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Inferences about Change-Points in Rehabilitation on
the outcome of a Knee Arthroscopy as a result of
Patello Femoral Pain Syndrome in Sport

by

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DISSERTATION

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Interns 2001, BioLinda, thanks for a lovely year socially wise. Although we didn't have very much to offer "in-turn", we will definitely cherish our "2001-days" deeply in our hearts and thoughts of each other.

To my family and friends, thanks, my heart belongs to you.



Copy from one, it's plagiarism; copy from two, it's research.

Wilson Mizner (1876-1933)

Keep away from people who try to belittle your ambitions. Small people always do that, but the really great ones make you feel that you too, can become great.

Mark Twain

Don't measure yourself by what you have accomplished, but by what you should have accomplished with your ability.

John Wooden

Everything should be made as simple as possible, but not simpler.

Albert Einstein (1879-1955)

信仰

BELIEVE

Striving for excellence motivates you; striving for perfection is demoralizing, therefore, strive for excellence, not perfection.

Harriet Braiker

Any intelligent fool can make things bigger and more complex... It takes a touch of genius, and a lot of courage to move in the opposite direction.

Albert Einstein (1879-1955)

Knowledge speaks, but wisdom listens.

Jimi Hendrix

Try not to become a man of success but rather to become a man of value.

Albert Einstein (1879-1955)

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ABSTRACT

In many experiments, data are collected over time or space, on a number of subjects or sites. In rehabilitation experiments, for example, it is often of interest to know if the introduction of an intervention, such as a training modality during the process of rehabilitation, affects the distribution of a certain variable(s) recorded over the course of the trial. In such investigations, each patient generates a sequence of data that may or may not contain a point in time where the sequence reaches stationarity, i.e. no gradual change in the variable.

Hence, the Biokineticist will want to know what the position and distribution of this Change-Point is, as well as the corresponding value of the variable at this point. In some future study of the same injury, he/she will then know in advance, when to expect no further change in the observed values. This will have a significant effect on the time and cost of the rehabilitation program. We motivate and explain our ideas by outlining a clinical study involving Patello Femoral Pain Syndrome where the methodology can be effectively employed. The methodology, models and results are presented in a very simple form, and the 0.05 and 0.01 levels of significance are applicable throughout the study.

Key words and phrases: Change-Points, Patello Femoral Pain Syndrome, Arthroscopy, Isokinetic Test Design, Bayesian Statistics.

CHAPTER 1

INTRODUCTION, OPTIMIZATION AND PROBLEM STATEMENT

1.1 PROLOGUE

One of the most interesting and at the same time controversial issues that have been investigated on the grounds of rehabilitation, is the effect or the influence of exercise on the final outcome of any form of surgery. This includes surgical procedures performed on the ankle, hip, back, shoulder, and the knee. For the purpose of this study we will specifically focus on knee surgery and to be more exact, knee arthroscopy as a result of Patello Femoral Pain. Many different opinions/views exist regarding the influence of rehabilitation on the outcome of knee arthroscopy. In our constant changing environment, where sports became a fulltime occupation, the length of time it takes to fully recover and return to sport after surgery, became critically important.

However, up to date, very few literatures exist regarding the time periods mentioned above. Another aspect that has never been implemented as an aid to evaluate and monitor the progression of rehabilitation is the application of Change-Point Analysis. Change-Point Analysis is a technique widely used in various different fields (such as pharmaceutical industry, medical research, environmental studies and consumer behaviour) to predict a change point in a certain sequence in time.

Although the procedures are well documented and profound, as far as we are aware, this is the first time Change-Point analysis is taken for inference about rehabilitation data. We believe that Change-Point analysis can be of high value to the Biokineticist in helping him/her to evaluate the progress of rehabilitation. We are also convinced that by calculating a patients' Change-Point during his rehabilitation process, one will be able to either take a more aggressive, or a more conservative approach when adjusting the exercise prescription of a patient during the different phases of the rehabilitation process. In this thesis we present such a model and we hope to shed some valuable light on what maybe a whole new direction in rehabilitation as we know it.

1.2 OPTIMIZATION OF REHABILITATION

Rehabilitation conventionally implies restoration of function. It is an outcome driven process, the measures of which are invariably based on the interaction with the external environment. Rehabilitation may be necessary as a result of age, trauma, degenerative disease, or sudden onset of pathology.

The process of rehabilitation then involves two interfaces. Firstly, there is the interface between the patient and the environment surrounding him, and secondly, the interface between the therapist and the patient (Kumar, p. 97-99, 1992). In both these cases, the measure of success can be gauged by the degree of independence and functional

INTRODUCTION, OPTIMIZATION AND PROBLEM STATEMENT – CHAPTER 1

normality gained by the patient. The question that frequently needs to be asked is, "...am I doing what I think I am doing...?" Thus, to optimise rehabilitation outcome, objectivity at the therapist/patient interface is essential. Similarly, for the patient/environment interface, it will be of significant value to have an objective and holistic assessment of patient's performance and a profile of the tasks to be performed by the patient. Such matching for determination of deficits as advocated by Kumar (p. 104,106, 1992) will be essential to focus the rehabilitation attempts for optimising the rehabilitation outcome.

Indeed, the maximum force that can be developed by a given muscle or muscle group depends largely on its size which in turn depends on the cross-sectional area of the constituent fibres, however, to achieve maximum strength in a movement the action of these muscles needs to be coordinated and each muscle fully activated. In order to achieve a maximal force output it is also necessary to have maximal neural drive to all the motor-units within the muscle. For the majority of tasks this requires practice and a period of immobilisation may result in a loss of the neural pattern required to produce a smooth, coordinated movement (Rutherford, p. 1-3, 1995). An important objective of rehabilitation is then to re-learn these patterns through different strength training regimes.

It will be only through these concerted and well thought out efforts that we can begin to optimize the outcome of rehabilitation.

1.3 AIMS OF STUDY

Often in rehabilitation, measurements on the same variable on one or a number of subjects are collected on several occasions during a trial, a geographic region, or some other index set, then the following are of main interest:

1. What proportion of the patients would respond to the intervention?
2. Has there been a Change-Point in the response of interest, and if so,
3. What is the position and distribution of the Change-Point?

This dissertation presents a single- (primary aim) and multi-path (secondary aim) Change-Point model and illustrates how it can be used to address a variety of issues in the rehabilitation process of Patello Femoral Pain syndrome. We motivate and explain the models by outlining the injury where the methodology can be effectively employed. Important, only 3 patients are included in the present study because the research only aids as an illustration of Change-Point analyses in rehabilitation data. Although the procedures are well documented and profound, as far as we are aware, this is the first time Change-Point analysis is taken for inference about rehabilitation data (Pretorius *et al.*, p. 3, 2001). This possible contribution by the Magister laboratory at the University of the Free State will be continued through future research which will be aimed at more serious and complex injuries in sport, and setting up norms via Change-Point analyses for these injuries. Surely this will make room for a bigger sample size.

Details of the models and methodology are presented in a very simple form since the readers of this thesis are not necessarily statisticians, rather sport scientists and Biokineticist (Further statistical details are reported in Groenewald, p. 2-5, 2000).

We believe that Change-Point analysis can be of high value to the Biokineticist in helping him/her to evaluate the progress of rehabilitation.

1.3.1 Primary aim of research

In the framework of a rehabilitation experiment, consider the following: The Biokineticist develops a rehabilitation program for Patello femoral pain syndrome. The following parameters are identified that will aid in evaluating the progress of the patient:

- Pain
- Range of motion
- Circumference (Swelling)
- Surface EMG
- Cybex Power Assessment (After the experiment)

During the first stages of rehabilitation there will, e.g. be an increase/decrease in the patient's recorded data sequences of these parameters. Now, at some point in time, the

sequence reaches stationarity, i.e. no gradual change in the variable. Hence, the Biokineticist will want to know:

- what is the position and distribution of this Change-Point and the corresponding value of the variable at this point.
- in some future study for the same injury, he/she will then know in advance, when to expect no further change in the observed values.

This will have a significant effect on the time and cost of the rehabilitation program.

Moreover, from the analysis

- he/she will also be able to report the magnitude of the observed variable corresponding to a “ready-to-return” value.

We analyze each patient’s data individually and determine the probability for each sequence of having a Change-Point. This type of statistical inference has been extensively studied in diverse fields such as geology and medicine, including clinical trial (Joseph *et al.*, p. 690-697, 1997). The proposed Bayesian approach involves the calculation of posterior distributions of the Change-Points for the set of parameter in the study. These posterior distributions can be very useful in setting up norms and confidence intervals.

1.3.2 Secondary aim of research

The problem now calls for the analysis of not one patient, but more than one. This is known as multi-path Change-Point estimation and is accomplished by assuming an underlying distribution for the position and value of each Change-Point of the different patients. In finding such a distribution, one can address any type of injury, and the results will shed some very valuable light on the success of the rehabilitation program and the progress that is made during the process of rehabilitation.

In the multi-path settings, the data consists of several sequences, each one containing a possible different Change-Point (also known as the *multi-path Change-Point problem*). This methodology is explored in the secondary aims where the assumption is made that the individual Change-Points come from a common distribution. From a practical point of view, the implementation of a multi-path change point model offers substantial challenges (Bélisle *et al.*, p. 117-119, 121, 1998), especially in a rehabilitation experiment where more than one patient is enrolled in the program.

1.4 FUTURE RESEARCH

The application of ISOKINETIC STRENGTH TRAINING (IST) to sport specific training and rehabilitation is attractive and it became very popular during the past few years in rehabilitation; although, the exact isokinetic parameters that facilitate optimal isokinetic strength training still eludes both the athlete and researcher. Since the rehabilitation process for the Patello femoral pain syndrome is taken over 6 weeks – thus does not allow for isokinetic rehabilitation, we felt that understanding the performance parameters of this training discipline is a crucial key to an effective approach to isokinetic strength training when, indeed, it forms part of the rehabilitation process.

1.5 CONCLUSION

Rehabilitation is recognized as a critical component in the treatment of sports injuries, and has been the subject of intense research over the past decade. As a result, sound scientific principles have been applied to the realm of rehabilitation data and results. Indeed, this has improved the understanding and interpretation thereof in the present dissertation.

CHAPTER 2

INFORMATION FEEDBACK ON PATELLO FEMORAL PAIN SYNDROME

2.1 PROLOGUE

Patello Femoral disorders, especially the **Patello Femoral Pain Syndrome (PFPS)** are a well-known problem in all age groups. This disorder is a very common complaint amongst the general population and is much more frequent in females than in males. However, the cause of this pain, which is felt under and around the kneecap, is complex and not well known. Exercise is the most commonly chosen method of conservative treatment, with rehabilitation focusing on the *quadriceps* femoris muscle group. Once it has begun, *PFPS* frequently becomes chronic, thus forcing the patient to decrease or even stop physical activities. It is therefore critically important to make a precise diagnosis; otherwise, the treatment will not be successful (Callaghan & Oldham, p. 384-387, 1996).

A brief feedback on the structure of the knee joint will first be given. This will aid in studying and understanding the precise details of the syndrome. All figures/illustrations used in this Chapter are taken from *Clinically Orientated Anatomy* by Keith L. Moore and Arthur F. Dalley, p. 503-663, 1999 unless stated otherwise.

2.2 KNEE ANATOMY

The knee joint is a junction of three bones. The distal ends *femur* and the *tibia* meet to form a hinge joint. Anterior to them is the *patella* (kneecap). The *patella* sits over the other bones and slides when the leg moves (See Figure 2.1).

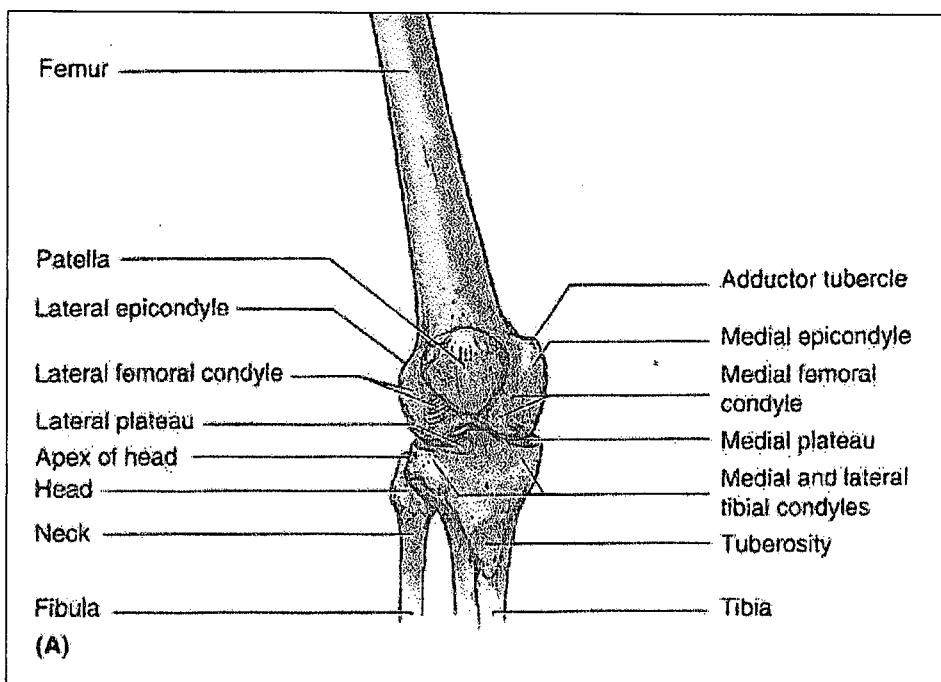


Figure 2.1 Anterior view of the bony anatomy of the knee.

The ends of the three bones are covered with *articular cartilage*. This tough elastic material basically cushions the joint. Also helping to cushion the knee are two C-shaped pads of *cartilage* called *menisci* (Moore & Dalley, p. 620, 1999), which is shown in Figure 2.2. They lie between the *tibia* and the *femur* and consist of a *lateral meniscus* and a *medial meniscus*.

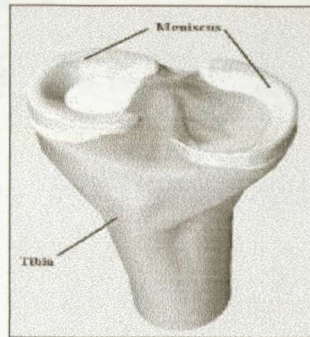


Figure 2.2 The *lateral* and *medial menisci* that provide extra cushioning to the knee.

Ligaments help to stabilize the knee. These are strong elastic bands of tissue that connect one bone to another. The four main stabilizing ligaments of the knee are the *anterior cruciate ligament (ACL)*, *posterior cruciate ligament (PCL)*, *medial collateral ligament (MCL)*, and *lateral collateral ligament (LCL)* and are displayed in Figure 2.3 below (Moore & Dalley, p. 625, 1999).

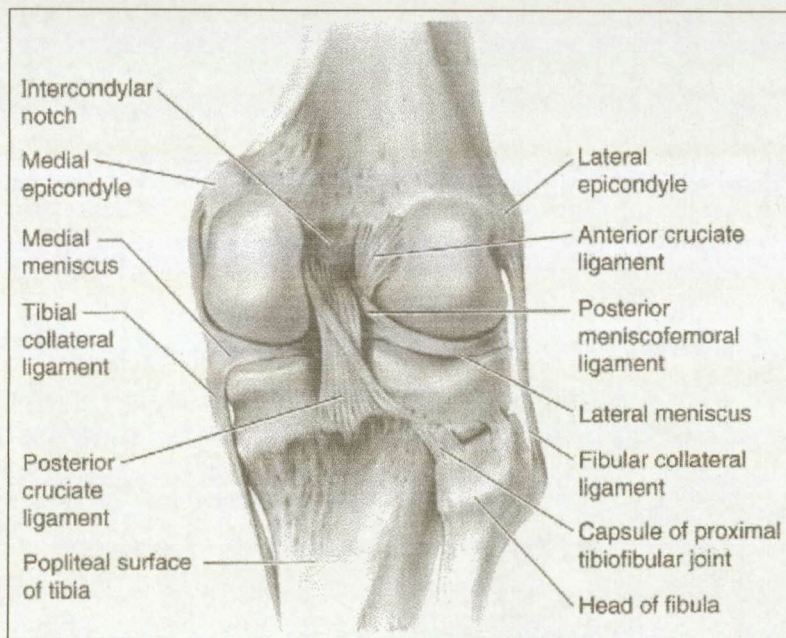


Figure 2.3 Posterior view of the ligaments of the knee.

Furthermore, there are two basic groups of muscles superior of the knee. Anterior to the knee are the *quadriceps femoris* muscles, which consist of the *Vastus Medialis Oblique (VMO)*, *Vastus Lateralis (VL)*, *Vastus Intermedius* and *Rectus Femoris*. The *quadriceps femoris* muscles' function is extension of the knee. Posterior to the knee are the *hamstring* muscles that assist in flexing the knee and extending the hip. The *hamstring* muscle group consists of *Biceps Femoris*, *Semitendinosus* and *Semimembranosus*. Figures 2.4 – 2.6 provide illustrations of these muscle groups.

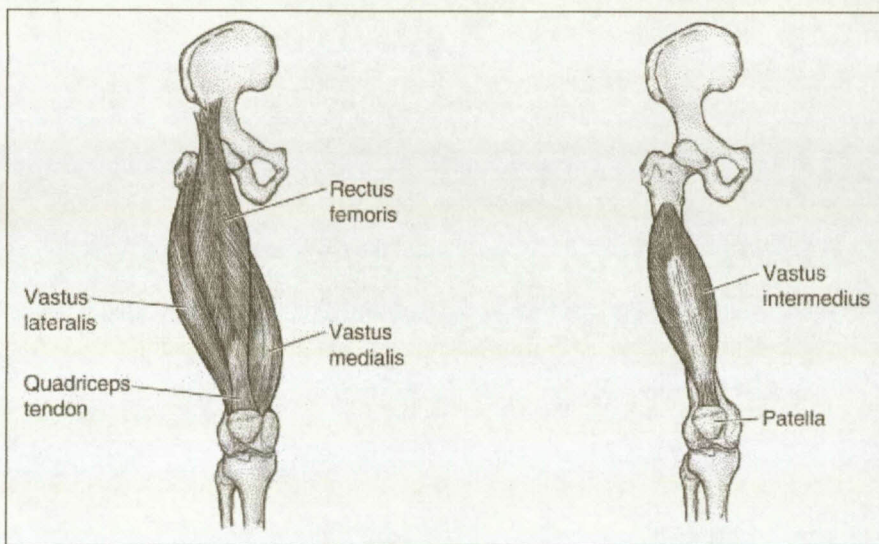


Figure 2.4 Main extensor muscles of the knee, namely the *quadriceps muscles*, observed from the anterior position.

