead to peripatellar pain" (p. 49).

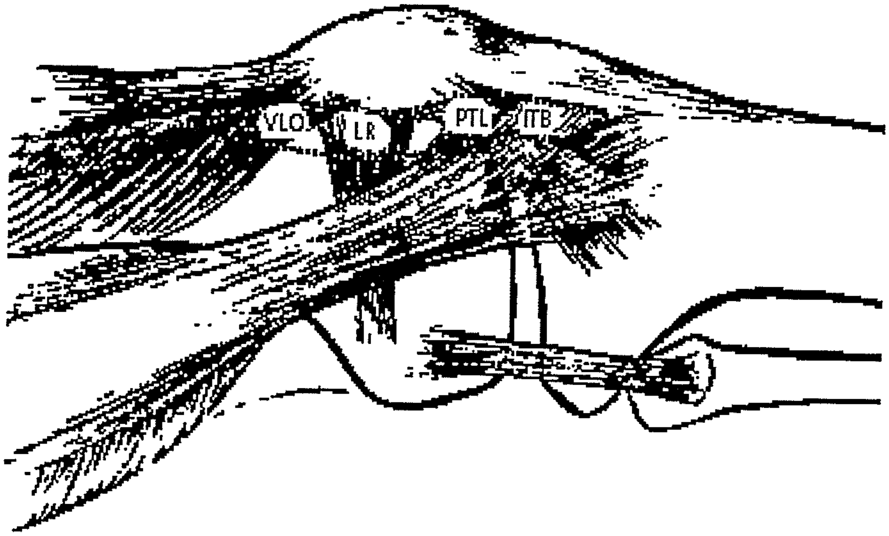

Figure 6. This semidiagramatic drawing of the lateral side of the knee redrawn according to Johnson (1989) shows the vastus lateralis, so-called because the oblique distal portion has its own separate attachment into the patella. The lateral retinaculum (LR) is shown here as a single restraint on the lateral side of the knee. PTL is the patellar lateral ligament. This was much more consistent than the patello-femoral ligament, which is not shown here. The anterior fibers of the iliotibial band (ITB) usually attach to the inferior pole of the patella and along the lateral margin of the patellar ligament.

Neurovascular Supply of the Patello-femoral Joint

Nerve Supply

The nerve supply to the entire knee joint comes from the articular branches of the tibial nerve. These articular branches are adjacent to the superior and inferior genicular arteries. The cutaneous distribution of the knee joint is supplied by the lateral femoral cutaneous, the anterior femoral cutaneous and the saphenous (a branch of the femoral nerve) nerves. These cutaneous nerves form a plexus around the patella. The articular cartilage of the patello-femoral joint is aneural (Moore, 1985; Bergeron, 1992).

The surrounding musculature of the patello-femoral joint is innervated by the following nerves; quadriceps by the femoral nerve (L2-L4), the adductors by the obturator nerve (L2-L4) and the hamstrings by the tibial division of the sciatic nerve (L4-L5 and S1-S3). The adductor magnus (hamstring portion), is innervated by the tibial division of the sciatic nerve (Moore, 1985).

Arterial Supply

Ficat and Hungerford (1977), Fulkerson and Hungerford (1990) and Clemente (1985) all state that the patello-femoral joint has a rich vascular supply. Six arteries make up the peripatellar ring; the supreme genicular (SG), the medial and lateral superior genicular (MSG : LSG), the medial and lateral inferior genicular (MIG : LIG), and the anterior tibial recurrent (ATR) (Figure 7). LaPrade and Noffsinger (1990) listed three additional arteries; the ascending parapatellar (APP), oblique prepatellar (OPP) and the transverse infrapatellar (TIP).

The supreme genicular artery is a branch of the descending genicular artery. The LSG, MSG LIG, and MIG are all branches of the popliteal artery which is derived from the femoral artery. The LSG supplies the superolateral part of the patella while the MSG and SG supply the superomedial border of the patella. The LIG and MIG arteries supply the inferior aspect of the patella and they anastomose with the two superior genicular arteries. The anterior tibial recurrent artery completes the peripatellar ring by supplying inferior pole of the patella. This artery is derived from a branch of the anterior tibial artery. The three arteries described by LaPrade and Noffsinger (1990) arise from the anastomotic branch from LSG and LIG arteries and send branches to the anterolateral aspect of the patella. Blood vessels enter the patella via the anterior vascular foramina on the middle third of the patella, the apex of the patella and a deep anatomoses posteriorly.

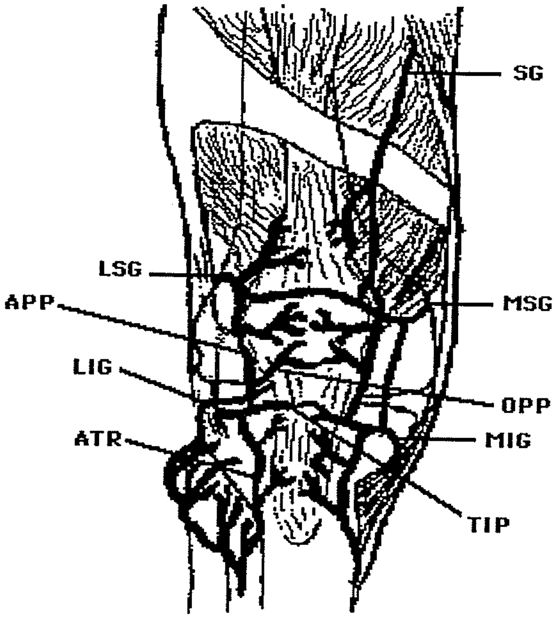

Figure 7. The blood supply of the patello-femoral joint. The arteries are; SG=supreme genicular, MSG=medial superior genicular, MIG=medial inferior genicular, LSG=lateral superior genicular, LIG=lateral inferior genicular, TIP=transverse infrapatellar, APP=ascending parapatellar, OPP= oblique parapatellar, ATR=anterior tibial recurrent. Redrawn according to Fulkerson and Hungerford (1990).

Venous Supply

The veins which supply the patella and patello-femoral joint follow and mirror the arterial system by creating a venous loop (Bergeron, 1992). This venous loop is drained primarily by the popliteal vein and secondarily by the saphenous veins (Moore, 1985, Fulkerson & Hungerford, 1990). According to Arnoldi (1991) and Waisbrod and Noam (1980), researchers who conducted studies on venous flow in the patella, slow or impaired venous drainage may be a probable cause of patello-femoral pain.

Articular Cartilage

The posterior articular surface of the patella and the anterior surface of the distal femur are both covered with hyaline articular cartilage. Articular cartilage is an avascular and aneural tissue. The cellular component of cartilage is made up of chondrocyte cells which are embedded in an extracellular matrix. According to Arnoczky and Torzilli (1984), the main components of cartilage and their general compositions are; collagen (10-15%), and a ground substance made up of protein polysaccharides (10-15%) and water (70-80%). Mow, Myers and Wirth (1982) have reported slightly different chemical compositions. The physical properties of articular cartilage make it a resilient, durable, strong and efficient weight-bearing and gliding surface. It is specifically designed to withstand high compressive and shear forces (Hunter & James, 1984). According to Mankin (1974), cartilage is well suited to its dual role as a shock absorber and a weight-bearing surface. The structure and composition of articular cartilage makes it permeable to synovial joint fluids and this permeability varies with the amount of compressive load imposed on the joint. These fluids are important in maintaining proper joint lubrication and cartilage nutrition.

Articular cartilage is arranged into four distinct zones; tangential, transitional, radial, and calcified (Arnoczky & Torzilli, 1984) (Figure 8). In the tangenital layer there is a layer of collagen fibers that are arranged in tight bundles oriented parallel the surface. This layer forms a protective skin over the articular cartilage and functions to reduce frictional forces by load diffusion (Bergeron, 1992; Arnoczky & Torzilli, 1984). In the transitional and radial zones, the collagen fibers are irregularly oriented except near the chondrocyte cells where they appear coiled around the cells. There are large spaces between the fibers. The fibers in this zone are larger than those found in the tangenital zone. These zones are said to act as areas of deformability and energy storage (Bergeron, 1992). The calcified zone is also known as the deep zone (James, 1979). The collagen fibers in this zone are oriented perpendicular to the subchondral bone. The fibers in this zone are tightly arranged and form a mesh network. The opposing cartilage and bony surfaces are irregularly shaped whose fit reinforces their attachment. This zone progressively creates an area of mechanical stiffness to withstand shearing forces (Mow et al, 1982). The radial and calcified zones are separated by a line called the tidemark. Hunter and James (1984) stated than this line may function as an anchor and/or spacer between the two zones.

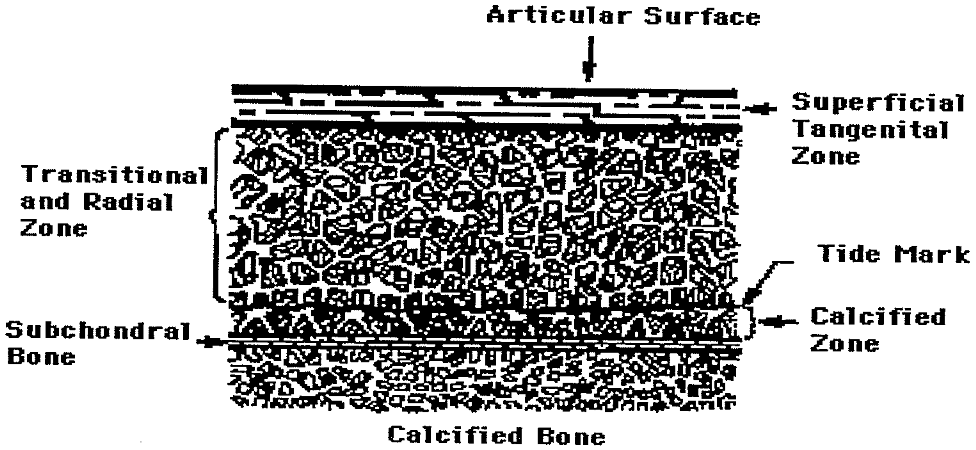

Figure 8. Schematic representation of collagen fibril ultrastructure orientation, as seen from the scanning electron microscope, depicting the four zones of articular cartilage (Mow, Myers and Wirth, 1982).

BIOMECHANICS OF THE PATELLO-FEMORAL JOINT

All of the anatomical stabilizers of the patello-femoral joint are interrelated and therefore balance between them is critical. Normal functioning of these structures allows this joint to operate at its maximum potential. Therefore, any imbalances or disruptions could alter the joint's normal biomechanics and result in certain structures becoming unduly stressed. Ultimately the end result would involve damage to the stabilizing structures and subsequent development of patello-femoral pain (Terry, 1989). For example, Galea and Albers (1994) reported that malalignment of the patello-femoral joint may cause repetitive subluxation and relocation. This condition could therefore result in irritation of the synovium, retinaculum or impingement of the patellar facets against the femoral tochlear surface. The impingement could possibly cause abnormal pressure on the subchondral bone and therefore the development of pain. The synovial irritation could be due to articular cartilage degeneration . Abnormal lateral tracking of the patella could cause strain on the medial retinaculum and result in pain because it is richly innervated by pain fibers (Gaelea & Albers, 1994). These structures became irritated or stressed due to the altered biomechanics of the patello-femoral joint. Therefore it is essential to study the normal patello-femoral biomechanics in order to fully understand of the pathologies associated with this joint (Hungerford & Barry, 1979).

The Patella

The patella facilitates knee extension by lengthening the moment arm of the quadriceps muscles through the full range of motion (ROM). The efficiency of the quadriceps muscle group is enhanced (Reid, 1992). The patella allows for better distribution of compressive forces on the femur by increasing the surface area of contact between the patella and the femur (Hungerford & Barry, 1979; Levine, 1984; Hunter & James, 1984). The patella also functions to centralize the converging fibers of the quadriceps muscle (Bergeron, 1992). Additionally, the patella serves to protect the anterior structures of the knee joint and provide an aesthetically cosmetic appearance.

Normal Biomechanics

During knee flexion and extension, the patella moves through the femoral groove. This is commonly referred to as patellar tracking and its pattern is usually described as a gentle "C" opened laterally (Hungerford & Barry, 1979; Bergeron, 1992). In full extension, the patella sits above the femoral groove and lies on the suprapatellar pouch and or fat pad. In this position and through the first 20° of flexion, the patella is not supported by the buttressing affect of the femoral groove. The patella therefore relies solely on its dynamic and static stabilizers for stability. According to Bose et al (1980), during knee flexion beyond 20°, the patella is stabilized mainly by the anterior projection of the lateral femoral condyle. The patella moves in an inferior and lateral direction as it begins to engage in the femoral groove. The patella displaces anteriorly as it rides over the lateral ridge. This increases the moment arm and offsets the compressive force on the joint (Ficat and Hungerford, 1977). The patella becomes well established in the groove after 90° flexion. The effectiveness of the lever arm decreases because the patella is drawn into the intercondylar notch of the femur (James, 1979). After 90° of knee flexion, the quadriceps tendon articulates with the groove to share some of the compressive load on the joint (Grana and Kriegshauser, 1985). With increasing flexion, the patella continues to move laterally along the lateral aspect of the femoral groove. At 130° flexion the patella rotates medially about its longitudinal axis. Now the medial facet contacts the medial aspect of the femoral groove. In full flexion the patella rotates further so that the previously unloaded odd facet contacts the medial femoral condyle.

Patellar Contact Areas

The patellar contact surfaces change as the knee joint flexes and extends (Figure 9). During flexion the patellar contact area moves from distal to proximal. The exact opposite occurs on the articular surface of the femur. First contact is made between 10 and 20° of flexion along the inferior margin of the patella in a narrow, broad continuous band across both the medial and lateral facets (Hungerford & Barry, 1979; Reid, 1981). At this point, the odd facet is not loaded. At 45° of knee flexion, the contact area moves proximally to the midpatellar region.

The size and breadth of the contact area increases as well (Figure 9). According to Hungerford and Barry (1979), the total weight bearing surface of the patella area increases between 20 to 90°. They reported the following results; at 30° the total surface area was 2 square centimeters, at 60° it was 3.1 square centimeters, and at 90° it was 4.7 square centimeters.

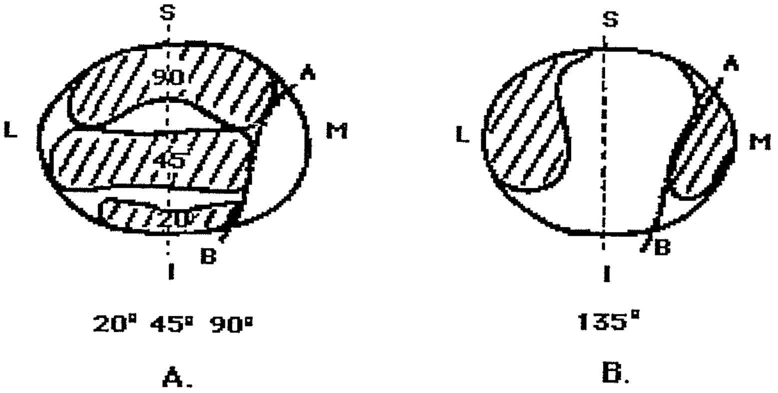

Figure 9. Diagramatic representation of contact areas on the patella in varying degrees of flexion. Figure A at 20, 45 and 90° and Figure B at 135°. S=superior, M=medial, L=lateral, I=inferior. Line AB represents the secondary ridge between the medial and odd facet (Goodfellow, 1983).

At 90° flexion, the patella is in contact with the femoral condyles, distal to the femoral groove. The quadriceps tendon also contacts the femoral groove and is said to absorb some of the compressive forces that would otherwise be exerted on the patella. According to Huberti and Hayes (1982), only a small amount of the forces are absorbed by the tendon. They believe that the majority of the compressive forces are assumed by the patello-femoral joint. Beyond 90°, the patella begins to rotate medially on its longitudinal axis (Bergeron, 1992). The contact areas of the patella are now distinctly described on each patellar facet rather than the broad band extending the width of the patella as previously described. The contact also shifts from the median ridge to the secondary ridge (Reid, 1981). At 135° of knee flexion, the contact area is localized to the odd facet. Hungerford and Barry (1979) stated that the increased surface area available for load bearing that occurs with increasing knee flexion, is important for offsetting or compensating for the increase in patello-femoral compressive forces. The authors stated that these forces cannot be completely offset and as a result, load per unit area increases with increasing knee flexion.

Q- Angle and Valgus Force

In the normal biomechanics of the patello-femoral joint there is a valgus force which pulls the patella laterally. The quadriceps muscle group, in seeking the shortest route between its origin and insertion, creates a lateral vector force and pulls the patella laterally (Figure 11). The Q-angle contributes to this lateral vector force and it is considered to be a critical component of patello-femoral biomechanics (Fox, 1975; Bergeron, 1992). The Q-angle is defined as angle created by the bisection of two lines (Percy & Strother, 1985). One line extends from the anterior superior iliac spines (ASIS) down the anterior part of the thigh to the mid-point of the patella. The other line extends from the tibial tubercle to the same point on the patella (Figure 10). The Q-angle allows for lateral displacement of the patella (Fox, 1975). The average Q-angle for men is 14 ° and for women 17° (Percy and Strother, 1985). Angles in excess of 20° are considered abnormal (Levine, 1979; Ficat & Hungerford, 1977) and according to Fox (1975), the greater the Q-angle, the greater the forces moving the patella laterally. Increased Q-angles can be caused by increased femoral neck anteversion. This anteversion is usually associated with genu valgus and external tibial rotation.

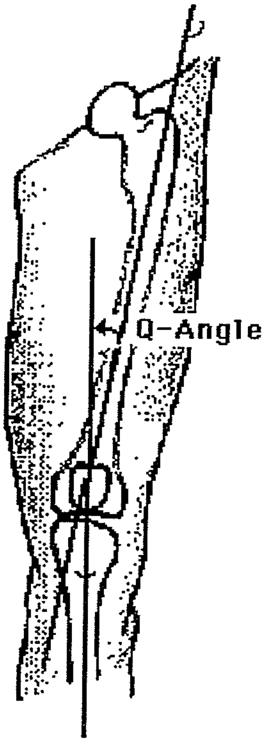

Figure 10. The Q-angle of the lower limb, redrawn according to Magee (1992).

There was some disagreement in the literature as to the degree in which an abnormal Q-angle affected patello-femoral biomechanics. Minkoff and Fein (1989) stated that increased Q-angles did not necessarily indicate the presence of a pathological condition but that the deviations, along with other signs of lateral instability, could be causal. Some researchers stated that abnormally high Q-angles resulted in lateralization of the patella, as the quadriceps contracted. This lateralization is thought to be a precursor to patellar malalignment syndromes (Bergeron, 1992). Grana and Kriegshauser (1985) stated that slightly over half their recurrent patellar dislocation subjects had abnormal Q-angles. Similar findings were reported by Insall, Falvo and Wise (1976), in their subjects who suffered from chondromalacia patellae. Smaller than normal Q-angles can also be damaging. Huberti and Hayes (1982) found maximum contact pressures for both increased and decreased Q-angles and in some instances, they found higher pressures for decreased Q-angles. Changes in the Q-angle can occur with the contraction of the hamstring muscles. These muscles act on the tibia and cause it to rotate medially and laterally, thereby increasing or decreasing the angle (James, 1979). Minns, Birnie and Abernathy (1979) reported that compressive forces on the patella decreased when the Q-angle was changed from 15 to 5 ° with flexion. The authors also stated that if this change did not occur then the compressive forces could become significant enough to cause the joint to become pathogenic. These authors believed that the Q-angle was important in causing high tensile stresses on the medial and odd patellar facets.

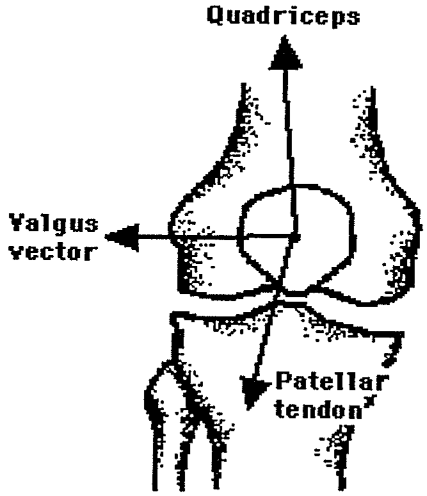

Figure 11. The Q-angle imposes a valgus vector on the terminal degrees of extensor movement, redrawn according to Fulkerson and Hungerford (1990). Orientation of the quadriceps force in the coronal plane.

In addition to a vector force pulling the patella laterally, a resultant force compresses the patella against the underlying femur. This causes a compressive force referred to as the patello-femoral joint reaction force, PFJR (Figure 12).

Patello-femoral Joint Reaction Forces

During most dynamic activities, the contraction of the quadriceps muscles and body weight exert compressive forces on the patello-femoral joint. These forces are directly related to the amount of flexion that occurs at the knee joint. So, as knee flexion increases, the magnitude of quadriceps muscle force and PFJR forces also increases (Hunter & James, 1984; Hungerford & Barry, 1979). In other words, PFJR forces increase as the amount of knee flexion increases. This occurs because greater quadriceps muscle tension is required to overcome the flexion moment of body weight. Levine (1984) stated that the forces at the patello-femoral joint are enormous. Patello-femoral forces vary with activity (Reid, 1992; Ficat & Hungerford, 1977; Reid, 1981). Hunter and James (1984) reported that during level walking, PFJR forces are approximately 0.5 times the body weight because the amount of knee flexion is very small. Stair climbing creates a PFJR force that is approximately 3.5 times body weight. This value is roughly seven times that value obtained for level walking, because stair climbing requires greater knee flexion. Deep knee bends or squats produced PFJR forces of approximately 2.5 to 3 times body weight (Reilly & Martens, 1972). Levine (1984) reported that walking down a ramp produced PFJR forces of approximately 1.9 times body weight. Huberti and Hayes (1972) reported that these compressive forces doubled when the knee was flexed to 90°. According to Bergeron (1992), the magnitude of these forces stresses the patello-femoral joint and this could result in microtrauma and therefore pain. He also stated that these forces could lend some insight into the types of activities that precipitate anterior knee pain, especially those that require knee flexion and repetitive strong quadriceps muscle contractions. An effective mechanism for decreasing the PFJR force is to minimize knee flexion.

Knee extension against a resistance creates increased PFJR forces. Reilly and Marten (1972) reported that leg extension against a weighted boot produced forces that equaled 1.4 times body weight at 36° flexion. As the knee joint reached full extension, the PFJR forces began to decrease while the quadriceps muscle force increased. PFJR forces are low at full extension because the patella sits above the femoral groove. Individuals with patello-femoral disorders can usually exercise using resistance as long as knee flexion is not greater than 20° (Hunter & James, 1984; Reilly & Martens, 1972).

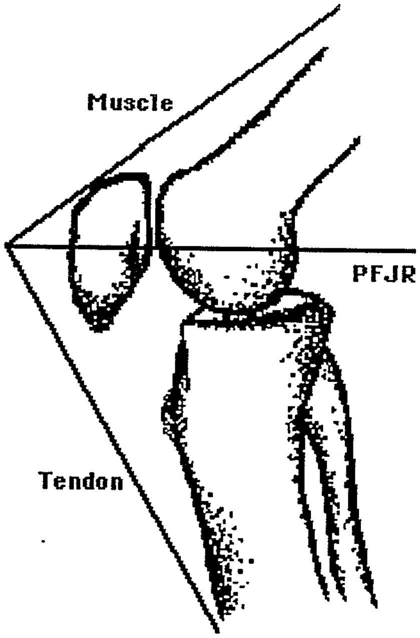

Figure 12. Schematic depiction of patello-femoral joint reaction (PFJR). The PFJR force is that vector developed in the quadriceps and patellar tendons which is directed against the joint (Pickett & Randin, 1983).

PATELLO-FEMORAL PAIN

Pain is a complex and private sensory experience (Wall & Melzack, 1989). It is influenced by many psychological factors, as well as, by the physiological events initiated by an injury (Chesworth et al, 1989; Melzack, 1985). Patients suffering from patello-femoral pain syndrome often experience pain in the anterior aspect of the knee joint that is somewhat chronic in nature. Pain is usually located beneath the patella on either its medial or lateral aspect (Galea & Alberts, 1994; Reid, 1990, Winslow & Yoder, 1995; Garrick, 1989). This often depends on the structures involved. This pain is often described as being a dull ache with episodes of sharp pain (Galea & Alberts, 1994; Reid, 1990; Malek & Mangine, 1981). Young adults between the ages of 15 to 40, either active or inactive, are the population most affected by this condition (Galea & Alberts, 1994; Reid, 1990 and Kramer, 1986; Arnoldi, 1991; Eisele, 1991). Arnoldi (1991) and Fulkerson (1982) stated that women are afflicted more often than males and this is likely correlated to their increasing participation in more physically active sports. Garrick (1989) stated that patello-femoral pain is related to activity. He reported that the majority of the patients reporting to his clinic with knee pain, were involved in activities where a lot of knee flexion was required. Activities like tennis, cycling, swimming, figure skating, soccer and modern or aerobic dance.

Some patello-femoral patients report that inactivity exacerbates their pain. For example sitting with their knees flexed for long periods of time, like in a movie theatre or long car or plane journeys (Garrick , 1989; Wise, Fiebert & Kates, 1984; Eisele, 1991; Fulkerson & Hungerford, 1990). Of these individuals who get increased pain at rest, it usually occurs after engaging in activities not often pursued by the patient (Arnoldi, 1991).

The classic clinical sign or symptoms for PFPS are pain, normal range of motion, ligamentously stable joint, possible swelling and/or joint crepitus. Another sign may be atrophy of the vastus medialis muscle. Upon examination PFPS patient often present with a positive patellar grind test or Clarke's sign. These are special tests used to detect patello-femoral joint pathology (Magee, 1989). In the patellar grind test the patient is lying supine with knee extended. The examiner applies pressure on the patella while it is in the femoral groove. A positive test is indicated when the patient reports pain. The Clarke's sign has the patient in the same position as the grind test. The examiner places the web of his/her hand on the superior part of the patella and asks the patient to contract their quadriceps muscle while maintaining a downward pressure on the top of the patella. A positive test is also indicated when pain or apprehension is reported. Pain and crepitus are the usual findings with this condition but one does not necessarily implicate the other.

Treatment of Patello-femoral Pain Syndrome

PFPS is usually treated conservatively rather than operatively. Most treatment programs focus on controlling the symptoms and strengthening the quadriceps, particularly the vastus medialis muscle (Garrick, 1989). The treatments would therefore include rest, quadriceps strengthening, medication and external support devices, such as orthotics or braces (Garrick, 1989; Fulkerson, 1982).

Rest usually comes in the form of activity modification. Most clinicians have their patients avoid activities that create or increase patello-femoral contact pressure. For example, activities like squatting, stairs, kneeling, jumping or running and to some degree walking (Fulkerson, 1982). People with mild or moderate pain can usually be managed with little modification of activities but they should be advised to avoid the above mentioned activities. Patients who get pain from prolonged sitting in a flexed position are advised to relax the knee in extension while either driving, on a plane or sitting in a theatre. Cycling pain can be alleviated by moving the seat height to a higher position. Water jogging or swimming can be substituted for jogging or running on land (Fisher 1986).

Many authors advocated a quadriceps strengthening program as an essential component of the conservative approach to patello-femoral pain (Fulkerson, 1982; Bergeron, 1992; Radin, 1979; Garrick, 1989). Quadriceps weakness or wasting are usual accompaniments to PFP disorders and many theorize that this weakness of the quadriceps alters the contact surface of the patella and femur and the surrounding soft tissue support structures (Fulkerson, 1982; Bergeron, 1992; Garrick, 1989; Fisher, 1986). Weakness of the VMO muscle has been implicated in poor patellar tracking which can cause damage to either the patello-femoral joint surfaces and/or the surrounding retinaculum. Percey and Strother (1985) believe that the vastus medialis muscle is important in the medial stabilization of the patella.

Components of strengthening program consist mainly of isometric and progressive resisted exercises with the knee in extension. The type of exercise chosen depends on the level of pain the patient is experiencing at the time of treatment. Patients with severe pain usually start with isometrics exercises and progress to straight leg raises and terminal extensions with ankle weights (Garrick, 1989; Percy & Strother, 1985). The full range of motion from full flexion to extension is avoided because it invariably leads to pain and an exacerbation of symptoms. All patients are advised to continue a maintenance program to prevent reoccurrence of pain.

Medications such as anti-inflammatories and analgesics have been prescribed for PFPS but the effectiveness has not been proven in the literature (Fulkerson, 1986; Garrick, 1989). Intra-articular injections of steroids are not recommended due to their adverse effects on articular cartilage (Fulkerson, 1986).

Foot orthoses and braces have also been prescribed to help alleviate PFPS (Garrick, 1989). Neoprene braces provide general support of the knee and relieve direct pressure on the patella by creating an uplift of the patella. Some even function to prevent patellar subluxation laterally (Villar, 1985). Patients who have pronated feet and associated PFPS have found orthotics useful. The reason for this that some researchers believe excessive pronation causes malalignment of the lower extremity which produce malalignment at the patello-femoral joint, thereby causing dysfunction (Tiberio, 1987).

<u>ABNORMAL BIOMECHANICS OF THE PF JOINT AND ITS RELATION TO THE ETIOLOGY OF PF PAIN</u>

Introduction

The following section will attempt to describe the literature concerning how thee anatomical structures of the patello-femoral joint become stressed or damaged. It will look at the abnormalities of the patello-femoral joint, specifically patellar shape and malalignment. Disruption of the joints soft tissue supports, in particular the static and dynamic structures. Finally the abnormalities of the lower extremity will be discussed with special attention focused on excessive Q-angles and foot pronation.

Normally during extension, the patella moves smoothly in the femoral groove of the femur without pain. However, there are numerous conditions which can alter this normal patellar movement. The patello-femoral joint stability depends on the congruency of the patello-femoral articulation and on the static and dynamic joint stabilizers (Micheli & Stanitski, 1981). Failure of any one of these allows for inappropriate lateral movement of the patella. Therefore, this would increase the loading on the articular surfaces of the joint, especially laterally. Malfunction or malalignment of the patella can occur as a result of abnormalities of the patello-femoral joint; abnormalities of the soft tissue patellar stabilizers; and abnormalities of the lower extremity.