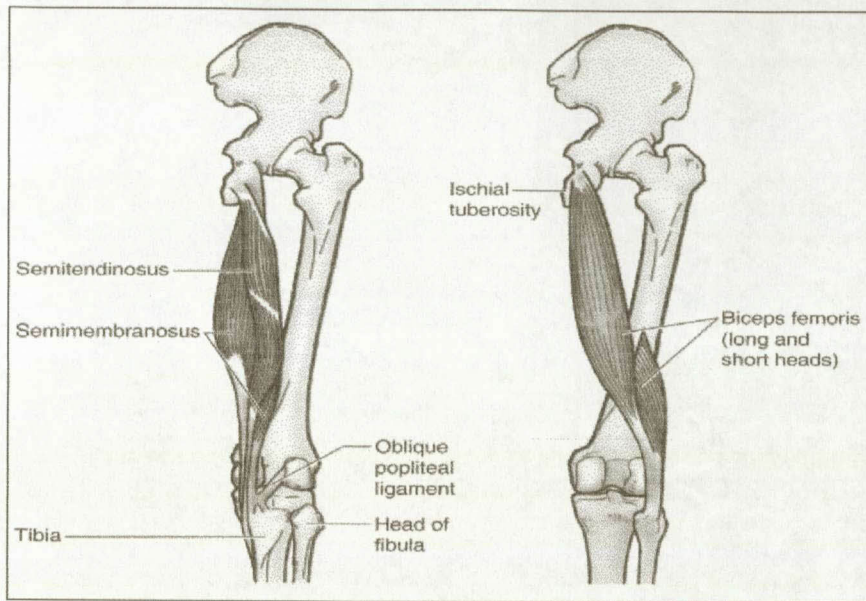


Figure 2.5 Main flexor muscles of the knee, namely the *hamstring muscles*, observed from the Posterior position.

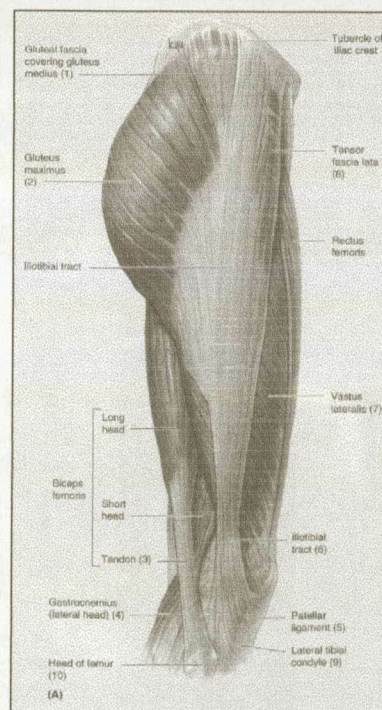


Figure 2.6 Lateral view of the *quadriceps* and *hamstring* muscle groups.

Several of these muscle forces act on the *patella* to provide its stability and keep the tracking normal, as can be seen in Figure 2.7 (Mark & Juhn, p. 2013, 1999).

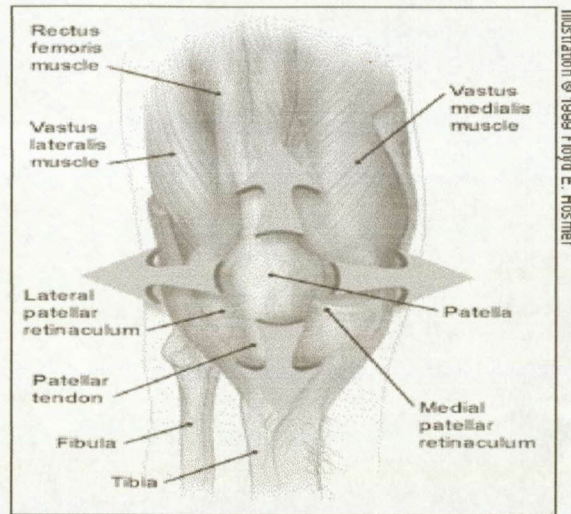


Figure 2.7 Anterior view of the stabilizers of the *patella* of the right knee. Various forces are responsible for *patellar* movement. The *iliotibial band* (not shown) has some fibers that attach to the lateral aspect of the *patella*.

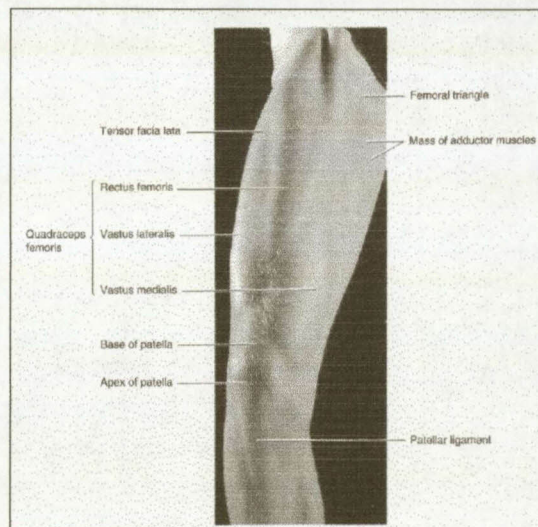


Figure 2.8 The Figure illustrates the orientation of the muscles mentioned above as it appears on the leg.

2.3 CAUSES OF PFPS

2.3.1 Introduction

The cause of this pain is complex and not well known and the basic etiology and exact pathogenesis of *PFPS* are still unknown, but many predisposing factors have been proposed. Factors such as acute trauma, knee ligament injury and surgery, instability, overuse, immobilization, overweight, genetic predisposition malalignment or dysfunction of the extensor mechanism and *Vastus Medialis Oblique (VMO)* insufficiency are only but a few to mention (Williams, p. 143-145, 1990). In many cases, however, there are no obvious reasons for the symptoms, and there seems to be no clear association between the severity of the symptoms and the radiological and arthroscopic findings (Moore & Dalley, p. 626-630, 1999).

The differential diagnosis of anterior knee pain is extensive and includes *prepatellar bursitis*, *patellar* and *quadriceps tendinitis*, *patello femoral arthrosis*, *patellar* subluxation and dislocation, knee ligamentous and *meniscal* pathology and rarely soft tissue and bony tumors. First used by Aleman in 1917, "*chondromalacia patella*" was the name given to a degeneration of the *patellar articular cartilage*, therefore specifically meaning the abnormal softening of the *articular cartilage* on the undersurface of the *patella* (Kipnis & Scuderi, p. 2, 4-6, 1995). True *chondromalacia patella*, however, involves the degeneration of the *articular facets* of the *patella*, with resulting ragged fronded edges (Welsh & Hutton, 1990).

This is a very common condition amongst both men and women of the sporting population (Williams, p. 146-147, 1990).

Along with *osteoarthritis*, *chondromalacia patella* is a type of *cartilage* damage resulting in anterior knee pain. It is also named as a cause of the symptoms of *Patello Femoral Pain Syndrome* (Reid, p. 361-362, 395, 1992).

The diagnosis of “*chondromalacia patella*”, however, requires direct surgical observation and should not be used synonymously with *Patello Femoral Pain Syndrome*. Figure 2.9 illustrates a normal *patella* and Figure 2.10 *chondromalacia patella* as seen through the arthroscope (anonymous, 1997a).

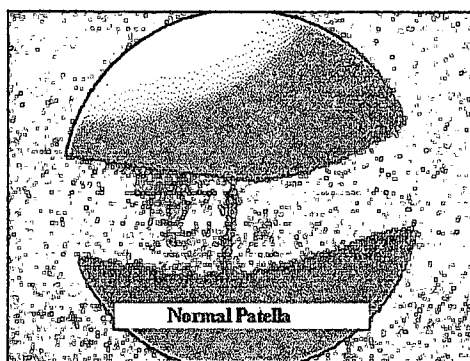


Figure 2.9 Arthroscopic view of the normal *patella*.

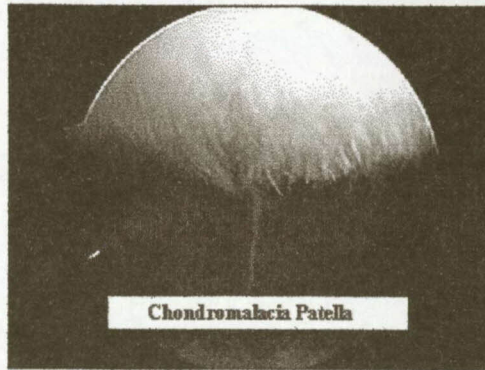


Figure 2.10 Arthroscopic view of *Chondromalacia Patella*.

With knee flexion and extension, the *patella* glides through a groove (*patellar surface*) in the distal *femur*. When the bones in the lower leg are not lined up ideally, it can cause the gliding between the *patella* and *femur* to become abnormal. This "malalignment" can lead to overloading of the articulation, generally on the outside or lateral side of the knee (Tria & Alicea, p. 54-57, 1995). This abnormal lateral tracking can be painful and lead to accelerated wear between the surfaces of the bones. Eventually, the protective *articular cartilage* surface over the bone can wear away, leading to *arthritic degeneration (osteoarthritis)* as seen in Figure 2.11 (anonymous, 1997a).

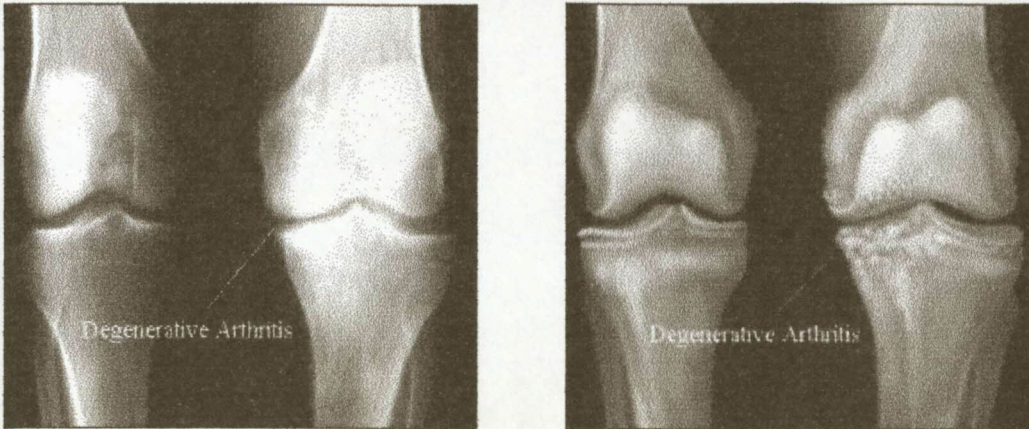


Figure 2.11 Malalignment can lead to *arthritic degeneration* that can be seen on the X-ray on the left and on the illustrated Figure on the right.

A dramatic example of maltracking between the *patella* and *femur* is *patellar* dislocation or subluxation (partial dislocation). These events are typically traumatic and may be caused either by an indirect mechanism (typically twisting of the body) or by a direct blow. Often a single instability episode becomes the precursor for recurrent instability episodes, particularly when the limb is malaligned to begin with.

Moreover, several anatomic and congenital factors may lead to a predisposition towards *Patello Femoral* pain and/or instability. Tightness of the *quadriceps* muscles, *hamstrings* and *iliotibial band*, and relative weakness of the *quadriceps* muscle are probably the most common causes (Moore & Dalley, p. 536-537, 626-629, 1999). Other factors that can contribute to this problem include *femoral anteversion* (excessive rotation of the hips), *tibial torsion* (excessive rotation of the shin bone), *genu valgum* (knock knees), *genu*

varum (bow legs), *genu recurvatum* (hyper-extended knee) and excessive *pronation* (flat feet). *Genu varum* and *valgum* are displayed in Figures 2.12 and 2.13.

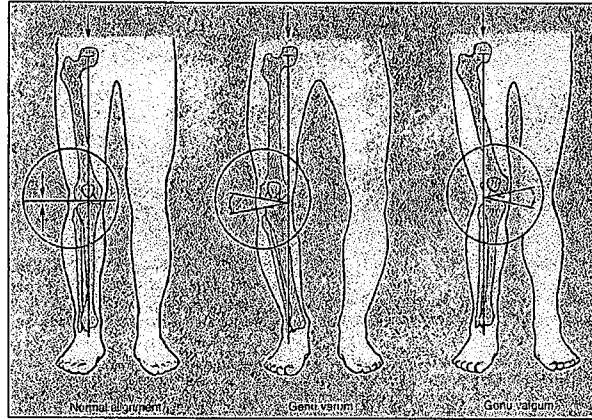


Figure 2.12 Normal alignment, *genu varum* (bow legs) and *genu valgum* (knock knees).

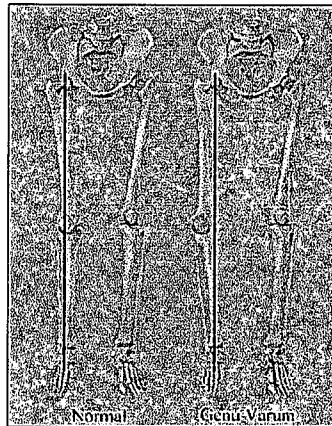


Figure 2.13 By means of X-rays, a line can be drawn to indicate malalignment.

2.3.2 Functional Knee Anatomy.

Normally the *patella* has a wedge shape, with a medial and lateral facet and a central crest. The *patella* has the thickest *cartilage* of any joint (Figure 2.14 and 2.15 shows the *patella*). The *patella* slides on extension and flexion in the *patellar surface* (on the central distal part of the *femur*, called the *trochlea*), which creates the geometric stability of the joint (Moore, & Dalley, p. 534, 537, 1999). The cause of anterior knee pain may not always be found (idiopathic pain). Possible causes, however, may include trauma and malalignment or instability (consider Figure 2.16).

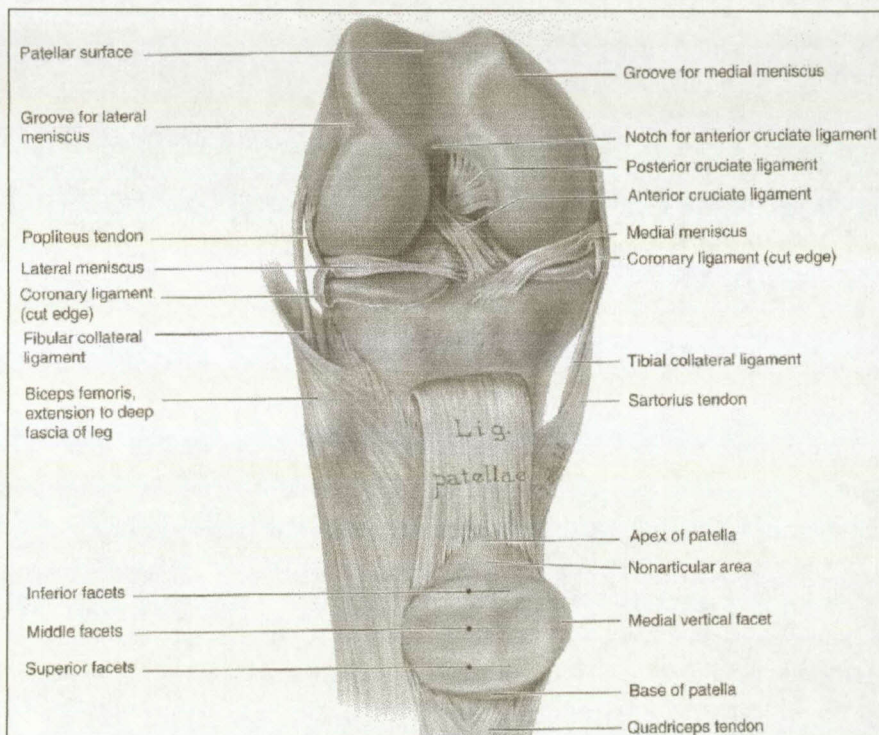


Figure 2.14 Anterior view of the *patella* (cut away) with the surrounding structures of the knee.

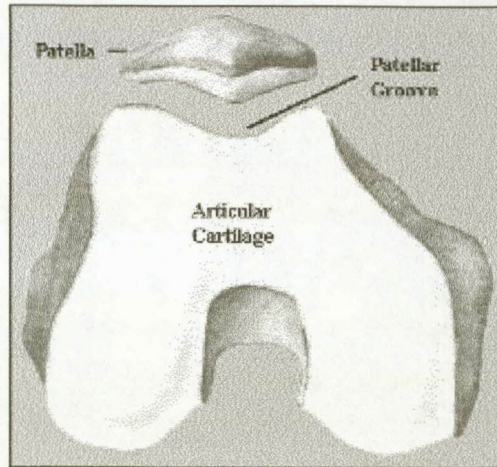


Figure 2.15 The *patella* has a wedge shape and glides through a groove in the distal *femur*, called the *trochlea*.

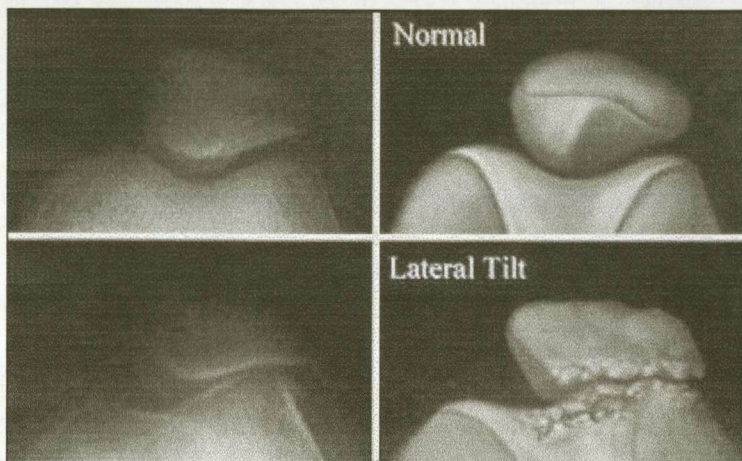


Figure 2.16 Abnormal *patellar* alignment has been postulated as a possible cause of *PFPS* and can lead to *articular degeneration*.

2.3.3 Idiopathic Pain

Anterior knee pain is often present in growing individuals and often there is no cause to be found (idiopathic). Before the pain is labeled as idiopathic, other pathological causes must be excluded, such as *bursitis*, *fat pad syndrome*, *plica syndrome*, and *meniscus* problems. Therefore, in order to classify pain as Idiopathic, the reason or cause of the pain should be convincingly unknown.

2.3.4 Trauma

Many athletes with *patellar* knee pain have a history of direct trauma to the *patella* joint. This can damage the *subchondral bone*, as well as the *articular cartilage*, and cause pain.

The *patella* can dislocate (completely out of the joint) or subluxate (partially out of the joint) laterally. This injury is combined with tearing of the *medial retinaculum* and the *Vastus Medialis Oblique* muscle (Moore, & Dalley, p. 537, 1999).

Predisposing factors include a high-riding *patella* (*patella alta*), hyper-mobile *patella*, generalized ligament laxity, an increased Q-angle and changes in the relationship between the *femur* and *tibia*, hypertrophy of the muscles, *valgus* deformity of the knee, and abnormal shape of the *patella* and the *patellar groove*. Dislocation may recur in 15-45 % because of these predisposing factors.

2.3.5 Malalignment/ Instability

Instability is believed to be a very frequent cause of *Patello Femoral* pain. *Patello Femoral* disorders are very common in the general population, and symptoms related to the extensor mechanism of the knee are the most common complaint in sports-related injuries. About 30 % of all overuse injuries are related to the knee and 35 % involve the extensor mechanism (Figure 2.17). In activities such as running, jumping, gymnastics, or ballet dancing, the incidence can be as high as 75 %. *Patella* instability or malalignment are therefore important background factors.