Patellar Shape

Normally the patella is closely associated with the femur's articular surface. This close union provides stability to the patello-femoral joint. The shape of the patella can influence the stability and tracking of the patello-femoral joint (Paulos et al, 1985). Wiberg (1941) identified three different types of patella and described their orientation with the femur. This description was based on the width and shape of the patellar facets. In a type one patella, the lateral and medial facets are equal in size, slightly concave and symmetrical. A type two orientation is the most common (Ficat and Hungerford, 1977). The medial facet is slightly smaller than the lateral. The surface of the facets are still slightly concave, however, the medial facet is slightly convex. The third type has an even smaller medial facet and its surface is convex (Figure 13). This patella also has a markedly predominant lateral facet. These patellar types provide stability and distribute the PFJR forces equally over well formed medial and lateral facets. According to Kramer (1986) and Carson (1985), dysplasic shapes of either the patella or the femur can cause improper and inappropriate tracking of the patella. The consequence of this improper tracking is an unequal distribution of compressive forces on the articular surfaces.

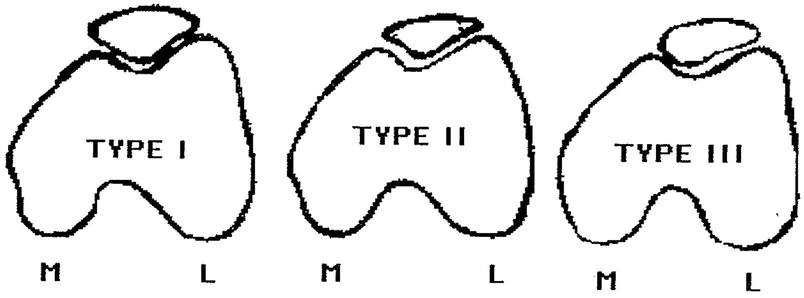

Figure 13. Patello-femoral configurations classified by Wiberg and redrawn according to Mehrdad and Mangine (1981).

Patellar Malalignment

Patellar malalignment is often described in three orientations; the frontal plane (medial and lateral deviation), sagittal plane (patellar rotation about its longitudinal axis) and in its proximal/distal orientation. There are three measures which influence the symmetry, congruence and ultimately the alignment of the patello-femoral joint; the sulcus angle, congruence angle and the patellar tilt angle. The sulcus angle is created by the lines drawn from the tops of the medial and lateral facets of the femur to a midpoint on the floor of the femoral groove (Fulkerson & Hungerford, 1990) (Figure 14a). Normally, the patello-femoral joint has a sulcus angle of approximately 138 degrees (Kramer, 1986). If this angle is greater than 138 degrees than it is considered abnormal because it results in the flattening of the groove. Flattening of the groove will allow lateral deviation of the patella. This lateral deviation is enhanced if it is accompanied by either a tight lateral retinaculum or a weak VM muscle (Grana & Kriegshauser, 1985). The depth of the femoral groove is measured from the highest points of the femoral condyles to the lowest point of the femoral groove (Insall et al, 1976).

The congruence angle measures the lateral displacement of the patella or the centering of the patella (Figure 14b). In order to determine the congruence angle, a zero reference line must be established. This line is made by bisecting the sulcus angle. Another line is then extended from the lowest point on the median ridge of the patella to the bisection point of the zero reference line. The angle created by this line and the zero reference line is called the congruence angle. All values medial to the zero reference line are designated as minus and those lateral, as plus (Pickett & Radin, 1983; Hungerford & Barry, 1979).

Patellar malalignment about a longitudinal axis is a measure of patellar tilt (Figure 14c). Tilting of the patella can result in increased lateral pressure on the lateral facet and its articular cartilage. The patellar tilt angle is created by drawing two lines; one describing the lateral articular surface of the patella and the other describing the lateral surface of the femoral groove. If these lines are parallel or converge together, it is indicative of abnormal patellar tilting. Chronic tilting can lead to the development of ELPS and subsequent damage to the lateral patello-femoral structures.

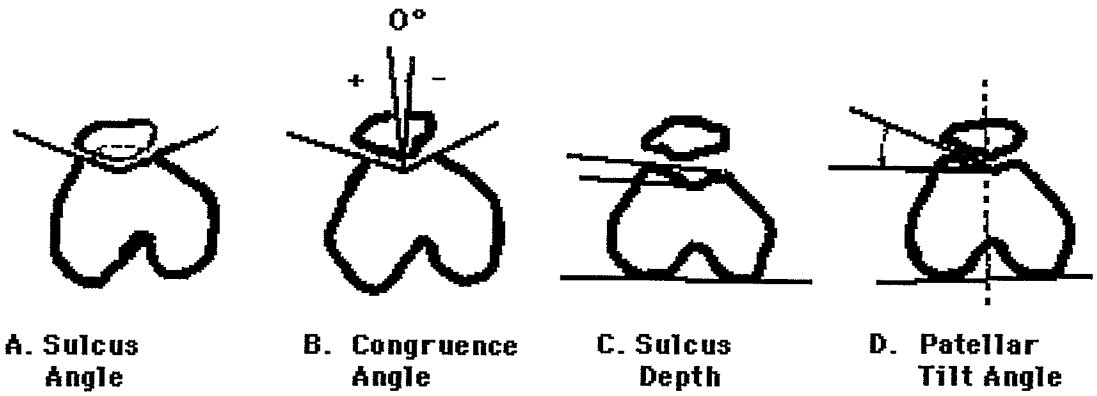

Figure 14. Diagramatic depiction of the A=sulcus angle, B=congruence angle, C=sulcus depth and D=patellar tilt angle. Redrawn according to Bergeron (1992).

High riding or patella alta is a condition where the patella is positioned unusually high on the femur in extension. Structurally this condition can be described when the length of the patellar tendon is longer than the greatest diagonal length of the patella. Normally these lengths result in a one to one ratio (Kramer, 1986). Because the patella enters the femoral groove later in knee flexion, it is unstable for a longer period of time. This results in excessive contact pressures applied to parts of the articular cartilage that are ill-equipped to withstand the stress.

A low riding patella, or patella baja, occurs as a result of a shortened patellar tendon. This condition is also associated with excessive patellar compression because the patella has a tendency to get pulled into the femoral groove earlier than normal which all increases the compressive forces on the patella (Bergeron, 1992).

Levine (1979) stated that moderate degrees of malalignment could cause PFJR forces greater than the limits of the patello-femoral joint and therefore set off a process of degeneration.

Abnormalities of the Peripatellar Soft Tissues

The soft tissues surrounding the patello-femoral joint consist of the; muscular and tendonious portions of the VM and VL, the medial and lateral retinaculum and patello-femoral ligaments. Normally the vasti muscles exert counter-acting forces against each other therefore neutralizing their effects on the patella. They act as dynamic stabilizers. If there is an imbalance between the function of these muscles, the patella will track abnormally. For example, if the VM is atrophied or has a particularly high insertion point on the patella, the efficiency of this muscle will be altered, decreasing its counterbalancing effect on the lateral valgus vector. The patella will therefore drift laterally (Carson, 1985;

Outerbridge & Dunlop, 1975; Grana & Kriegshauser, 1985). According to Jacobson and Flandry (1989), the lower the insertion of the VM, the greater the mechanical advantage. If the VL becomes hypertrophied, it can cause the patella to deviate laterally. The VL will overpower the medial stabilizing force of the VM and therefore the static stabilizers would be put on stretch (Kramer, 1986; Fulkerson & Hungerford, 1990). Paulos et. al (1980) stated that malalignment of the patella usually occurs laterally due to the imbalance between VM and VL.

Adolescent growth spurts can also cause muscular imbalances. Grana and Kriegshauser (1985) termed this transient dysplasia. Transient dysplasia occurs when rapid skeletal development occurs without muscular maturation. The VM is affected more than the VL. This leaves a weakness in the dynamic stabilizers of the patello-femoral joint. The valgus vector force of the VL will not be counteracted by the weak VM and thus the patella will deviate laterally. According to Carson (1985) and Fox (1975), the VM is the weakest quadriceps muscle because it is the first to atrophy and the last to be rehabilitated.

The retinaculum and associated patello-femoral ligaments can also be affected. Fulkerson and Hungerford (1990) stated that the lateral retinaculum could tighten and adaptively shorten in response to a chronically tilted patella. During flexion, large stresses develop in the fibers of the lateral retinaculum as the patella is drawn into the femoral groove. Fulkerson (1989) stated that this may contribute to the damage of small sensory nerves located with the lateral retinaculum. Laxity of the medial retinaculum can also cause an abnormal shift of the patella laterally against the lateral femoral condyle. It can also become stretched or torn when the patella dislocates or subluxes.

Jacobson and Flandry (1989) stated that the hamstrings can create increased compressive forces in the patello-femoral joint when they are excessively tight or when the normal strength ratio between them and the quadriceps has been exceeded. The hamstrings are antagonistic to the quadriceps, so excessive tightness requires the quadriceps to work harder. This puts a greater load on the patello-femoral joint which results in increased lateral compression and abnormal patellar tracking.

Abnormalities of the Lower Extremity

Malalignment of the lower extremity can cause abnormal tracking of the patella. Torsional abnormalities from the hip and foot can also contribute to the lateralization of the patella (Ficat & Hungerford, 1977). Several factors have been implicated in causing malalignment of the lower extremity; increased Q-angle, femoral anteversion, genu valgum and recurvatum, and excessive subtalar joint pronation.

Q-angles in excess of 20° have been labeled abnormal. These larger than normal angles produce greater valgus vectors which result in lateral deviation of the patella. Paulos et al (1980) reported that an abnormal Q-angle may not always present a problem in itself but could be a factor if combined with other deficiencies. According to Kramer (1986) there are many factors that can increase a Q-angle; increased femoral anteversion, external rotation of the tibia, genu valgum and recurvatum, and excessive foot pronation. Increased femoral anteversion causes relative internal rotation of the femoral condyles. If this is accompanied by compensatory external tibial rotation, the Q-angle will increase. External tibial rotation moves the tibial tuberosity in a lateral direction in relation to the quadriceps pull (Garrick, 1989). This also increases the Q- angle. Genu valgum increases the valgus vector by displacing the tibial tuberosity laterally through external tibial rotation.

The normal gait cycle is sequential and synchronous. Excessive subtalar joint pronation will disrupt this normally smooth cycle and affect the biomechanics of the knee joint. At heel strike the foot supinates slightly. When the foot begins contact in the midstance phase, the foot pronates and the tibia internally rotates. This occurs along with knee flexion. Once the foot is in full ground contact, the foot reverses it function and begins to supinate. This supination occurs along with external tibial rotation and knee extension. Subtalar joint supination continues throughout the midstance and propulsive phases (Tiberio, 1987). Excessive subtalar joint pronation will delay the normally occurring external tibial rotation which usually accompanies foot supination. This delay results in a compensatory reaction at the knee joint. Tiberio (1987) stated that this compensatory reaction is responsible for patello-femoral symptoms. Normal biomechanics dictate that the knee joint extends during midstance but because of excessive subtalar joint pronation, external tibial rotation does not occur. This external rotation is required for extension. The body's locomotor system must therefore compensate somehow or the supporting structures around the patella will be traumatized. Tiberio (1987) explained that one way to compensate is for the femur to internally rotate on the tibia so that the necessary relative external rotation of the tibia occurs. Tiberio also stated that this compensatory reaction disrupts the normal mechanics of the joint and creates increased compression between the lateral patellar facet and the lateral femoral condyle. Ultimately it results in abnormal lateral tracking of the patella when in full extension.

ETIOLOGY OF PATELLO-FEMORAL PAIN

The patello-femoral articulation has long captivated medical minds and continues to pose a diagnostic challenge whenever it malfunctions (Galea & Albers, 1994). It now becomes apparent that PFPS has many causes. When discussing the etiology of patello-femoral pain one must keep in mind that pain can only originate from tissues which contain pain receptors. In the case of the patello-femoral joint that means the source of pain must originate from either of the following structures or a combination of them; subchondral bone, the synovium, the retinaculum and/or the venous supply to the patella (Radin, 1979). According to Fulkerson and Hungerford (1990) abnormal patello-femoral function can lead to progressive articular cartilage breakdown and degeneration. Since articular cartilage is devoid of a nerve supply, it does not seem to be a likely source of pain. Besides, articular cartilage damage does not correlate well with the symptoms of pain. Not all patients with softening of the cartilage (chondromalacia) experience pain. Alternatively, some patients have pain but no observable articular cartilage damage (Ficat & Hungerford, 1977; Fulkerson & Hungerford, 1990).

The Subchondral Bone and Synovium

The subchondral bone and the synovium have an abundant supply of pain fibers. According to Minns et al (1978) the subchondral bone is the most likely source of pain because of its rich innervation. Pain from the subchondral bone is thought to occur as a result of basal degeneration of the articular cartilage (Goodfellow, Hungerford & Woods, 1976). Basal degeneration is described as fibrillation of cartilage in the intermediate (radial-transitional zones) and deep (calcified) zones, without first affecting the superficial Tangential zone.

Grana and Kriegshauser (1985) found that pain occurred secondary to increased metaphyseal intra-osseous pressure because of the excessive mechanical forces acting on the cartilage and its attachment to the underlying bone. This could eventually lead to reduced absorptive capacity of the articular cartilage of the patella. Forces would then be absorbed by the subchondral bone (Percy & Strother, 1985) thereby causing pain.

In the case of excessive lateral pressure syndrome (ELPS), the lateral facet of the patella is excessively loaded thereby damaging the articular cartilage. At the same time, the medial patellar facet is not receiving enough compression. According to Outerbridge and Dunlop (1975) and Fulkerson and Shea (1990), this lack of compression can cause the cartilage on the medial facet to soften because it is not receiving sufficient nutrition to keep it viable.

An inflamed synovium can also transmit pain. Pickett and Radin (1983) stated that pain came from "gunk synovitis" which involved synovial and capsular reactions to joint debris or chemical products of articular cartilage degeneration or immunological responses of certain diseases (Grana & Kriegshauser, 1985).

Retinaculum

Stress from abnormal patellar tracking can also manifest itself in the peripatellar soft tissues, particularly the retinaculum. ELPS was described by Fulkerson and Hungerford (1990). It can occur traumatically or congenitally. Excessive lateral patellar tilting can occur after the disruption of the patello-femoral stabilizers. For example, when the patella dislocates, the medial retinaculum is often stretched or ruptured. The VM muscle can also atrophy because of disuse. This creates an imbalance between the medial and lateral patellar stabilizers. The lateral forces acting on the patella overpower those forces on the medial side. The result is that the patella is pulled laterally and becomes chronically tilted or malaligned (Fulkerson & Hungerford, 1990; Fulkerson, 1989).

ELPS usually affects the lateral patellar facet, the lateral retinaculum and the articular cartilage of the patella and femur. Excessive tilting of the patella can cause the lateral retinaculum to be chronically shortened and therefore perpetuate further patellar malalignment (Figure 15). This short lateral retinaculum is now stretched during flexion, irritating small sensory nerves contained within (Fulkerson & Shea, 1990; Fulkerson, 1989; Grana and Kriegshauser, 1985). Studies using gomori trichrome staining have revealed microscopic nerve damage or injury within the lateral retinaculum (Fulkerson & Hungerford, 1990). This helps to explain why patient complain of knee pain without evidence of chondromalacia (Fulkerson, 1982; Fulkerson & Hungerford, 1990).

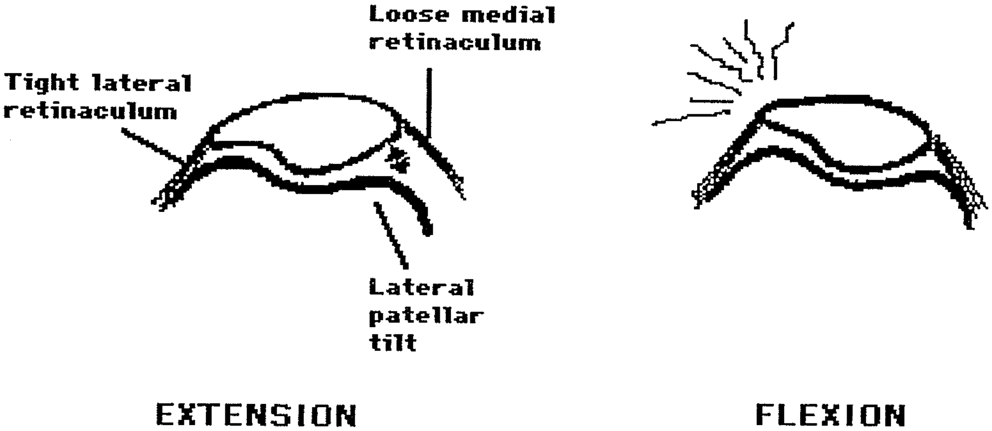

Figure 15. When the knee moves into flexion, the retinaculum draws the patella into the groove. If the lateral retinaculum is unusually tight, there will be lateral retinacular strain. Redrawn according to Fulkerson and Hungerford (1990).

Patellar Blood Flow

Patellar malalignment and abnormal forces acting on the patello-femoral joint can also manifest themselves by altering blood flow patterns in the patella. According to Waisbrod and Noam (1980) and Arnoldi (1990), patello-femoral pain can be caused by increased venous engorgement of the patella. Venous flow from the patella has been studied by means of intra-osseous phlebography and venography. A contrast medium is injected into the patella and the time of dissipation recorded. In the normal patella, most of the contrast medium disappears from the patella after a minute. The extra-osseous circulation is also almost clear (Waisbrod & Noam, 1980). In patients suffering from chondromalacia or patello-femoral osteoarthritis, the authors observed a stasis or pooling of blood that took a longer period of time to dissipate. After one minute, most of the contrast medium still remained in the patella. This could create increased pressure within the patella which would result in pain.

PAIN MEASUREMENT

A review of the literature did not encounter any studies investigating the daily variability of patello-femoral pain. The majority of studies that investigated patello-femoral pain did it on a test, re-test basis to evaluate treatment efficacy (Bergeron, 1992; Chesworth, 1989). Complaints of knee pain in the studies conducted by Chesworth et al (1989) and Bergeron (1992) were measured using the VAS and the McGill Pain Questionnaire, respectively. Bergeron (1992) used the McGill Pain Questionnaire to measure the effect of quadriceps strengthening on patello-femoral pain. One of the recommendations from his study was that patello-femoral pain should be evaluated on a daily basis rather than on a test, re-test basis. He felt it would yield a more accurate picture of patello-femoral pain.

Chesworth et al (1989) used a VAS to measure complaints of knee pain in his subjects also using a test, re-test design. He took measurements at three different times; time 0 was the baseline measure of pain and time 1 was done 24 hours later. Time 3 was the measurement taken after a course of treatment.

In the clinical setting patients anecdotally report that the nature of patello-femoral pain changes day to day. They can usually relate it to a particular activity and/or event. Therefore it seems logical to study it over an extended period of time on a daily basis.

With respect to PFPS and its relationship to physical activity, the literature focuses on anecdotal reports of pain caused or exacerbated by specific activities. The activities reported consistently associated with patello-femoral pain included squatting, kneeling, running, stairs, walking, jumping and sitting for prolonged periods of time with the knee flexed (Galea & Alberts, 1994; Reid, 1990, Winslow & Yoder, 1995, Arnoldi, 1991, Fisher, 1986; Percy & Strother, 1985). One study did however look at a functional index questionnaire (FIQ) of eight physical activities and their association with pain (Chesworth et al, 1989). The subjects indicated on the questionnaire to what degree the pain affected their ability to execute specific activities. They had three choices; unable to do, can do with problem and no problem. FIQ scores were compared to pain scores as measured by a visual analogue scale (VAS). The authors found that after a period of treatment, VAS measures of pain had decreased and their functional capacity (FIQ) had increased. The conclusion was that te FIQ and the VAS measurement techniques were valid outcome measures when assessing patients with PFPS but that they exhibited poor day-to-day reliability. They attributed this to the variability in the day-to-day complaints of the PFPS population.

According to Melzack (1989) pain is a complex experience that is influenced by a great number of interacting physical, mental, biochemical, social, emotional, psychological and physiological factors. All interactions are dynamic and constantly changing therefore the pain that is perceived to be a given intensity at any one time, may at another time be perceived as being less or more intense, even when other factors are the same (Melzack, 1989). The Taber medial dictionary defined pain as a sensory and emotional experience associated with actual or potential tissue damage. This pain includes perception of an uncomfortable stimulus but also the response to that perception. So, pain is by nature subjective and private. These qualities can make quantifying an individual's pain a difficult task. It is for this reason that the patient is the only one who can measure its severity or intensity. The search of relevant literature revealed a variety of tools used to measure pain intensity and quality. Pain charts, questionnaires (McGill), numerical rating scales (NRS), graphic rating scales (GRS) and visual analogue scales (VAS). Authors, Wall and Melzack (1989) outlined in their article, five points regarding the properties of an ideal pain measurement (See Table 1.1). The pain measurement tool most applicable to these points is the visual analoque scale (VAS).

Table 1.1 Properties of An Ideal Pain Measurement Tool

- be sensitive and free from bias
- provide immediate information about accuracy and reliability
- separate the sensory discrimination aspects of pain from its hedonic qualities
- assess experimental and clinical pain on same scale in order to be useful in comparisons
- provide absolute instead of relative scales that allow assessment of pain between and within groups over time

One of the initial pain measurement tools was developed by Keale (1948). He was one of the first researchers to address the problems associated with pain measurement in human subjects. He found that subjects had difficulty in describing an unusual or unique experience like pain. He used a tool called the pain chart which consisted of 24 spaces for each hour of the day. His subjects were required to record hourly observations of their pain intensity. by using descriptors like agony, severe, moderate, slight or nil to describe a continuum of pain experiences. The author used these standard descriptors in order to reduce the difficulty a subject may have in choosing an appropriate word.

Over several years this simple pain chart evolved into various types of rating scales. Scales such as the graphic rating scale and the numeric rating scale. Huskisson (1974) felt that the word groupings in Keale's pain chart did not allow enough quantitative measurement and therefore he designed a graphic rating scale (GRS). This GRS had a horizontally or vertically oriented line with descriptive words placed at intervals along its length. The descriptors were slight, moderate and severe. These descriptors were provided in order to help the patient in deciding the position of his or her score. Huskisson (1974) stated that the main disadvantage of a GRS is that the relative diiffernce between descriptors is unknown and that it has to be assumed when attaching scores to them. Other authors stated the GRS lacked senstivity for small changes and only offered a few choices (Downe, Leatham, Rhind, Wright, Branco & Anderson, 1978).

Numerical rating scales (NRS) had a line calibrated with numbers, from one to twenty (Reading, 1989; Scott & Huskisson, 1976). No descriptive terms were used in combination with this scale, except the extreme terms applied to the ends of the lines. Scott and Huskisson (1976) found that this scale did not yield very uniform results and therefore, according to them, lacked sensitivity. They even found that certain numbers were favored by their patients. Flandry et al (1989) warned against superimposing numbers on the line because they felt that the patients or subjects could introduce bias for a certain number or group of numbers. This could therefore interfere with the distribution of the results.

Although researchers or authors have used these scales successfully in psychology, more accurate measuring tools or instruments eventually evolved over time (Freyd, 1925; Aiekan, 1969). An example of this is the visual analogue scale (VAS). The VAS is a continuous method of expression by which the rater or patient may describe the magnitude of their subjective experience or symptom. It consists of either a vertical or horizontal line which represents a graphic continuum which is bounded by two descriptors. These descriptors are the two extremes of the pain experience, the absolute maximum and minimum that could be experienced. The extremes usually consist of descriptors stating "no pain" or "pain as severe as it could be" (Flandry et al, 1991; Chesworth et al, 1989). These descriptors function to anchor the ends of the scale and are used so that intermediate points can be assessed non-verbally. They are also used to lessen the opportunity for widely different interpretations made by the various raters. The length of the line is usually specified at ten centimeters or 100 millimeters (Revill, Robinson, Rosen & Hogg, 1976). Flandry et al (1991) stated that having a measuring technique which has responses that range from zero to one hundred with as many decimal places, boosts statistical power tremendously, especially over those rating scales where only a few categorical answers are possible. The rater reads the descriptors and places a mark on the line at the point the rater feels best describes their own experience, relative to the two extreme descriptors. The rater's responses are then converted into a numerical value by simple measuring techniques. These numerical values are then used for future analysis (Chesworth et al, 1989).

The simplicity of the VAS makes it a popular choice of measurement especially when pain intensity or severity is being studied. The authors stated that the VAS was the most frequently used methods of assessing pain in the clinical environment because it assesses the variation in the intensity of pain (Chesworth, Culham, Tata and Peat, 1989). Chesworth et al (1989) stated that even though the VAS is considered a sensitive and reliable method for measuring pain, evidence of its use in patients who suffer from patellofemoral pain is limited. The authors also reported that the VAS used in another study was found to be a valid outcome measure when assessing patients with PFPS (Stratford, 1982).

Carlsson (1983) identified two types of VAS; the absolute and the comparative. The absolute VAS consisted of a 100 mm line with no word descriptors under it. The comparative VAS used the words "slight-moderate-severe" under a 200 mm line. This comparative VAS is similar to the GRS previously described. The authors compared the validity and reliability of these two types with respect to the factors that influence them. Factors such as learning, memory and perceptual judgment. Their results showed that the absolute type seemed to be less prone to bias and therefore they recommended its use. They stated it was the best method because it provided a continuous scale for magnitude estimation of pain severity or pain relief. VAS also minimize bias, especially because pain severity is a subjective phenomenon. Flandry et al (1991) developed a VAS for analyzing subjective knee pain and used it on one hundred and seventeen patients. They showed that the VAS method of pain assessment was valid and comparable to the other methods of evaluating knee pain; the Noyes knee scale and the Lysholm scales. They stated that the VAS brought better sensitivity and greater statistical power over the other methods. They also found that the patients or subjects in their study preferred the VAS over the other methods because it was easier to complete. Flandry et al (1989), recommended the use of VAS because it uses an open structure which allows for responses that did not force the patient to interpret the definition of terms such as slight, moderate or severe, nor do they assign themselves to such categories. VAS is also used because of the ease by which the patient's responses can be converted into objective measures. This allows for the magnitude (severity) and temporal nature (how often) of pain to be quantified and therefore bias is minimized and statistical power is boosted (Flandry et al, 1989).

The concept of VAS is simple and easily understood. It is interesting and requires minimal motivation and can be completed quickly. Reading (1989) commented that it was user friendly. As a result of these findings, most authors recommended its use and also stated that because of these positive qualities, subjects or patients were more apt to complete the VAS form. Higher completion rates were reported if the patient or subject was allowed to fill out a trial response under supervision in order to familiarize themselves with the form and the VAS (Flandry et al, 1989; Scott & Huskisson, 1976; Carlsson, 1989). Downe et al (1978) stated that the main advantage of VAS is that it offers the greatest freedom of choice (Carlsson, 1983; Reading, 1989; Melzack, 1975).

The primary criteria for accurate pain measurement are validity, reliability and versatility. The validity and reliability of VAS has been reported favorably in the literature (Scott & Huskisson, 1976; Dixon & Bird, 1989; Carlsson, 1989; Reading, 1989; Revill et al, 1976; Price, McGrath, Rafii and Buckingham, 1983; Joyce et al, 1975). The test-retest reliability for VAS is high and its effectiveness has been demonstrated in the measurement of pain intensity. Downe et al (1978) conducted a study which compared four different rating scales; the NRS, four point GRS, horizontal VAS and vertical VAS. The scales were randomly given to one hundred patients. They found high correlations between the four scales, especially for the horizontal VAS. Dixon and Bird (1981) reported that vertical VAS presented an additional source of error because if it is viewed at an angle it could alter the patient's perspective of the line and therefore their mark. Joyce et al (1975) stated that the VAS is accurate and as reliable as the GRS but is more sensitive in measuring pain intensity. The authors had their subjects complete four rating scales each week for four weeks. Everyday the subjects recorded their pain intensity before and after an analgesic drug was taken. They recorded at hourly intervals for up to four hours each day. The authors used a horizontal VAS and a modification of the GRS called the four point fixed interval scale (FPFI). The scale consisted of a line with two extremes at either end and two descriptors under the line. The terms used under the line were "some pain" and "considerable pain". Numbers one, two, three, and four were assigned to the terms in the scales. According to the authors, this made it easier to score and convert to numerical values which was much less work than measuring out the values on the VAS. The authors found however, that their patients preferred the VAS over the FPFI scale because they felt that it was more accurate and sensitive and therefore gave a better indication of their pain. Other patients stated that the VAS was easier and needed less imagination to complete. Revill et al (1976) tested the reliability of the VAS, looking specifically at the patient's ability to place a mark on the line where they intended to put it (visual and motor coordination). The authors conducted line marking tests and memory tests. They found that patients consistently put a mark on the line very close to where they meant it to be. Testing of memory yielded results that showed that the patients could easily remember where they made their first mark.

The McGill Pain Questionnaire (MPQ) is a questionnaire that utilizes word descriptors to measure pain. It consists mainly of three word descriptor categories; sensory, affective and evaluative domains of pain (Melzack, 1975 & 1989). The MPQ is primarily used to specify the individual's subjective pain experience and according the Melzack (1975) it provides quantitative information that can be analyzed statistically which is sensitive enough to evaluate the efficacy of various treatment methods. The MPQ is recommended for those researchers who are studying chronic pain (Bergeron, 1992). One advantage is that the patients are provided with word lists which save them from having to grope for words to communicate with their physician (Melzack, 1975). The categorization of pain into sensory, affective and evaluative domains also provides some qualitative insights into the painful experience which may lead to better understanding of the causal factors. The MPQ, however, may not be conducive to daily use because it is a lengthy measurement tool. Patient can easily remember the selected worlds from one day to the next, which could bias the results.

Physical Activity Reporting Methods

The search of the relevant literature revealed many ways in which to record physical activity on a daily basis. Self-reports are probably the most commonly used type of measure of physical activity (Sallis, 1991). The reason they are so common is because they are conveniently administered, inexpensive and could collect many activity variables over time. It is also very reasonable to ask individuals to report their own physical activity because they have personally experienced it. Sallis (1991) reported that many physical activities are salient events that even children were likely to remember them and thus report them.

Physical activity reports have been used for many different purposes, but mainly in studying children's patterns of physical activity. They have been utilized in the public school system to assess the effectiveness of various sport and health programs (Sallis, 1991; Freedson, 1991; McKenzie, 1991). Diaries have also been used in the assessment of activity behaviors and pain in patients who suffer from chronic pain (Frollick, Ahern and Lasser-Wolston, 1985). On several occasions, self-reports and diaries have been specifically adapted to suit individual studies. Freedson (1991) stated that even though there are many forms of self-reporting instruments available, no standard format has been universally accepted.

Though frequently used, data from self-reports have been viewed in the literature with some suspicion because the actual behavior is not directly assessed. It relies on memories of the behavior which can be affected by time, bias, and perceptions. It was also reported that the memories can be affected by competing memories and misunderstanding of instructions (Sallis, 1991; Freedson, 1991).

Sallis (1991) reviewed several different types of self-report measures for reliability and validity. He reviewed diaries, self-administered recall, interviewer-administered recall and proxy reports. He found that reliabilities of all methods were acceptable but that with younger children the reliabilities were lower. He attributed this fact to age being strongly related to the quality of physical activity recall. He found that children younger than 10 could not be expected to provide useful information on these activity diaries or activity recall. Sallis (1991) found the diary measures had the strongest validity but that the burden to the subject in terms of completing it were high. Interviewer-administered and self-administered recalls also yielded results that were consistently high, especially considering the age of the subject population (3-18 years old). As a result of these findings the author concluded that these measures could be used with a degree of confidence and that children could report their own physical activity with a degree of accuracy. The author finally concluded that children younger than 10 should have their activity measured by either direct observation or by activity monitors. Sallis (1991) however did not do any studies with adult subjects.

Freedson (1991) did a study on various electronic motion sensors and found that they allowed for more objective monitoring because they eliminated the problems of recall of activity, especially in children. The main disadvantage of these motion sensors is that specific activities and the times spent in them could not be shown. A self-report or diary would address this particular dilemma.

Follick et al (1984) evaluated a daily activity diary in terms of its reliability and validity. The diary assessed postures and times spent in various activity such as lying, sitting, standing and walking. Patient self-reporting was compared to spousal observations of the same activities, as well as to electromechanical devices. Reliability coefficients for the daily activity diary categories were all positive and statistically reliable as were the correlations between patient and spouse ratings on activities. The comparison to the electromechanical devices were also positive (Freedson, 1991). Overall these results indicated that the daily activity diary is a reliable and valid instrument for the assessment of daily activity patterns for pain in their natural environment (Follick et al, 1984).

SUMMARY

Understanding the anatomical structures and biomechanical function of the patello-femoral joint is important in determining the cause of patello-femoral pain. (Fulkerson, 1989). Imbalances between the static and dynamic stabilizers, structural malalignments of the lower extremities or vascular insufficiencies could be responsible for the excessive stress and strain of the patello-femoral joint and its eventual breakdown and degeneration.

The exact etiology of patello-femoral pain is poorly understood and somewhat of a mystery (Bergeron, 1992). Most authors believe it stems from abnormal patellar tracking or patellar malalignment (Ficat & Hungerford, 1977; Fulkerson & Hungerford, 1990; Fulkerson, 1989). The postulated sources of pain are the subchondral bone, the synovium, the retinaculum, or venous engorgement of the patella.

There are various methods available for measuring pain including pain charts and various rating scales. These methods were described including their advantages and disadvantages. Various studies in the literature compared these various methods against the VAS. It is generally accepted that the VAS is an accurate, reliable and valid way to assess pain intensity. Various methods of physical activity assessment were reviewed and it was also found that physical activity diaries or self-reports were reliable and valid ways in which to measure various forms of physical activity.

In review, it is the purpose of this study to investigate the daily variability of patello-femoral pain and to look at what activities are deemed responsible for that pain. In connection with the daily variability this study will also investigate if time of day or gender has an effect on patello-femoral pain.

CHAPTER 3

METHODOLOGY

Introduction

Does patello-femoral pain vary from day to day? At different times of the day? Is it affected by various types of physical activities? It is the purpose of this study to investigate patello-femoral pain and answer these questions. Part of the methodology for this study was adapted from Bergeron (1992) and Chesworth et al (1989), specifically in regards to subject selection criteria. Subjects involved in the study will be described in terms of their method of recruitment, numbers, description of their background and inclusion and exclusion criteria. The proceeding section describes the procedure used for data collection, in particular the questionnaire, profile sheet and consent form. The data was analyzed using parametric and non-parametric techniques.

Subjects

The majority of subjects for this study were referred by the University of Manitoba Athletic Therapy Centre. A small percentage of subjects were recruited through various advertisements made through the university student newspaper (The Manitoban) or through two community newspapers (The Lance and The Metro). Posters were also distributed around the university (see Appendix D). Despite extensive letter mailouts to doctors and therapists in the city, no referrals were made to this study (see Appendix E).

A total of 30 subjects, between the ages of 16 to 35 years, were desired when the search for subjects initially began. A total of 67 people responded to the advertisements, posters and the U of M Athletic Therapy Centre. After phone calls and/or personal screenings with potential participants, a total of 30 subjects remained. Involvement in the study required that subjects have a physician or therapist diagnosis of patello-femoral pain syndrome. They also had to meet the inclusion/exclusion criteria outlined in Table 3.1. The criteria for this study were similarly based on those used by other authors (Bergeron, 1992; Chesworth, 1989; Insall, Falvo & Wise, 1976). The gender split for these subjects was 16 females and 14 males. By the end of the data collection, only twenty-eight subjects, 14 males and 14 females, remained . Two female subjects failed to return their questionnaires despite several follow-up calls. As a result they were not included in any further discussions or the final results of the study.

Table 3.1 Subject Inclusion and Exclusion Criteria

Criteria for Subject Inclusion: Subjects had to have two or more of these symptoms

- pain is elicited when the patella is directly compressed and moved up and down in the femoral groove, while the knee is in full extension
- patellar pain or tenderness is elicited when the medial retinaculum and undersurface of the patella is palpated
- patellar pain is elicited when using stairs, especially going downstairs
- positive Clarke's sign (pain behind the patella is elicited when the quadriceps muscles are contracted and the therapist provides downward resistance above the patella
- positive Movie or Theatre sign (individual experiences pain behind the patella after sitting in one position for long periods of time)

Criteria for Subject Exclusion: Subjects were excluded if they said yes to any of following.

- history of patellar trauma (i.e. fractures) that is responsible for present knee pain
- history of dislocating or subluxing patella
- previous history of any type of knee surgery (i.e scope, reconstruction) or have surgery pending
- evidence of osteochondral or chondral fractures
- confirmed damage of meniscal, ligamentous or fat pad tissue that is responsible for present knee pain
- evidence of upper and/or lower motor lesion
- evidence of referred pain from either the back or hip
- radiological evidence of degenerative disease

Twenty-five subjects were students, 17 from physical education and 8 from other faculties. All of these individuals lead relatively active lifestyles and were currently involved in various sports or physical activities, such as, cycling, running, volleyball, hockey, basketball, gymnastics, ringette and weight lifting. The remaining three participants were employed as full time secretaries at different agencies in the city. Overall these individuals lead a more sedentary lifestyle as compared to the other twenty-five.

Procedure for Data Collection

Upon admission to the study and after obtaining informed consent, the subjects met to go over the instructions for the questionnaire. Subjects were instructed to complete the daily questionnaire for a period of three (3) weeks. At the end of each week, subjects submitted the completed questionnaire booklet to the researcher at the University of Manitoba. If this was not feasible, other arrangements were made.

Information for the study was obtained using three small questionnaire booklets (Appendix A). Each booklet consisted of an instruction sheet and seven daily questionnaires. Each daily questionnaire was divided into five three-hour blocks. Each block started at seven o'clock in the morning and went to ten o'clock in the evening. Each time block or period was separated into two sections. Section one required the subjects to indicate the intensity of their patello-femoral pain by using a 10 centimeter horizontal visual analog scale (VAS). To record their pain intensity, they simply marked a point on the VAS line that best described their knee pain, relative to the words at the ends of the line. Carlsson (1983) stated the VAS is considered to be one of the best methods available for the estimation of pain intensity. Chesworth et al (1989) also utilized VAS in their study to measure the severity of PFPS and they found it to be reliable for documenting patello-femoral pain. The second section asked each subject to report which activity they felt made their patello-femoral pain worse. To record this, they were asked to check one of the activities listed and then specify exactly what it was they were doing during that activity. Each day, subjects completed pain measurements and activity identification at five different times periods throughout the day. The five time periods were 7-10 am, 10-1 pm, 1-4 pm, 4-7 pm and 7-10 pm

Data Analysis

Part one of the data analysis looked specifically at analyzing the variability of patello-femoral pain over twenty-one days. Systat 6.0 for Windows was the statistical package used for this analysis (Wilkinson, 1990). Subjects were divided into gender categories for males and females and their patello-femoral pain scores were collected for each day and time of day (see Appendix H). A MANOVA was run on the raw data to test for effects of gender, day and time of day plus their interactions. The level of significance was set at .05.

The second part of the analysis explored the significance of different types of physical activities and the frequency by which they were cited as being connected with patello-femoral pain. Statview 2.0 for Macintosh was the statistical package used (Feldman, Hofmann, Gagnon & Simpson, 1987). Frequency counts for each of the nine activities were tallied for each subject and these tallies were ranked according to their frequency. The ranks were then analyzed non-parametrically using the Friedman test (Hassard, 1992).

CHAPTER 4

RESULTS

The purpose of this chapter is to report the results of the investigation of patello-femoral pain. The first section describes the profile statistics concerning the subjects involved in the study. The second section deals with the results concerning the significance of daily patello-femoral pain and how it varies within subjects. Section three deals with between subjects variation when looking at time of day its interactions with day and gender. The fourth and final section describes the findings concerning the types of activities frequently cited as being responsible for patello-femoral pain.

Subjects

Twenty-eight subjects, 14 female and 14 male, were involved in this study. The overall mean age, height and weight for the subjects was 26 years, 171.66 cm and 72.09 kg respectively. The average age was 27 years for females and 26 years for males. The average height in centimeters for females was 166.40 and 177.00 for males. The average weight in kilograms was 61.70 for females and 82.50. On average the males tended to be taller and heavier than their female counterparts (see Table 4.1).

Table 4.1 Age, Height, Weight for Female and Male Subjects

	Female Age (yrs)	**Female Height (cm)**	**Female Weight (kg)**	**Males Age (yrs)**	**Males Height (cm)**	**Males Weight (kg)**
	21	166.30	68.10	23	180.00	86.00
	35	157.50	51.80	21	170.10	67.00
	21	152.50	50.90	20	177.50	84.10
	26	162.50	61.40	21	172.50	75.00
	35	165.10	77.30	35	185.00	92.00
	29	167.50	59.10	26	185.00	88.90
	22	177.50	69.50	22	172.50	68.20
	27	162.50	61.40	28	175.00	84.10
	22	162.50	57.30	32	185.00	91.80
	22	165.00	70.00	22	168.80	72.70
	34	167.50	57.70	24	163.80	79.60
	27	177.50	49.60	24	175.00	88.60
	28	175.00	56.80	34	185.00	89.10
	24	170.00	72.70	33	182.50	87.70
Means	**27**	**166.40**	**61.70**	**26**	**177.00**	**82.50**

Variability of Patello-femoral Pain

A MANOVA was used in the analysis of patello-femoral pain over twenty-one days. Subjects were assigned into categories according to their gender. Their pain scores were recorded for each of the five time periods, each day (see Appendix K). The results of the analysis are found in Table 4.2. The results from the analysis address several questions; Did patello-femoral pain vary day-to-day? Did gender affect patello-femoral pain? Did it vary at different times of the day? Was there an interaction between day, time of day and gender?

Daily Variation of PF Pain and Its Interactions

According to Table 4.2 there was no statistically significant variation within subjects for patello-femoral pain on a day-to-day basis (p-value = 0.613). However, when the data is interpreted descriptively it showed that eighteen subjects (64.3%) had a wide varability in pain from day-to-day which, although not statistically significant, may have some clinical relevance. These subjects reported pain scores which varied between 1 to nine out of ten on the VAS pain scale. The remaining ten subjects had little or no changes over the twenty-one day period. These ten subjects (35.7%) had pain scores ranging between zero and one out of ten on the VAS pain scale. Twelve subjects (42.9%) reported pain scores ranging from one to five out of ten, while six subjects (21.4%) reported pain scores ranging from six to ten out of ten (Figure 4.3)

The interaction between day and gender did not indicate any significant differences (p= 0.418). There was also no significany difference within subjects for day and time of day (p=0.943). The interaction between day, time of day & gender also within subjects did not yield significant results (p=0.891).

Table 4.2 A Comparative Analysis of Reported Pain Scores for Between and Within Subjects to Gender, Daily Pain Scores, Time of Day and Their Interactions.

MS	SS	DF	MS	F	P
Between Subjects					
Gender	368.882	1	368.882	7.191	0.013*
Error	1333.720	26	51.297		
Within Subjects					
Day	88.082	20	4.404	0.880	0.613
Day & Gender	103.646	20	5.182	1.035	0.418
Error	2602.798	520	5.005		
Time	209.419	4	52.355	14.247	0.000*
Time & Gender	15.114	4	3.778	1.028	0.396
Error	382.180	104	3.675		
Day & Time	93.354	80	1.167	0.760	0.943
Day & Time & Gender	99.118	80	1.239	0.807	0.891
Error	3191.928	2080	1.535		

* indicates significance at p>.05

Figure 4.3 The Variability of Reported Pain Scores Categorically Defined for All Subjects.

Little-No Pain Change (0-1) Subject Number	Small Pain Change (2-5) Subject Number	Large Pain Change (6-10) Subject Number
2	1	3
7	4	5
10	8	6
11	9	16
13	12	19
14	15	20
21	17	
26	18	
27	22	
28	23	
	24	
	25	
TOTAL SUBJECTS	TOTAL SUBJECTS	TOTAL SUBJECTS
10/28	12/28	6/28
35.7%	42.9%	21.4%

Gender Variation and Patello-femoral Pain

A gender significance between subjects was identified. The p-value of 0.013 was obtained and it indicated a significant difference. When male and female patello-femoral pain scores were averaged for each day they showed that on average females had more pain than males (see Table 4.4).

Time of Day and Variation of PF Pain

Table 4.2 revealed a significant time of day variation in patello-femoral pain within subjects (p=0.000). No significant differences arose with the interactions between time (p=0.396), time of day & gender (p=0.943) and day, time of day & gender (p=0.891).

In order to visualize time of day differences, the average patello-femoral pain for each of the five times of day was calculated (see Table 4.5). The table showed that for females the time period between 7-10 pm revealed the highest average pain value. For males, the time period between 4-7 pm had the highest value. When the average pain values for males and females were combined, they showed that the time period between 7-10 pm yielded the highest average pain values (Table 4.5). Interactions between day and gender did not yield significant p-values.

Table 4.4 Daily Average Patello-femoral Pain for Females vs. Males

Day	Females	Males
1	1.43	0.96
2	1.76	0.50
3	1.61	0.71
4	1.08	0.96
5	1.11	0.70
6	1.70	0.68
7	1.66	0.88
8	1.58	1.28
9	1.42	0.73
10	1.74	0.41
11	1.14	0.56
12	1.12	0.47
13	0.87	0.49
14	1.30	0.44
15	1.62	0.32
16	1.39	0.59
17	1.35	0.30
18	1.16	0.73
19	1.05	1.10
20	1.25	0.70
21	1.61	0.55

Table 4.5 Time of Day Averages for Females and Males and All Subjects

Time of Day	Females	Males	All Subjects
7-10 pm	1.78	0.90	2.68
4-7 pm	1.50	1.00	2.50
1-4 pm	1.50	0.77	2.27
10-1 am	1.36	0.44	1.70
7-10 am	0.86	0.32	1.18

Physical Activity and Patello-femoral Pain

Chesworth et al (1989) was the only study in the literature that recorded physical activities and their connection to patello-femoral pain. These authors evaluated the effectiveness of the VAS and FIQ in assessing pain and functional ability of subjects while performing activities commonly associated with patello-femoral pain. They were mainly concerned with finding out what their subjects were able to or not able to do over the course of their study. They also wanted to see if patello-femoral pain and functional ability changed after a course of treatment. They were not interested in those activities which were frequently connected to patello-femoral pain. It was the purpose of this present study to look at this connection and see if their interaction yielded significant results.

Nine physical activities were consistently identified in the review of literature as being commonly associated with PFPS (Galea & Alberts, 1994; Reid, 1990, Winslow & Yoder, 1995, Arnoldi, 1991, Fisher, 1986; Percy & Strother, 1985). Over the course of this study, subjects recorded the activity they felt was responsible for their PF pain. These numbers were tallied for each activity and the values were ranked and analyzed using the Friedman test. According to Table 4.6 a significant p-value of 0.0001 was found. This value indicated that there was a significant variation in the frequency of physical activities associated to each subject's PF pain. Appendix I shows the graphs of the most frequently cited reasons for patello-femoral pain for all twenty-eight subjects.

Table 4.6 Friedman Test Results for Frequently Cited Types of Activity Causing Patello-Femoral Pain Listed from Most to Least Frequent.

DF	8	
# OF SAMPLES	9	
# OF CASES	28	
CHIr-SQUARED	101.067	p = .0001*
CHI CORRECTED FOR TIES	113.993	p = .0001*
# TIED GROUPS	47	
ACTIVITIES	**SUM RANKS**	**MEAN RANKS**
Sitting	221.0	7.893
Walking	204.5	7.304
Vigorous Physical Activity	179.0	6.393
Stairs	144.5	5.161
Standing	127.5	4.554
Squatting	114.0	4.071
Lying	109.0	3.893
Kneeling	84.0	3.000
Running	76.5	2.732

* indicates significance at p>.05.

In order to see where the significance was, frequency counts for each activity were tallied together and averaged (Table 4.7). The results were then graphed to depict the overall outcome for all subjects (see Appendix I). It would appear that the activities that had the highest average frequency counts were; sitting, walking, vigorous physical activity, stairs and squatting. Smaller frequency counts were associated with standing, lying, kneeling and running. If one looks at the graphs for individual subjects it becomes apparent that these frequency counts vary from subject to subject (Appendix I).

Table 4.7 Physical Activity Frequency Counts and Means for S1-S28

Subject	S	ST	L	W	R	STR	SQ	K	VPA
1	43	1	5	20	1	3	2	1	3
2	11	0	0	1	0	0	0	0	0
3	3	0	2	4	1	0	2	0	7
4	33	0	0	18	0	0	0	0	17
5	4	2	0	8	1	5	2	2	16
6	5	0	0	27	0	3	22	0	0
7	2	0	1	1	0	0	1	0	1
8	13	6	1	14	1	10	1	2	7
9	40	4	13	11	2	0	0	0	13
10	0	3	2	13	0	2	57	2	0
11	2	1	0	1	0	4	0	0	1
12	3	0	0	8	0	0	0	0	2
13	2	0	0	0	0	0	0	0	2
14	10	4	1	3	1	3	0	0	4
15	12	2	7	36	1	10	12	0	16
16	34	15	3	6	1	1	1	6	5
17	25	4	3	15	0	0	0	0	11
18	9	1	4	0	0	0	0	0	8
19	18	4	1	18	1	15	4	1	2
20	41	12	0	2	2	1	5	1	13
21	0	0	0	4	0	23	0	0	10
22	36	4	0	6	0	11	1	1	11
23	7	5	6	14	1	12	2	1	6
24	43	0	0	2	1	4	2	2	1
25	28	6	0	19	0	0	1	0	17
26	11	2	2	20	1	13	2	0	9
27	13	6	3	16	0	10	0	0	11
28	23	4	5	20	0	8	0	1	7
Means	**16.82**	**3.07**	**2.11**	**10.96**	**0.54**	**4.93**	**4.18**	**0.71**	**7.14**

LEGEND:

S=Sitting ST=Standing L=Lying W=Walking R=Running STR=Stairs
SQ=Squatting K=Kneeling VPA=Vigorous Physical Activities

CHAPTER 5

DISCUSSION

Introduction

Research on the daily variability of PF pain and its interaction with various types of physical activity is noticeably lacking. The connection between these two areas seems to be covered in the literature only in an anecdotal fashion. Researchers seemed to have relied on subject or patient reports rather than on scientific investigation. Patello-femoral pain research in the area of gender and the variability of pain throughout any given day, is also absent in the literature. Many of the articles and books reviewed focused on the anatomy and biomechanics of the patello-femoral joint and its relation to PF pain. Some authors discussed current and popular theories of PFPS etiology , while others reported information on the prevalancy of PFPS, its signs and symptoms and ways in which the problem can be treated.

Other authors and researchers studied various methods of pain measurement. The majority of these researchers did not take daily measurements of PF pain. Instead they tested prior to and after the intervention of different treatment regimes.

This lack of information required further investigation to answer three questions concerning patello-femoral pain; Does it vary day-to-day? Does it vary at different times in a day? Is it affected by different types of physical activities?

Daily Variation of Patello-femoral Pain

The results did not reveal any statistically significant variation in PF pain for all subjects from one day to the next. To explain this lack of variation, pain scores for all subjects were tallied and averaged for each day. Figure 16 below helps to illustrate this finding. The line depicting average daily pain does not appear to fluctuate a great deal. With a significant result one would expect the graph to display greater differences in pain over the twenty-one days.

It is however important to realize that even though statistically significant results were not found, average daily PF pain results may be clinically relevant. Descriptively interpreted, the graphs in Appendix F show that subjects reported fluctuations in PF pain over the twenty-one period. These changes in average daily PF pain were notably visible especially for subjects 3, 5, 6, 15, 16, 20 (Appendix F).

Ten subjects (35.7 %) reported minimal to no fluctuations (0-1) over the study period. Twelve subjects (42.9 %) reported slight fluctuations (2-5), while six subjects (21.4 %) reported large fluctuations (6-10). Overall, 64.3 % of the subjects experienced fluctuations in PF pain that could be described as having clinical relevance when comparing from one day to the next.

These fluctuations seem to occur at different times of the day. This phenomena is observed quite often in the clinical setting. Patients commonly report on the transient nature of their PF pain. Patients can report very little pain one day and two days later they complain of pain that renders them unable to participate in normal every day activities. Often these individuals report that certain activities exacerbate the pain. Activities such as stairs, squatting, kneeling, running, jumping, cycling or sitting for long periods of time.

These individuals also report that certain sports affect their pain, especially those sports that require a lot of knee flexion or those whose main components include those mentioned above (Galea & Alberts, 1994; Reid, 1990, Winslow & Yoder, 1995, Arnoldi, 1991, Fisher, 1986; Percy & Strother, 1985).

Even though statistically there does not seem to be any difference, clinically patients do report variability in pain but perhaps over a 21 day period, they learn to recognize the need to avoid the pain causing activities. It may also be that the wide day-to-day variability in individual pain precludes any statistically significant data when compared as a group. Some individuals may be experiencing significant pain which is negated statistically by another subject who happens to be having a pain-free day.

Gender Effects on Patello-femoral Pain

Does gender affect patello-femoral pain? According to the results, females did demonstrate significantly greater PF pain than their male counterparts. To explain where the significance occurred, average pain scores for all male and then female subjects were calculated and graphed. According to the graph, females had greater pain values than males (Figure 17).

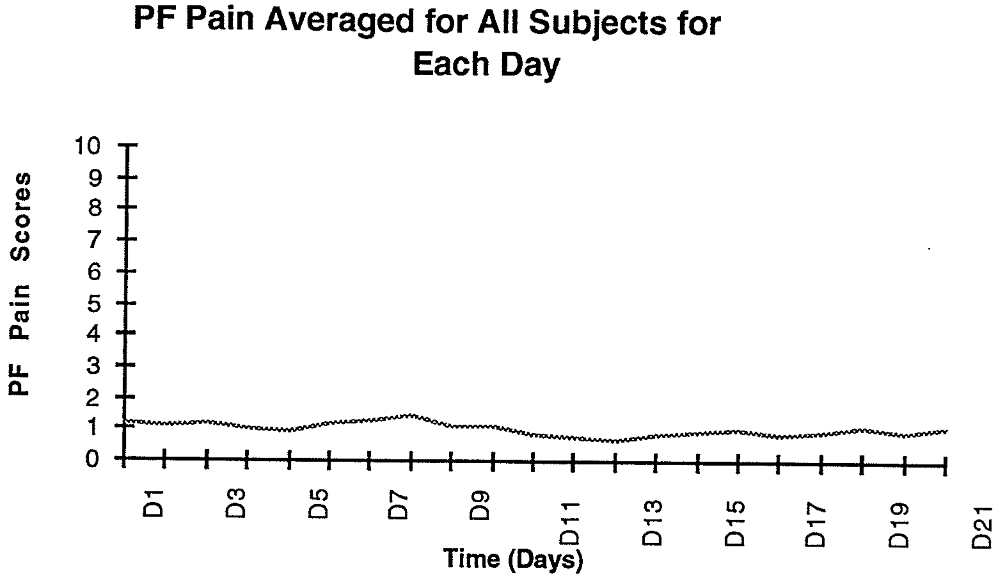

Figure 16. The averaged patello-femoral pain as measured on a VAS for all subjects, each day.

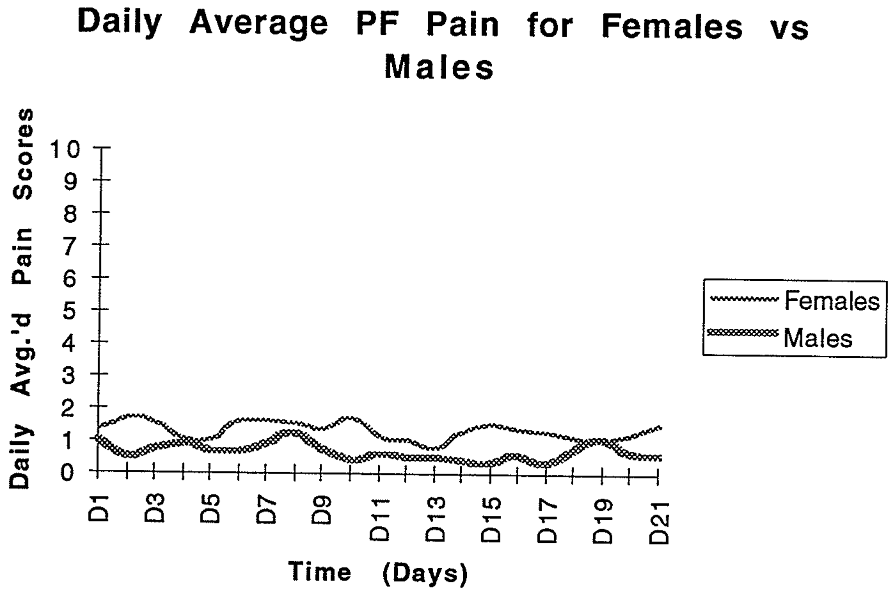

Figure 17. Daily average patello-femoral pain for females vs. males.

Information on the topic of gender and its interaction with PF pain was primarily epidemiological in nature and did not address any predisposition or causal factor. The specific reasons for gender variation were somewhat inconclusive and generally hypothesized. One study reported that patello-femoral related problems occurred twice as often in females as compared with males (Powers, Maffucci and Hampton, 1995).

Although the relative frequency of injury is not known and there seems to be a general lack of research related to female injury patterns, it was generally reported that females appeared to have a disproportionately greater incidence of injury than their male counterparts (Beck and Wildermuth, 1985; Clement et al, 1982, Whiteside, 1980; Powers, 1979; Eisenberg & Allen, 1978; Jackson, Furman & Berson, 1980). This was particularly true when considering the knee joint. When reviewing the literature it was revealed that the types of injuries in females and males differed. The most common types of injuries in females involved non-contact ligamentous sprains or patello-femoral condition/disorders (Beck & Wildermuth, 1980, Clement et al, 1982, Eisenberg & Allen, 1978, Whiteside, 1980). Males tended to sustain contact related ligamentous sprains or meniscal injuries (Clement et al, 1982; Jones, 1980; Whiteside, 1980).

What causes this difference in injury types between females and males? The arguments in the literature tended to be generic in nature but a few did focus on patello-femoral conditions. One argument that authors presented was that there were anatomical differences in females that favored patello-femoral disorders. Anatomic factors, such as, relatively smaller muscle masses and bone structures, greater joint laxities and biomechanical limb malalignments like excessive Q-angles (Powers, 1979. Eisele, 1991; Percy and Strother, 1985; Levine, 1979; Ficat & Hungerford, 1977; Fox, 1975). Many authors tried to correlate anatomic and alignment factors with the type of injury but only noted trends without clear cut differences (Powers, 1979; Beck & Wildermuth, 1985).

Beck and Widermuth (1985) however, concluded that anatomic differences could not alone account for the increased incidence of knee injuries in females.

Another explanation blamed higher incidence of injury in females than in males to factors such as lack of opportunity, less experience and fewer sport varieties. They also thought that females tended to have inadequate skills due to poorer conditioning and lack of qualified coaching (Jackson, 1980; Jones, 1980). When considering these factors, Beck and Widermuth (1985) postulated that the increased incidence rates in patello-femoral stress conditions were directly related to the relative lack of fundamental motor skills experienced in the developmental years. These authors also stated that this theory did not hold true for highly trained athletes. When professional men and women basketball players were studied, no differences in patellar injury rates were observed. Therefore they finally concluded that the observed differences in injury rates and patterns for females diminished as the level of conditioning increased and became comparable to that of their male counterparts.

A third explanation was postulated by two researchers Arnoldi (1991) and Fulkerson (1982). They reported that the reason women were afflicted more often than males, with PFPS, is that females now-a-days are becoming more involved in physically active sports. One must consider however, that males are still exposed to at least the same amount of risk inherent in various sports. As a result of this increased participation they are more apt to become injured due to the increased susceptibility to risks and stresses inherent in sports. Overall, there seemed to be no uniform agreement in the literature with regards to differences between females and males.

In my opinion, there may be a combination of reasons why females tended to report greater daily PF pain than males. One reason, already postulated by several authors, is the biomechanical/anatomical differences between males and females. These biomechanical or anatomical abnormalities seem to exist in females and according to the literature, they are commonly associated with PFPS. Women have wider hips and therefore greater Q-angles (Levine, 1984;Powers, 1979; Eisele, 1991; Ficat & Hungerford, 1977; Fox, 1975). This leads to a lateral vector force at the PF joint which can cause the patella to migrate laterally, causing tracking problems which can be manifested as degeneration of the patellar facets, femoral trochlear or soft tissue damage. This situation, in conjunction with smaller muscle mass and greater joint hypermobility can be potentially injurious and detrimental.

Another reason females had greater PF pain may be related to the fact that this study's females tended to much more physical active than the males. Eleven of the 14 females were enrolled in various physical education classes in the faculty and all were involved in some sort of recreational activity. By comparison, 8 of the 14 males were enrolled in the faculty, three of these individual participated in collegiate sports. The remaining female and males subjects were not in physical education and lead a somewhat less active lifestyle.

Possibly another reason for greater daily PF pain in females could be that the females had lower pain thresholds than the males. The literature did not address this theory and was it was not the scope of this study.

Pain Variability at Different Times of the Day

The analysis of variance revealed that there were significant differences in the level of PF pain from one time of the day to the next. It did not, however, indicate what specific times were significant. Graphing the average pain scores for all subjects illustrated a linear trend (see Figure 18). The end result is that the time of day with the highest average PF pain was between 7 and 10 pm. The observation that can be made, therefore, is that PF pain tends to worsen as the day progresses. This makes sense because the majority of subjects were students and they tended to be in class for the earlier parts of the day. They were not particularly active at this time because they spent most of the time sitting. As the day progressed and classes ended, the subjects engaged in some form of sport or leisure activity. These activities consisted primarily of sports such as, volleyball, hockey, ringette, basketball, running or weights. They also consisted of activities like shopping in the mall or visiting with friends.