The *patellar ligament* has both passive and active functions. It acts as a ligament in stabilizing the *patella* for proximal traction, and acts as a tendon via the *patella* to the *quadriceps* muscle (Figure 2.17). The active stability of the *patella* is controlled by the *quadriceps* muscles: the *Vastus Medialis Oblique* exerts medial traction; the *Vastus Lateralis* lateral traction, and the *Rectus Femoris* and the *Vastus Intermedius* axial traction on the *patella* (Hertling & Kessler, p. 355-357, 1996). These forces acting on the *patella* are caused by different muscle groups, tendons and ligaments and are displayed in Figure 2.18 (Mark & Juhn, p. 2020, 1999).

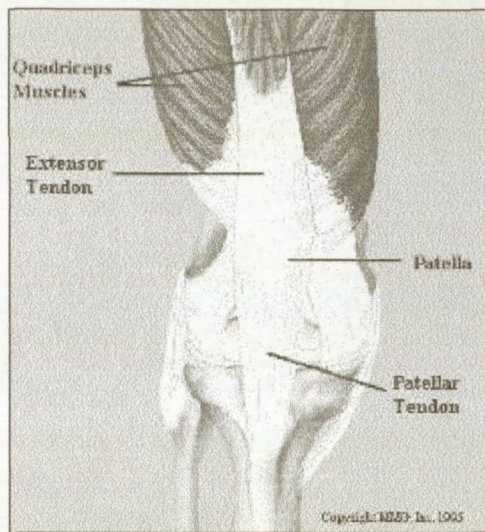


Figure 2.17 The extensor tendon and the patellar tendon is clearly identified.

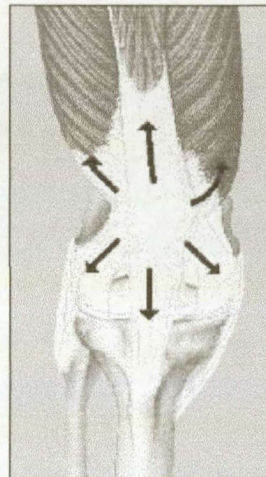


Figure 2.18 Traction forces on the *patella*, caused by the different muscle groups, tendons and ligaments.

The *quadriceps angle* (Q-Angle, Figure 2.19, Mark & Juhn, p. 2015, 1999) is the angle formed between the lines through the longitudinal axis of the *Rectus Femoris* muscle through the *patellar ligament*. These lines meet in the center of the *patella*. An increased Q-angle will, during *quadriceps* contraction cause lateral tracking of the *patella* (Figure 2.20). An increased Q-Angle is said to be a possible contributing factor to the occurrence of *Patello Femoral* pain. This statement, however, has been questioned by various researchers.

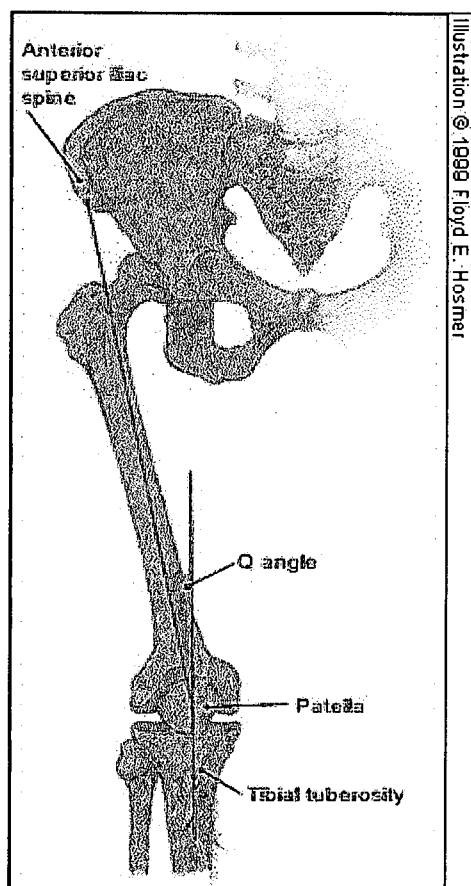


Figure 2.19 This illustration displays how to Q-angle is determined and accordingly measured.

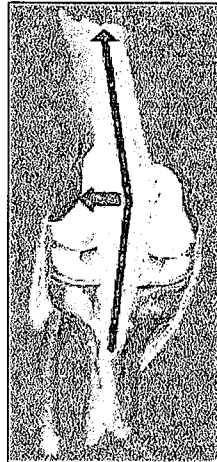


Figure 2.20 An increased Q-angle will cause lateral tracking of the *patella* during *quadriceps* contraction.

Even minor abnormalities in the passive and active stability of the *patella* may give rise to *Patello Femoral* symptoms and *patellar* instability (Smith *et al.*, 1996). *Patella* instability due to *Patello Femoral* dysplasia (underdevelopment of the *Patello Femoral* joint) may be an important factor for *Patello Femoral* pain. *Patello Femoral* dysplasia may be a genetic or developmental abnormality. The lack of geometric instability along with an increased Q-angle will create *patellar* instability, and could furthermore be increased by muscular imbalances especially due to weakness of the *Vastus Medialis Oblique*.

Patello Femoral dysfunction is a commonly seen condition in most outpatient physiotherapy practices. While there are many potential causes or factors, which will predispose any one individual to this condition, weakness or an inability to activate the *Vastus Medialis Oblique (VMO)* muscle is one factor physiotherapists frequently attempt to correct.

As demonstrated by McConnell (p. 217-221, 1986), the *Vastus Medialis Oblique (VMO)* is most accurately thought of as an active stabilizer of the *patella*, rather than as an extensor of the knee. As a stabilizer, the *VMO* attempts to compensate for a variety of mechanical forces acting at the *Patello Femoral* joint that can result in a lateral vector, drifting the *patella* to the lateral edge of the femoral *articular* surface or groove. Once out of its correct plane, abnormal compression forces at the *Patello Femoral* joint can result in pain, effusion and eventually, inhibition of the *quadriceps*.

2.3.6 Strengthening the VMO

If *VMO* weakness were a contributing factor to a patient's *Patello Femoral* dysfunction, strengthening the *VMO* would seem a logical therapeutic approach. The difficulty of course is in preferentially strengthening the *VMO* relative to the remainder of the *quadriceps*, especially the *Vastus Lateralis* (Callaghan & Oldham, p. 384-389, 1996). Over the years, we have heard of a wide variety of exercises used by various clinicians to improve the strength or performance of a patient's *VMO*. Some of these are listed below:

- Straight leg raises (SLR)
- SLR with the lower extremity externally rotated from the hip
- Knee extension from -30° to 0° extension
- Knee extension (as above) with the lower extremity externally rotated from the hip

- Various hip adduction exercises, usually involving squeezing a ball between the knees
- McConnell's partial squat with isometric glute squeeze

2.4 SYMPTOMS AND DIAGNOSIS

Most of the symptoms found in literature are listed below:

- Widespread anterior knee pain occurs in the knee joint and behind the *patella* during exertion or load such as sitting with a bent knee
- The pain problems are accentuated in walking and running up hills and stairs, and then especially during descent.
- Pain and stiffness can be felt when rising from a sitting to a standing position, typically after watching a film or movie (the “movie sign” or “movie-goers knee”).
- Pain problems are often made worsened by squatting.
- Pain occurs with isometric contractions of the *quadriceps* under resistance at 0° and 20°.
- Local tenderness may be present on the medial or lateral *patellar facets* around the *patella* and on compression of the *patella*.
- *Crepitation* or creaking during flexion and extension of the knee may be experienced behind the *patella*, indicating *chondromalacia*.

- Sometimes a light swelling in the knee joint is noticeable.
- The Q-angle should be measured: at 30° flexion, the angle is normally less than 10° in men and less than 15° in women, and at 90° of flexion it is less than 8°.
- Malalignment of the lower limb including increased pronation of the foot, malrotation of the *tibia* or *femur* (*femoral anteversion*), *genu valgum* (increased angle between the *tibia* and the *femur*), and tight lateral *retinaculum* may be significant factors, which also increase the Q-angle.
- Active and passive tracking of the *patella* should be evaluated.
- The Apprehension Test is positive. This test is performed with the knee on 0° of flexion. The examiner fixes the *patella* laterally with his hand. When the athlete bends the knee, the *patella* tries to sublux and thereby causes pain.
- The Passive Patella Tilt Test evaluates the tension of the lateral *retinaculum* structures.
- Plain X-rays of the knee should be taken. The *patella* in relation to the joint line can be evaluated by lateral plain views.
- A CT scan and Bone scan can also be done. A Bone scan can be used in cases with prolonged symptoms of anterior knee pain. The diagnosis is confirmed by an increased uptake of nuclide (radioactive agent) by both *patella* and *femur*, and indicates a poor prognosis.
- Arthroscopy can evaluate the extend of the *patella articular* damage and confirm the clinical and radiographic alignment and establish whether *synovitis* is present (Caylor *et al.*, p. 11-16, 1993).

2.5 TREATMENT

2.5.1 Introduction

Treatment for *Patello Femoral Pain Syndrome* involves a combination of activity modification, anti-inflammatory modalities and a comprehensive stretching and strengthening program (Grimby, p. 70-75, 1985). Surgical intervention is rarely necessary and is generally reserved for cases of recalcitrant instability or symptomatic malalignment (Kipnis & Scuderi, p. 4-6, 1995).

The Athlete should:

- Rest from painful activities;
- In the acute phase, apply ice;
- Use a brace with a notch and support for the *patella*, sometimes taping can also be helpful;
- Exercise the *quadriceps* and *hamstring* muscles, especially the *Vastus Medialis Oblique*.
- Follow a stretching program as flexibility is important;
- Understand that the effect of this type of treatment/training may, however, take a long time to be noticed (Callaghan & Oldham, p. 390-390, 1996).

Managing *Patello Femoral Pain Syndrome* is a challenge, in part because of lack of consensus regarding its cause and treatment. Contributing factors include overuse and

overload of the *Patello Femoral* joint, biomechanical problems and muscular dysfunction (Papagelopoulos & Sim, p. 150-155, 1997). The initial treatment plan should include *quadriceps* strengthening and temporary activity modification. Additional exercises may be incorporated as dictated by the findings of the physical examination. Footwear should be closely evaluated for quality and fit, and the use of arch supports should be considered. (Mark & Juhn, p. 2012-2022, 1999).

2.5.2 Surgery

Surgery for *Patello Femoral Pain Syndrome* is considered a last resort. True *chondromalacia* (fraying of the *retropatellar cartilage*) may be amenable to an arthroscopic surgical procedure to smooth out the undersurface of the *patella*. Unfortunately, the *chondromalacia* may return.

If the problem is clearly caused by excessive lateral tracking, a "lateral release" is sometimes appropriate. This procedure involves cutting the lateral *retinaculum* to reduce the amount of lateral pull (Pierce, p. 108, 1997). Before the decision is made to perform a lateral release, other options and treatments should be considered thoroughly (Lessard *et al.* p. 17-21, 1997). For example, the physician should consider whether the lateral tracking could simply be due to a tight *iliotibial band* or weak *quadriceps* muscles. Taping the knee to enhance medial glide should be tried.

Having the patient wear a quality running shoe or arch support is another measure to try before surgery is contemplated. Although the lateral release is effective in a select group of patients, it is often considered an overused procedure, even among some orthopaedic surgeons.

Chronic, recalcitrant *Patello Femoral Pain Syndrome* is much more difficult to treat (Mark & Juhn, p. 2014-2019, 1999). It can be a frustrating problem for physicians and patients alike. The mainstay of treatment for chronic *Patello Femoral Pain Syndrome* is a combination of *quadriceps* strengthening exercises in addition to *quadriceps*, *hamstring* and *iliotibial band* stretching exercises. It is often helpful to refer patients to a physical therapist for one or two sessions of hands-on instruction in the appropriate exercise program.

Occasionally, electric stimulation, biofeedback and McConnell (p. 220-222, 1986) taping techniques are useful. Prolonged physical therapy with modalities such as ultrasound is generally not helpful or cost effective. Orthotics to correct *pes planus* and soft braces with *patellar* cutouts may be indicated and provide modest symptomatic relief in selected cases.

A more detailed feedback on the knee surgery procedure and complications is given in the next chapter. Also, consider Appendix A for summarized tables 1 and 2 that explain the muscular etiologies of *Patello Femoral Pain Syndrome*.

2.6 CONCLUSION

Patients suffering from the *PFPS*, complain of pain that is felt under and around the kneecap, more often than not, they are however, unable to point out the precise location of the pain. The exact nature of this particular disorder is very complex and therefore the cause(s) is believed to be multi-dimensional and not well known.

Due to the fact that the cause(s) of *Patello Femoral Pain* can range from acute trauma to malignment of the *patella* and even obesity, it becomes difficult to treat this condition without at least some indication of an abnormality or cause. In many cases, however, there are no obvious reasons for the symptoms (idiopathic pain), and there seems to be no clear association between the severity of the symptoms and the radiological and arthroscopic findings. In these cases, the only thing a therapist can really do, is to take the whole *kinetic chain* into consideration when trying to correct any form of imbalance or abnormality when treating a patient. Until proven otherwise, the exact cause of *Patello Femoral Pain* or anterior knee pain, remains a mystery and treatment should be guided by the patients' symptoms (symptomatic treatment).

CHAPTER 3

INFORMATION FEEDBACK ON THE KNEE ARTHROSCOPY

3.1 PROLOGUE

The word *arthroscopy* comes from two Greek words, "arthro" (joint) and "skopein" (to look). The term literally means, "to look within the joint." In an *arthroscopic* examination, an orthopaedic surgeon makes a small incision in the patients' skin and then inserts a pencil-sized instrument that contain a small lens and lighting system to magnify and illuminate the structures inside the joint. Light is transmitted through fiber optics to the end of the *arthroscope* that is inserted into the joint. By attaching the *arthroscope* to a miniature television camera, the surgeon is able to see the interior of the joint via the *arthroscope* inserted through this very small incision.

3.2 HISTORY OF ARTHROSCOPY

The beginnings of *arthroscopy* go back to 1918 when Professor Kenji Takagi of Tokyo University performed the first successful *arthroscopy* of the human knee with a *cystoscope* and the knee of a cadaver. His desire to have a better way of viewing the

internal knee joint was not to help those with arthritis or fractures, but for those who might have tuberculosis. Tuberculosis was causing many Japanese to suffer from what they called "stiff knee." Takagi wanted to diagnose tuberculosis in its early stages and treat it before it caused major problems. By 1936, Takagi had developed a way to obtain color pictures and video of the interior of the knee joint (Andrews & Timmerman, p. 3-30, 1997).

One year after Takagi's first procedure was performed, Dr. Eugene Bircher became the first to perform an *arthroscopy* on live patients. He examined the knees of 21 patients with *osteoarthritis* using a *Jacobeous laparoscope*.

In 1922, Bircher was the first to publish results on *arthroscopy*, which he called "*arthroendoscopy*." From 1925 through 1939, many other pioneers in this field were researching and experimenting new methods and better equipment including Drs. Michael Burman, Phillip Reuscher, E.W. Geist and Wilke. However, many people were still skeptical of this idea, and the technology at the time caused several problems with equipment. A lapse in research of the subject was caused by World War II until in the 1950s when Dr. Masaki Watanabe, a former student of Takagi, began to make several major contributions to the field of *arthroscopy* (Andrews & Timmerman, p. 3-30, 1997).

Dr. Watanabe made many improvements to the design of the *arthroscope*. In fact, he developed the first truly successful *arthroscope* called the Watanabe 21, which had a

much-improved lens. The 22 used fiber light and the 24 was made smaller by using a single glass fiber for the use in very small joints. With these new instruments, Watanabe performed the first recorded surgical procedures in which he used an *arthroscope* to remove tumor cells in the supra-patellar pouch and also performed a partial *meniscectomy*. In 1957, Watanabe along with his colleagues published his first edition of the "*Atlas of Arthroscopy*" (Andrews & Timmerman, p. 3-30, 1997).

Further contributions to the field of *arthroscopy* occurred during the early 1970s. At the University of Toronto, two doctors, Drs. Jackson and Abe, who had learned from and studied Watanabe's techniques, published the "*Journal of Bone and Joint Surgery*," which is now a well known scientific journal in orthopedics. Dr. Lanny Johnson who is known for his teaching and technical innovations developed the "Needle Scope." Also, the *International Arthroscopy Foundation* was developed in which Watanabe was the first president (Andrews & Timmerman, p. 3-30, 1997).

Up to this point in *arthroscopic* history, the techniques of *arthroscopy* were only used for diagnosing problems in certain joints. During the 1980's, technology had improved enough for the technique to be used for surgery. The use of the *arthroscope* in joint surgery was a major revelation that spurred many new instruments and techniques to be developed.

New instruments that were developed for surgery included suction punches, graspers, cutting tools, and power tools such as the shaver and drill. The techniques of *meniscus* repair and transplantation were greatly improved along with *anterior cruciate ligament* reconstruction. With new research and technology, not only was *arthroscopic* surgery on the knee being performed, but also on other joints such as the shoulder, ankle, wrist and elbow (Andrews & Timmerman, p.3-30, 1997).

The new technical innovations of the 1980s made surgery of the joints the simple procedure it is today. This type of surgery, being minimally invasive, causes less pain, great accuracy and fewer complications than any other type of surgery available.

Arthroscopic surgery has virtually replaced *arthrotomy*, a crude, invasive method used before the development of the *endoscope* (Nelson *et al.*, p, 501-504, 1996). Today, more than 1.5 million *arthroscopic* procedures are performed every year, and the technique has completely transformed the field of sports medicine (Pierce, p. 108, 1997).

3.3 WHAT IS KNEE ARTHROSCOPY?

Arthroscopy is a minimally invasive surgical procedure that can be performed for the purpose of diagnosing and the following treatment of problems within the internal structure of joints, such as the knee joint (Andrews & Timmerman, p. 37-43, 1997). *Arthroscopy* is therefore a surgical procedure orthopaedic surgeons use to visualize, diagnose and treat problems inside a joint. *Arthroscopy* has become one of the most frequently used procedures for diagnosis and treatment of knee injuries.

Knee *arthroscopy* is an operative procedure that allows the surgeon to look directly inside the knee. It is a minor surgical procedure that is done as an outpatient (patient is able to go home on the same day as the surgery). Using small incisions, the *arthroscope* is inserted into the knee, and images are then transmitted to a television-monitor by means of a camera. This procedure then produces an actual picture of the interior of the knee. This allows the physician to see the entire knee joint and permits the repair of some injuries (Andrews & Timmerman, p.37-43, 1997). The television camera displays the image of the joint on a television screen, allowing the surgeon to look, for example, throughout the knee - at *cartilage* and *ligaments*, and under the kneecap (illustrated in Figure 3.3). The surgeon can determine the amount or type of injury, and then repair or correct the problem, if it is necessary. Figure 3.1 displays the basic patient – setup for *arthroscopic* knee surgery and Figure 3.2 a knee *arthroscopy* being performed. All figures/illustrations are from anonymous 1997a/b unless stated otherwise.