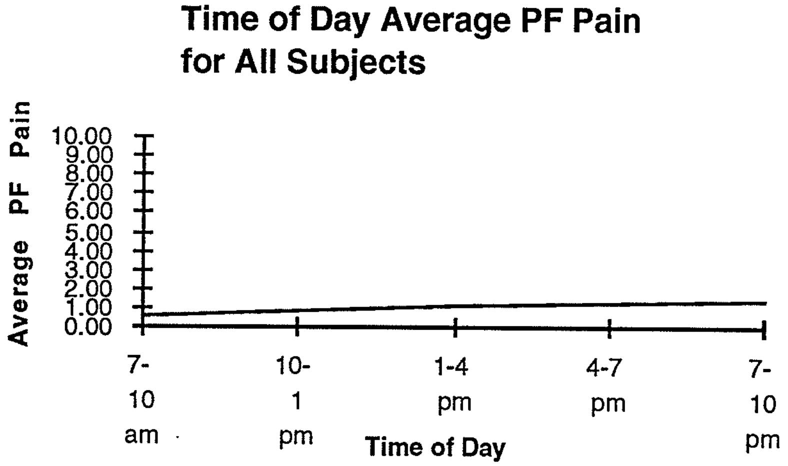

Figure 18. Average patello-femoral pain for each time of day for all subjects.

When averages were calculated for males and females individually they showed that females had higher average PF pain values between 7 and 10 pm and males between 4-7 pm (see Figures 19 & 20). The graph for the females showed the similar linear trend as was illustrated by the graph depicting averages for all subjects. The graph for males also showed a linear trend but with the exception of the last period. The PF pain averages for 7 to 10 pm were lower than those reported for 4 to 7 pm but higher than the earlier time periods.

When the questionnaires for subjects were reviewed, the majority of the females involved in the study tended to have their fitness workouts or sport activities scheduled between 7 and 10 pm. One of the sedentary female subjects consistently reported PF pain between 7 to 10 pm because this time was slotted for her film studies class. The class required that she sit in a theater and review films for three hours. She therefore consistently reported one of the classic symptoms of PF pain; movie theater sign (Garrick, 1989; Wise et al, 1984; Eisele, 1991; Fulkerson & Hungerford, 1990). A large portion of the male participants, on the other hand, had their activities scheduled consistently between 4 and 7 pm. For three male subjects in particular, this time was associated with collegiate wrestling and football practices. Therefore, it may be then that the variability in PF pain throughout any given day may be a consequence of scheduling rather than a progressive increase in pain simply due to the passage of time.

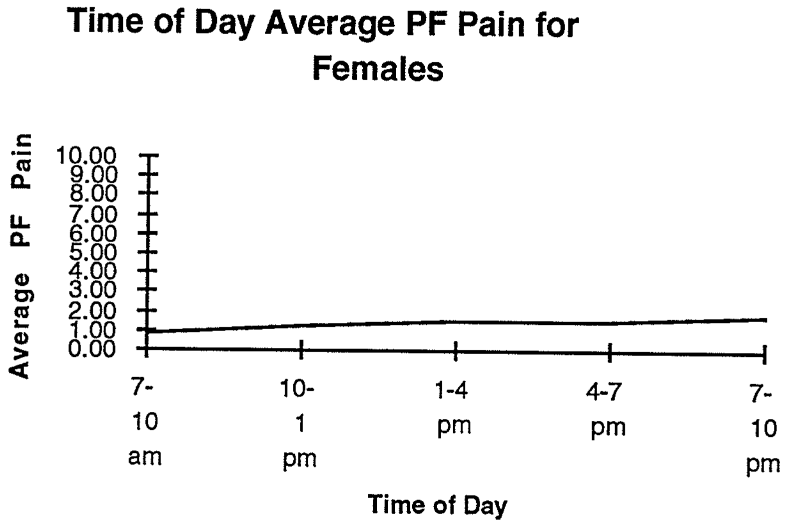

Figure 19. Average patello-femoral pain for females each time of the day.

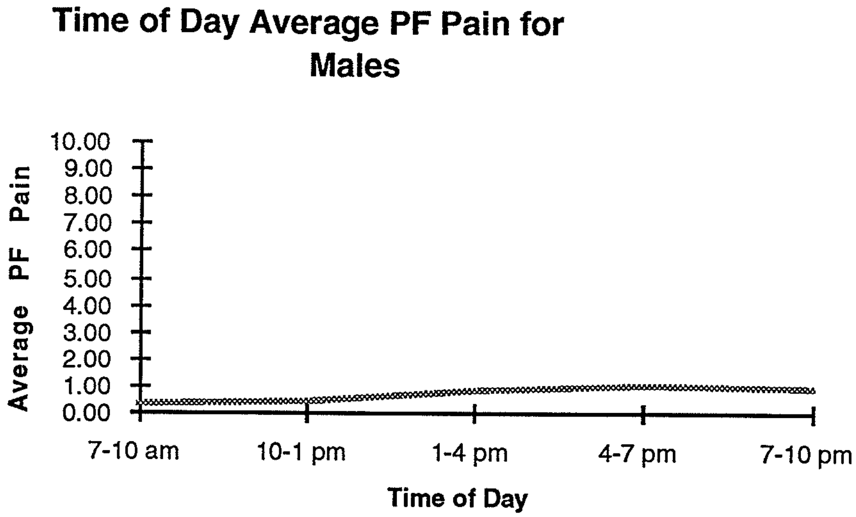

Figure 20. Average patello-femoral pain for males each time of the day.

The Effects of Physical Activity and Patello-femoral Pain

It would appear from the graphs in Appendix F & J, that most of the subjects experienced varying levels of PF pain. The majority of subjects (64.3%) reported variations in pain that could have clinical relevance. What caused this fluctuation in pain? Subjects were asked to identify, one of nine activities they felt was most responsible for their pain. The analysis of the frequency which each of the nine activities was selected, demonstrated a significant difference between activities

The frequency counts of all subjects were tallied and the average calculated for each activity. The findings from this were graphed (see Figure 21). The graph illustrates that the activities which were most frequently identified as the cause of the subjects PF pain were; sitting, walking, vigorous physical activity, stairs and squatting. Standing, lying, kneeling and running had, on average, much lower overall counts.

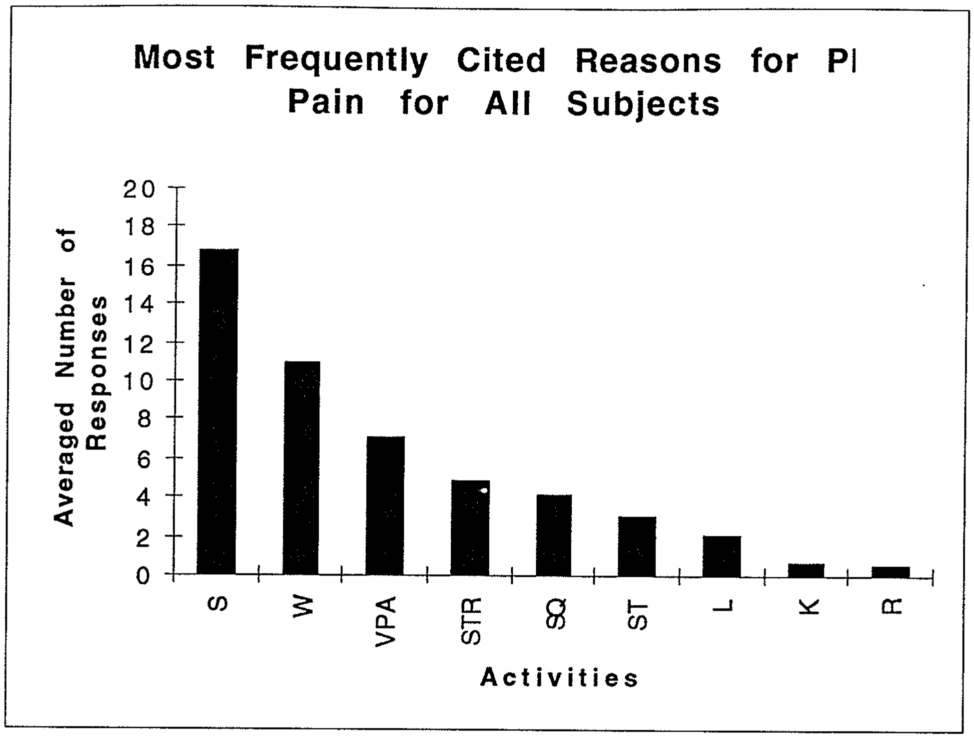

Figure 21. Most frequently cited reasons for patello-femoral pain averaged for all subjects.

According to Figure 21, sitting was identified as the activity with the highest average frequency count. An explanation for this result is that the bulk of subjects (twenty-five out of twenty-eight) were students who spent the majority of their day sitting in classes. An example of this can be observed by looking at the graphs in Appendix H for subject one, nine, twenty and twenty-four. These student subjects each reported frequencies in excess of forty over a three week period. The remaining three subjects were non-students who were employed as secretaries. Their job involved a lot of sitting behind a desk. One subject in particular reported nothing but prolonged sitting as the primary cause of their PF pain (see Graph 2 in Appendix H).

According to the literature PFJR forces are directly related to the amount of flexion at the knee joint (Hunter & James, 1984; Hungerford & Barry, 1979). Sitting involves a flexion in the vicinity of 90° or greater, depending whether or not the legs are crossed or uncrossed. One would therefore expect that sitting in this position for long periods of time would create increased compressive forces and therefore pain.

Walking was the next most frequently reported activity responsible for PF pain. The majority of the reports were related to walking between classes, at work or in malls while shopping. One subject, a part-time student and waitress, reported in excess of thirty-five frequency counts for walking. This pain was experienced mainly while she was waitressing. The majority of her shifts lasted for four hours and she worked several times a week (see Graph 15 in Appendix H). According to research done by Levine (1984), level walking created PFJR forces equivalent to 0.5 times body weight. How does this statement account for walking being, on average, the most frequently cited activity causing PF pain? One explanation may be that this activity is engaged in on a daily basis. We simply cannot get from point A to point B without walking. The raw data revealed that although walking was frequently cited, it was usually associated with milder intensities of PF pain, approximately less than three out of ten.

When considering PF pain, vigorous physical activity (VPA) was the third most frequently cited activity. A possible explanation for such a high average is that the majority of the subjects in the study were students whom were enrolled in the Faculty of Physical Education and Recreation Studies. They were active individuals who pursued a relative healthy and fit lifestyle. During the day they were often involved in activity courses and classes. According to the questionnaires, many these individuals worked out or engaged in various sports, three to five times a week (i.e. volleyball, cycling, basketball, jogging, hockey, ringette, ballet). In particular, subjects four, five, fifteen and twenty-five each reported VPA frequency counts in excess of fifteen over the course of the study (Appendix H).

The main activities these individuals were involved in were cycling, jogging, dancing, and lower body weight training. Most dynamic activities of this nature, exert compressive forces on the patello-femoral joint. As stated previously, these forces are directly related to the amount of flexion at the knee joint. The activities identified above require a lot of knee flexion. So, we can surmise that as flexion at the knee joint increased so did the PFJR forces. These increased forces created microtrauma which ultimately resulted in the production of PF pain (Bergeron, 1992; Hunter & James, 1984; Hungerford & Barry, 1979; Levine, 1984).

Stair climbing and squatting activities followed VPA as being one of the top frequently cited reasons for PF pain. In the literature PFJR forces reported for these activities were enormous. Stair climbing created a PFJR force that is approximately 3.5 times body weight. This value is roughly seven times that value obtained for level walking. This occurred because stair climbing required greater knee flexion. Deep knee bends or squats produced PFJR forces of approximately 2.5 to 3 times body weight (Reilly & Martens, 1972). According to this and the fact that PFJR forces can cause microtrauma, it is not surprising that these activities were identified frequently as being responsible for PF pain.

Lying, standing, running and kneeling were reported with consistently lower average frequency counts. The first two activities do not require a lot of knee flexion and according to the literature they would not exert significant PFJR forces. This would therefore result in less trauma to the patello-femoral joint and hence less pain produced. Running was likened to short mini dashes and not with sustained activities like jogging. For example, running to catch a bus or running because they were late for an appointment. Overall this was the lowest average frequency count. These individuals reported that pain was produced while attempting to catch a bus. Kneeling was the activity which had the second lowest average frequency count and in the questionnaires, it was often associated with pain while tying shoelaces or getting items from a low cupboard. The highest frequency count reported for kneeling and running was two. This was particularly true for subjects five, eight, nine, ten, twenty and twenty-four (see graphs in Appendix H). One possible reason these two activities reported such low counts maybe that subjects suffering with PFPS avoided these activities because they knew they would cause a lot of pain. This however, could be true of any or all of the nine activities discussed in this section.

CHAPTER 6

CONCLUSIONS, SUMMARY AND RECOMMENDATIONS

In conclusion, this study found that:

1. Statistically, PF pain does not significantly change from one day to the next but the observable changes in reported PF pain may have clinical relevance. Therefore studies looking at subjectively reported pain using a test/re-test protocol may have some inherent bias. Future studies should therefore consider a larger sample size than the present study and the data should be collected for a longer period of time.

2. Pain does significantly differ depending on the time of day and therefore the time of day for testing should be constant.

3. There are significant gender differences and therefore future studies should be restricted to one gender or the other.

4. Because females had significantly higher levels of PF pain, this population should receive closer attention in future studies.

Summary

It was the purpose of this study was to determine if PF pain varied from day to day; between different times in a day; and if there was a relationship to physical activity. A questionnaire was used on a daily basis to collect data over a three week period. Data was analyzed both parametrically and non-parametrically. From this analysis, this study concluded that PF pain varies from subject to subject for different reasons. PF pain varied significantly between different times in the day and specifically demonstrated a linear trend as the day progressed. Even though each subject demonstrated fluctuations in PF pain over the twenty-one days, a statistically significant variation was not detected between subjects or from one day to the next. However, it would be erroneous to state that subjects did not experience any variability in pain over the twenty-one day period. These reported changes in PF pain do affect the subject's daily function and do present with clinical relevance. Females experienced significantly more PF pain than did males. The between subject interactions for daily variability, time of day and gender did not yield significant results (Table 6.1). The type of physical activity identified as the causal factor for PF pain was significant. Subjects ranked sitting, walking, vigorous physical activities, stairs and squatting respectively as the cause of their PF pain over the twenty-one days. Standing, lying, kneeling and running were less of a factor. This may be because subjects intuitively avoided the painful activities or the nature of the day's activities in this subject population was unique.

Table 6.1 Summary of Results

Study Variables	**Significance Differences**
Daily Variability of PF Pain	No
Gender vs. PF Pain	Yes
Day vs. Time of Day	No
Day vs. Gender	No
Gender vs. Time of Day	No
Time of Day vs. PF Pain	Yes
Time of Day vs. Gender vs. Day	No

Recommendations

1. This study only looked at the intensity of pain over a short period of time. In order to get a more encompassing and accurate portrayal of PF pain, future studies should look at the full aspect of the pain experience (intensity, affective, sensory and evaluative domains). This can accomplished through the use of a VAS and MPQ together.

2. Pain measurements were taken at five different time of the day. It may be more beneficial to take hourly readings over the course of the entire day. This would therefore give a better indication of how PF pain changes throughout the day and from day-to-day.

3. In terms of physical activity and PF pain, it is my opinion that future studies should focus on gathering information on the amount of time spent on certain activities rather than frequency counts. This could be done by either having subjects report this information in a diary, with measurements taken on a hourly basis. Another way this could be examined is to conduct a single person study and have this individual followed by a second person, who would record time spent on certain activities. If funds are available, subjects could record this data on electronic daytimers. When an alarm sounded, they would record their pain intensity and activity duration and type.

4. In studies where male and females are studied, it is difficult to control for potential structural variations that exist between the sexes. Therefore, in future studies, it may be beneficial to study either males or females.

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APPENDIX A

Subject Instruction Sheet and Questionnaire

UNIVERSITY OF MANITOBA

Faculty of Physical Education and Recreation Studies

PATELLO-FEMORAL SYNDROME QUESTIONNAIRE

(July 1994)

INSTRUCTION SHEET

Patello-Femoral Syndrome Questionnaire

1. You will be completing this questionnaire for three weeks. Please fill-in the questionnaire at the end of each three hour time period or before bedtime for the last time period.
2. On your questionnaire please indicate the day of the week by circling S, M, TU, W, TH, F, S.
3. To record your pain, please mark a point on the line that best describes your knee, relative to the words at the end of the line.

   The following is an example of how to mark the line:

   No pain ____________________ Pain as severe as it could be

   The point on this line indicates that patello-femoral pain was average.

4. Report which activity you believe made your patello-femoral pain worse. To record this, check one of the listed activities and specify exactly what you were doing during that activity.

Example 1:

S	ST	L	W	R	STR	SQ	K	VPA
								Step Aerobics

Example 2:

S	ST	L	W	R	STR	SQ	K	VPA
Sat on plane for 2 hours								

S = **Sitting** (eg. in a movie theatre, on a plane, in a bus or while driving a car, or while watching TV or playing cards)

ST = **Standing** (eg. as a cashier, doing dishes or while cooking)

L = **Lying** (eg. sleeping, suntanning, watching TV)

W = **Walking** (eg. while shopping, house cleaning, vacuuming, raking lawn, mowing the lawn or taking dog out)* Not for exercise like power walking *

R = **Running** (eg. to catch a bus, late for an appointment)

STR **Stairs** (eg. office on 3rd floor, elevator is broken, get to your apartment or upstairs or downstairs in your home)

SQ = **Squatting** (eg. catcher's position in baseball, to pick up boxes, participating in a curling bonspiel)

K = **Kneeling** (eg. washing/waxing floors, gardening, tie your shoes)

VPA = **Vigorous Physical Activity** (eg. tennis, rollerblading, aerobics, cycling, skating, hockey, basketball, racquetball, squash, volleyball, baseball, soccer, skiing, swimming, weight training, power walking,)

Day of the Week : S M W TH F S

Complete the questionnaire at the end of each time period (before bedtime, for the last period.

7:00 - 10:00 am

No Pain ____________________ Pain as severe as it could be

S	ST	L	W	R	STR	SQ	K	VPA

Specify:

____

10:00 - 1:00 pm

No Pain

Pain as severe as it could be

S	ST	L	W	R	STR	SQ	K	VPA

Specify:

1:00 - 4:00 pm

No Pain

Pain as severe as it could be

S	ST	L	W	R	STR	SQ	K	VPA

Specify:

4:00 - 7:00 pm

No Pain

Pain as severe as it could be

S	ST	L	W	R	STR	SQ	K	VPA

Specify:

7:00 - 10:00 pm

No Pain

Pain as severe as it could be

S	ST	L	W	R	STR	SQ	K	VPA

APPENDIX B

Subject Consent Form

SUBJECT CONSENT FORM

UNIVERSITY OF MANITOBA
Faculty of Physical Education and Recreation Studies

"The daily variability of patello-femoral pain related to the level of physical activity".

You have been selected to participate in a research study that is designed to investigate the daily variation of patello-femoral pain related to the level of physical activity. Information for the study will be obtained using three small questionnaire booklets. Each booklet consists of a single week of questionnaires which have been divided into five three-hour blocks. Each time block or period, is separated into two sections. Section one requires you to indicate the intensity of your patello-femoral pain using a 10 centimeter horizontal visual analog scale (VAS). To record your pain intensity, you simply mark a point on the VAS line that best describes your knee pain, relative to the words at the ends of the line. The second section asks you to report which activity you felt made your patello-femoral pain worse. To record this, you are asked to check one of the activities listed and then specify exactly what it was you were doing during that activity. Completing each time period requires only a small amount of your time.

The patello-femoral pain questionnaire will be completed daily for a period of three weeks or twenty-one days. You will be required to fill-out the questionnaire at the end of each time period or before bedtime for that last time period. A sheet of instructions outlining the use of the questionnaire, along with a phone number to contact the researcher in case you have any questions or concerns, is located at the front of the questionnaire booklet. At the end of each week you are asked to drop off the questionnaire booklet to the researcher at the University of Manitoba. If this is not possible, other arrangements can be made.

- All my personal identifiable records and information collected for the purposes of this study, will be kept strictly confidential.

- My participation in this study is completely voluntary and I have the right to discontinue my involvement at any time without prejudice or penalty.

- I hereby declare that I have read and understood this form and that I willingly consent to participate in this study.

____

print name of participant

____ ____________

signature of participant **date**

____

print name of witness

____ ____________

signature of witness **date**

For further information please do not hesitate to contact researcher at 474-6956.

APPENDIX C

Subject Profile and History Form

SUBJECT PROFILE AND HISTORY

PART I: PERSONAL INFORMATION

Name: ______________________________ Date: __________

Address:

____

____

____

Phone Number: ____________________

Date of Birth: ______ / ______ / ______
M D Y

Height: ____________________ (cm)

Weight: ____________________ (kg)

PART II: INJURY INFORMATION:

Date of Injury: ____________________ Knee: R L

Activity related to pain:

____

____

____

Previous History: ______________________________

____

____

____

Medication(s): Yes No

Type of Medication(s): ______________________________

____

Subjects cannot be referred to this study if they have evidence or history of the following conditions:

- patellar trauma that is the present cause of knee pain (i.e. fractures);
- dislocating or subluxing patella;
- previous history of any type of knee surgery;
- confirmed damage to mensical, ligamentous or fat pad tissue that is present cause of knee pain;
- upper and/or lower motor neuron lesions;
- osteochonral or chondral fracture;
- referred pain from either the back or hip;
- radiological evidence of degenerative diseases.

APPENDIX D

Newspaper Advertisement for Subjects

ATTENTION !!

SUBJECTS NEEDED FOR A STUDY ON KNEE PAIN

ARE YOU EXPERIENCING ANY OF THE FOLLOWING SYMPTOMS:

- Pain in your knee when going up and down stairs?
- Pain behind you kneecap when it is gently pressed and moved against your lower thigh bone?
- Pain after sitting in one position for a long period of time (i.e. movie theater, in a car or on a plane)?
- Pain when touching the inside edge of your kneecap or its under surface?

If you say yes to two or more of the above symptoms (or have been diagnosed with patello-femoral pain syndrome) and would like to be involved in this study, call **Jackie Elliott at 474-6956 or 261-5338.**

Involvement in this study will require you to complete a daily questionnaire over a period of three weeks.

THANK YOU.

APPENDIX E

Subject Referral Letters to Doctors and Therapists

Dear ;

I am writing to you to kindly request subject referrals for my thesis study on patello-femoral pain syndrome. My topic will focus on patello-femoral pain to see how it varies on a daily basis. I will also be looking indirectly at how physical activity affects this daily variation of patello-femoral pain.

Male or female subjects referred to this study, should be between the ages of 16 to 35 and must meet the inclusionary and exclusionary criteria (see next page for the criteria). Each subject will complete a questionnaire on a daily basis for a period of three weeks or twenty-one days. The questionnaire itself consists of two sections. The first part has the subject reporting their pain level on a visual analogue scale for five individual time periods. In part two the subject reports what one activity they felt made their patello-femoral pain worse, for each of the five time periods.

If you have any eligible patients, could you please contact me and leave their name and phone numbers. I will follow this up with a phone call to talk with the subject about the study and arrange a time for us to meet. You can contact me at the following phone numbers: **474-6956 OR 261-5338**.

If you have any questions, concerns or would like more information, please contact me at the above phone numbers and I can meet you to further discuss this request and my study. Thank you for your time.

Sincerely,

Jackie Elliott
Graduate Student Researcher

CC: Glen Bergeron, Graduate Supervisor

Subject can only be referred to this study if they exhibit two or more of the following criteria upon assessment:

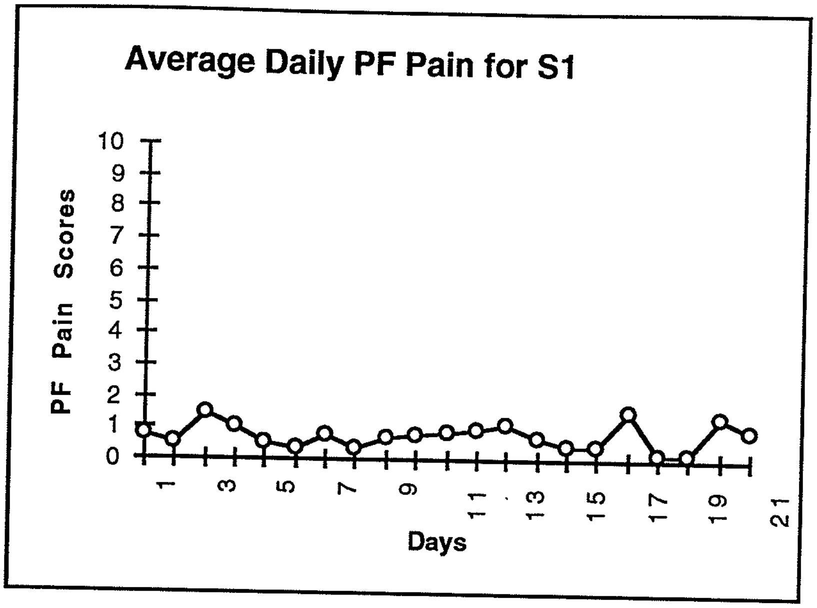
- pain is elicited when the patella is directly compressed and moved up and down in the femoral groove, while the knee is in full extension;
- patellar pain or tenderness is elicited when the medial retinaculum and undersurface of the patella is palpated;
- pain is elicited when the knee is extended from a 20 degree flexed position;
- patellar pain is elicited when using stairs, especially going downstairs;
- positive Clarke's sign (pain behind the patella is elicited when the quadricep muscles are contracted and the therapist provides resistance above the patella);
- positive Movie or Theater sign (individual experiences pain behind the patella after sitting in one position for long periods of time).

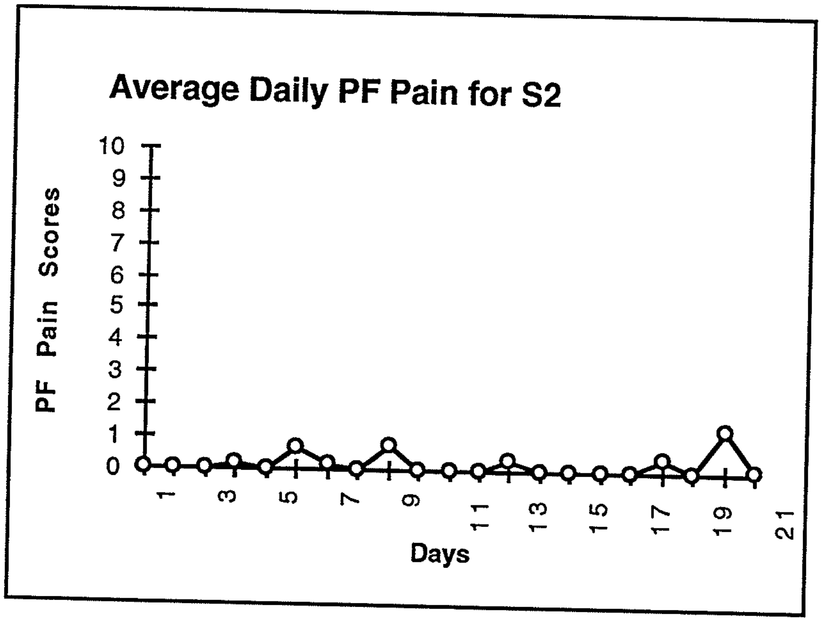
Subjects cannot be referred to this study if they exhibit any of the following:

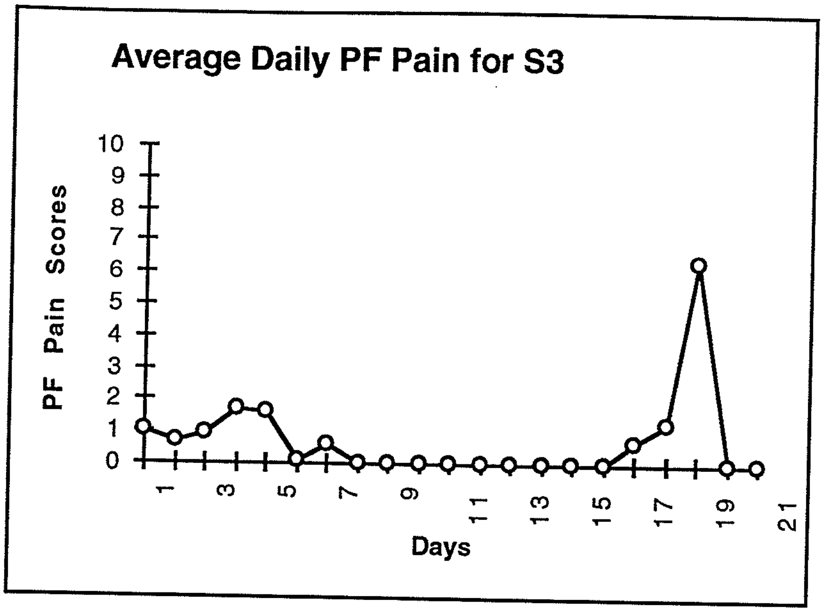
- history of patellar trauma (i.e. fractures) that is responsible for the present knee pain;
- a history of dislocating or subluxing patella;
- previous history of any type of knee surgery (i.e.. scope, reconstruction) or have surgery pending during the time period of the study;
- evidence of osteochondral or chondral fractures;
- confirmed damage of meniscal, ligamentous or fat pad tissue that is responsible for the present knee pain;
- evidence of upper and/or lower motor lesions;
- evidence of referred pain from either the back or hip;
- radiological evidence of degenerative disease.

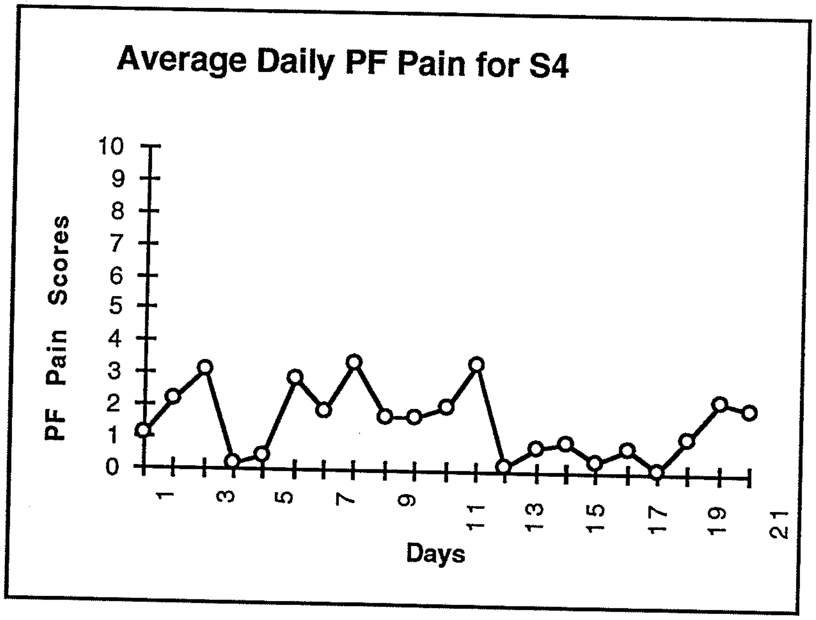
APPENDIX F

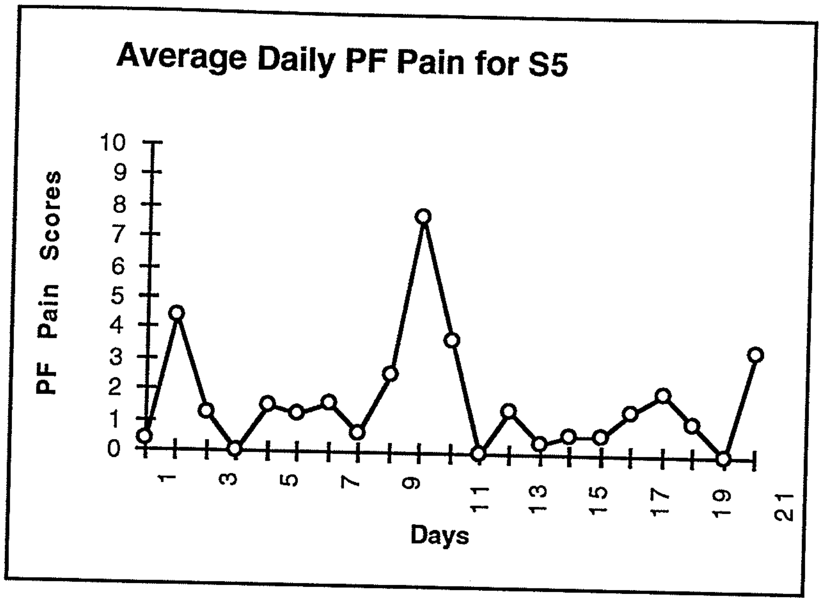
Graphs of Average Daily Patello-femoral Pain for S1-S28


Average Daily PF Pain for S1
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

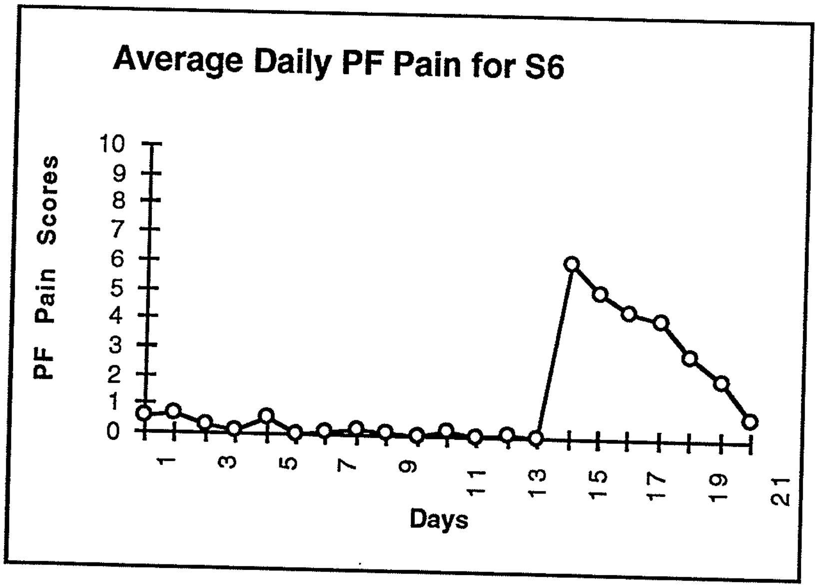

Average Daily PF Pain for S2
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days


Average Daily PF Pain for S3
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

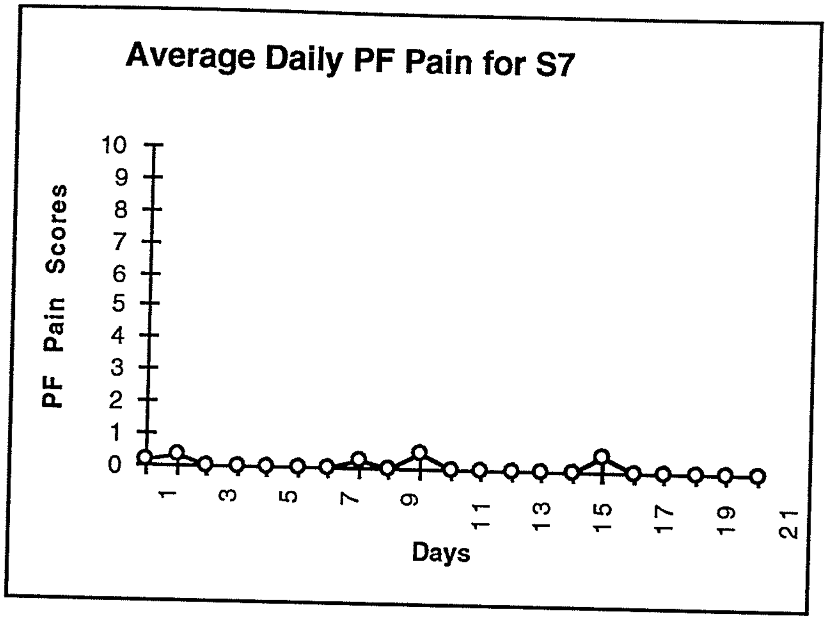

Average Daily PF Pain for S4
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

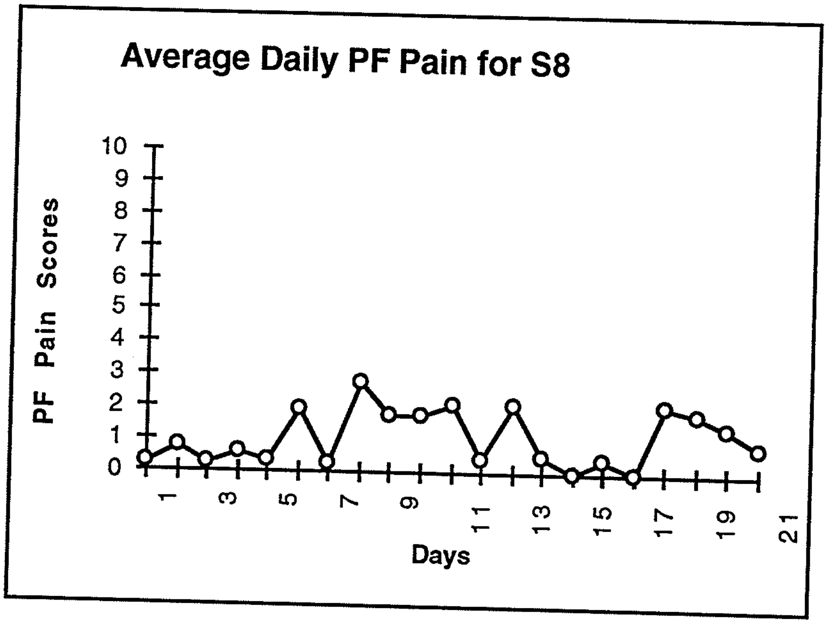


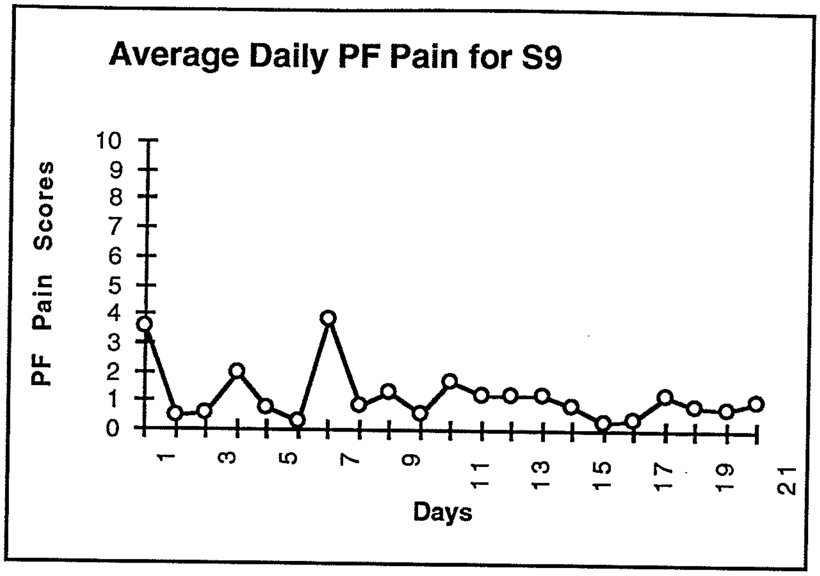
Average Daily PF Pain for S5

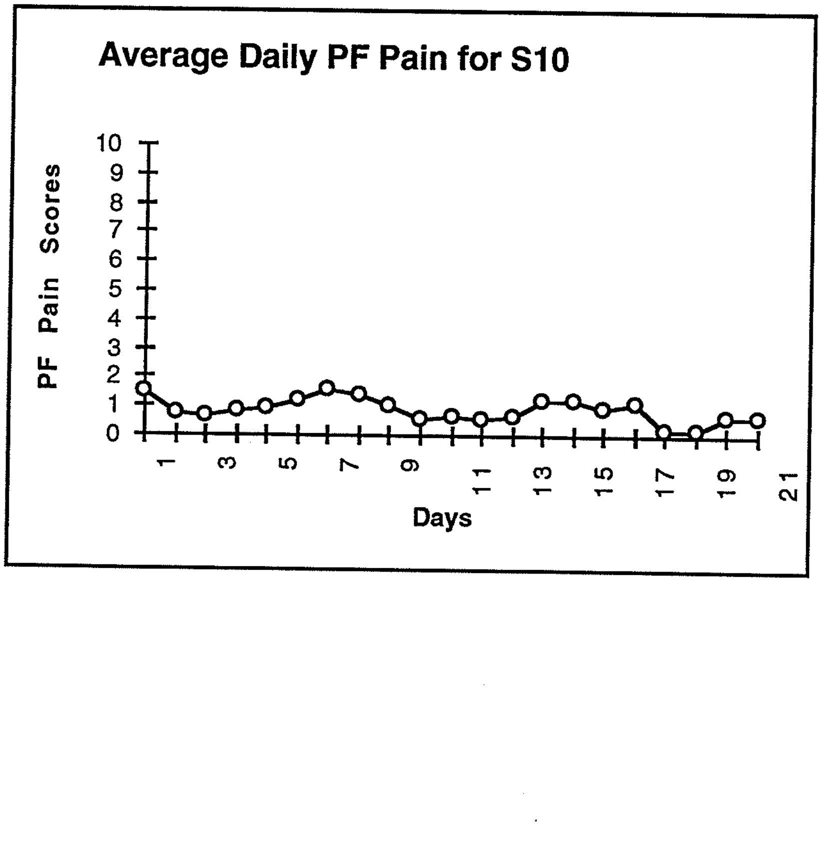


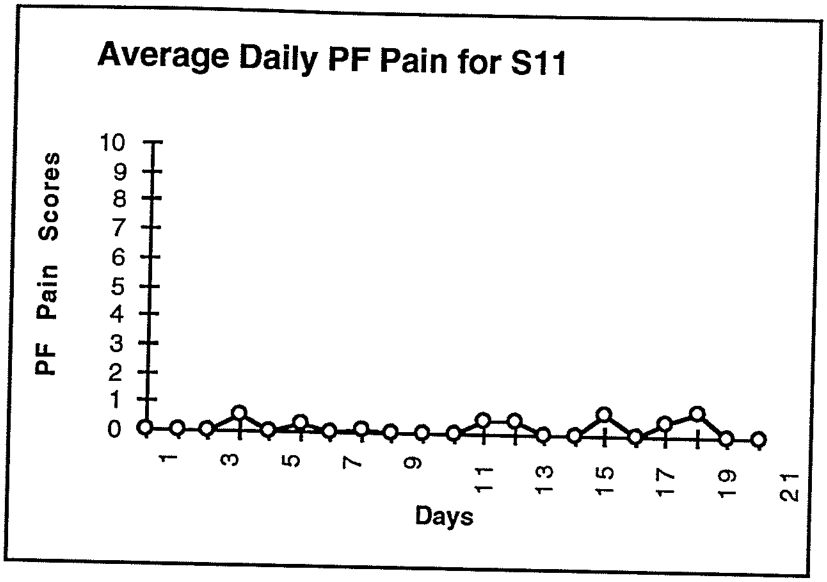
Average Daily PF Pain for S6

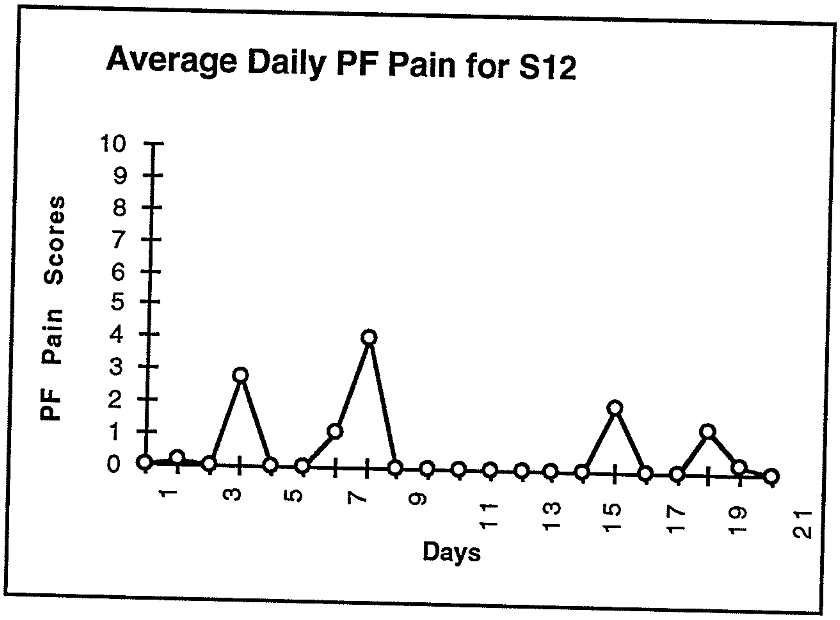

Average Daily PF Pain for S7
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

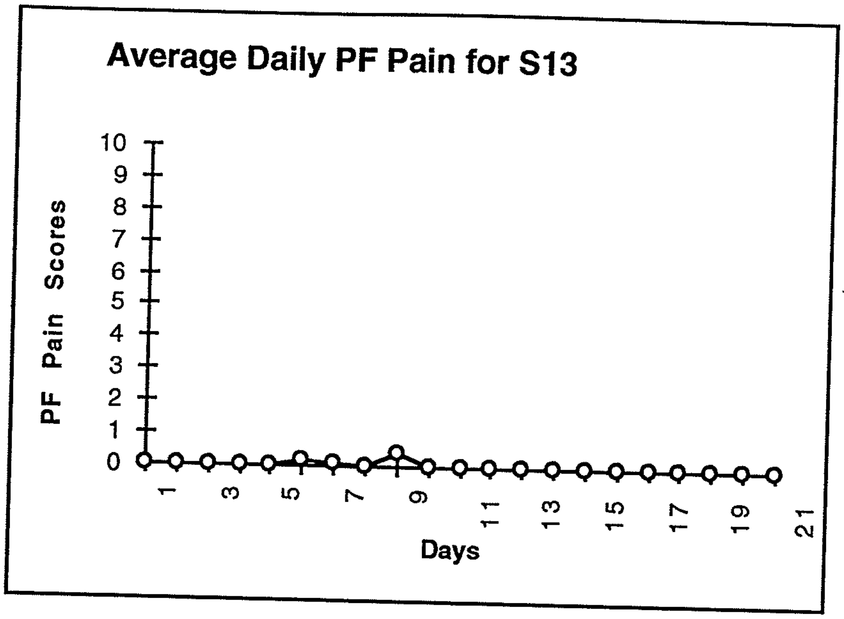

Average Daily PF Pain for S8
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days


Average Daily PF Pain for S9
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

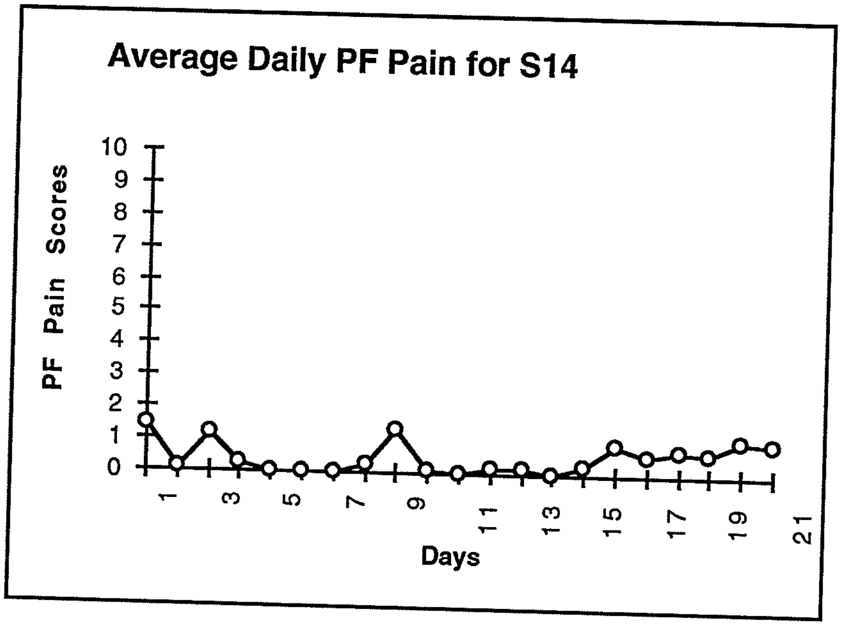

Average Daily PF Pain for S10
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days


Average Daily PF Pain for S11
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

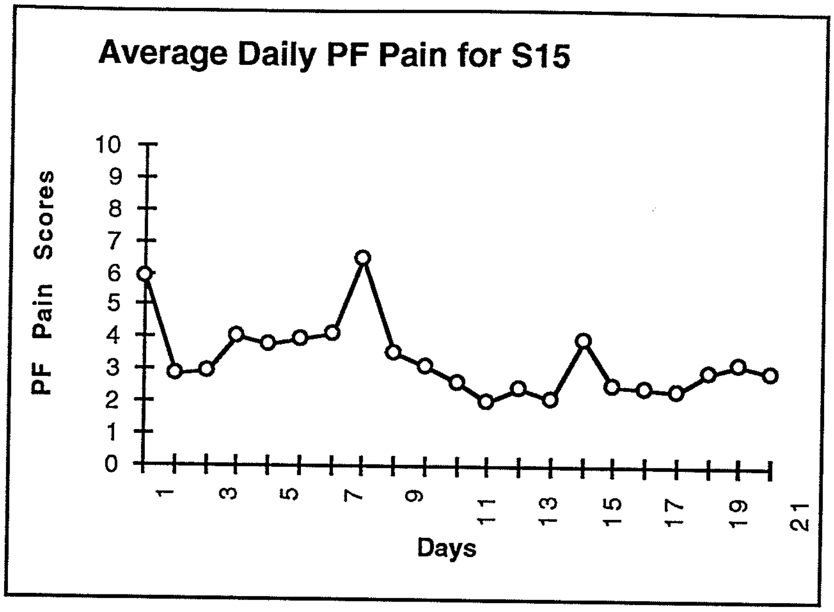

Average Daily PF Pain for S12
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

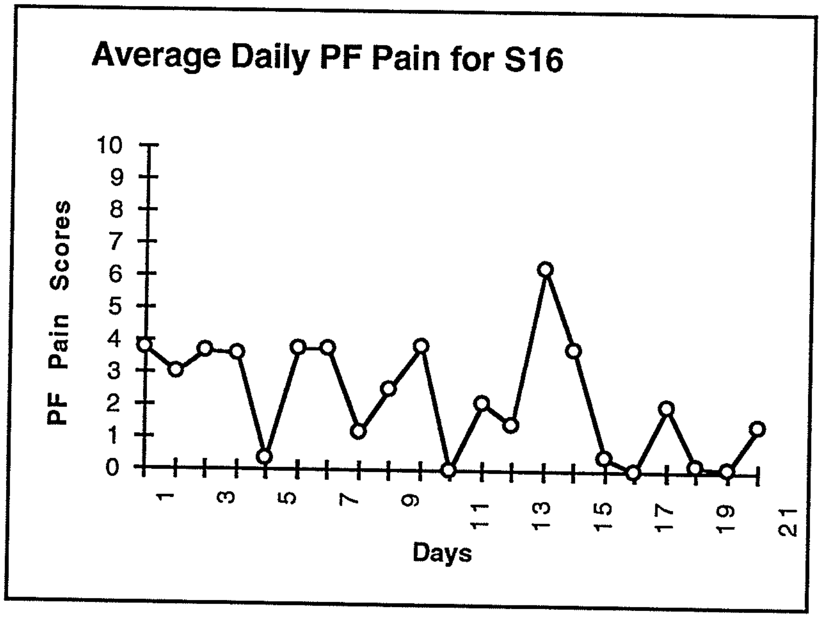


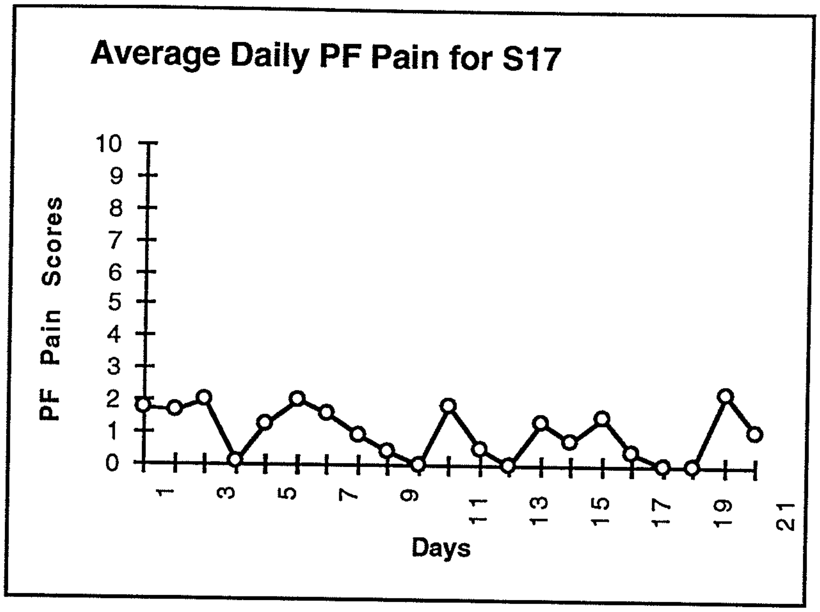
Average Daily PF Pain for S13

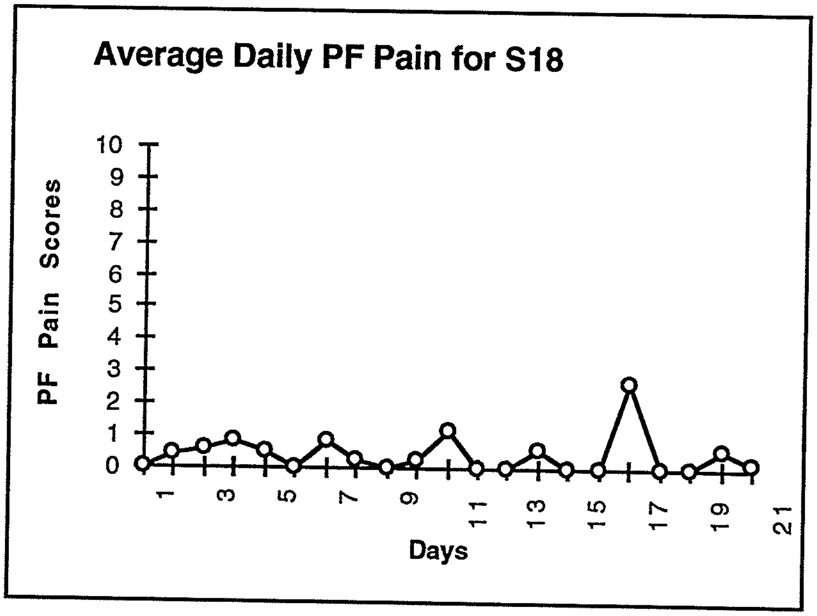


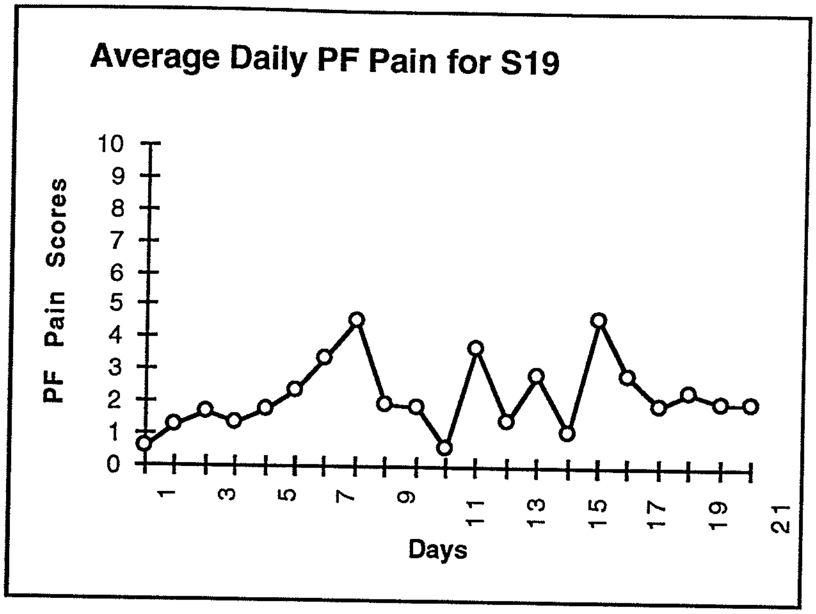
Average Daily PF Pain for S14

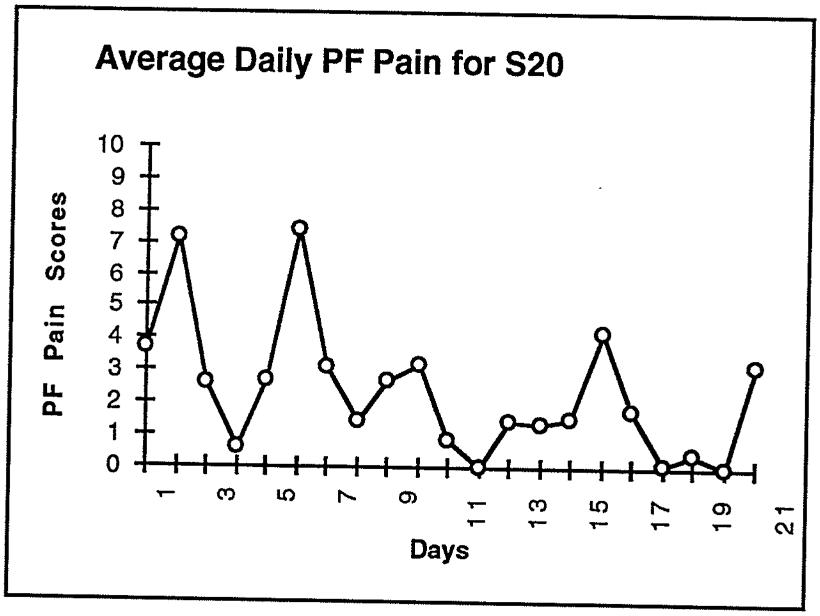

Average Daily PF Pain for S15

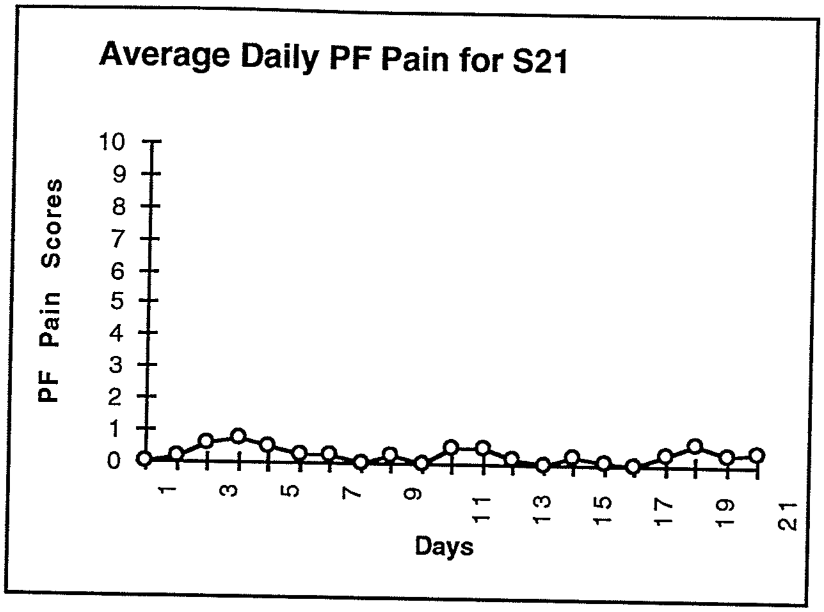

Average Daily PF Pain for S16

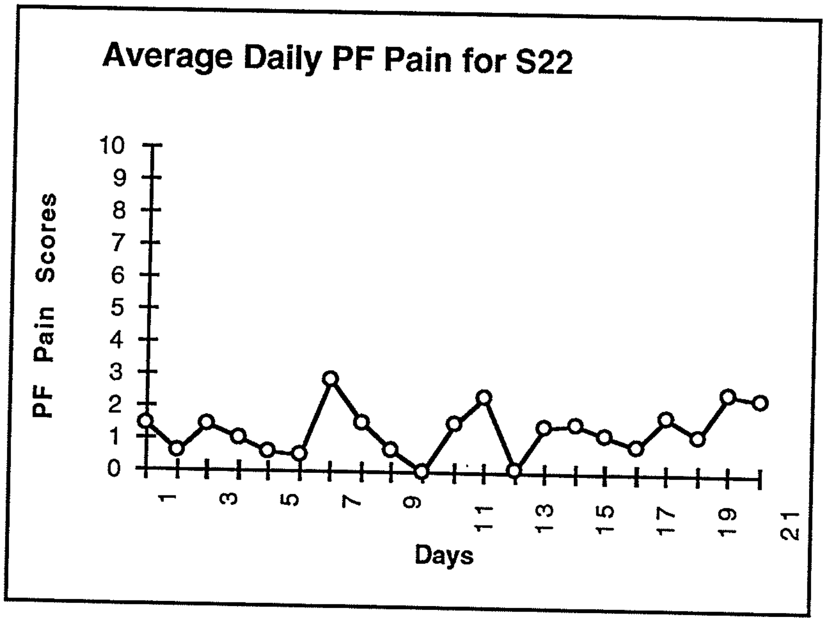

Average Daily PF Pain for S17

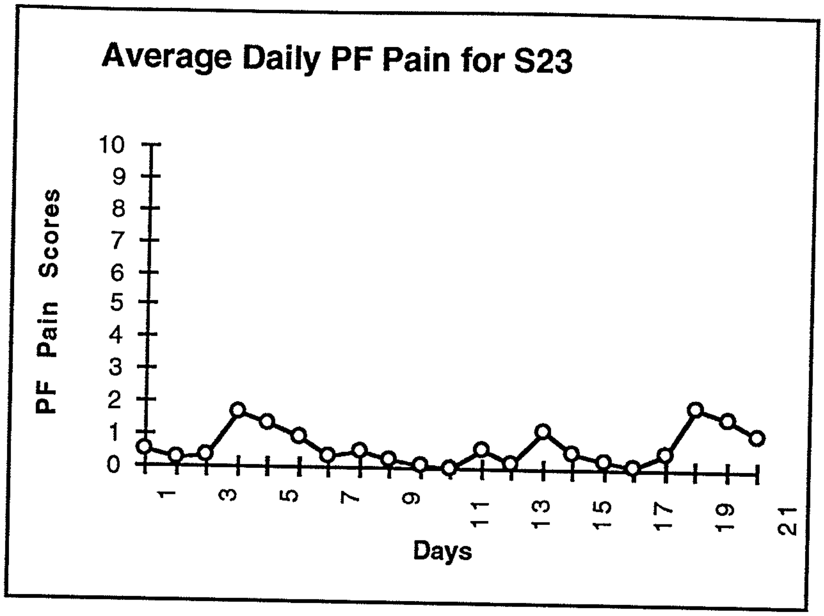

Average Daily PF Pain for S18


Average Daily PF Pain for S19
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