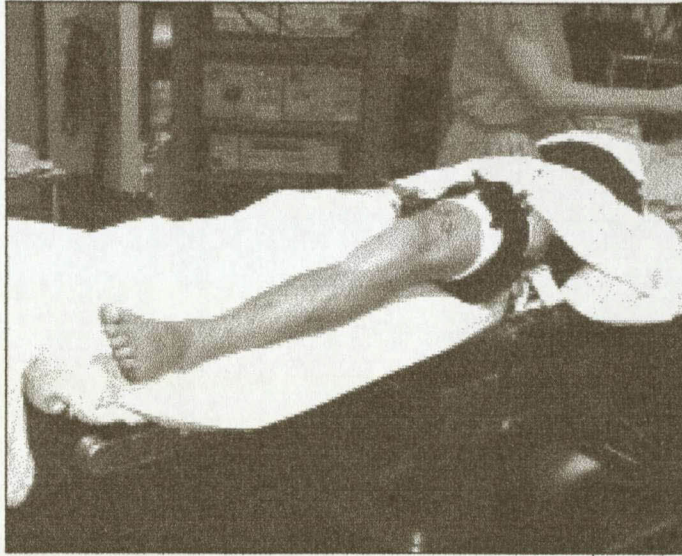


Figure 3.1 Basic patient – setup for *arthroscopic* knee surgery.



Figure 3.2 Knee *arthroscopy* being performed.

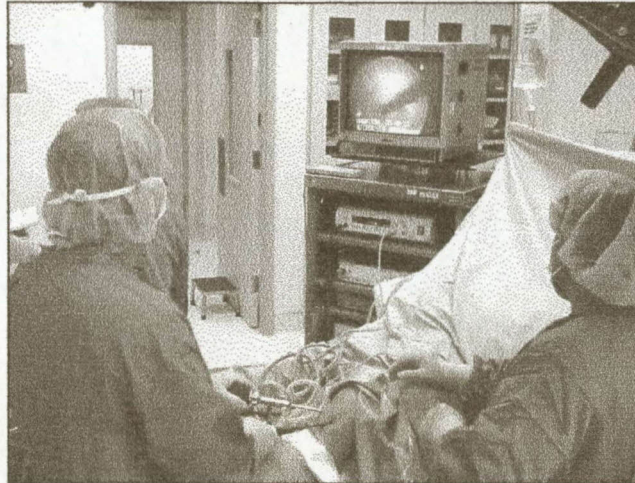


Figure 3.3 The *arthroscope* is inserted into the knee and images are then transmitted to a television-monitor by means of a camera. The television camera displays the image of the joint on a television screen. This allows the surgeon to have a very close look inside the knee joint.

Knee *arthroscopy* is used in three ways. The first is for diagnosing, that is to look inside the knee to make a diagnosis. The second is operative *arthroscopy*, actually performing a surgical procedure by means of the *arthroscope* and small surgical tools.

Finally, the *arthroscope* may be used in combination with extensive surgery as part of a reconstructive procedure. By performing an *arthroscopy* on a patient with a knee injury, the physician can now make a correct diagnosis because he sees the knee from the inside (for example see Figures 3.4 and 3.5 below).

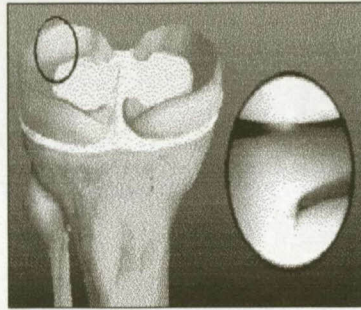


Figure 3.4 A normal *meniscus* as seen through the *arthroscope* appears as a smooth, white wedge-shaped structure.

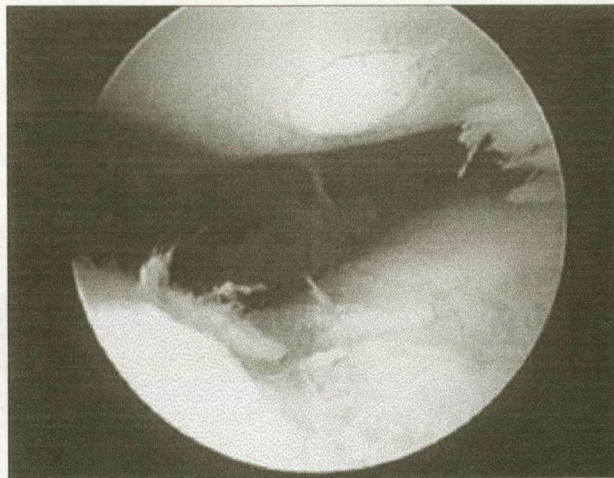


Figure 3.5 The above picture is an example of degeneration in the *Patello Femoral* joint found during a knee scope. A routine *arthroscopy* corrected the problem.

Other applications of the *arthroscope* include the treatment of certain fractures, arthritis, infections, and diseases that involve the knee joint lining.

3.3.1 General Procedure

The general surgical procedure in *arthroscopy* today is fairly simple and routine. The portal placements, or places where the incisions are to be made, are drawn on the patient with a special methylene-blue pen that is typically used as a surgical pen (Figure 3.6). This is an important step because the portal placements are essential for optimal visualization of the interior of the knee joint. The TV monitor needs to be placed where it is easily viewed by the surgeon. The patient is then given *anesthesia* and hooked up to an IV, which administers fluids and medication during surgery (Andrews and Timmerman, p. 37-43, 1997).

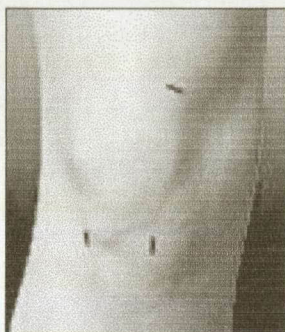


Figure 3.6 Incision marks are made on the knee for all the instruments to be used during an *arthroscopy*.

There are several common entry sites for an *arthroscopy*. These entry sites are displayed in Figure 3.7 below.

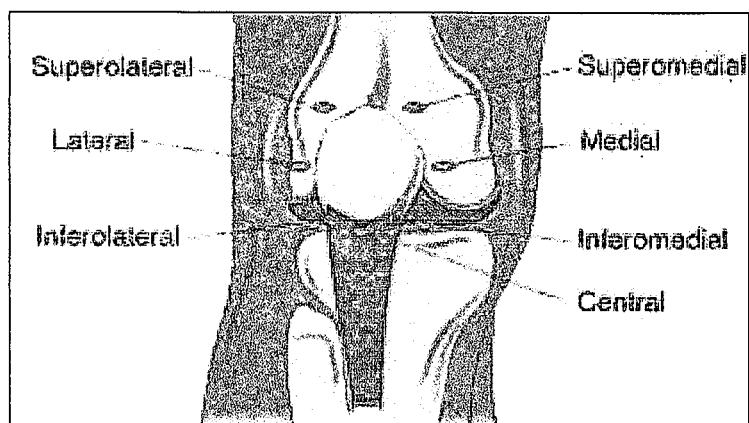


Figure 3.7 Common entry sites for an *arthroscopy*.

A thigh tourniquet is placed on the upper thigh of the affected leg. Before an incision is then made, the tourniquet may be inflated. This reduces the amount of bleeding in the joint space, and also allows for better viewing. The first incision is then made on one side of the knee for the *arthroscope* to enter. A second incision is made for the insertion of certain *arthroscopic tools* (see Figures 3.8 and 3.9). These tools can be used in order to cut, remove, and sew damaged tissue. Sometimes a third incision is made to allow for better fluid flow within the joint. Once the operative procedure is over, the surgical tools are removed and the incisions are sewn together if needed (Andrews and Timmerman, p. 47-51, 1997). Usually the cuts are so small that they only require, at most, one stitch.

Sometimes a brace or Ace wrap is used after surgery to provide protection and stability to the joint. It is normally done as an outpatient procedure, which means that the patient is able to go home on the same day the surgery was performed.

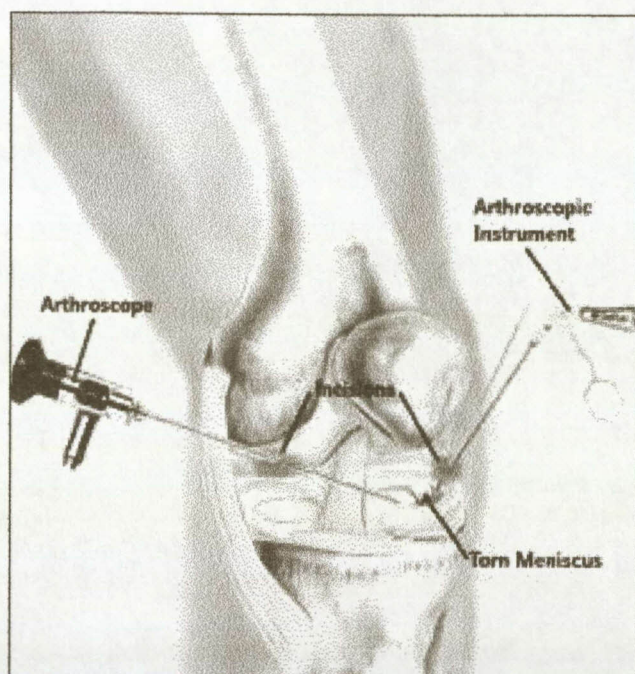


Figure 3.8 The basic working of the *arthroscopy* operation.

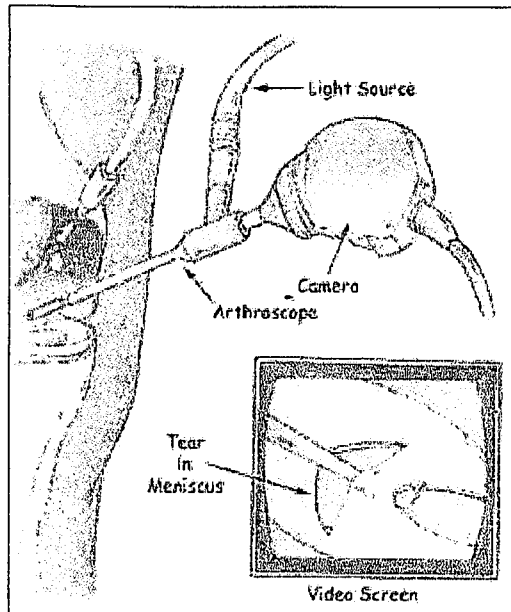


Figure 3.9 Close-up of the knee *arthroscopy* being performed.

3.3.2 Basic Surgical Instruments

- **BORE NEEDLE:** Inserted to puncture the capsule of the knee joint.
- **ARTHROSCOPE:** The tool that *arthroscopy* centers on, which is composed of special optic fibers and a light source, allows the visualization of the interior of joints. The size and focal length of the scope vary according to which joint and for what purpose it is being used. The *arthroscope* is displayed on Figure 3.10 and the effect of the light source in Figure 3.11.

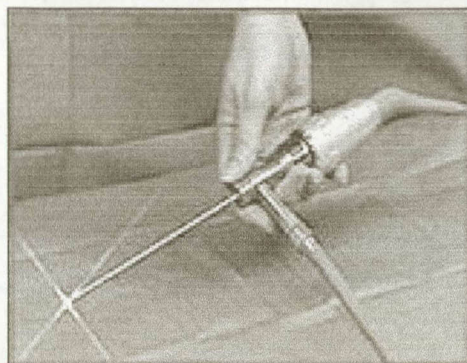


Figure 3.10 The *arthroscope*, the tool that arthroscopy centers on, which is composed of special optic fibers and a light source, allows the visualization of the interior of joints.

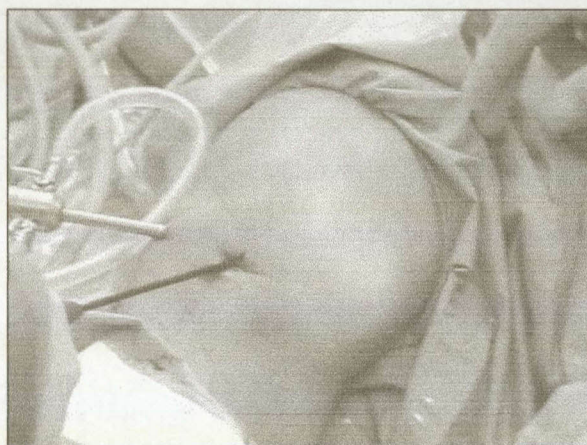


Figure 3.11 In this Figure the effect and magnitude of the light source is illustrated very clearly.

- **PROBE:** Used to lift and maneuver the *cartilage* and tissue around the joint. It is also helpful in evaluating the type and depth of any *articular* defects (Figure 3.12).

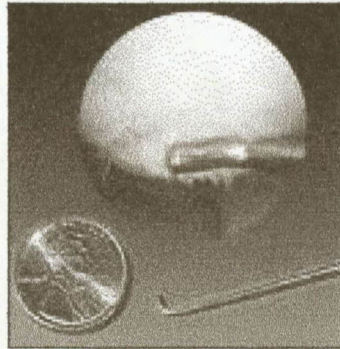


Figure 3.12 The Probe, used to lift and maneuver the *cartilage* and tissue around the joint.

- **GRASPERS and FORCEPS:** These are needed to grasp and/or remove loose debris or tissue from within the joint. Several different types are available. They may automatically lock or require continuous pressure. Some have sharp teeth for easier grasping.
- **CHONDRAL AWLS:** Used to establish vascular channels in *subchondral bone* for examining *chondral* defects.
- **SUCTION PUNCHES:** These are able to grab “hard-to-get” tissue into forceps by using suction.

- **SUTURE ANCHORS:** Inserted into a joint to attach soft tissue onto a particular bone.

3.4 TYPES OF COMPLICATIONS

The most common use of *arthroscopy* involves the treatment of *meniscal lesions*. The *menisci* are “*cartilage*” structures within the knee, which can tear and then cause pain or restrict motion or range of movement. The *arthroscope* is also used to remove “loose bodies”, which are pieces of bone and / or *cartilage*, which are free or loose within the knee. These “loose bodies” may arise from injury or degenerative changes within the knee.

Certain *patella* (kneecap) problems are also treated with the *arthroscope*. These include *chondromalacia*, which is basically a roughness or irregularity underneath the *patella*, producing pain. In addition, some types of patella alignment problems can also be treated with *arthroscopic* surgery, either alone or in combination with more extensive surgery.

3.4.1 Surgical and Rehabilitation Complications Following Knee Surgery

Although uncommon, complications do occur occasionally during or following an *arthroscopy*. Infection, phlebitis (blood clots of a vein), excessive swelling or bleeding, damage to blood vessels or nerves, excessive blood in the joint cavity, excessive fluid in the joint cavity, stiffness, delayed wound healing and instrument breakage are the most common complications, but occur in far less than 1 percent of all *arthroscopic* procedures being performed.

Your physician should be called if you are experiencing pain that is not relieved by medication, elevation, or ice. If there is any increased swelling, discoloration, numbness or tingling of the leg, fever or chills, he should also be notified.

3.4.1.1 Pain and Effusion

Advances in surgical techniques, pharmaceutical intervention, and rehabilitation methods have helped decrease the pain and effusion associated with any form of knee surgery. Despite these innovations, postoperative pain, effusion, and the related muscular weakness or inhibition they induce can be problematic and warrant early therapeutic intervention. Knee effusion or pain has been shown to directly and negatively affect *quadriceps femoris* contractility and ankle effusion or pain has been shown to similarly affect functionally synergistic muscles in the hip and lower leg.

Cryotherapy in the form of ice packs, ice massage, and cold-intermittent compression can definitely diminish postoperative pain and effusion, particularly when combined with lower-extremity elevation (Nyland, p. 907-914, 1999).

In a prospective, randomized study of 45 postminor *arthroscopic* knee surgery patients, Lessard *et al* (p. 14-22, 1997) reported that subjects who received a 1-week home program of *Cryotherapy* and exercises demonstrated increased exercise compliance, improved weight-bearing status, and lower prescription pain medication consumption than those who used exercise alone.

In addition to *Cryotherapy*, knee effusion can be reduced with combinations of lower-extremity elevation, compression wrapping, and electric stimulation. Electrical stimulation may be more effective for edema or effusion control by its pumping action rather than its polarity effects. Localized pain can be managed with iontophoresis and an analgesic or anti-inflammatory agent, as well as ultrasound.

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3.4.1.2 Muscular Weakness or Inhibition – Disuse Atrophy

Knee rehabilitation has traditionally focused on sagittal plane isotonic exercises for the *Vastus Medialis Oblique (VMO)* because of its obvious *atrophy* following knee surgery. Based on considerations of their synergistic function with the *Anterior Cruciate Ligament (ACL)*, rehabilitation emphasis evolved to improving the strength, power, endurance, and reactivity of the *hamstrings* following *ACL* surgery. More recently, the importance of dynamic knee-stabilizing contributions from the hip and lower-leg musculature has been emphasized. Knee rehabilitation has evolved from focusing on isolated *quadriceps femoris* (particularly *Vastus Medialis Oblique*) rehabilitation to a more integrated, holistic approach, concentrating on synergistic lower-extremity function while monitoring for and, when necessary, addressing isolated deficiencies (Nyland, p. 915, 919, 1999).

A properly functioning *Vastus Medialis* muscle is vital to proper *patellar* orientation within the *femoral trochlea*. *Patellar* orientation refers to its three-dimensional position, including components of slide, rotation and tilt. When the *Vastus Medialis* is dysfunctional, the *patella* tends to slide and tilt laterally, and also rotate laterally from its inferior pole, thereby increasing lateral *Patello Femoral* compression. This *patellar* position contributes to decreased lateral *retinaculum-iliotibial* tract extensibility, thereby decreasing the overall effectiveness of the *quadriceps femoris* muscle as a dynamic stabilizer. The *Vastus Medialis* portion of the *quadriceps femoris* seems to be the primary neuromuscular inhibition and *atrophy* target following knee injury or surgery.

Werner *et al.* (p. 85-92, 1993) reported good results in strengthening the *Vastus Medialis* of patients with *Patello Femoral* pain using neuromuscular electric stimulation and a *Vastus Lateralis* – stretching program. Biofeedback had been used for many years as a tool to volitionally increase motor-unit recruitment for improved muscle strength or to decrease motor-unit recruitment for relaxation. Several reports have demonstrated its efficacy for the postoperative management of patients with *Patello Femoral* pain following minor *arthroscopic* procedures.

What Closed Kinetic Chain (CKC) exercises may lack in isolating *quadriceps femoris* function they make up for in its activation with synergistic lower-extremity muscles and generally reducing *ACL* strain.

3.4.1.3 Decreased Joint Range of Motion (ROM)

Decreased knee ROM secondary to *capsulo-ligamentous* adhesions, fat-pad *fibrosis*, or *cyclops* lesions, although managed effectively by *arthroscopy*, is best avoided. The restoration of normal knee ROM is vital to the long-term success of knee rehabilitation and the avoidance of degenerative *articular cartilage* lesions.