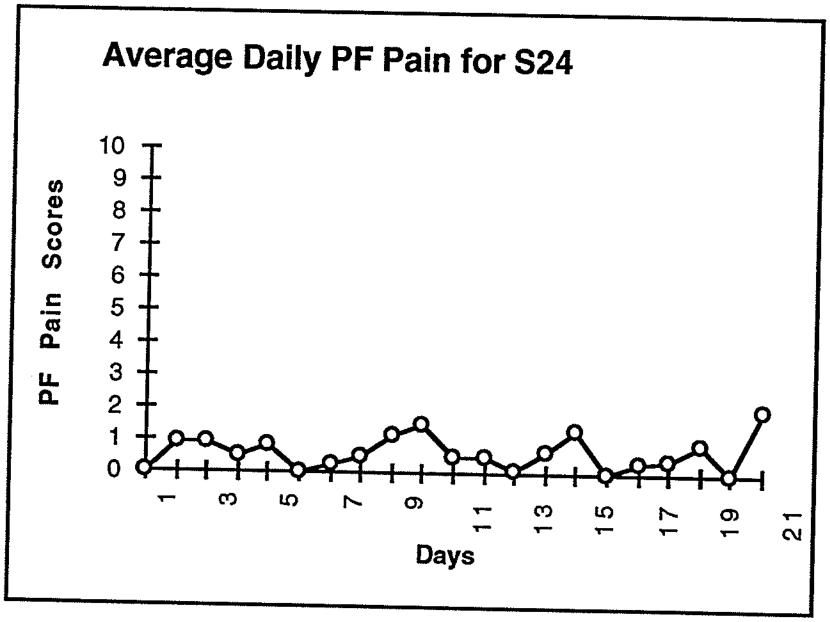

Average Daily PF Pain for S20
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days


Average Daily PF Pain for S21
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

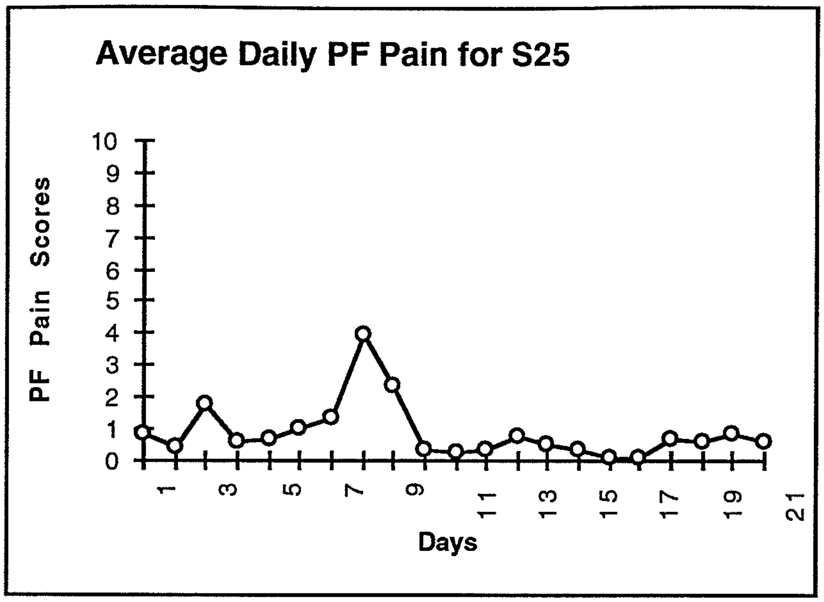

Average Daily PF Pain for S22
PF Pain Scores
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
9
11
13
15
17
19
21
Days

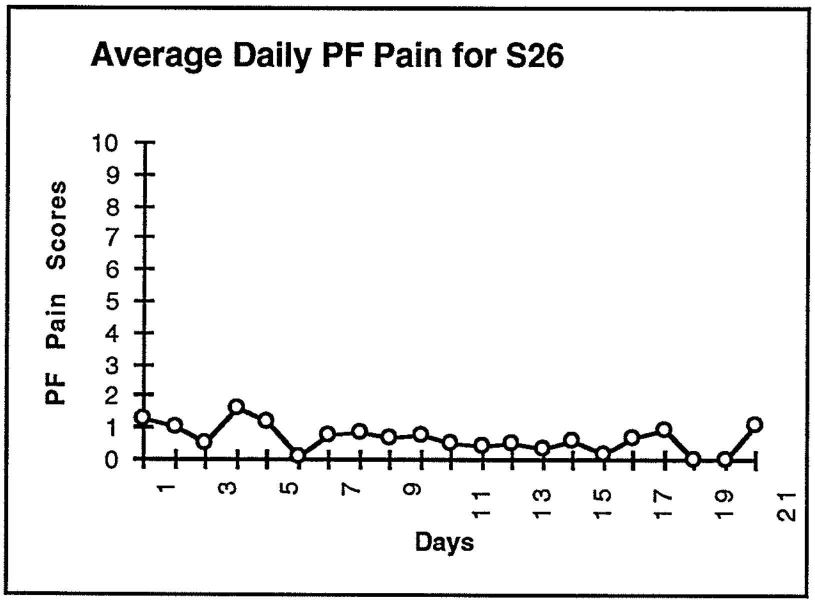


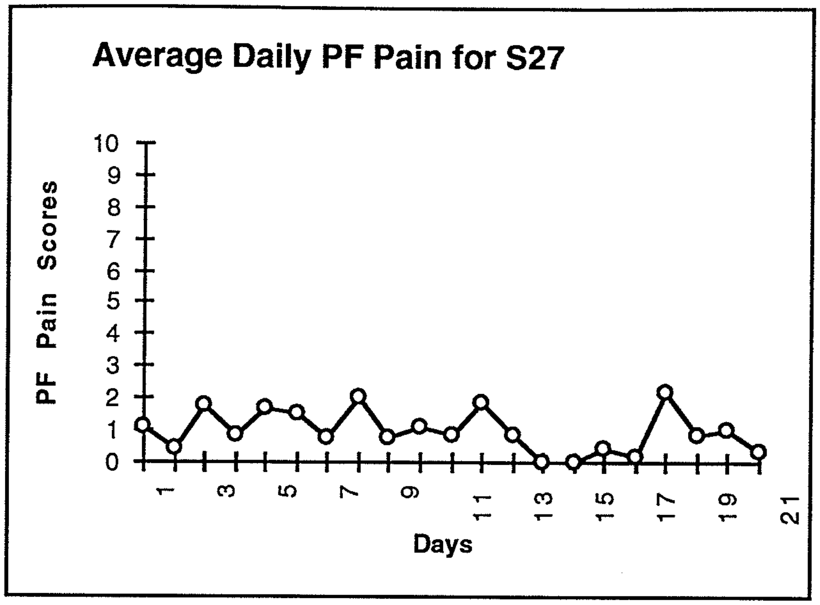
Average Daily PF Pain for S23



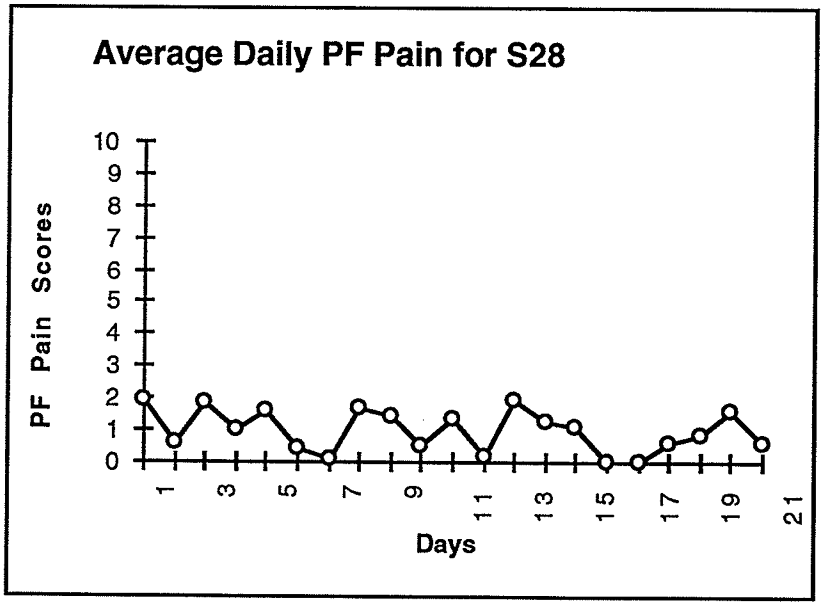
Average Daily PF Pain for S24


Average Daily PF Pain for S25


Average Daily PF Pain for S26



Average Daily PF Pain for S27



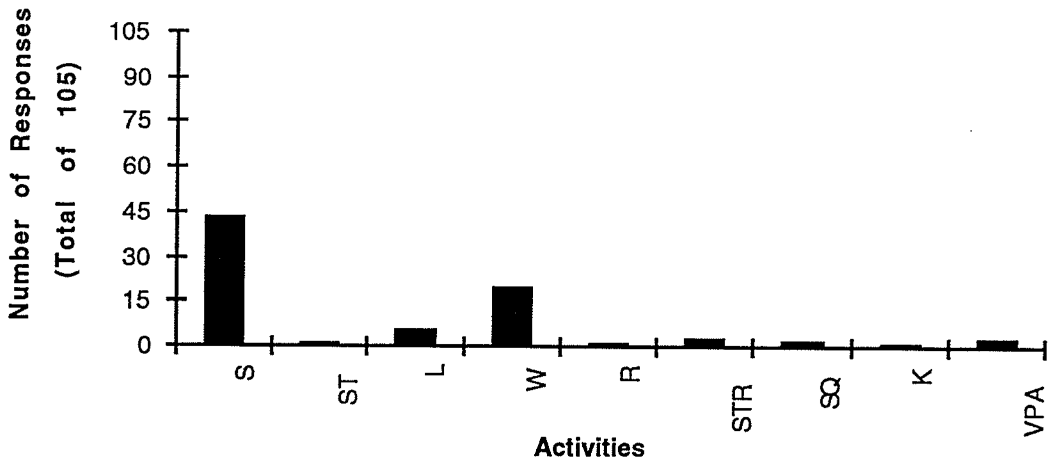
Average Daily PF Pain for S28

APPENDIX G

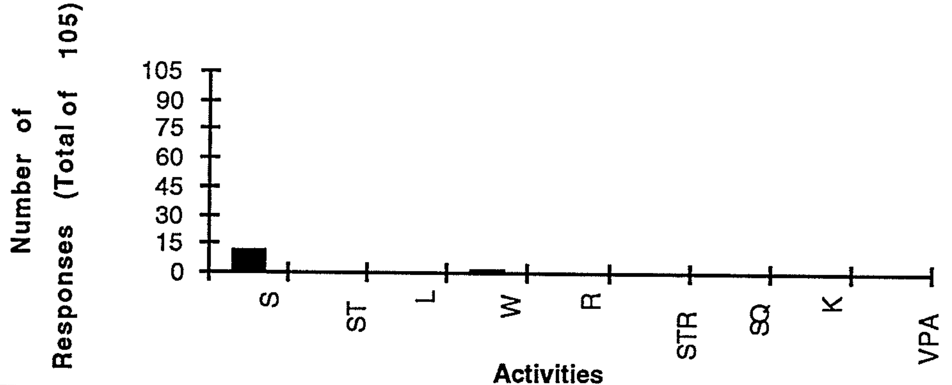
Most Frequently Cited Reasons for Patello-femoral Pain Graphs

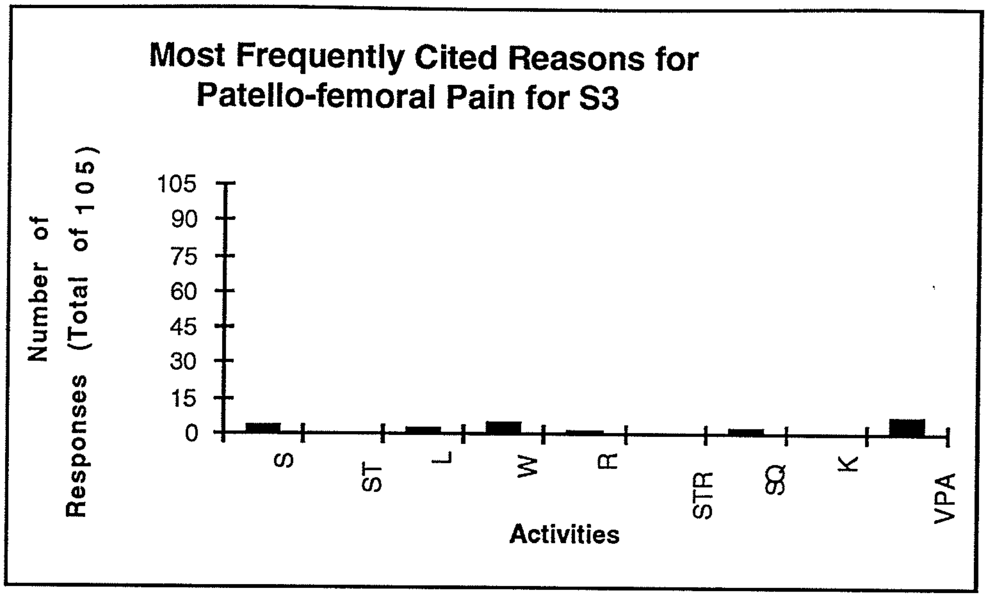
For Subjects 1-28

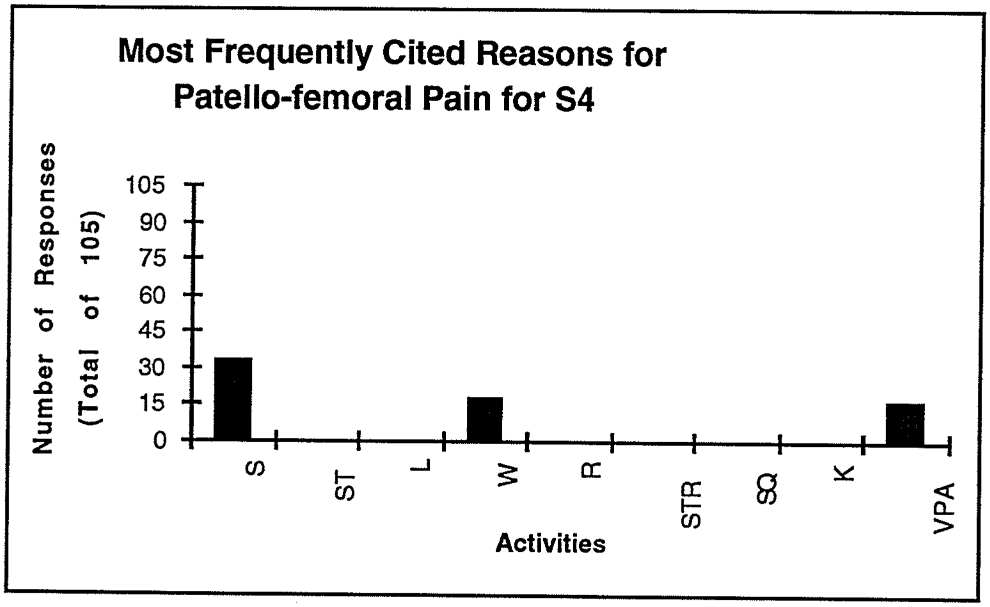
Most Frequently Cited Reasons for Patello-femoral Pain for S1

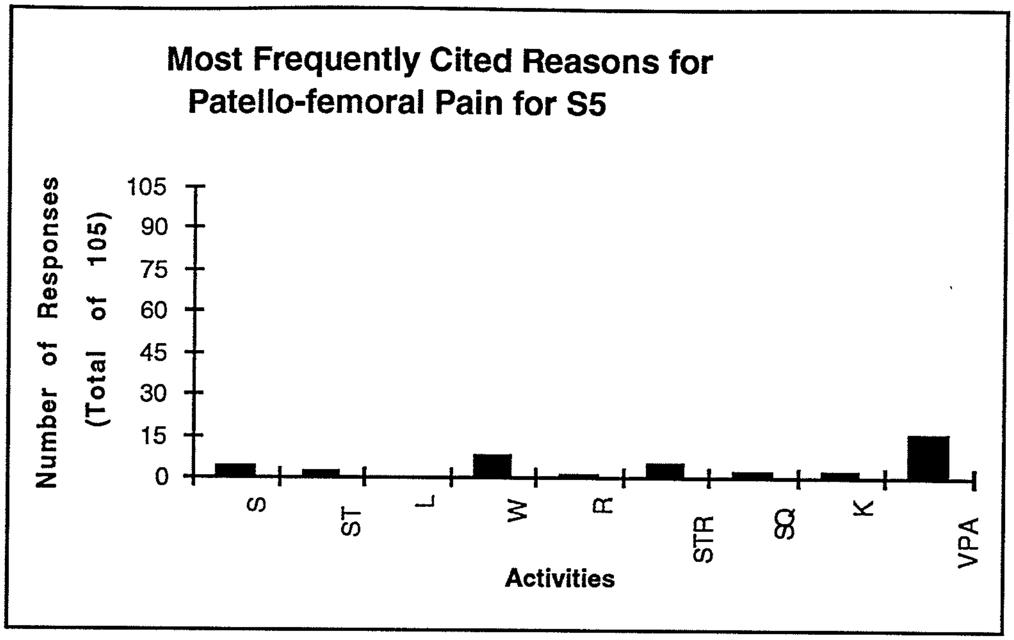


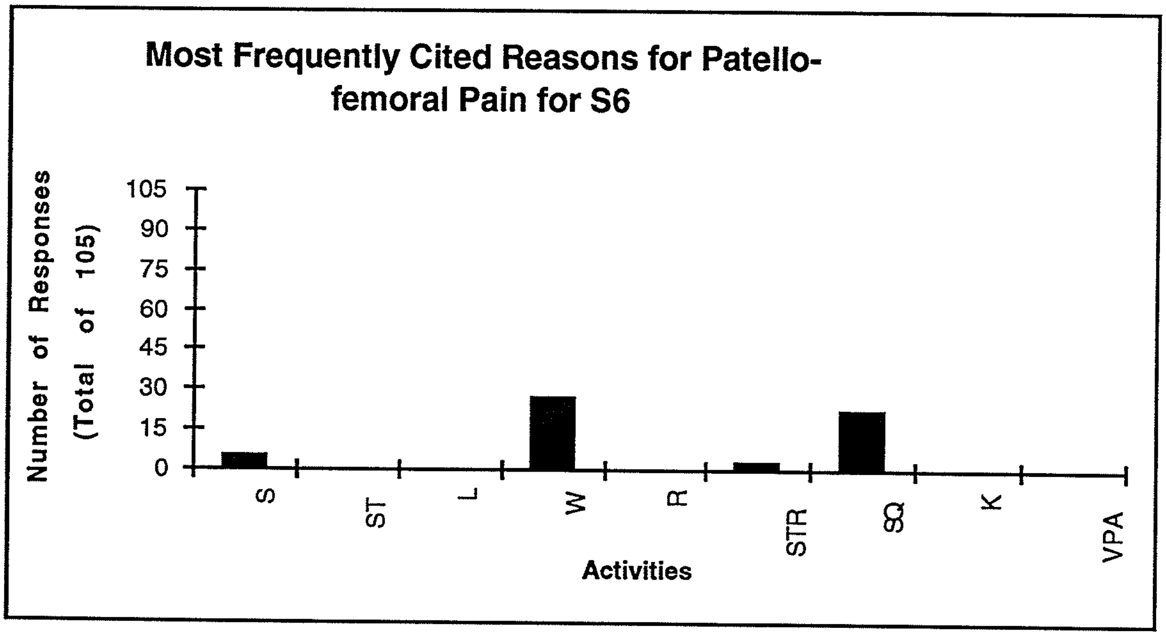
Most Frequently Cited Reasons for Patello-femoral Pain for S2

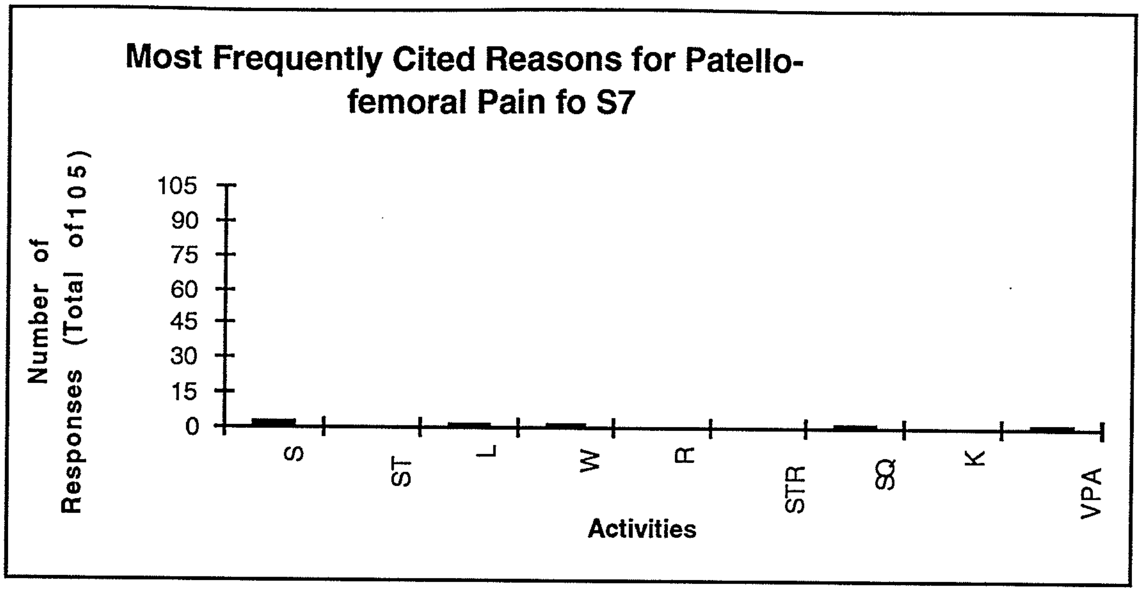



Most Frequently Cited Reasons for Patello-femoral Pain for S3

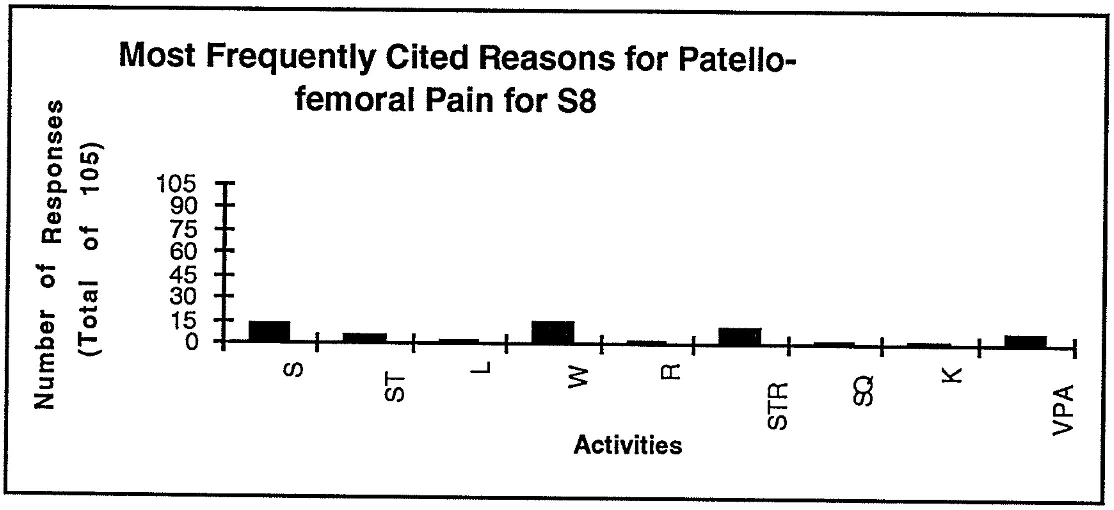

Most Frequently Cited Reasons for Patello-femoral Pain for S4


Most Frequently Cited Reasons for Patello-femoral Pain for S5

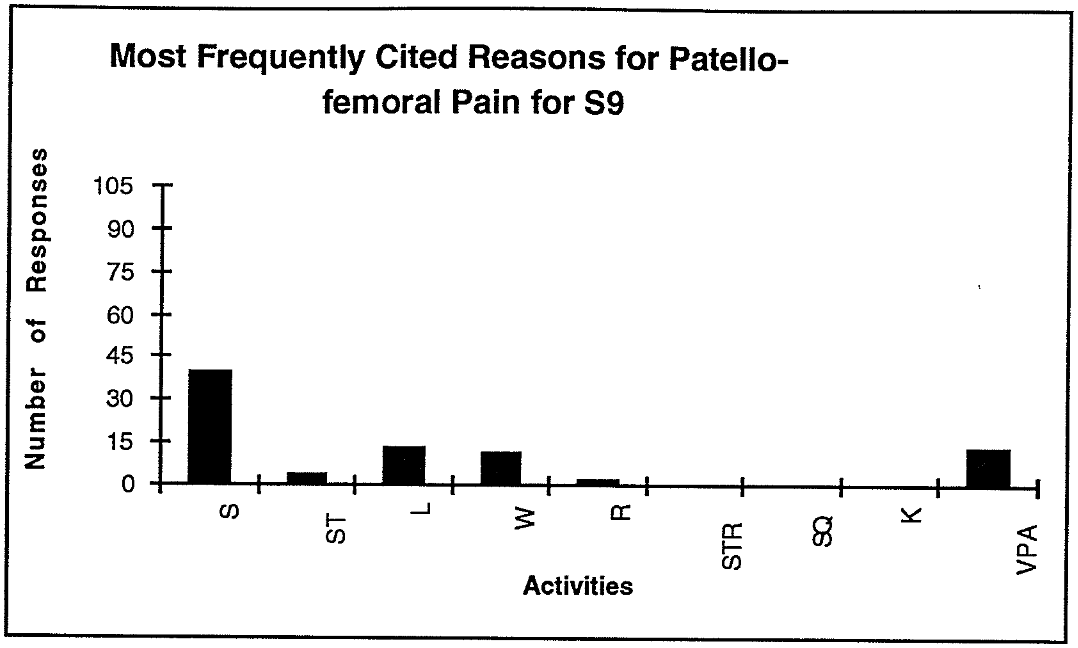

Most Frequently Cited Reasons for Patello-femoral Pain for S6

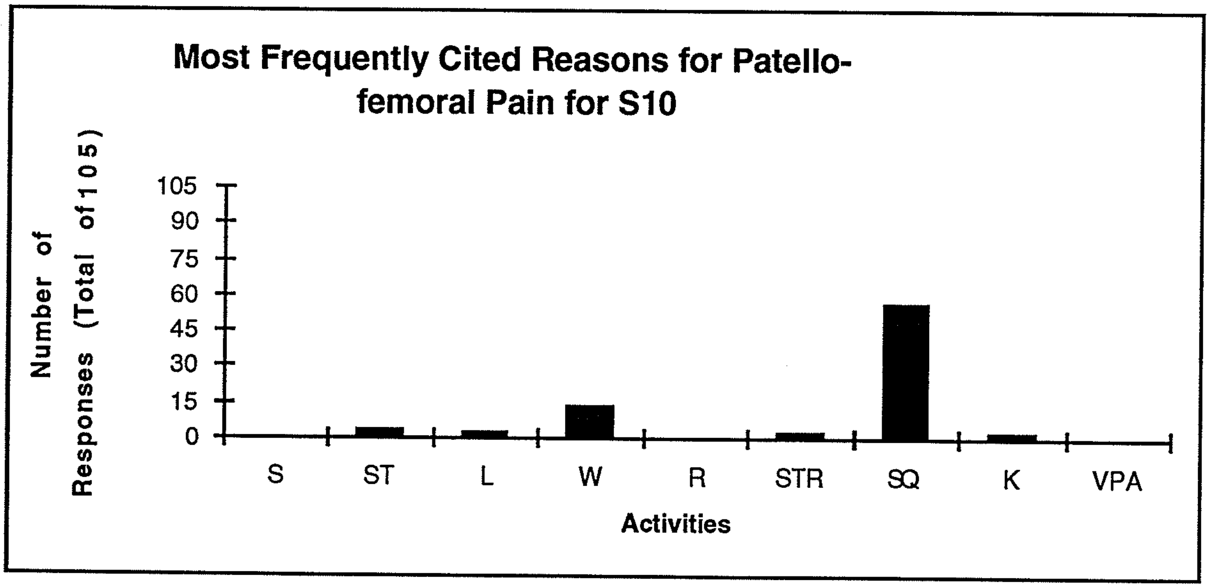


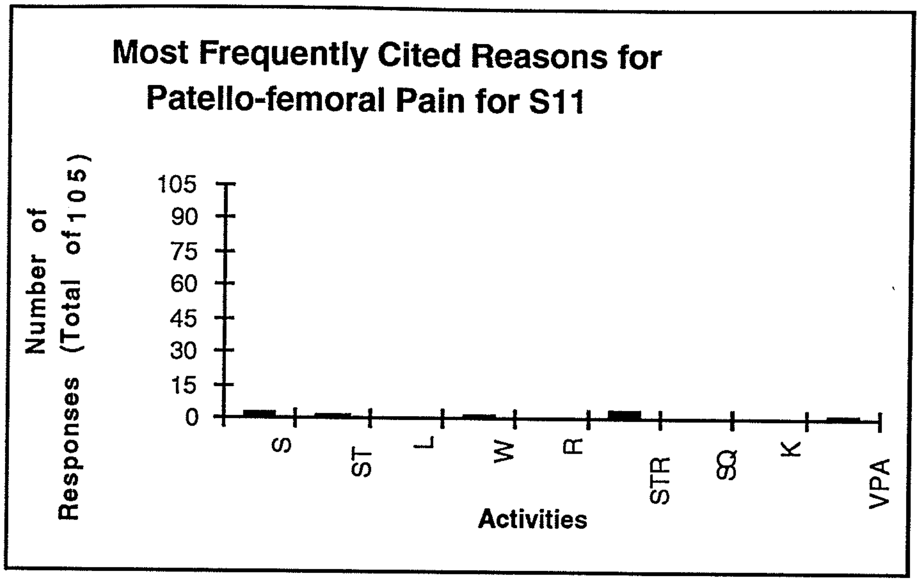
Most Frequently Cited Reasons for Patello-femoral Pain fo S7