Therapists have traditionally emphasized knee-flexion restoration, but as improved operative techniques have enabled earlier ROM, postoperative knee flexion deficits have become less common. Knee-extension restrictions can be particularly devastating when

the abnormal *articular* forces that they create are combined with the excessive impact forces of running and jumping. Knee-extension restrictions have become less prevalent with the development of improved graft placement methods, an appreciation of early postoperative *quadriceps femoris* exercises out of the continuous passive motion device or postoperative brace, early increased weight-bearing, and increased time in a prone resting position.

Repetitious, active-knee ROM within pain-free limits early in the rehabilitation process strongly decreases the likelihood of postoperative restrictions. When the return of knee ROM is behind schedule, active exercises with slight volitional overpressure are recommended.

Following surgical wound healing, swimming pools provide an excellent environment for improving knee ROM, neuromuscular control, and cardiovascular conditioning. Because a person is non-weight-bearing in a swimming pool, there is no jarring on the operated knee. This greatly reduces edema and effusion.

3.4.1.4 Neuromuscular Fatigue

Exercises performed in the presence of joint pain or with poor technique are of little value to recovering patients and may serve as a catalyst to the development of a *knee pain - muscle inhibition cycle*.

With consideration for the differing timetables for tissue histologic and mechanical maturation, the return of graft mechanoreceptor function, and the integrity of bony and soft-tissue fixation following surgical reconstruction, therapists generally attempt to restore normal neuromuscular function as soon as possible (Nyland, p. 910-913, 1999). To achieve this, exercise selection and variables, such as sets, repetitions, total exercise number, order, and frequency, are and should be manipulated according to the progression of the patient.

3.4.1.5 Cardiovascular Deconditioning

Maintaining or improving cardiovascular conditioning following injury or surgery must be achieved without disturbing the healing process. Cardiovascular conditioning is best served when the attributes of the chosen exercise(s) encourage joint healing, are of low impact, train synergistic muscle activation, are relevant to the sport (and the position within that sport), can be performed without joint pain, and can provide patients with the feeling of well-being and sense of accomplishment commonly provided by aerobic

training. There are many different types of equipment that can serve to reach the goals of improving cardiovascular fitness, and one can use ones own creativity when compiling an exercise program, provided this program is constructed according to the demands mentioned above.

3.4.1.6 Hip and Ankle Muscle Weakness or Inhibition

Dynamic control of the *femur* and *tibia* by means of the hip and ankle musculature is critical to knee-injury prevention or re-injury. During running, jumping and walking, the power provided by the hip and ankle is vital to dynamic knee stability in addition to propulsion and impact force attenuation.

Hip *abductor* and external rotator weakness affects three-dimensional dynamic lower extremity control, leading to an increased *femoral* internal rotation during the locomotion stance phase, which tends to increase the dynamic Q-angle at the knee. Hip and ankle muscle functioning may be affected following knee injury or following other related primary dynamic knee stabilizer dysfunction. During Closed Kinetic Chain (CKC) function, the *gluteus maximus* serves as both hip and knee extensor and as the pre-eminent hip external rotator. Hip external rotator function is vital to *femoral* internal rotation deceleration during jump landings and running stops (Nyland, p. 92-922, 1999). The hip *abductors* and *adductors* serve to maintain horizontal *lumbopelvic* alignment during all movements.

The actions of the *gastrocnemius* and the *soleus*, the deep compartment muscles, and the *anterior tibialis* at the ankle and *subtalar* joints assists with dynamic sagittal and transverse plane dynamic knee control. Although isolated *rectus femoris* (particularly the *Vastus Medialis*) exercise is generally warranted following knee injury or surgery, exercises that integrate the hip and ankle or *subtalar* joint muscles are essential to the ultimate success of the rehabilitation program. A holistic approach to exercise prescription is therefore an absolute necessity, and one has to remember that you have to consider the complete kinetic chain when treating any injury or weakness in any part of the body.

3.4.1.7 The Changing Role of the Physical Therapist

Outcomes following surgery and rehabilitation may be influenced by multiple factors. Improving our understanding of patients' likelihood for a successful outcome after surgery is an area of increasing interest. Tools that predict which patients are most likely to benefit from surgery and the ensuing rehabilitation would be particularly useful when reconstructive surgery is deemed an option rather than a necessity. These data may also influence surgical timing, graft choice (*autograft* versus *allograft*, *hamstring* versus *patella tendon*); surgical method; rehabilitation approach and timetable (accelerated versus decelerated); and ultimately, postoperative expectations. With limited treatment visits and reduced staffing, therapists must be more resourceful than ever in delivering effective patient care. Communication with patients and other caregivers is essential to

maximize time efficiency. Designing functionally relevant, individualized rehabilitation plans that consider realistic, achievable, and functionally significant goals, facilitating patient progressions towards achieving those goals, and determining the appropriate time to evaluate goal achievement all become more challenging when the total number of patient visits are limited. In general, the more complex the evaluation task, the more practice time is needed to ensure measurement reliability.

Increased emphasis on knee injury prevention or re-injury prevention programs and health-club based, return-to-play conditioning programs provide an excellent opportunity for therapists to serve patients outside of traditional hospital and outpatient clinic settings.

3.5 RECOVERY AFTER ARTHROSCOPY

The small puncture wounds take several days to heal. The operative dressing should be left alone until 5 days after surgery. Adhesive strips can be seen covering the small healing incisions, these will come off, on their own, a few days after removing the dressing. The knee does not need to be covered after the 5th day.

Although the puncture wounds are small and pain is minimal, it takes several weeks for the joint to recover fully. To aid this recovery, you should maintain muscle strength and flexibility. This is done by walking on the affected leg and, several times during the day, performing straight leg raising exercises (Nelson *et al.*, p. 501-504, 1996). These are

done by locking the knee out straight, while lying down, and lifting the straight leg to 45° then holding it and slowly lowering it. You should try this ten times every few hours for the first 5 days after surgery (Dervin *et al.*, p. 405-411, 1998).

It is not unusual for patients to go back to work or school or resume daily activities within a few days. Athletes and others who are in good physical condition may in some cases return to athletic activities within a few weeks.

Immediately following surgery, patients may feel sleepy especially if general *anesthesia* was used. They also may feel slight pain or stiffness in the joint. Most patients, however, are active, healthy individuals who are able to resume normal activities within a couple of days after surgery (Anonymous, 1997a). There are several post operative activities doctors recommend in order for the quickest healing process to occur. The first week after surgery should involve activities that decrease the swelling and increase the strength and range of motion at the joint. Applying ice for about 15 to 20 minutes, 3 to 5 times per day, elevating the joint whenever possible, and wearing an ace wrap, can reduce the swelling. In order to increase strength during the first week after surgery, certain exercises and weight lifting activities need to be done. In cases where the joint worked on is in the lower extremity, crutches may be used until the joint can bear weight again (Nelson *et al.*, p. 501-501, 1996). To increase the range of motion of a joint, special stretching and resistance exercises are recommended depending on the type of joint (Beynnon & Johnson, p. 57-63, 1996).

One week after surgery, most patients are able to return to functional activity and within a few weeks, they are able to actively participate in recreational or competitive sporting events. Further strengthening of the joint is still needed until its strength levels are back to normal. This typically occurs within 8 weeks. As illustrated, quick recovery is one of the main advantages of *arthroscopy* (Beynnon & Johnson, p. 63-64, 1996).

3.6 ADVANTAGES OF KNEE ARTHROSCOPY

With the use of the *arthroscope*, many types of procedures can be done without having to make large incisions into the knee. As a result, *arthroscopic* procedures can usually be done as an outpatient, which means that the patient goes home on the same day the surgery was performed. Without any large incisions, the surgery is less painful and the recovery is much quicker. Although *arthroscopic* surgery has received a lot of public attention because it is used to treat well-known athletes, it is an extremely valuable tool for all orthopaedic patients and is generally easier on the patient than “open” surgery. *Arthroscopy* is one of the most valuable tools a surgeon has. Instead of making big incisions, which can disturb and expose large areas of tissue when executing surgical investigations and procedures, arthroscopy enables the surgeon to have a great view of the injury with minimal disturbance to the body tissue.

Arthroscopic surgery is a very useful way to perform surgeries in the joint area, and is used whenever possible because of its method of minimal disturbance to the injury and the surrounding areas. The methods and techniques of *arthroscopic* surgery have greatly improved and increased over the years, thus enabling surgeons to perform a wider variety of complicated surgeries with very high success rates.

3.7 LIMITATIONS OF ARTHROSCOPY

Arthroscopy has many uses, but it is not the perfect solution for every condition. Successful use of the *arthroscope* involves selecting the right patient with the right problem for *arthroscopic* treatment. In addition, full recovery includes a period of healing followed by rehabilitation of the knee musculature.

Overall, *arthroscopic* knee surgery has produced a major advancement in the treatment of knee injuries and knee disorders. As an outpatient procedure, with decreased recovery time, many patients are able to resume work and sport activities in a short period of time. In today's active and demanding society, the *arthroscope* is an invaluable tool in diagnosing and treating knee disorders.

Although *arthroscopy* was first used for knee problems, refined techniques and improved instruments have expanded the uses of arthroscopy. Today, other joints are being *arthroscoped* with increasing frequency, including the shoulder, ankle, wrist and elbow.

3.8 FUTURE OF ARTHROSCOPY

There have recently been some amazing advancements in the field of bi-polar electro-surgery, which can be applied to arthroscopy. In fact, based on its success, this new technology may soon replace the currently used laser surgery. *Electro-surgery* is a process in which a special tool, the *ArthroWand*, is used to create a high frequency arc for wearing away or ablating tissues. The *ArthroWand* is very useful because of its ability to ablate only the tissue that is hit with its electric arc and therefore causes very little damage to any healthy tissue nearby. This tool is the main part of a system called the *ArthroCare Multi-Electrode System* (Anonymous, 1997b).

The *ArthroWand* is a disposable instrument with a seven-inch handle containing a collection of short electrodes on its tip. This collection of electrodes form the positive pole of the wand while the negative pole lies at the other end. Either saline or Ringer's solution is used to irrigate the negative end electrodes through holes in the wand. The irrigation is necessary to produce low resistance between the tissue and the wand. Then when

electricity is transferred through this medium, a high frequency electric arc is induced which will ablate the tissue it comes in contact with (Anonymous, 1997b).

Arthroscopic electro-surgery can be used in several types of reconstructive surgery, including *PCL* and *ACL* reconstruction. Both of these have been performed using *electro-surgery* at Union Memorial Hospital for over a year (Anonymous, 1997b). *ACL* (*anterior cruciate ligament*) reconstruction is performed in the U.S. more than 50,000 times per year. It is also estimated that about 95,000 injuries of this type occur in one year. This clearly emphasizes the importance of a timely, cost efficient procedure for knee injuries (Frank & Jackson, p. 1558-1563, 1997). More investigations are now underway to develop *electro-surgery* for *meniscal* repair and other common joint problems (Anonymous, 1997b).

The main advantages of the *ArthroCare Multi-Electrode System* include the following:

- It does not damage healthy tissue;
- costs around \$13,000 which is relatively inexpensive when compared to a laser surgery system worth at least \$60,000;
- can be used in smaller joint cavities that have limited working space;
- provides good haptic feedback;
- reduces time in the operating room;
- can be used with electrolyte irrigation and
- maintains homeostasis, the control of blood loss (Anonymous, 1997b).

Despite these advantages, *electro-surgery* of the joints is such a new procedure that it lacks the long-term research needed to prove its credibility. For example, there has not yet been any research published about the long-term effects of *electro-surgery* on the tissue. However, there has been enough success with this technique that is soon to become common in *arthroscopic* surgery (Anonymous, 1997b).

3.9 CONCLUSION

No comparison exists between traditional knee surgery and *arthroscopic* knee surgery. Fortunately, the *arthroscopy* made it possible to leave the patient with three small incisions on his knee, instead of a ten-centimeter cut left after traditional knee surgery. However, not all surgical procedures can be done by means of an *arthroscopy*, but for those who can, there are numerous post-operative advantages, which include no visible scars on the skin, less pain, and a much quicker recovery. Medical bills are also reduced because the patient can leave the hospital on the same day he/she underwent the surgery.

When a patient needs to be treated for an abnormal knee condition, the *arthroscopy* is an excellent means of making the correct diagnosis. This is very important, because if we, for example, consider the *Patello Femoral Pain Syndrome*, the correct diagnosis can ensure a quicker rehabilitation process because the patient received the correct treatment from day 1. It is evident that there are a lot more advantages than disadvantages concerning the *arthroscopy*. Maybe one day, all surgical procedures will be performed by means of a simplified *arthroscopy*.

CHAPTER 4

STATISTICAL INFERENCE

4.1 PROLOGUE

Rehabilitation is recognized as a critical component in the treatment of sports injuries, and has been the subject of intense research over the past decade. As a result, sound scientific principles have been applied to the realm of rehabilitation data and results, and have improved the understanding and interpretation thereof (Hopkins *et al.*, p. 475-480, 1999).

Often in rehabilitation, measurements on the same variable on one (single-path data) or a number of subjects (multi-path data) are collected on several occasions during a trial, a geographic region, or some other index set. For example, if a test battery is introduced during a trial that may affect the distribution or behavior of a patient's leg strength, then the following are of main interest:

1. What proportion of the patients would respond to the intervention?
2. Has there been a Change-Point in the response of interest, and if so,
3. What is the position and distribution of the Change-Point?

The latter question is especially relevant in the framework of the Biokineticist and the process of rehabilitation, i.e. “*When is the patient ready to return to competition?*” Indeed, this type of estimation can be very useful in constructing confidence intervals and norms (Pretorius *et al.*, p. 2, 2001).

Furthermore, in the framework of a rehabilitation experiment, consider the following: The biokineticist develops a rehabilitation program for a specific injury. One or several variables are then identified that will aid in evaluating the progress of the patient. During the first stages of rehabilitation there will, e.g. be an increase/decrease in the patient’s recorded data sequence. Now, at some point in time, the sequence reaches stationarity, i.e. no gradual change in the variable. Hence, the biokineticist will want to know what is the position and distribution of this Change-Point and the corresponding value of the variable at this point. In some future study for the same injury, he/she will then know in advance, when to expect no further change in the observed values. This will have a significant effect on the time and cost of the rehabilitation program. Moreover, from the analysis he/she will also be able to report the magnitude of the observed variable corresponding to a “ready-to-return” value.

This dissertation presents a single- and multi-path Change-Point model and illustrates how it can be used to address a variety of issues in the rehabilitation process of *PFPS*. We believe that Change-Point analysis can be of high value to the biokineticist in helping him/her to evaluate the progress of rehabilitation. We motivate and explain the models

by outlining a clinical study involving *PFPS* where the methodology can be effectively employed. Details of the models and methodology are presented in a very simple form since the readers of this paper are not necessarily statisticians, rather sport scientists and biokineticist (Further statistical details are reported in Groenewald, technical report nr. 278, 2000).

In paragraph 4.2, we analyze the patients' data individually and determine the probability for each sequence of having a Change-Point. Statistical inference about an unknown Change-Point in a single sequence of observations, known as the *single-path Change-Point problem*, has been extensively studied in diverse fields such as geology and medicine, including clinical trail (Joseph *et al.*, p. 690-701, 1997).

In the multi-path settings, the data consists of several sequences, each one containing a possible different Change-Point. This methodology is explored in paragraph 4.3 where the assumption is made that the individual Change-Points come from a common distribution. From a practical point of view, the implementation of a multi-path change point model offers substantial challenges (Bélisle *et al.*, p. 113-123, 1998), especially in a rehabilitation experiment where more than one patient is enrolled in the program.

The proposed Bayesian approach involves the calculation of posterior distributions of the Change-Points and corresponding values of the observed variable(s) at the Change-Point. As mentioned before, this can be very useful in setting up norms etc.

4.2 DETECTION OF A CHANGE-POINT IN A SINGLE PATH

Consider a rehabilitation experiment in which a random variable y_i is observed over time (For the present study, e.g. pain, swelling, ROM etc.). At a certain point in the sequence a treatment is introduced which may have an effect on the observed values. This experiment is repeated m times on independent patients. Then, under the assumption of a linear relationship (straight line) between response and time, a Change-Point x_0 is said to occur at time t_k in the sequence of n observed values. This Change-Point at time t_k is usually considered discrete. The mathematical formulation of such a problem is as follows: Let y_1, y_2, \dots, y_n be the sequence of observed values so that

$$y_i = \begin{cases} a_1 + b_1 x_i + e_i & \text{for } 1 \leq i \leq x_0 \\ a_2 + b_2 x_i + e_i & \text{for } x_0 < i \leq n \end{cases}$$

where $e_i \sim N(0, \sigma^2)$, $i = 1, \dots, n$. Thus, we assume that for time t_1 to t_k the linear relationship between the response variable and time is given by the equation

$$a_1 + b_1 x_i + e_i,$$

then there occurs a Change-Point x_0 in the response variable and the relationship between the response variable and time is now given by the equation

$$a_2 + b_2x_i + e_i.$$

Note that e_i is the random error of the regression model, a_i the y -intercepts and b_i the slopes of the regression lines. Also, we assume exactly on Change-Point and that this Change-Point lies between the second and $(n - 1)^{th}$ observed value of the independent variable.

From the above definition it is evident that

$$a_1 + b_1x_o = a_2 + b_2x_o,$$

i.e. at the Change-Point, the relationship between the variables are the same.

4.3 CHANGE-POINTS IN MULTI-PATH REHABILITATION DATA

Considering again the above section, the problem now calls for the analysis of not one patient, but more than one. Thus, the researcher is interested in finding a Change-Point for a specific injury when analyzing the data of more than one patient. This is known as multi-path Change-Point estimation and is accomplished by assuming an underlying distribution for the position and value of each Change-Point of the different patients. In finding such a distribution, one can address any type of injury, and the results will shed

some very valuable light on the success of the rehabilitation program and the progress that is made during the process of rehabilitation.

4.4 THE EXPERIMENT

4.4.1 The Patients and Protocols

We utilized 3 patients within the protocol. All patients qualified on the criteria as determined by the Orthopaedic Surgeon. The patients underwent an arthroscopy performed by the Surgeon involved and the same Physiotherapist treated them all. The Physiotherapist saw them after the arthroscopy on Day 3, Day 7, Day 10 and Day 14. His standardized exercise protocols are included in the Appendix B.

Hereafter the patients were given home exercise programs by the Physiotherapist for Day 1 to Day 14 as well as from Day 14 to Day 28. From Day 28 to Day 42 they exercised in the rehabilitation centre of the University of the Free State on an exercise program given by myself, the Biokineticist (also standardized).

Note, ALL exercise protocols are included in Appendix B and as mentioned above, are standardized. The evaluation sheets used by the Surgeon and the Physiotherapist, as well as the evaluation sheet used by myself, are also included.