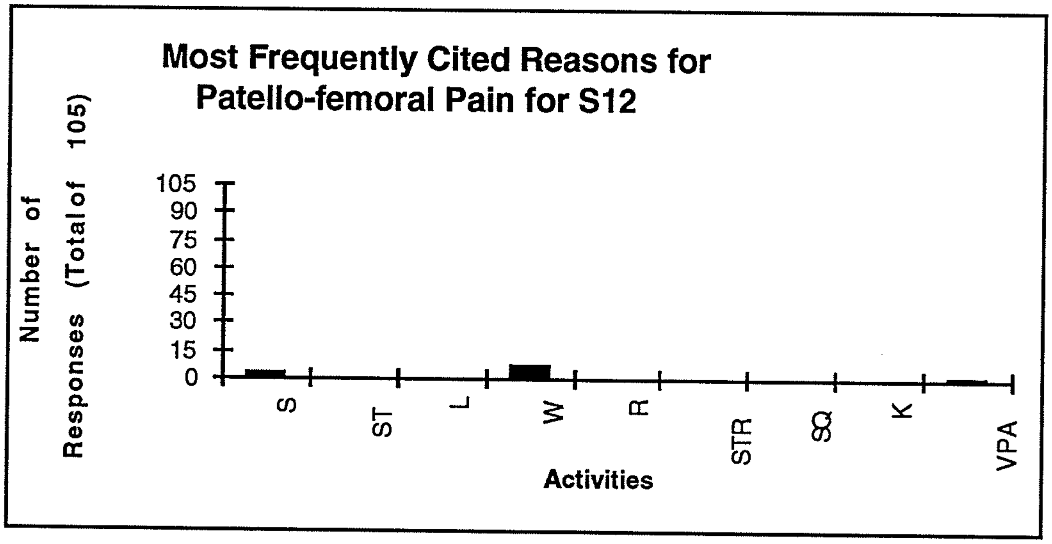


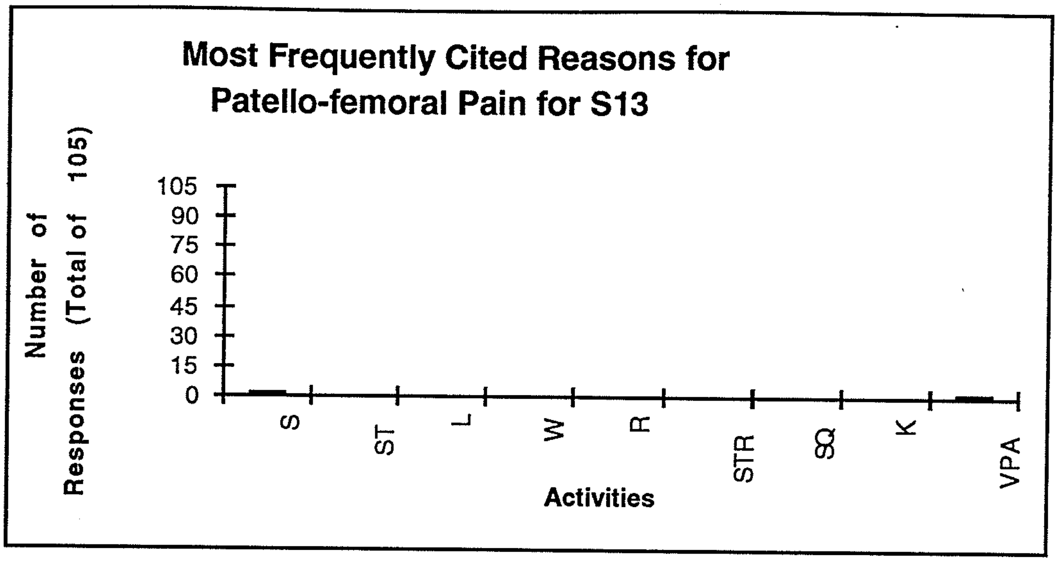
Most Frequently Cited Reasons for Patello-femoral Pain for S8


Most Frequently Cited Reasons for Patello-femoral Pain for S9

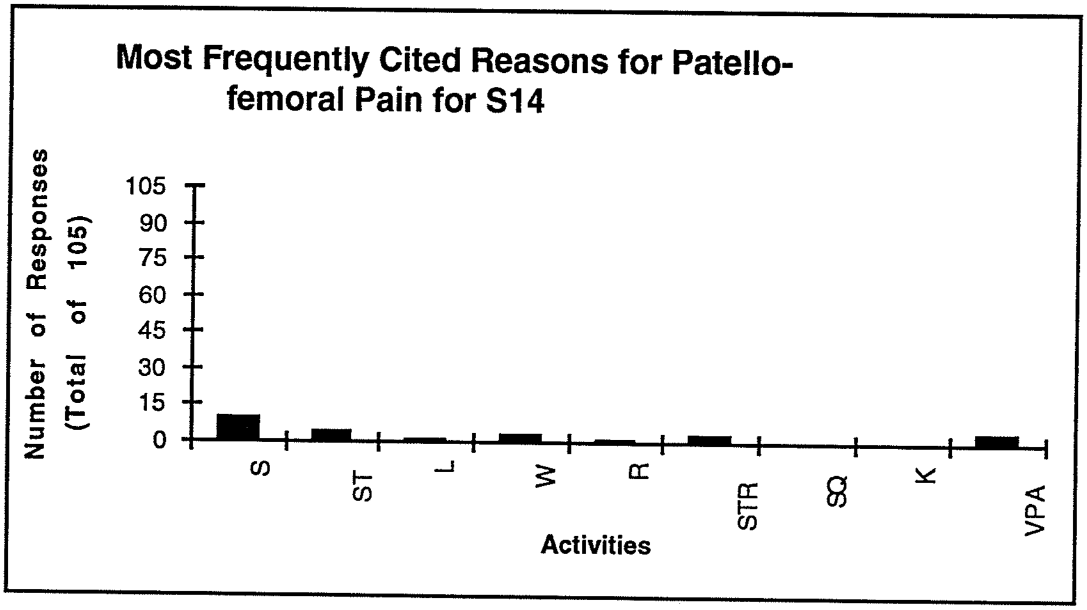

Most Frequently Cited Reasons for Patello-femoral Pain for S10


Most Frequently Cited Reasons for Patello-femoral Pain for S11

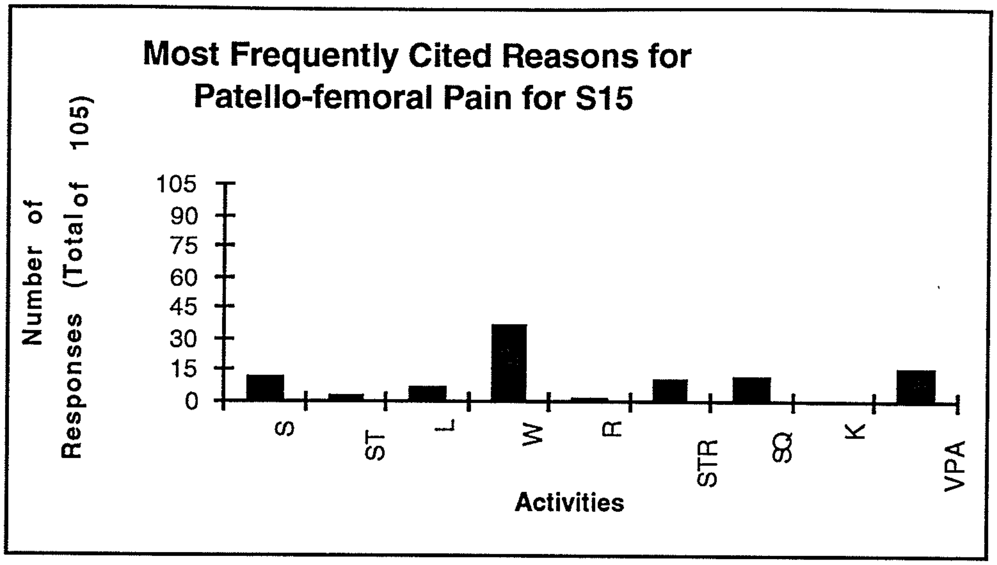

Most Frequently Cited Reasons for Patello-femoral Pain for S12



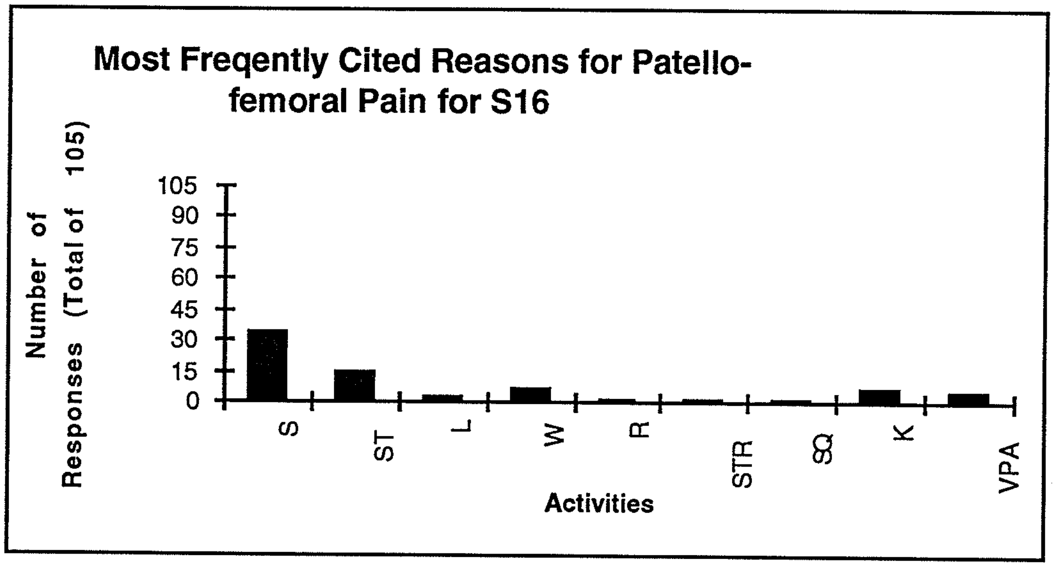
Most Frequently Cited Reasons for Patello-femoral Pain for S13



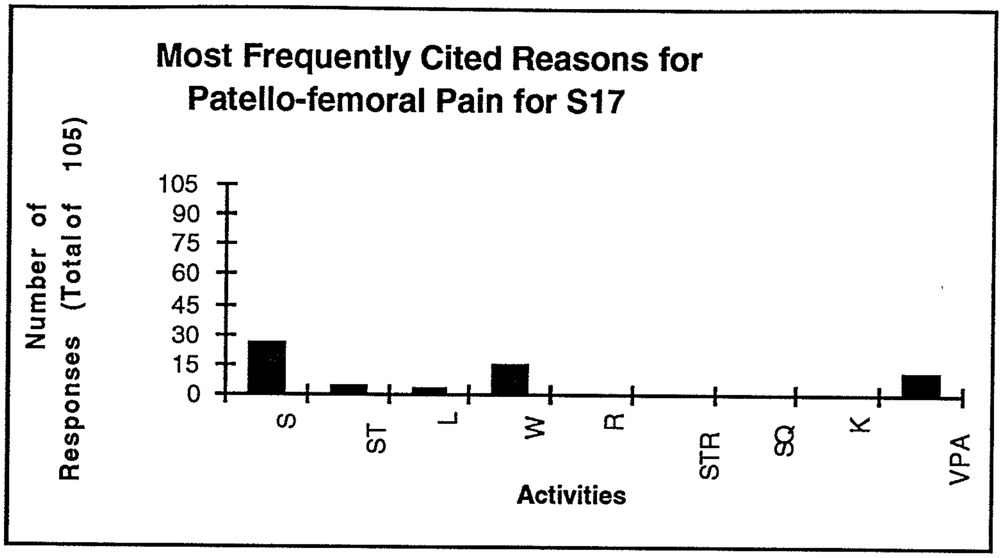
Most Frequently Cited Reasons for Patello-femoral Pain for S14

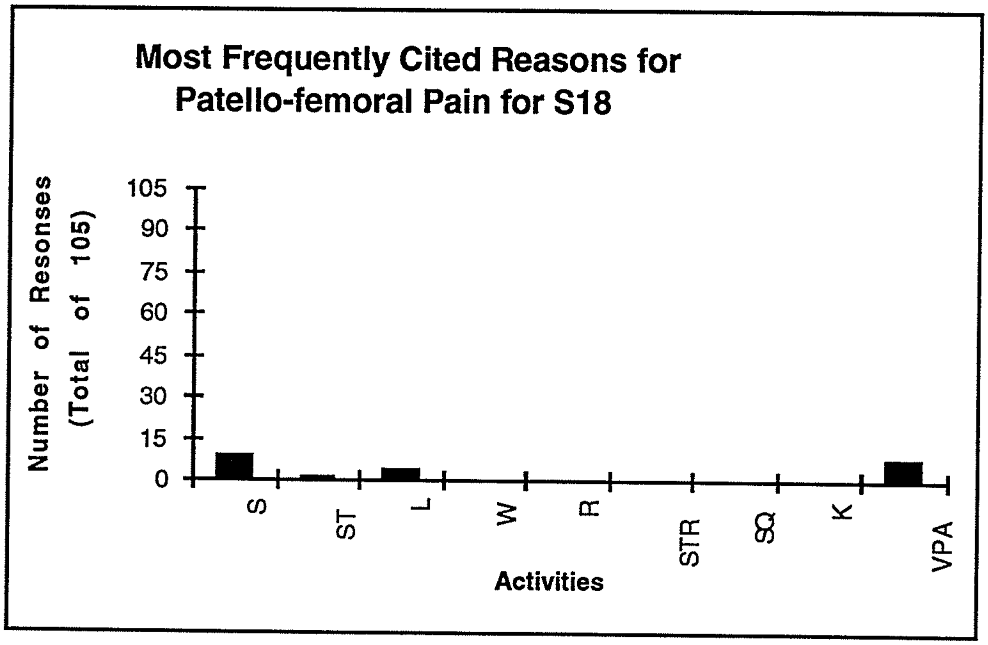


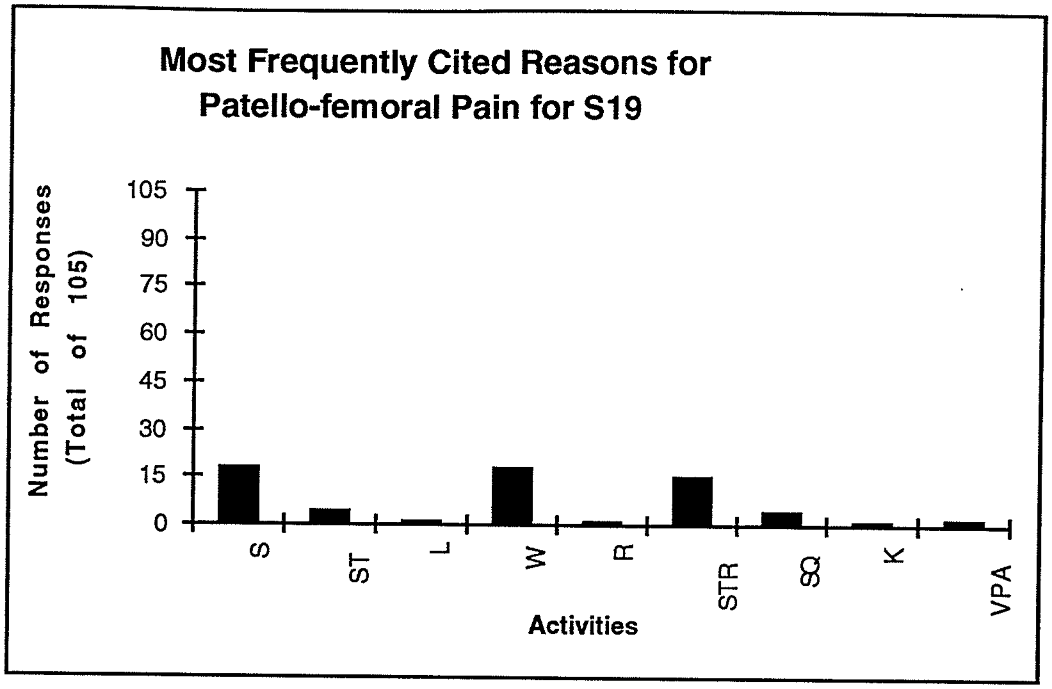
Most Frequently Cited Reasons for Patello-femoral Pain for S15



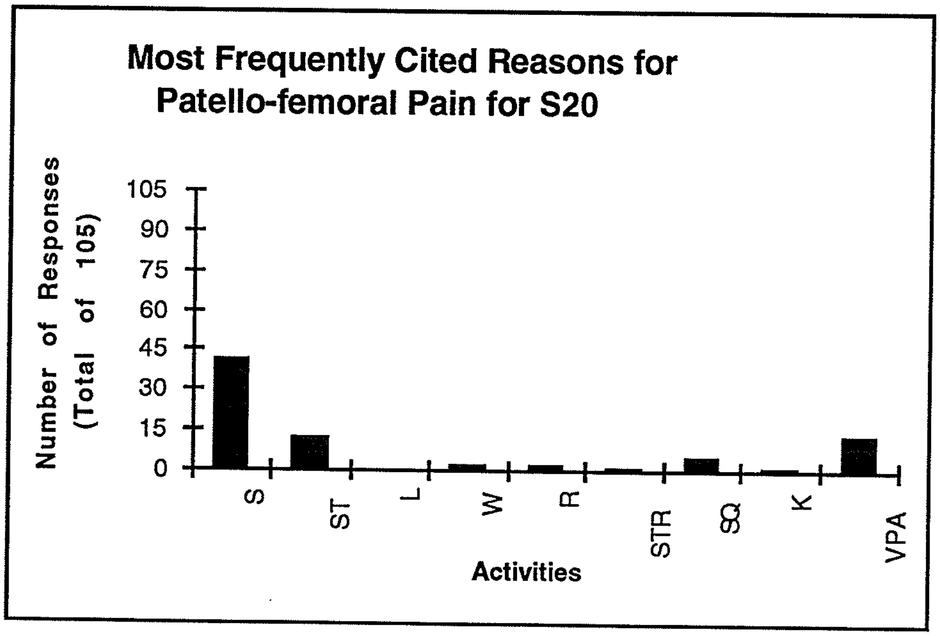
Most Freqently Cited Reasons for Patello-femoral Pain for S16


Most Frequently Cited Reasons for Patello-femoral Pain for S17

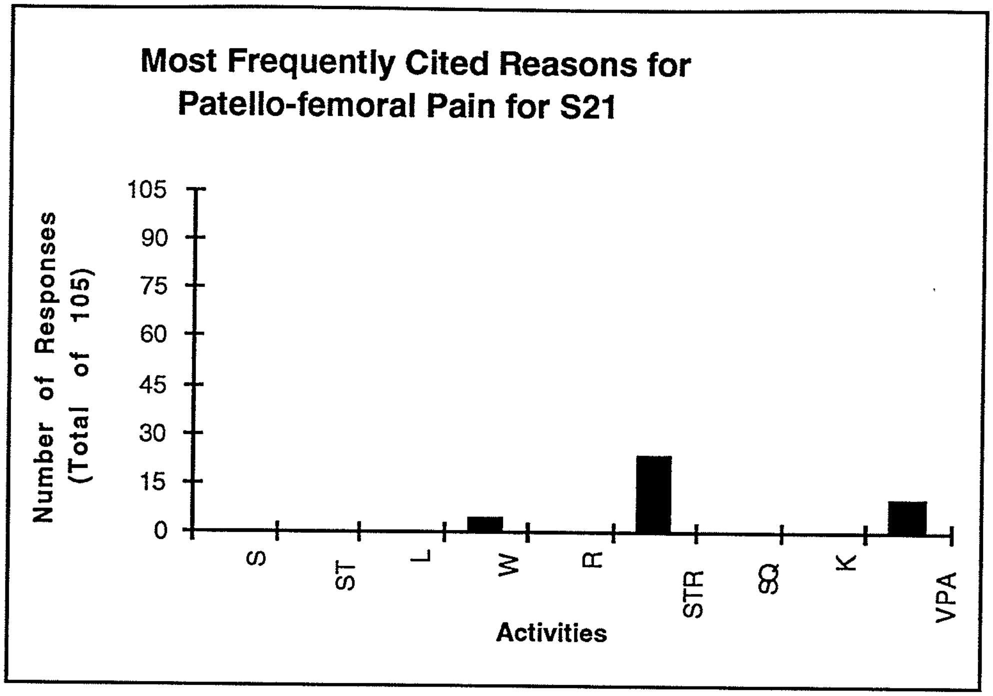

Most Frequently Cited Reasons for Patello-femoral Pain for S18

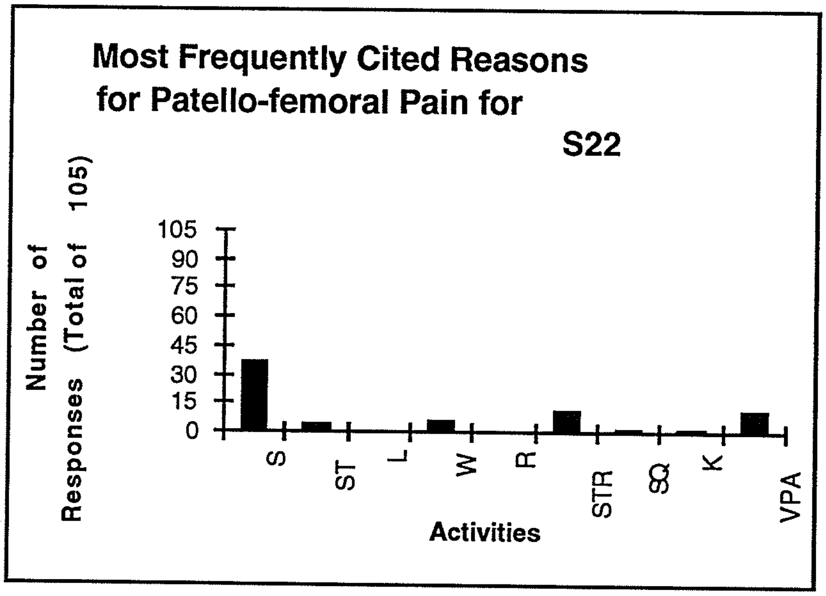


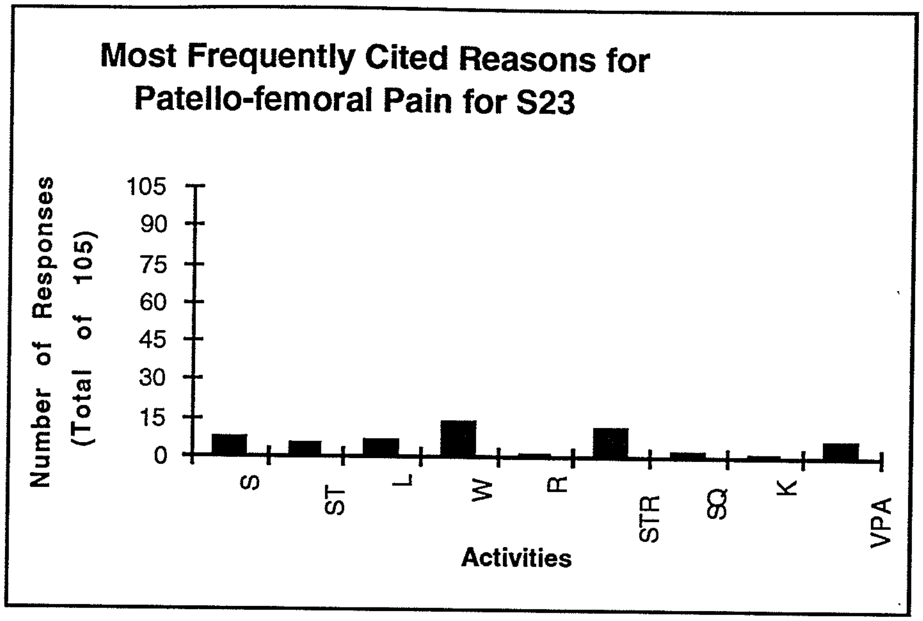
Most Frequently Cited Reasons for Patello-femoral Pain for S19

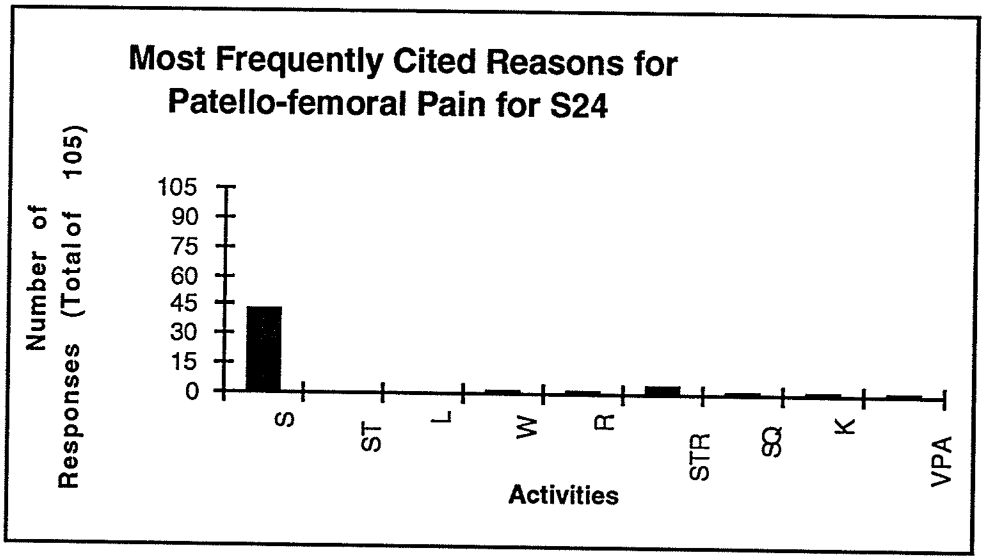


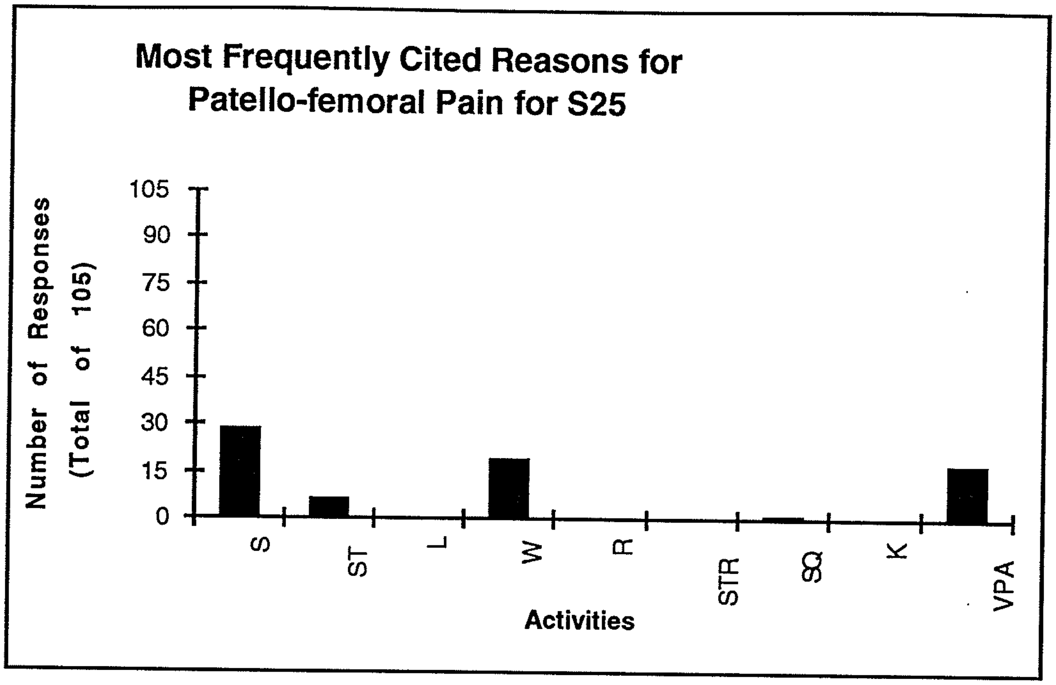
Most Frequently Cited Reasons for Patello-femoral Pain for S20