4.4.2 The Data and Parameters

The recorded data for the different patients are displayed in Appendix C. The variables of interest are: pain, circumference (cm), range of motion (ROM) and surface EMG. Pain is categorized according to the standard *Oxford* pain scale. The circumference is taken at two different places, i.e. 15cm above the *patella* and around the *patella*. This parameter and the ROM parameter are analyzed via the Change-Point methodology. This involves scatter plots of the data as measured over the 42 days, tables that display the probabilities of Change-Points in the patients' data sequences and most important, distributions of these Change-Points. The values of the Surface EMG and Cybex values are reported in APPENDIX C.

4.5 RESULTS AND DISCUSSION

The data were analyzed by the software packages STATISTICA Ver. 5.1 and MATLAB Ver. 12. All descriptive statistics are expressed as means \pm SE. Further, significant results, correlations and differences are accepted at 0.05 (indicated with *) and 0.01 (indicated with **) levels of significance.

4.5.1 Descriptive Statistics

Figure 4.1 displays the observed histograms for pain during an one leg squat for the 3 patients. It is clear that the patients experienced high levels of pain during the pre-op stages of the study, whereas; lower to 0 pain levels were recorded at day 42.

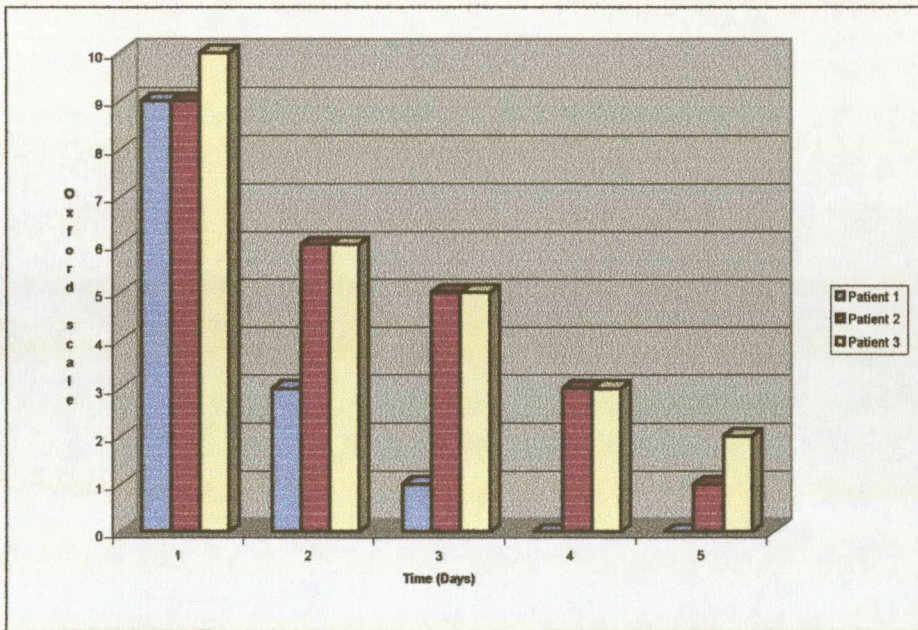


Figure 4.1 Observed histogram of the pain levels of the three patients. Categories: 1 = Pre-op; 2 = 28 days; 3 = 33 days; 4 = 38 days; 5 = 42 days.

Table 4.1 displays the recovery, in % notation (Final/Pre-op x 100%), from the pre-op values of circumference to the final values after 42 days. These % values directly indicate the response of the patients to the rehabilitation (As mentioned in table 4.1)

Table 4.1 Pre-op and final circumference values for the 3 patients.

<i>ABOVE PATELLA</i>			
Subject	Pre-op	42 days	Recovery %
Patient 1	54.7	53.1	97.1%**
Patient 2	47.2	45.0	95.3%**
Patient 3	48.1	47.4	98.5%**

<i>AROUND PATELLA</i>			
Subject	Pre-op	42 days	Recovery %
Patient 1	36.2	35.8	98.9%**
Patient 2	34.6	34.2	98.8%**
Patient 3	36.0	35.6	98.9%**

$p < 0.05^*$; $p < 0.01^{**}$

4.5.2 Change-Point analysis

We analyzed the patients' circumference and ROM values individually and determined the probability for each sequence of having a Change-Point (Single-path estimation).

The observed data sequences of the 3 patients are displayed in Figure 4.2 and 4.3 for

circumference and Figure 4.4 for ROM. The corresponding probabilities are reported in Table 4.2.

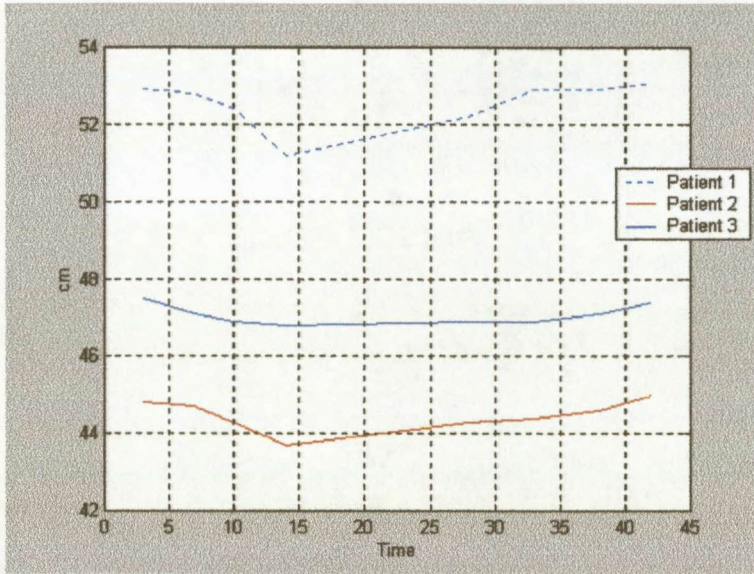


Figure 4.2 Data sequence of circumference values **above** the *patella*. Please note that Time on the X-axis is measured in days.

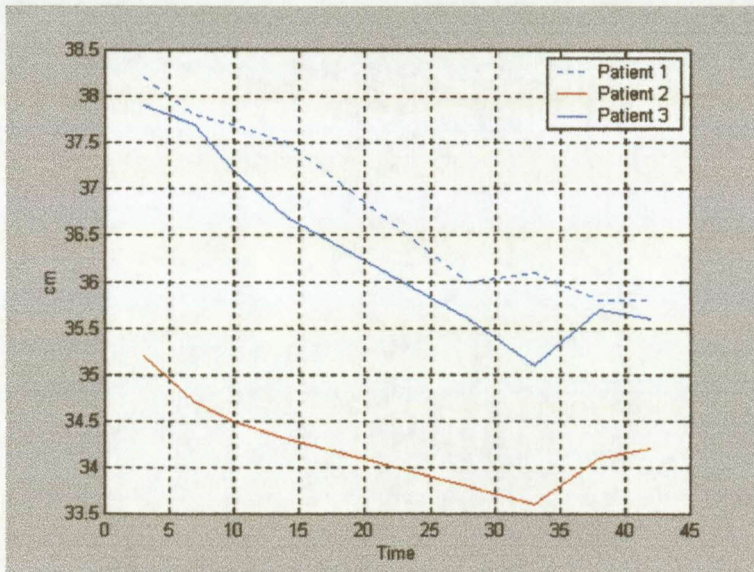


Figure 4.3 Data sequence of circumference values **around** the *patella*. Please note that Time on the X-axis is measured in days.

From Figure 4.2 it is clear that for patient 1 and patient 3 there are clearly points in time where there is a change in the behavior of the circumference values. Thus, these points can be classified as Change-Points with certain probabilities (see Table 4.2). Patient 2's results indicate a more gradual change, which will definitely result in a low probability of having a Change-Point. However, although patient 2 does not show a significant change in circumference values, the data sequence will still be included in the multi-path estimation where a common Change-Point will be estimated. In Figure 4.3 similar behavior is recorded for all 3 patients.

Table 4.2 Probabilities of Change-Points in the 3 patients' data sequences.

	<i>ABOVE PATELLA</i>	<i>AROUND PATELLA</i>	<i>ROM</i>
Patient 1	0.78**	0.81**	0.91**
Patient 2	0.51	0.85**	0.94**
Patient 3	0.74**	0.84**	0.88**

$p < 0.05^*$; $p < 0.01^{**}$

It is clear from the table of probabilities that indeed there occurred some Change-Points in these data sequences. The same analysis is conducted using the ROM variable. The data sequence is displayed in Figure 4.4, and the probabilities in Table 4.2.

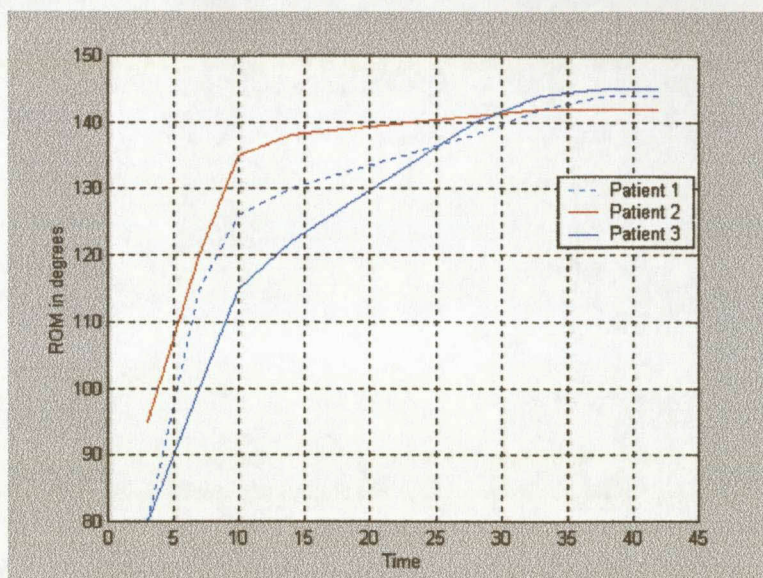


Figure 4.4 Data sequence of ROM values of the 3 patients.

Once again, it is evident from Figure 4.4 and the resulting probabilities that during the first stages of rehabilitation there was a steep increase in the patient's ROM data sequences. Now, at some point in time, the sequences reached a point where only gradual changes were visible. Hence, the Biokineticist will want to know what is the position and distribution of this Change-Point.

As mentioned earlier, the problem now calls for the analysis of not one patient per Change-Point model, but all three. Indeed, we are interested in finding a common Change-Point and its distribution for the circumference – and ROM values (known as multi-path Change-Point estimation). In finding such a distribution, one can address the recovery of the injury, and the results will shed some very valuable light on the success

of the rehabilitation program and the progress that is made during the process of rehabilitation. These distributions are displayed in Figures 4.5 and 4.6.

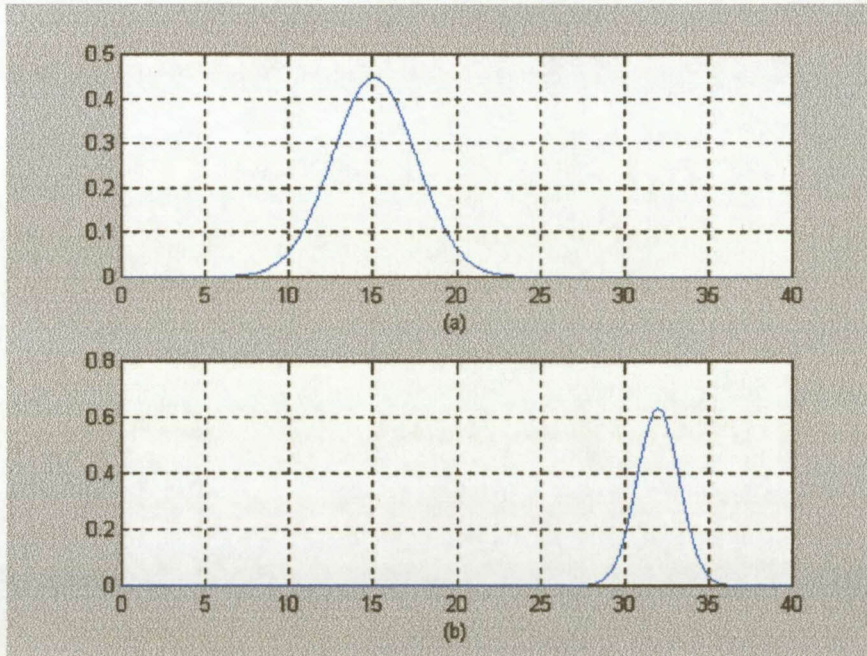


Figure 4.5 Posterior distribution of the Change-Point for the circumference values (a) above the *Patella*, i.e. 15.1 ± 2.25 days; and (b) around the *Patella*, i.e. 32 ± 1.25 days where $Y = f(x) \equiv$ probability and $X \equiv$ days.

Thus, from the above figure it is clear that from day 15.1 ± 2.25 (mean \pm SE) the Biokineticist can expect a change in the circumference variable above the *Patella* with probability 0.68. Further, for the circumference variable around the *Patella*, a change after 32 ± 1.25 days with probability 0.83 will be evident. These results will have a significant effect on the time and cost of the rehabilitation program.

Moreover, from the analysis the Biokineticist can now tell the time of the “ready-to-return” state of these patients. The same conclusions can be drawn from Figure 4.6 below with probability of having a Change-Point in the ROM sequence equals 0.91 after 10.8 ± 2.0 days.

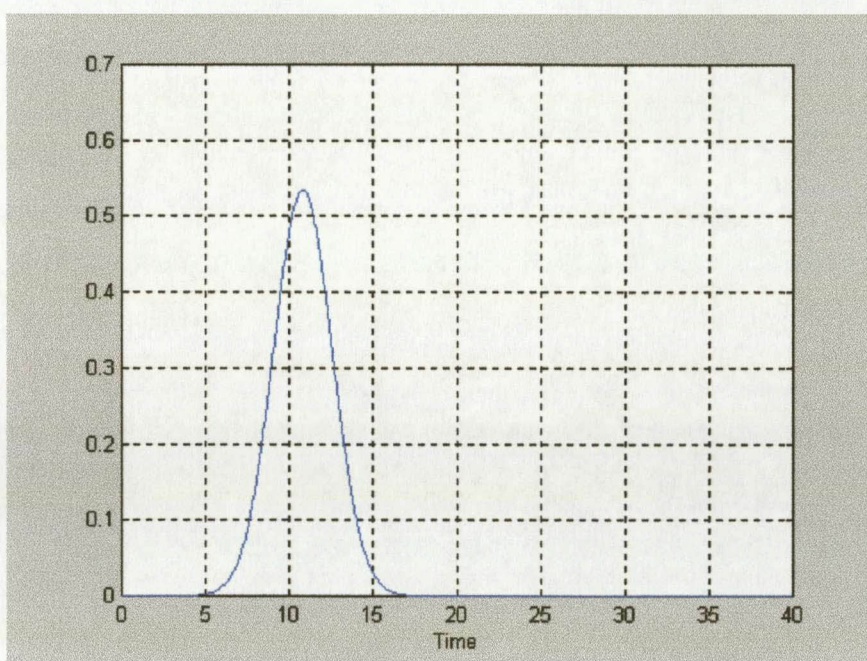


Figure 4.6 Posterior distribution of the Change-Point for the ROM, i.e. 10.8 ± 2.0 days with probability 0.91 where $Y = f(x) \equiv$ probability.

4.6 CONCLUSION

Change-Point methods could be used along with standard methods of analyzing rehabilitation data. They offer estimates of the proportion of patients in a given population who response to the treatment, as well as the magnitude of and time delay to the change.

In this chapter, a statistical method for analyzing rehabilitation data/sequences containing a Change-Point is proposed. The methods may be extended in many directions. In the analysis, the first step is to find the probability of a Change-Point for each patient's data, and the position in time of that Change-Point. Then multi-path analysis is used to address the value of the response variable at the Change-Point. We have found significant evidence for a Change-Point model using rehabilitation data where the results are overwhelming and very convincing. The next step will be to identify an injury, and report the behavior of the rehabilitation process for that injury based on the results of sufficiently enough patients.

CHAPTER 5

CONCLUSION

5.1 Prologue

We have found significant evidence for a Change-Point model using rehabilitation data. It would be of great interest to see if other practical applications involving rehabilitation data exhibit the same type of change near diagnosis that we have discovered. Furthermore, the methodology introduced in the present dissertation has many other practical applications. One potentially useful application is in the analysis of data from more serious injuries where the following questions are of interest:

- Have the patients responded to the therapy (i.e., has there been a change in the level of the health status indicator)?,
- and if so, how long after the therapy was initiated did the patient respond?

On the other hand, although the techniques introduced are immediately applicable, much work still remains to be done when tackling more complex data resulting from serious injuries, e.g., the change in each patient's sequences may occur gradually rather than abruptly (as in present research) at one point in time. The resulting Change-Points and probabilities of obtaining Change-Points in the dataset may then be directly influenced by

the gradual changes. This will call for some adjustments in the presented multi-path Change-Point models. Besides the extensions to the models, there remains also some theoretical work to be done, e.g. the identification of parameters to evaluate during the process of rehabilitation. Here the Biokineticist should be very careful in the selection criteria since some parameters may be inappropriate to utilize in Change-Point analysis. Parameters that are highly correlated with time would be more significant in modeling the Change-Points in the different sequences.

We are convinced that Change-Point analysis may be a completely new direction in rehabilitation as we know it. By calculating a patients' change point during his rehabilitation process, one will be able to either take a more aggressive, or a more conservative approach when adjusting the exercise prescription of a patient during the different phases of the rehabilitation process. Remember though that people who have arthroscopy can have many different diagnoses and preexisting conditions, so each patient's arthroscopic surgery is unique to that person. Recovery time will reflect that individuality.

Life in the world as we know it is fast becoming a flustering playground that also affects rehabilitation as such, and especially the cost and time of the rehabilitation programs prescribed. Therefore, as mentioned previously, we believe that Change-Point analysis can be of high value to the Biokineticist in helping him/her to evaluate the progress of

rehabilitation more successfully. By developing ways to minimize time-consuming efforts and at the same time optimize the efficiency of a rehabilitation program, will we be able to keep up with our constant changing world. Only then, will we as Biokineticists truly fulfill the mission of our profession, which is to improve the quality of life of our fellow human beings.

“If something is worth doing at all; it is worth doing it well”

With that in mind, we would like to conclude this dissertation with the inspiring words:

“...In navigating through the waters of analyzing rehabilitation data, comparing results and methods, we found that the Change-Point inferences brought us to familiar harbors or to new exciting lands.

However, a great deal of explorations remains ahead...”