Most Frequently Cited Reasons for Patello-femoral Pain for S21

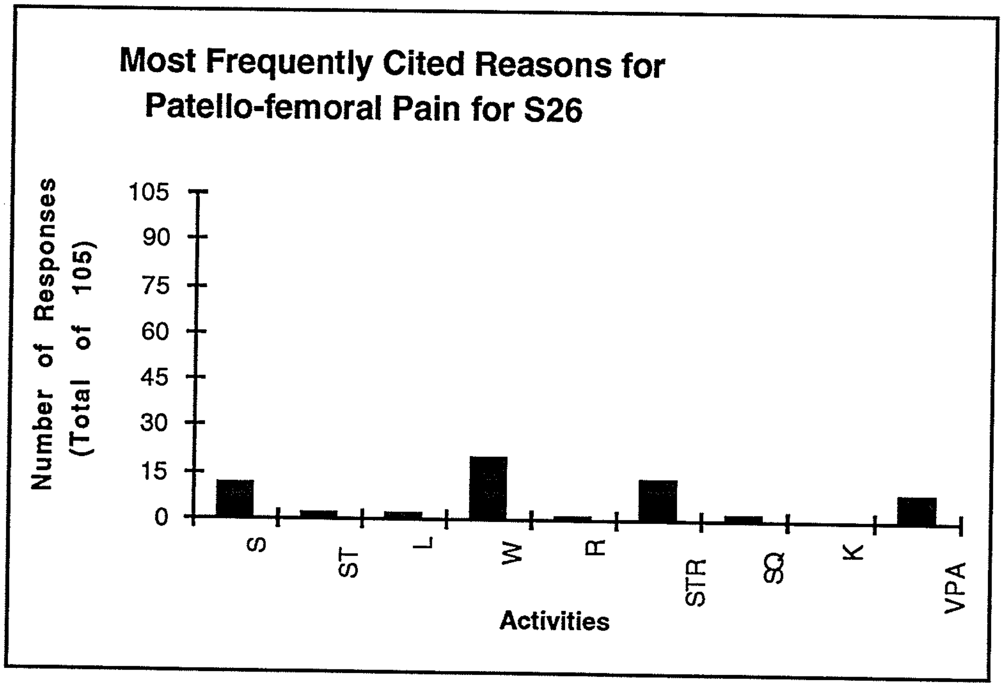

Most Frequently Cited Reasons for Patello-femoral Pain for S22


Most Frequently Cited Reasons for Patello-femoral Pain for S23
Number of Responses (Total of 105)
105
90
75
60
45
30
15
0
S
ST
L
W
R
STR
SQ
K
VPA
Activities

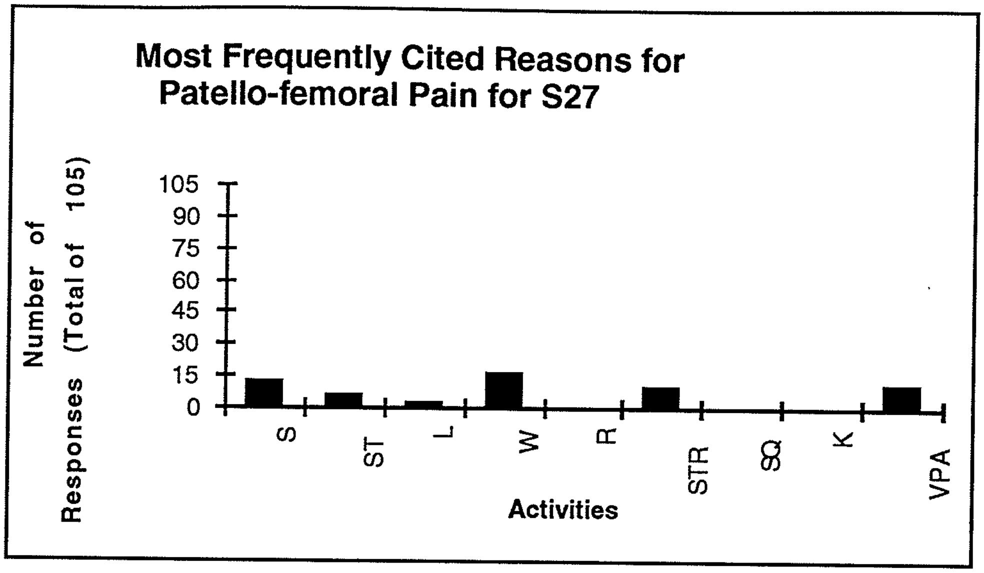

Most Frequently Cited Reasons for Patello-femoral Pain for S24
Number of Responses (Total of 105)
105
90
75
60
45
30
15
0
S
ST
L
W
R
STR
SQ
K
VPA
Activities

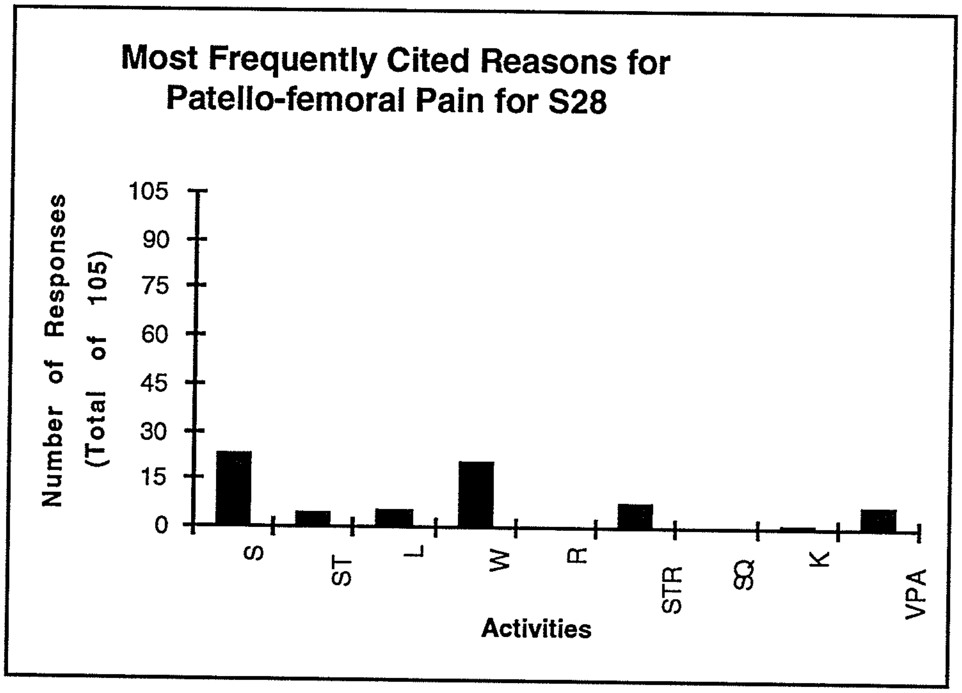


Most Frequently Cited Reasons for Patello-femoral Pain for S25



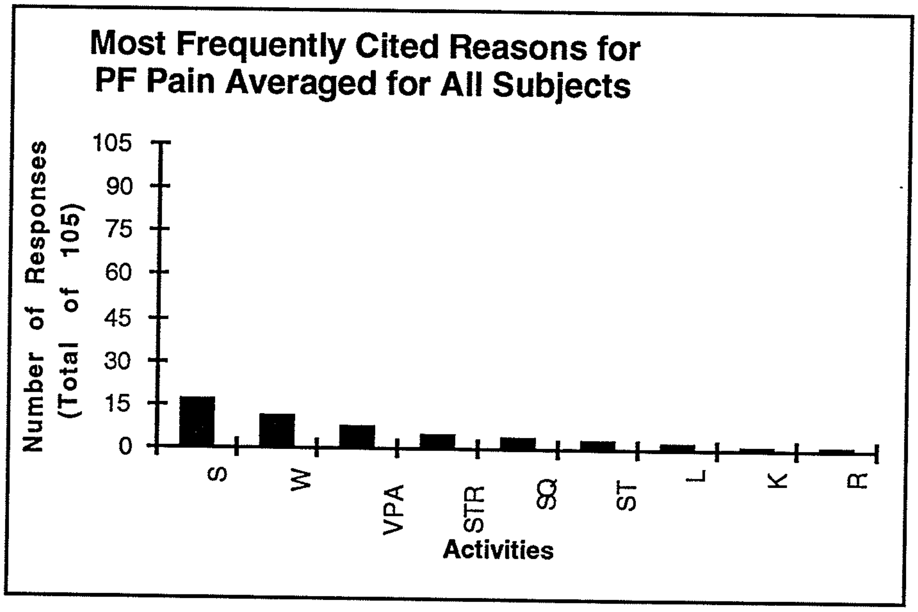
Most Frequently Cited Reasons for Patello-femoral Pain for S26


Most Frequently Cited Reasons for Patello-femoral Pain for S27
Number of Responses (Total of 105)
105
90
75
60
45
30
15
0
S
ST
L
W
R
STR
SQ
K
VPA
Activities


Most Frequently Cited Reasons for Patello-femoral Pain for S28
Number of Responses (Total of 105)
105
90
75
60
45
30
15
0
S
ST
L
W
R
STR
SQ
K
VPA
Activities

APPENDIX H

Most Frequently Cited Reasons for Patello-femoral Pain Graphs for All Subjects



Most Frequently Cited Reasons for PF Pain Averaged for All Subjects

APPENDIX I

Raw Data Tables for Patello-femoral Pain for Subjects 1-28

(Day and Time of Day for Females and Males)

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

Gender	D1T1	D1T2	D1T3	D1T4	D1T5	D2T1	D2T2	D2T3	D2T4	D2T5	D3T1	D3T2	D3T3	D3T4	D3T5	D4T1	D4T2	D4T3
F	0.10	1.30	0.90	0.50	0.90	0.00	0.60	1.25	0.50	0.40	0.20	0.50	2.50	1.30	2.80	0.60	1.40	1.70
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.00	0.00	0.00	4.95	0.00	0.00	0.00	0.00	3.50	0.90	0.00	3.70	0.00	0.00	0.00	0.00	0.00
F	2.20	2.25	0.00	0.90	0.00	3.30	4.10	3.60	0.00	0.00	7.30	4.60	2.55	1.00	0.30	0.00	0.10	0.10
F	0.00	0.00	0.00	1.80	0.00	4.40	1.90	4.80	3.80	7.10	0.00	0.00	3.60	2.70	0.00	0.00	0.00	0.00
F	0.60	0.30	0.70	0.40	0.70	0.75	1.20	0.50	0.60	0.40	0.40	1.10	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.70	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.10	0.00	0.85	0.00	0.50	1.50	1.40	0.30	0.40	0.20	0.10	0.25	0.20	0.25	0.30	0.40	0.95	1.10
M	0.60	2.30	5.90	3.60	5.50	0.00	0.00	1.30	0.60	0.55	0.60	0.00	0.00	1.30	1.05	2.90	2.70	0.30
M	2.90	1.20	0.80	1.30	1.10	0.45	0.65	0.70	0.70	1.00	0.00	0.30	0.90	1.00	1.00	0.00	0.00	1.30
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.00	0.00	5.50	1.80	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.50	4.20	0.00	0.00	1.20	0.00
F	6.30	2.10	6.20	6.60	8.10	2.45	2.00	2.40	3.35	4.10	0.00	5.65	2.40	3.40	3.05	4.00	4.20	4.30
F	6.80	1.30	0.00	1.55	9.30	0.00	0.00	0.00	8.00	7.05	2.40	2.00	7.30	0.00	6.60	0.00	0.00	4.00
M	0.00	1.70	5.20	1.50	0.60	0.00	0.95	0.80	5.35	1.50	0.40	1.50	6.20	1.50	0.60	0.00	0.00	0.30
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	3.00	0.00	0.00	0.00	0.00	1.30	0.00	2.70
F	0.00	0.00	0.00	0.00	2.80	2.70	1.10	1.15	1.40	0.00	0.00	0.00	4.20	4.40	0.00	0.00	0.00	2.80
F	4.40	3.60	4.00	4.90	1.75	1.70	8.20	8.90	8.60	8.45	2.50	2.60	2.20	2.00	3.80	0.00	0.70	0.65
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.50	0.00	0.00	2.60	1.50	0.50	0.70
F	0.70	0.70	1.10	1.20	3.50	0.20	0.40	1.35	0.45	0.35	0.00	0.00	3.30	3.50	0.40	0.80	0.50	0.00
M	0.00	1.40	1.00	0.25	0.00	0.00	0.70	0.50	0.00	0.00	0.00	0.00	1.10	0.40	0.00	1.40	1.10	0.20
F	0.00	0.00	0.00	0.00	0.00	1.50	1.50	1.40	0.00	0.00	0.30	0.95	1.50	0.00	2.00	0.40	0.80	1.40
M	1.30	2.50	0.20	0.00	0.00	0.00	0.35	0.10	0.60	1.20	2.60	0.40	4.20	0.90	0.90	0.10	1.50	0.65
M	0.00	0.60	0.00	4.65	1.10	0.00	0.00	1.40	2.90	0.80	0.00	0.00	0.60	1.20	0.85	0.00	1.00	0.40
M	0.00	0.30	0.60	1.30	3.30	0.30	1.10	0.00	0.30	0.40	0.00	0.00	0.00	6.10	2.80	0.00	0.00	1.00
F	0.00	1.10	3.30	4.00	1.10	0.40	0.40	0.60	1.50	0.10	0.00	1.55	1.90	4.10	1.90	0.00	1.00	0.60

Legend: D1=Day One; T1=Time One

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

D4T4	D4T5	D5T1	D5T2	D5T3	D5T4	D5T5	D6T1	D6T2	D6T3	D6T4	D6T5	D7T1	D7T2	D7T3	D7T4	D7T5	D8T1	D8T2
0.50	0.95	0.00	0.60	1.00	0.20	0.80	0.00	0.20	0.00	0.00	1.65	0.10	0.20	1.00	1.40	1.30	0.00	0.60
0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	0.90	0.00	0.00	0.00	0.00	0.00	0.00
4.00	4.60	0.00	0.00	2.20	0.80	4.95	0.00	0.00	0.20	0.30	0.00	0.00	3.05	0.00	0.00	0.00	0.00	0.00
0.50	0.00	0.55	0.90	0.00	0.00	0.75	2.25	0.45	5.60	4.00	1.80	0.10	0.20	1.60	0.85	6.30	4.90	3.55
0.00	0.00	0.00	0.00	7.50	0.00	0.00	0.00	6.30	0.00	0.00	0.00	0.00	0.00	0.00	2.20	5.80	0.00	3.20
0.35	0.00	1.25	0.70	0.50	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	1.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.35	0.00	1.70	0.00	0.10	0.00	0.00	0.00	0.00	1.45	5.70	2.50	0.00	0.45	0.80	0.00	0.00	1.20	2.25
0.00	4.05	1.00	0.40	1.30	0.80	0.30	0.85	0.00	0.35	0.00	0.40	1.50	3.70	2.60	7.00	4.20	1.15	0.80
1.15	1.60	0.60	1.10	1.10	1.15	0.80	0.00	1.70	1.45	1.65	1.40	1.10	1.70	1.60	1.80	1.70	1.25	1.30
0.00	1.05	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00
2.70	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	0.00	2.20
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.35	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.10	3.50	3.25	3.60	4.10	5.80	2.10	4.20	4.00	3.20	4.00	4.40	4.00	3.60	4.05	3.80	5.30	7.40	6.40
6.20	7.90	0.00	1.55	0.15	0.00	0.00	0.00	2.20	4.50	5.60	6.60	0.00	1.90	5.60	5.15	5.95	0.00	0.00
0.20	0.00	0.00	0.00	0.00	0.90	5.55	0.20	2.20	0.70	5.55	1.30	0.00	1.10	4.85	1.30	0.90	0.90	1.00
0.00	0.00	0.00	1.70	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	3.00	1.00	0.00	0.00	0.00	0.00
0.00	4.10	4.10	3.50	1.10	0.00	0.00	0.00	2.90	2.70	2.10	4.25	2.65	3.60	1.90	5.10	3.70	0.00	3.50
0.00	1.60	1.70	1.10	1.50	0.80	8.30	7.50	7.60	8.00	5.60	8.10	5.60	4.50	1.70	1.50	2.35	0.00	0.00
0.40	0.60	0.00	0.40	0.80	0.70	0.50	0.40	0.00	0.00	0.00	0.80	0.00	0.50	0.00	0.00	0.90	0.00	0.00
0.00	3.70	0.00	0.40	0.45	1.80	0.30	0.00	0.00	0.80	1.60	0.00	0.40	1.70	7.50	3.25	1.20	0.30	0.30
3.30	2.20	1.60	0.25	1.90	1.65	1.30	1.60	0.90	1.05	0.85	0.10	0.00	0.00	1.85	0.00	0.00	1.00	0.00
0.00	0.00	0.45	1.00	1.30	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.40	0.90
0.30	0.25	0.95	0.40	0.30	1.00	0.60	3.40	0.30	0.40	0.00	0.90	3.40	1.30	0.50	0.30	1.40	2.00	2.20
2.20	4.60	0.20	0.50	1.60	2.70	0.90	0.00	0.00	0.50	0.00	0.00	0.65	0.25	0.70	1.45	0.75	0.00	0.80
3.00	0.15	0.00	0.40	3.50	2.60	1.70	0.00	0.40	1.45	3.70	1.95	0.00	0.00	0.50	3.00	0.45	0.00	2.50
2.10	1.30	0.40	1.50	4.00	1.60	0.60	0.30	0.40	0.80	0.30	0.20	0.00	0.00	0.30	0.20	0.00	0.00	0.65

Legend: D1=Day One; T1=Time One

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

D8T3	D8T4	D8T5	D9T1	D9T2	D9T3	D9T4	D9T5	D10T1	D10T2	D10T3	D10T4	D10T5	D11T1	D11T2	D11T3	D11T4	D11T5
0.80	0.10	0.30	0.00	0.00	0.80	2.30	0.20	0.00	0.70	1.10	1.35	0.75	0.35	1.00	0.50	1.50	1.10
0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.10	0.00	6.10	6.30	0.00	0.00	0.80	1.20	0.00	0.30	1.60	0.00	6.35	0.25	0.80	0.00	0.80	8.05
0.00	0.00	0.00	0.00	2.10	0.00	3.80	6.65	7.90	6.65	9.00	6.20	8.70	2.60	7.40	8.60	0.00	0.00
0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00
0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.10	2.60	2.80	0.00	0.00	0.00	6.50	2.40	1.80	1.05	2.10	2.10	1.95	0.00	0.00	4.20	4.90	1.20
1.90	0.50	0.00	3.60	1.55	0.00	0.70	0.50	1.00	0.40	0.00	0.50	0.90	0.60	0.00	1.40	0.80	5.60
1.60	1.60	1.00	0.00	1.30	1.35	1.10	1.20	0.00	1.10	1.10	0.40	0.00	0.00	0.00	1.20	1.10	1.10
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.70	8.40	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	1.20	0.00	0.00	0.00	3.40	0.00	3.20	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.50	6.10	5.90	0.00	4.90	3.85	4.40	4.40	3.10	3.30	3.20	2.90	3.00	0.00	3.20	4.00	3.00	3.00
0.00	3.50	2.20	1.10	0.00	0.00	3.20	8.30	0.00	0.00	8.10	5.50	5.40	0.00	0.00	0.00	0.00	0.00
2.90	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.25	2.00	1.05
0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00	4.60	0.00	0.00	1.10
5.30	5.30	8.40	0.00	3.90	5.30	0.40	0.00	0.00	3.10	1.80	1.60	2.90	0.00	0.00	2.90	0.00	0.00
1.05	3.50	2.70	1.90	2.70	3.20	0.80	5.00	5.60	3.70	2.50	1.50	2.65	0.00	0.00	1.10	0.85	2.20
0.00	0.00	0.00	0.00	0.00	1.20	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50
0.50	4.80	1.80	0.00	0.00	1.50	0.00	1.70	0.00	0.00	0.00	0.00	0.00	0.60	0.90	0.65	0.00	5.30
0.00	0.00	1.40	0.00	0.70	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
1.10	0.30	0.00	0.00	0.30	1.30	4.00	0.40	0.65	1.10	1.60	0.70	3.40	0.00	0.50	0.00	1.60	0.50
3.45	5.20	6.80	1.80	2.40	3.10	2.80	1.65	1.10	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.25
0.30	2.40	0.70	0.00	0.00	0.50	0.50	2.50	0.00	0.50	0.55	1.60	1.30	0.00	0.60	0.00	1.40	0.40
2.10	4.20	1.40	0.00	0.50	2.60	0.70	0.00	0.00	0.00	0.00	3.20	2.30	0.00	1.30	2.90	0.00	0.00
1.95	5.00	0.70	0.30	1.00	0.70	4.30	0.90	0.00	0.00	0.00	1.25	1.20	0.30	2.10	1.70	2.60	0.20

Legend: D1=Day One; T1=Time One

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

D12T1	D12T2	D12T3	D12T4	D12T5	D13T1	D13T2	D13T3	D13T4	D13T5	D14T1	D14T2	D14T3	D14T4	D14T5	D15T1	D15T2	D15T3
0.70	0.50	1.60	1.50	0.40	0.00	0.50	1.05	3.10	1.00	0.00	1.65	0.90	0.70	0.10	0.00	0.00	1.20
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.20	3.35	4.65	2.40	4.00	0.00	0.00	0.30	0.50	0.00	0.00	0.00	1.20	0.00	2.50	0.00	0.00	0.30
0.00	0.00	0.00	0.00	0.00	2.55	3.60	0.90	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	0.00	2.05
0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	6.90	7.20
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.70	0.35	0.00	0.85	1.70	1.50	1.10	1.20	4.90	0.00	0.00	1.20	0.70	0.60	0.00	0.00	0.00
1.25	0.30	0.90	3.10	0.40	0.40	2.60	1.30	1.00	0.65	0.90	1.50	0.70	2.20	0.55	0.00	0.90	2.60
0.00	0.00	0.80	0.90	1.00	0.00	0.00	1.15	1.00	0.90	1.20	1.25	1.10	1.30	1.10	1.20	1.10	1.20
0.00	0.00	0.00	0.00	2.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
0.00	2.30	3.00	2.65	2.30	2.70	2.20	2.55	2.00	2.70	0.00	3.00	2.30	3.20	2.10	4.70	3.85	4.30
0.00	1.95	3.90	3.10	1.55	0.75	1.40	3.60	1.40	0.00	0.00	9.30	7.20	7.40	7.50	6.95	5.00	3.60
0.50	0.65	1.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	4.10	1.00	1.15	1.20	1.60
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30	0.80	0.00	0.00	0.00	0.00	0.00
5.10	4.70	0.00	4.70	4.05	0.00	1.90	2.75	0.00	2.70	2.10	4.75	4.20	3.05	0.00	0.00	2.70	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.95	2.50	2.80	0.00	0.80	0.90	0.45	4.50	0.00	0.00	0.00
1.00	0.95	0.25	0.30	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.40
0.50	0.20	3.20	3.80	4.05	0.00	0.10	0.15	0.00	0.20	0.00	0.00	0.65	0.00	6.60	0.00	0.30	0.50
0.00	0.00	0.75	1.70	0.60	0.80	0.00	0.00	0.00	0.00	0.80	2.55	0.50	0.00	1.85	1.10	1.20	0.20
0.00	0.00	0.50	1.80	0.35	0.00	0.00	0.00	0.00	0.45	0.00	0.00	1.25	1.00	0.90	0.30	0.40	0.60
0.00	0.00	0.00	0.80	1.00	0.50	0.55	1.20	1.70	0.00	0.00	0.00	0.00	0.85	1.55	0.00	0.00	0.00
0.00	0.00	1.10	0.00	0.90	0.00	0.00	0.00	0.00	2.40	0.90	0.80	0.00	0.00	0.00	0.00	0.50	0.30
0.00	0.00	1.40	6.10	1.70	1.10	0.70	0.80	0.90	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.35	0.00	0.70	0.00	0.00	0.30	0.70	7.10	1.30	0.30	0.00	0.00	0.30	2.60	3.30	0.00	0.00	2.40

Legend: D1=Day One; T1=Time One

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

D15T4	D15T5	D16T1	D16T2	D16T3	D16T4	D16T5	D17T1	D17T2	D17T3	D17T4	D17T5	D18T1	D18T2	D18T3	D18T4	D18T5	D19T1
1.15	0.00	0.00	0.00	0.30	1.40	0.65	0.00	0.90	1.10	4.15	1.70	0.00	0.00	0.75	0.00	0.20	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.90	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	0.00	0.00	0.00	0.00	0.00	6.20	6.10
1.70	2.60	0.00	0.00	0.00	1.10	0.70	0.00	0.00	1.50	2.30	0.00	0.00	0.00	0.00	0.00	0.30	2.20
1.20	0.00	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	0.00	7.10	0.00	2.70	4.95	2.30	0.00	0.00
7.70	7.50	4.40	4.90	5.30	5.20	5.40	4.30	4.50	3.90	4.10	5.20	4.50	4.10	4.10	4.00	4.00	3.00
0.00	0.00	2.20	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.80	1.10	0.40	0.00	0.00	0.00	0.00	0.00	0.00	2.70	2.65	4.00	1.10	0.00
0.60	0.00	0.00	0.00	0.40	0.85	0.00	0.00	0.00	0.50	0.80	0.60	0.50	1.40	0.60	1.50	2.10	0.80
1.45	1.00	0.00	1.10	1.25	1.20	1.00	1.00	1.50	1.30	0.90	1.05	0.00	0.00	0.00	0.00	0.90	0.00
0.00	0.00	0.00	0.00	0.00	0.00	3.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.90	0.00	2.55	2.10	0.00	0.00	0.00	0.00	1.90	0.00	0.95	0.00	0.00	1.25	0.00	2.40	0.00	0.00
3.70	3.40	0.00	3.20	3.90	3.00	2.70	2.20	2.50	2.50	2.40	2.40	0.00	3.00	2.90	3.10	2.90	0.00
2.70	0.70	0.30	0.35	0.35	0.40	0.60	0.00	0.00	0.00	0.00	0.00	1.75	2.55	2.50	1.60	1.50	0.20
0.00	0.00	0.00	0.00	5.00	1.30	1.25	0.00	0.45	0.65	0.50	0.30	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40	4.05	2.65	1.05	0.20	0.00	0.00	0.00	0.00	0.00	0.00
2.70	0.00	0.00	4.75	4.40	7.25	6.50	0.00	0.00	5.20	4.45	4.50	0.00	5.15	4.40	0.00	0.00	3.35
5.20	2.40	3.75	3.45	4.50	3.80	5.35	0.00	2.40	2.70	2.50	1.35	0.00	0.40	0.00	0.00	0.00	0.00
0.00	0.75	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.60
5.10	1.80	0.00	0.00	0.60	1.00	4.20	0.00	0.00	2.05	0.00	2.00	0.00	0.50	0.00	0.00	8.40	2.65
0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	1.70	0.70	1.15
5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.50	0.70	0.00	0.00	0.70	0.60	0.65	0.00	0.00
0.50	1.10	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.35	0.00	0.00	0.45	0.30	1.00	1.80	0.00
1.30	1.00	0.00	0.20	0.00	0.85	0.00	0.40	1.30	1.00	0.60	0.00	0.00	0.00	3.40	0.70	0.50	0.00
0.00	0.00	0.00	0.20	0.00	1.25	0.60	0.00	0.00	0.00	0.70	0.00	0.00	0.00	1.75	4.10	5.20	0.00
2.90	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	1.60	0.40	0.00

Legend: D1=Day One; T1=Time One

Patello-Femoral Pain Scores Per Day and Per Time Period for Each Sujbect

D19T2	D19T3	D19T4	D19T5	D20T1	D20T2	D20T3	D20T4	D20T5	D21T1	D21T2	D21T3	D21T4	D21T5
0.00	0.00	0.50	0.20	0.00	1.10	2.40	0.90	2.50	0.90	1.35	0.30	1.10	1.05
0.00	0.00	0.00	0.00	0.00	3.10	0.00	2.80	0.90	0.30	0.30	0.00	0.00	0.00
6.20	5.95	6.60	7.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.20	0.00	0.00	3.00	2.00	2.40	2.80	0.00	4.20	1.45	0.00	0.00	6.90	1.90
3.20	0.00	0.00	1.95	0.00	0.00	0.00	0.00	0.00	0.00	7.20	5.60	4.30	0.00
2.60	2.80	3.00	3.10	2.60	2.10	2.15	1.50	2.15	0.90	0.50	0.90	0.90	0.70
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	3.70	0.00	5.70	0.00	2.70	1.25	2.40	0.65	1.20	2.40	0.60	0.00	0.00
0.40	0.00	0.50	2.40	0.00	0.30	0.90	0.95	1.70	0.00	0.00	1.50	1.55	2.00
0.00	0.00	0.00	0.80	0.00	0.00	1.10	1.10	1.00	0.70	1.30	0.00	0.00	1.10
0.00	4.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	1.90	5.00	0.00	0.00	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	3.20	0.00	3.70	0.00	0.00	1.90	0.00	0.00	1.75	2.20	1.30	0.00
2.75	3.70	4.60	3.80	3.20	2.70	3.40	2.70	3.80	0.00	3.10	3.70	3.90	4.10
0.15	0.25	0.30	0.10	0.00	0.15	0.20	0.10	0.00	1.85	2.60	1.20	0.80	0.60
0.00	0.00	0.00	0.00	0.00	0.00	7.60	2.60	1.05	0.70	0.75	2.55	1.30	0.00
0.00	0.00	0.00	0.00	0.00	2.20	0.80	0.00	0.00	0.00	1.00	0.00	0.00	0.00
5.10	0.00	0.00	3.30	0.00	2.70	3.10	0.00	4.45	3.35	0.00	0.00	3.30	3.40
0.60	0.00	0.00	1.35	0.00	0.00	0.00	0.20	0.00	5.10	3.20	3.20	0.80	3.80
0.50	0.70	0.75	0.80	0.00	0.00	0.00	0.00	1.80	1.00	0.00	0.00	0.00	1.10
2.10	1.20	0.00	0.00	1.00	0.40	0.00	7.75	3.30	0.00	0.00	2.50	2.25	7.00
2.80	1.00	3.40	1.35	0.00	0.00	2.60	4.30	0.90	1.00	0.00	0.00	2.65	2.00
0.10	0.50	1.10	3.00	0.00	0.00	0.00	0.00	0.00	8.10	1.20	0.00	0.00	0.85
0.00	0.60	1.05	1.30	0.00	0.70	0.30	1.10	2.05	0.00	0.00	0.35	1.00	1.50
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.60	1.55	1.90
0.90	2.20	0.60	0.30	0.00	0.00	0.80	3.95	0.10	0.60	0.00	0.00	0.95	0.00
0.00	0.00	3.20	0.85	0.00	0.60	1.00	4.80	1.70	0.00	0.00	0.45	2.30	0.20

Legend: D1=Day One; T1=Time One