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APPENDIX A

TABLE 1

Muscular Etiologies of Patello Femoral Pain Syndrome and Their Pathophysiology	
Etiology	Pathophysiology
Weakness of the quadriceps	The "quads" include the vastus medialis, vastus medialis obliquus (VMO), vastus intermedius, vastus lateralis and rectus femoris. Weakness may adversely affect the Patello femoral mechanism. Quad-muscle strengthening is often recommended.
Weakness of the medial quadriceps, specifically VMO dysplasia	Weakness of the VMO allows the patella to track too far laterally. Although the role of the VMO is controversial, VMO strengthening is often recommended. However, the VMO is a difficult muscle to isolate, and most patients find general quadriceps strengthening easier to accomplish.
Tight iliotibial bands	A tight iliotibial band places excessive lateral force on the patella and can also externally rotate the tibia, upsetting the balance of the Patello femoral mechanism. This problem can lead to excessive lateral tracking of the patella.
Tight hamstring muscles	The hamstring muscles flex the knee. Tight hamstrings place more posterior force on the knee, causing pressure between the patella and femur to increase.
Weakness or tightness of the hip muscles (adductors, abductors, external rotators)	The VMO originates on the adductor magnus tendon. This is the anatomic basis for recommending adductor strengthening. Abductor (gluteus medius) strengthening helps to stabilize the pelvis. Dysfunction of the hip external rotators results in compensatory foot pronation; a simple stretch can improve muscular efficiency.
Tight calf muscles	Tight calves can lead to compensatory foot pronation and, like tight hamstrings, can increase the posterior force on the knee.

(Mark & Juhn, p. 2018, 1999)

Table 1 Muscular Etiologies of Patello femoral Pain Syndrome and their Pathophysiology

TABLE 2

Diagnosis	PATELLO FEMORAL PAIN SYNDROME
Definition	Patellofemoral pain syndrome describes a variety of possible disorders that cause pain in the joint between the kneecap (Patella) and the thigh bone (Femur).
Details	<p>Patellofemoral pain syndrome is known by other names such as: Patellar Chondromalacia, Excessive Lateral Pressure Syndrome and simply Anterior Knee Pain. It is a very common problem especially in women.</p> <p>The pain associated with this disorder may worsen with descending stairs climbing or deep squatting. Sitting with your knees flexed for a long period of time in a car or movie theatre may also aggravate the symptoms.</p>
Causes	<p>A variety of underlying anatomic abnormalities may result in patellofemoral pain syndrome. It can be caused by softening or cracking of the articular cartilage under the kneecap. This is known as chondromalacia. A malalignment of the kneecap or tight tissue around the kneecap can also create tension that may lead to patellofemoral pain syndrome.</p> <p>Usually, this disorder arises without a history of significant trauma. Occasionally, the pain may begin after a blow to the knee or a minor injury.</p>
Diagnosis	<p>Patellofemoral pain syndrome patients complain of pain in the front of the knee. This pain may be localized but more often is diffuse. The pain may be made worse by descending stairs or sitting with a flexed knee for an extended period of time. The patient may also complain of occasionally giving way or a grinding sensation behind the kneecap.</p> <p>The physical exam is critical to confirming the diagnosis. On inspection of the knee, an assessment of the alignment of the kneecap</p>

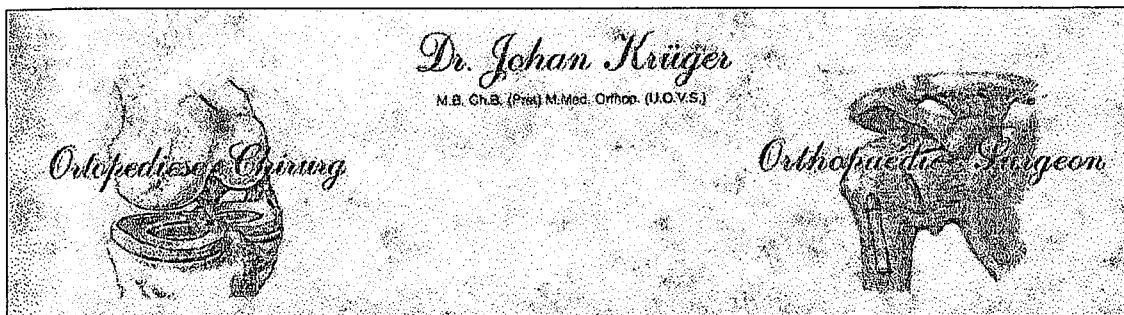
	<p>is done. The kneecap should fall in the center of the thigh. If it is riding on the outside portion of the knee or appears to tilt with knee bending, the patient is at higher risk for patellofemoral pain syndrome. Evaluation of the quadriceps muscle strength (especially its inside portion, the vastus medialis obliquus or VMO) is essential. Palpation of the kneecap and finding the area of maximal tenderness is done next. Assessing the kneecap for restricted movement and possible instability are other important components of the physical exam. Checking the knee for fluid (an effusion in medical terms) should also be done. Finally, it critical to evaluate the patient's quadriceps (thigh muscle) flexibility. This can be done by having the patient lie on their stomach and attempt to pull their heel toward their buttock. Comparison to the opposite side will help in this assessment.</p> <p>X-rays, CT Scans and or MRI Scans may be used to confirm the diagnosis.</p>
<p>Treatment</p>	<p>Non-operative</p> <p>Phase I Control of pain and inflammation with Rest, Icing, Stretching, Anti-inflammatory medication (RICE)</p> <p>Phase II Restore strength and function with continued stretching and a strengthening program.</p> <p>Phase III Return to sports or work via a customized program of exercises designed to maintain flexibility, coordination and endurance</p> <p>These phases may be directed by your physician or may be done under the supervision of a physical therapist. The exercise program should be designed to improve quadriceps and hamstring flexibility and emphasize VMO strengthening. Taping of the kneecap by a therapist may also provide some relief of the symptoms.</p> <p>It may also be important to evaluate the patient's feet for orthotics if excessive pronation is present or consider bracing for the kneecap if it is unstable.</p> <p>Operative</p> <p>If nonoperative measures fail, surgery may be required to smooth the articular cartilage or release tight structures around the kneecap. The operation may take the form of minimally invasive arthroscopic surgery or may require an open kneecap realignment procedure. Any surgery for this disorder should be individualized to the patient and is best discussed with the surgeon of your choice.</p>

<i>Prevention</i>	Avoid training errors such as overuse and knee extension exercises. Maintain strong and flexible quadriceps and hamstring muscles. Always warm up before playing and training.
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APPENDIX B

AN EXAMPLE

The Clinical Experiment



Rosepark Hospitaal/Hospital suite 04, Gustavsingel/Crescent 53, Fichardtpark, Bloemfontein 9301
Tel: 11076, UNIVERSITAS 9321, SUID-AFRIKA/SOUTH AFRICA
☎ +27 (0) 51- 522 8731 ☎ +27 (0) 51- 522 8892 E-mail: kruger@interkom.co.za

PROTOCOL FOR PATIENT SELECTION

DIAGNOSIS: CRITERIA FOR SELECTION

Patello Femoral Pain Syndrome (Anterior Knee Pain)

1. Patients should be under the age of 40 years.
2. Patients should participate actively in sport activities.
3. Patients should have no structural deformities (such as degeneration)

The Test Protocols

DOCTOR/PHYSIOTHERAPIST
PATIENT EVALUATION SHEET
(DAY 1 – 14)

Patient: _____

Date: _____

Sport: _____

Level of Participation: Social
Club
Provincial
International

Brief History of Injury or Pain

Present:

Before:

SPORT DISABILITY SCALE

- 0 = NO PAIN
- 1 = PAIN AFTER SPORT
- 2 = PAIN DURING SPORT – NOT AFFECTING PERFORMANCE
- 3 = PAIN DURING SPORT – AFFECT PERFORMANCE
- 4 = PARTICIPATION / ACTIVITY NOT POSSIBLE

CIRCUMFERENCE

- A measuring tape was used to measure circumference.
- All measurements were performed after 12 pm.

AREA	Pre-Op	DAY 3	DAY 7	DAY 10	DAY 14
15 cm Above Patella					
Around Patella					

RANGE OF MOTION IN DEGREES

- A Goniometer was used to measure the range of motion.

Pre-Op	DAY 3	DAY 7	DAY 10	DAY 14

SURFACE EMG – VMO:VL

Pre-Op	DAY 3	DAY 7	DAY 10	DAY 14

ADDITIONAL COMMENT

MEDICAL DIAGNOSIS OF UNJURY / CONDITION

BIOKINETICIST
PATIENT EVALUATION SHEET
(DAY 28 - 42)

Patient: _____

Date: _____

Sport: _____

CIRCUMFERENCE

- A measuring tape was used to measure circumference.
- All measurements were performed after 12 pm.

AREA	Pre-Op	DAY 28	DAY 33	DAY 38	DAY 42
15 cm Above Patella					
Around Patella					

RANGE OF MOTION IN DEGREES

- A Goniometer was used to measure the range of motion.

Pre-Op	DAY 28	DAY 33	DAY 38	DAY 42

OXFORD PAIN SCALE
ONE LEG SQUAT

SCALE (1 –10)

- 1 = NO PAIN
- 10 = VERY PAINFUL

Pre-Op	DAY 28	DAY 33	DAY 38	DAY 42

ADDITIONAL COMMENT

Exercise Protocols:

Included are the following:

Exercise Protocol A – Physiotherapist (Day 1-7)

Exercise Protocol B – Physiotherapist (Day 7-28)

Exercise Protocol C – Biokineticist (Day 28-42)

EXERCISE PROTOCOLS
THE APPLICATION THEREOF

WEEK 1 (Day 1- 7)

Exercise Protocol A, 3 times per day, 5 days per week.

WEEK 2 (Day 7-14)

Exercise Protocol B, 5 times per week.

WEEK 3 (Day 14 – 21)

Exercise Protocol B, 5 times per week.
Cybex Training 2 times in this week.

WEEK 4 (Day 21 – 28)

Exercise Protocol B, 5 times per week.
Cybex Training 2 times in this week.

WEEK 5 (Day 28 – 35)

Exercise Protocol C, 3 times per week.

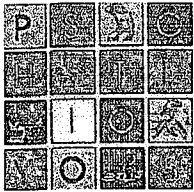
WEEK 6 (Day 35 – 42)

Exercise Protocol C, 3 times per week.

FINAL ASSESSMENT

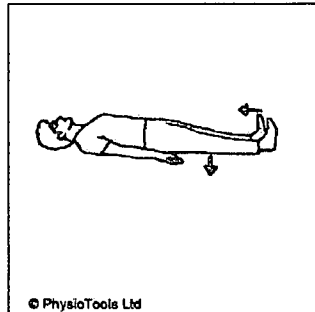
Cybex Test
Surface EMG
Circumferences
ROM
Pain

Exercise Protocol A (DAY 1-7)



JAMES WESSELS

GF 04 FICHMED CENTRE, GUSTAV CRES 53
FICHARDTPARKBLOEMFONTEIN, 9321, SOUTH AFRICA, 051-5227181,
051-5229303



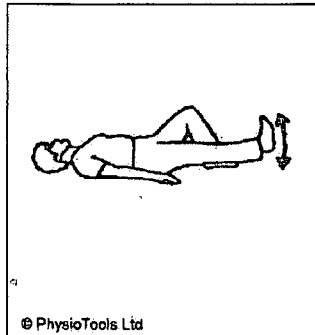
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INSTRUCTIONS

Lying on your back with your legs straight.

Tighten your leg muscles (Quadriceps) and push your knees firmly against the bed. Hold this position for 5 seconds and relax.

REPEAT 10 Times



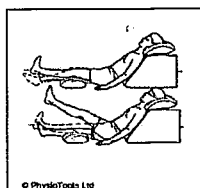
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INSTRUCTIONS

Lying on your back with your affected leg straight and the unaffected leg bent.

Exercise your straight leg by pulling your toes up, straightening the knee and then lifting the leg 20 cm off the bed. Hold this position for 5 seconds and then slowly relax.

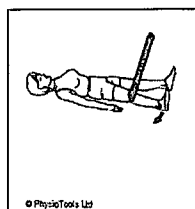
REPEAT 10 Times



INSTRUCTIONS

Long sitting with your back supported. Place a coffee tin under your affected knee. Lift your foot from the surface UNTIL your leg is completely straight. DO NOT lift the knee off the tin.

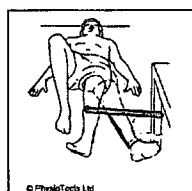
REPEAT 10 Times



INSTRUCTIONS

Lying on your back, place the THERABAND above your affected knee. Move your leg out to the side and then back to the mid position. Keep your foot in the mid position during the whole exercise.

REPEAT 10 Times



INSTRUCTIONS

Lying on your back on the floor with the unaffected leg bent. Put the THEARBAND around the KNEE and not the ANKLE of your affected leg. Keeping your leg straight, move your foot towards your other leg.

REPEAT 10 Times

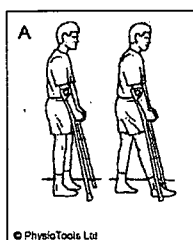


INSTRUCTIONS

Sit on a chair or table without your feet touching the ground. Support your affected leg with the other one. Lower your affected leg slowly. Once you have reached 90°, bend your leg further with the other one.

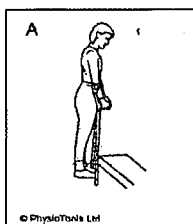
You must bend your affected leg 120° within 14 Days after the operation.

REPEAT 5 Times



INSTRUCTIONS

Walking with crutches. Order: **FIRST** the crutches, then the affected leg and then follow the unaffected leg. You are allowed to walk **FULL** weight bearing.



INSTRUCTIONS

Walking up stairs. Order: **FIRST** the Unaffected leg, then the Affected leg and then the crutches.

Going down stairs. Order: **FIRST** the crutches, then the Affected leg and then the Unaffected leg.

THINGS TO REMEMBER

1. The success of the operation depends on you as the patient. This means that you **HAVE** to do your exercises regularly.

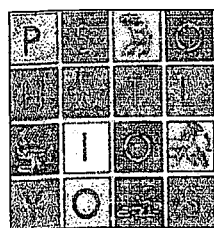
MUSCLE STRENGTH = PAIN CONTROL

2. You must exercise 3 Times per day and 5 Times a week.
3. During the exercises you must not experience any pain, only a slight discomfort is allowed. If you have any pain with the exercises, please **PHONE** us immediately.
4. If you are from the region, a follow up appointment must be made at our practice.
5. If you have any questions, please do not hesitate to give us a call!

HARD WORK WILL PAY OFF !!!!

*Pictures from ©Pysio Tools Ltd. Protocols build on Tools® 3.0.

Exercise Protocol B (DAY 7-28)



**Personal Exercise Program
JAMES WESSELS PHYSIOTHERAPIST**

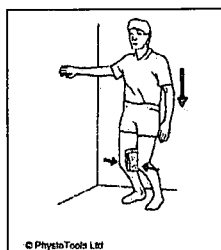
FICHMED MEDICAL CENTRE
BLOEMFONTEIN
051-5227161 PR N.7216556

ALL EXERCISES

REPETITIONS: 10

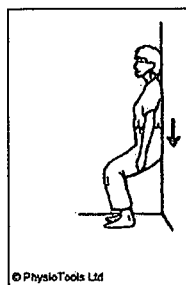
SETS: 3

REST: 20-30 seconds between sets.



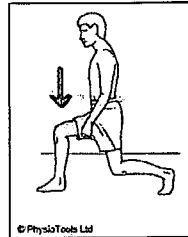
INSTRUCTIONS

Sit on a chair with your knees flexed between 50° and 60°. Squeeze a foam wedge/towel/ball between your knees. Continuously squeeze while gently pushing against the floor. Hold for 7 seconds and repeat.



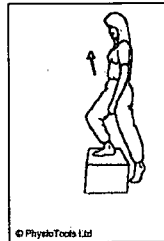
INSTRUCTIONS

Stand and lean with your back against a wall with your feet about 20 cm from the wall. Slowly slide down the wall until your hips and knees are flexed between 50-60°. Hold this position for 7 seconds and return to the normal standing position.



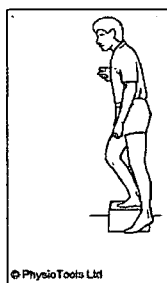
INSTRUCTIONS

Stand with your feet together. Give a stride forward with your affected leg. Bend both legs. Your knee should not move past your toes. Return to the starting position by pushing backward with the front leg.



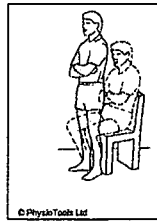
INSTRUCTIONS

Stand in front of a 20-40 cm step.
Step up with your affected leg leading the movement. Repeat exercise with your unaffected leg as well.



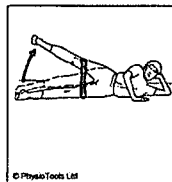
INSTRUCTIONS

Stand sideways on a step with one foot hanging over the edge of the step.
Slowly bend your knee allowing your hanging foot to brush the floor. You must not let your pelvis tilt towards the floor when bending your knee down. Keep your hips level.



INSTRUCTIONS

Sitting with your arms crossed on a chair. Your knees should be flexed 50-60°. Stabilize your core area and pelvis. Stand up and then sit down slowly on the chair.



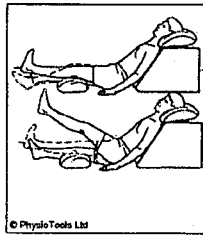
INSTRUCTIONS

Lie on your side and support yourself on your elbow. Roll the top hip slightly forward; use your top arm to support yourself in front. Put the THERABAND just above your knees. Keeping the top leg straight, lift it up towards the ceiling. Make sure that the leg stays in line with your body and that your toes point forward.



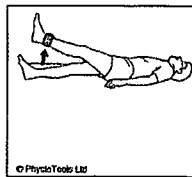
INSTRUCTIONS

Lie on your back on the floor with one knee bent. Put a THERABAND just above your knee and not around your ankle. Keeping your leg straight, move your foot towards your other leg. Feel the muscles on the inside of your leg working.



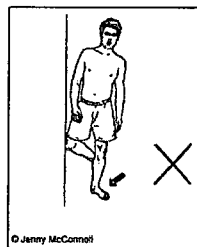
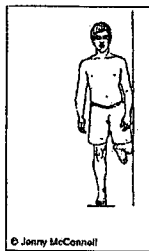
INSTRUCTIONS

Long sitting with your back supported.
Place a coffee tin under your affected knee. Straighten your leg by lifting your heel off the surface. Put an ankle weight around your ankle. Hold for 7 seconds and relax.



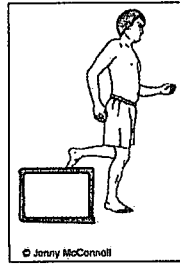
INSTRUCTIONS

Lie on your back. Put a 5-6 kg weight around your ankle.
Tighten your thigh muscles (quadriceps) and straighten your knee. Lift your leg 20-30cm off the ground. Hold for 5 seconds and relax by slowly lowering your leg.



INSTRUCTIONS

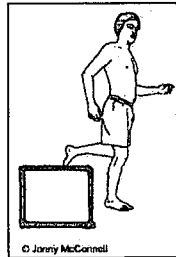
Gluteus Medius training – affected leg.
Tighten your buttock muscles. The hips and foot are kept parallel with the wall and the affected knee is turned outwards. This is an isometric exercise. Hold the knee turnout for 5-7 seconds and relax.



INSTRUCTIONS

Gluteus Medius training – affected leg.

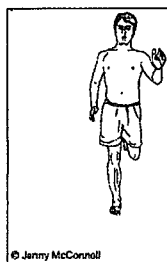
Stand on the affected leg. Support the other foot on a chair or box. Hang on the hip and then tighten the gluts muscles so that the hip straightens again. Do not lift the opposite hip; it must be lifted by means of the contraction of the muscles.



INSTRUCTIONS

Gluteus Medius training – affected leg.

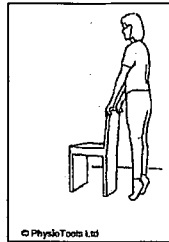
Stand on the affected leg and support the other leg on a chair or box. Stabilize (naval to spine plus the contraction of the pelvic muscles) and slowly bend your knee to 30°. Return to the starting position.



INSTRUCTIONS

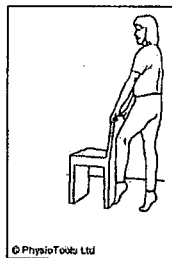
Gluteus Medius training – affected leg.

Same exercise as above with one difference: as you extend your knee you must go on to your toes and using your arms. As you come down off your toes, you must control the landing so that it is a soft one.



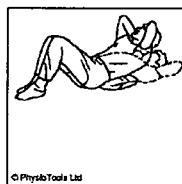
INSTRUCTIONS

Stand and lean on a chair.
Push up on your toes until fully extended.



INSTRUCTIONS

Stand on one leg at a time and lean on a chair.
Push up on your toes.

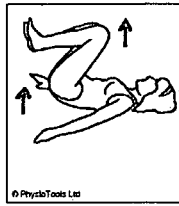


INSTRUCTIONS

Core Stability Exercise.

Lie on your back with your knees bent. Clasp your hands behind your neck. Breathe in and pull your naval towards your spine (stabilize).

Lift your head and shoulders off the floor by reaching your chest towards the ceiling. As you move up, breathe out and pull your naval further to your spine.

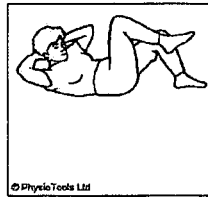


INSTRUCTIONS

Core Stability Exercise.

Lie on your back with your knees pulled up towards your chest and your arms relaxed at your side.

Tighten your lower stomach muscles and stabilize. Lift your knees and bottom of the floor. Remember to stabilize and breathe out as you lift your bottom off the floor.

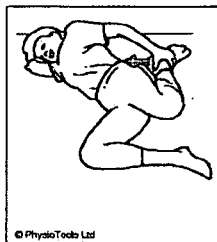


INSTRUCTIONS

Core Stability Exercise.

Lie on your back with your knees bend and your hands behind your neck.

Lift your upper trunk by bringing your chin towards your chest and tightening your stomach muscles, then reach with your elbow towards your opposite knee letting the knee come up a bit. Stabilize and breathe out as you come up. Return to the starting position and repeat with the other side.

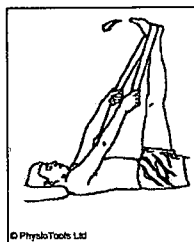


INSTRUCTIONS

Stretching. (Repeat stretches 3 times and hold them for 15-20 seconds at a time)

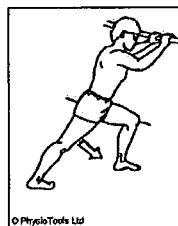
Lie on your side with your legs bend. Take hold of your ankle of the upper leg or put a towel around your ankle.

Gently draw your foot towards your buttock. Feel the stretch in the front of your thigh (quadriceps).



INSTRUCTIONS

Stretching. (Repeat stretches 3 times and hold them for 15-20 seconds at a time)
Lie on your back with a pillow under your head. Put a towel under the sole of your foot and hold onto the ends of the towel with both hands.
Lift your leg straight up. Pull the towel ends. This will flex your ankle and stretch the back of your thigh (hamstrings).



INSTRUCTIONS

Stretching. (Repeat stretches 3 times and hold them for 15-20 seconds at a time)
Stand in a walking position with the leg to be stretched straight behind you and the other leg bend in front of you. Take support from a wall or chair.
Lean your body forward and down until you feel your calve muscles stretch. Repeat with the other legs.



1. You can also start cycling. See to it that your saddle is the correct height and the load must be comfortable.
2. Swimming is also allowed – however: NO BREASTSTROKE kicking please.
3. Ask your Physiotherapist or Surgeon when running is allowed.
4. Stairmaster is permitted as long as it executed without pain.

***Pictures from ©Pysio Tools Ltd. Protocols build on Tools® 3.0.**

CYBEX Training

Exercises are performed on a Cybex® 340 Dynamometer.

Cybex training starts on Day 14 and is performed until Day 28, 2 times per week, i.e. four exercise sessions.

Cybex Exercise Protocol

Week 3 (Day 14 – 21):

SETS: 8
REPS: 10

- Full knee extension to 40 – 60° Knee flexion @ 150°/sec.

Week 4 (Day 21 – 28):

SETS: 10
REPS: 10

- Full Knee extension to 60 – 80° Knee flexion @ 150°/sec.

EXERCISE PROTOCOL C (DAY 28-42)



Jannie Oosthuizen

BIOKINETICIST

**BA HMS (UFS). BA HONS - BIOKINETICS
(UFS).**

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EXERCISE	Date: 22/10/2001	Date:	Date:	Date:	Date:	Date:
	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6
	Sets / Reps	Sets / Reps	Sets / Reps	Sets / Reps	Sets / Reps	Sets / Reps
Cycle (Warm-up)	10 min	10 min	10 min	10 min	10 min	10 min
Stairmaster (Without Pain)	5 min	5 min	5 min	5 min	5 min	5 min
Stretching (3 x 20 sec)	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves
¼ Squats (Against Wall)	2 x 6 Hold for 5 seconds	2 x 6 Hold for 5 seconds	2 x 6 Hold for 5 seconds	2 x 6 Hold for 5 seconds	2 x 6 Hold for 5 seconds	2 x 6 Hold for 5 seconds

APPENDIX B – Test Protocols

<p align="center">¼ Squats (Performed on 30 cm high Box)</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>	<p>Affected: 3 x 8</p> <p>Unaffected: 2 x 8</p>
<p align="center">Seated Alphabet Writing (Only Affected)</p>	<p align="center">2 x</p>	<p align="center">2 x</p>	<p align="center">2 x</p>	<p align="center">2 x</p>	<p align="center">2 x</p>	<p align="center">2 x</p>
<p align="center">Hip Extensions (Performed with Elastic Bands)</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>
<p align="center">Hip Flexions (Performed with Elastic Bands)</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>
<p align="center">Hip Flexions Knee Extensions (Performed with Elastic Bands)</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>	<p>Affected: 3 x 12</p> <p>Unaffected: 2 x 12</p>

APPENDIX B – Test Protocols

Leg Presses (Single Leg Presses will have different loads for the involved and uninvolved Legs)	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10
Seated Knee Extensions (Same as above)	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10
Hamstring Curls (Same as above)	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10	Affected: 3 x 10 Unaffected: 2 x 10
Adductions	2 x 15	2 x 15	2 x 15	2 x 15	2 x 15	2 x 15
Abductions	2 x 15	2 x 15	2 x 15	2 x 15	2 x 15	2 x 15
Seated Calf Raises	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12

APPENDIX B – Test Protocols

Stretching (3 x 20 sec)	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves	Quadriceps Hamstring Calves
Balance Board/Wobble Board (Proprioception)	3 min	3 min	3 min	3 min	3 min	3 min

- *All exercises should be performed without any pain. Only a slight discomfort is allowed.*
- *Loads will be varied according to the involved or uninvolved leg.*
- *Loads will be guided by the patients' pain level and will be adapted accordingly.*

APPENDIX C

PATIENT DATA

PATIENT EVALUATION SHEET

Patient Number 1: Johan van Es

Date of surgery: 20 – 09 - 2001

Sport: Squash

Age: 37

Affected Knee: Right Knee

Level of Participation: Social
Club
Provincial
International

Brief History of Injury or Pain

Present:

Patient presents with anterior knee pain and classic symptoms of the PFPS where the cause is not dead certain. He is actively involved in squash. The onset of pain was felt 2 weeks prior to the consultation with his Doctor. A possible cause of his anterior knee pain can be as a result of a traumatic incident on the squash court when he collided knee first into the wall. This is the first time he consulted a Doctor about his problem, although it has bothered him for quite some time.

Before:

He doesn't have a history of knee problems but he did however mention that the same knee was injured in a rugby game many years ago. No evidence of previous or permanent damage was found when the arthroscopy was performed.

PHYSIOTHERAPIST

Sport Disability Scale (Pre-Op)

- 0 = NO PAIN
- 1 = PAIN AFTER SPORT
- 2 = PAIN DURING SPORT – NOT AFFECTING PERFORMANCE
- 3 = PAIN DURING SPORT – AFFECT PERFORMANCE
- 4 = PARTICIPATION / ACTIVITY NOT POSSIBLE

BIOKINETICIST

OXFORD PAIN SCALE

ONE LEG SQUAT

SCALE (1 –10)

- 1 = NO PAIN
- 10 = VERY PAINFUL

Pre-Op	DAY 28	DAY 33	DAY 38	DAY 42
20 / 09 / 01	18 / 10 / 01	23 / 10 / 01	28 / 10 / 01	02 / 11 / 01
9	3	1	0	0

PHYSIOTHERAPIST
CIRCUMFERENCE (cm)

AREA	Pre-Op 20 / 09	DAY 3 23 / 09 / 01	DAY 7 27 / 09 / 01	DAY 10 30 / 09 / 01	DAY 14 04 / 10 / 01
15 cm Above Patella	54.7	52.9	52.8	52.4	51.2
Around Patella	36.2	38.2	37.8	37.7	37.5

BIOKINETICIST
CIRCUMFERENCE

AREA	Pre-Op 20 / 09 / 01	DAY 28 18 / 10 / 01	DAY 33 23 / 10 / 01	DAY 38 28 / 10 / 01	DAY 42 01 / 11 / 01
15 cm Above Patella	54.7	52.2	52.9	52.9	53.1
Around Patella	36.2	36.0	36.1	35.8	35.8

PHYSIOTHERAPIST

RANGE OF MOTION IN DEGREES

Pre-Op 20 / 09	DAY 3 23 / 09 / 01	DAY 7 27 / 09 / 01	DAY 10 30 / 09 / 01	DAY 14 04 / 10 / 01
0° - 145°	0° - 80°	0° - 115°	0° - 126°	0° - 130°

BIOKINETICIST

RANGE OF MOTION IN DEGREES

Pre-Op 20 / 09 / 01	DAY 28 18 / 10 / 01	DAY 33 23 / 10 / 01	DAY 38 28 / 10 / 01	DAY 42 01 / 11 / 01
0° - 145°	0° - 138°	0° - 142°	0° - 144°	0° - 144°

PHYSIOTHERAPIST

SURFACE EMG – Vastus Medialis Oblique : Vastus Lateralis (2 : 1)

DAY 21 11 / 10 / 01	DAY 28 18 / 10 / 01	DAY 43 03 / 11 / 01
1.15 : 1.00	1.3 : 1.00	1.90 : 1.00

DOCTOR

MEDICAL DIAGNOSIS OF UNJURY / CONDITION

Traumatic Chondromalacia of the right knee patella. Classified as a Grade III injury.

PHYSIOTHERAPIST

ADDITIONAL COMMENT

None, the prognosis is good for this patient.

BIOKINETICIST

ADDITIONAL COMMENT

The Patient responded very well to the exercise protocol and is now pain free and without any discomfort concerning his affected knee. He will be returning to his sport as soon as possible.

FINAL ASSESSMENT - DAY 43

Cybox Power assessment

Surface EMG

PATIENT EVALUATION SHEET

Patient Number 2: Mr. Dean Robertson

Date of surgery: 12 / 09 / 2001

Age: 28 years

Affected Knee: Left Knee

Sport: Running (Comrades)

Level of Participation: Social
Club
Provincial
International

Brief History of Injury or Pain

Present:

Patient presents with anterior knee pain and classic symptoms of PFPS where the cause is unknown. He actively competes in running events and completed the Comrades Marathon. Due to anterior knee pain he experienced for the last couple of months, he reduced his training and running to social level only. However, he definitely wants to start competing again.

Before:

He has a history of chronic knee pain that might relate to overuse due to his sport. Arthroscopies were performed on both knees 2 years ago. According to the patient the surgeon found nothing wrong and just did a patella-shave. In the beginning of this year he started to experience anterior pain in his Left Knee again. He doesn't have any problems with his Right knee.

PHYSIOTHERAPIST

Sport Disability Scale (Pre-Op)

- 0 = NO PAIN
- 1 = PAIN AFTER SPORT
- 2 = PAIN DURING SPORT – NOT AFFECTING PERFORMANCE
- 3 = PAIN DURING SPORT – AFFECT PERFORMANCE
- 4 = PARTICIPATION / ACTIVITY NOT POSSIBLE

BIOKINETICIST

OXFORD PAIN SCALE
ONE LEG SQUAT

SCALE (1 –10)

- 1 = NO PAIN
- 10 = VERY PAINFUL

Pre-Op 12/09/01	DAY 28 10 / 10 / 01	DAY 33 15 / 10 / 01	DAY 38 20 / 10 / 01	DAY 42 24 / 10 / 01
9	6	5	3	1

PHYSIOTHERAPIST
CIRCUMFERENCE (cm)

AREA	Pre-Op 12/09/01	DAY 3 15/09/01	DAY 7 19/09/01	DAY 10 22/09/01	DAY 14 26/09/01
15 cm Above Patella	47.2	44.8	44.7	44.3	43.7
Around Patella	34.6	35.2	34.7	34.5	34.3

BIOKINETICIST
CIRCUMFERENCE

AREA	Pre-Op 12/09/01	DAY 28 10/10/01	DAY 33 15/10/01	DAY 38 20/10/01	DAY 42 24/10/01
15 cm Above Patella	47.2	44.3	44.4	44.6	45.0
Around Patella	34.6	33.8	33.6	34.1	34.2

PHYSIOTHERAPIST

RANGE OF MOTION IN DEGREES

Pre-Op 12/09/01	DAY 3 15/09/01	DAY 7 19/09/01	DAY 10 22/09/01	DAY 14 26/09/01
0° - 145°	0° - 95°	0° - 120°	0° - 135°	0° - 138°

BIOKINETICIST

RANGE OF MOTION IN DEGREES

Pre-Op 12/09/01	DAY 28 10/10/01	DAY 33 15/10/01	DAY 38 20/10/01	DAY 42 24/10/01
0° - 145°	0° - 141°	0° - 142°	0° - 142°	0° - 142°

PHYSIOTHERAPIST

SURFACE EMG – Vastus Medialis Oblique : Vastus Lateralis (2 : 1)

DAY 21 04/10/01	DAY 28 10/10/01	DAY 43 25/10/01
1.20 : 1.00	1.30 : 1.00	1.80 : 1.00

DOCTOR

MEDICAL DIAGNOSIS OF UNJURY / CONDITION

Medial Plica Impingement.

PHYSIOTHERAPIST

ADDITIONAL COMMENT

None, the prognosis is good for this patient.

BIOKINETICIST

ADDITIONAL COMMENT

The Patient is experiencing a slight discomfort when performing some of the exercises. This discomfort, however is normal and will hopefully disappear within the following weeks.

FINAL ASSESSMENT - DAY 43

Cybex Power assessment

Surface EMG

PATIENT EVALUATION SHEET

Patient Number 3: Mrs. Marieta Jonker

Date of surgery: 10 / 09 / 2001

Sport: Hockey

Age: 39

Affected Knee: Left Knee

- Level of Participation:**
- Social
 - Club
 - Provincial
 - International

Brief History of Injury or Pain

Present:

Patient presents with anterior knee pain and classic symptoms of PFPS with the cause unknown. Previously she participated actively in Hockey and competed on provincial level for a couple of years. As she aged she reduced this level of competition to social level only. During the last year she has been experiencing immense pain in her Left Knee and this forced her to quit playing hockey. She still wants to play hockey on a social level and as the pain got worse, she went to see a surgeon.

Before:

The patient didn't have any complaints or history of previous pain regarding any one of her knees. She competed on provincial level well into her late twenties and thereafter she went on by playing for her club as well as socially.

PHYSIOTHERAPIST

Sport Disability Scale (Pre-Op)

- 0 = NO PAIN
- 1 = PAIN AFTER SPORT
- 2 = PAIN DURING SPORT – NOT AFFECTING PERFORMANCE
- 3 = PAIN DURING SPORT – AFFECT PERFORMANCE
- 4 = PARTICIPATION / ACTIVITY NOT POSSIBLE

BIOKINETICIST

OXFORD PAIN SCALE

ONE LEG SQUAT

SCALE (1 –10)

- 1 = NO PAIN
- 10 = VERY PAINFUL

Pre-Op 10/09/01	DAY 28 08/10/01	DAY 33 13/10/01	DAY 38 18/10/01	DAY 42 22/10/01
10	6	5	3	2

PHYSIOTHERAPIST
CIRCUMFERENCE (cm)

AREA	Pre-Op 10/09/01	DAY 3 13 / 09 / 01	DAY 7 17 / 09 / 01	DAY 10 20 / 09 / 01	DAY 14 24 / 09 / 01
15 cm Above Patella	48.1	47.5	47.1	46.9	46.8
Around Patella	36.0	37.9	37.7	37.2	36.7

BIOKINETICIST
CIRCUMFERENCE

AREA	Pre-Op 10/09/01	DAY 28 08 / 10 / 01	DAY 33 13 / 10 / 01	DAY 38 18 / 10 / 01	DAY 42 22 / 10 / 01
15 cm Above Patella	48.1	46.9	46.9	47.1	47.4
Around Patella	36.0	35.6	35.1	35.7	35.6

PHYSIOTHERAPIST

RANGE OF MOTION IN DEGREES

Pre-Op 10/09/01	DAY 3 13 / 09 / 01	DAY 7 17 / 09 / 01	DAY 10 20 / 09 / 01	DAY 14 24 / 09 / 01
0° - 145°	0° - 80°	0° - 100°	0° - 115°	0° - 122°

BIOKINETICIST

RANGE OF MOTION IN DEGREES

Pre-Op 10 / 09 / 01	DAY 28 08 / 10 / 01	DAY 33 13 / 10 / 01	DAY 38 18 / 10 / 01	DAY 42 22 / 10 / 01
0° - 145°	0° - 140°	0° - 144°	0° - 145°	0° - 145°

PHYSIOTHERAPIST

SURFACE EMG – Vastus Medialis Oblique : Vastus Lateralis (2 : 1)

DAY 21 01 / 10 / 01	DAY 28 08 / 10 / 01	DAY 43 23 / 10 / 01
1.05 : 1.00	1.25 : 1.00	1.75 : 1.00

DOCTOR

MEDICAL DIAGNOSIS OF UNJURY / CONDITION

Chondromalacia Patella Grade I with Medial Plica impingement.

PHYSIOTHERAPIST

ADDITIONAL COMMENT

None, the prognosis is good for this patient.

BIOKINETICIST

ADDITIONAL COMMENT

The Patient is pain free and experiences no problems in performing her daily tasks. She will return to her sport (on a social level) as soon as the occasion arises.

FINAL ASSESSMENT - DAY 43

Cybex Power assessment

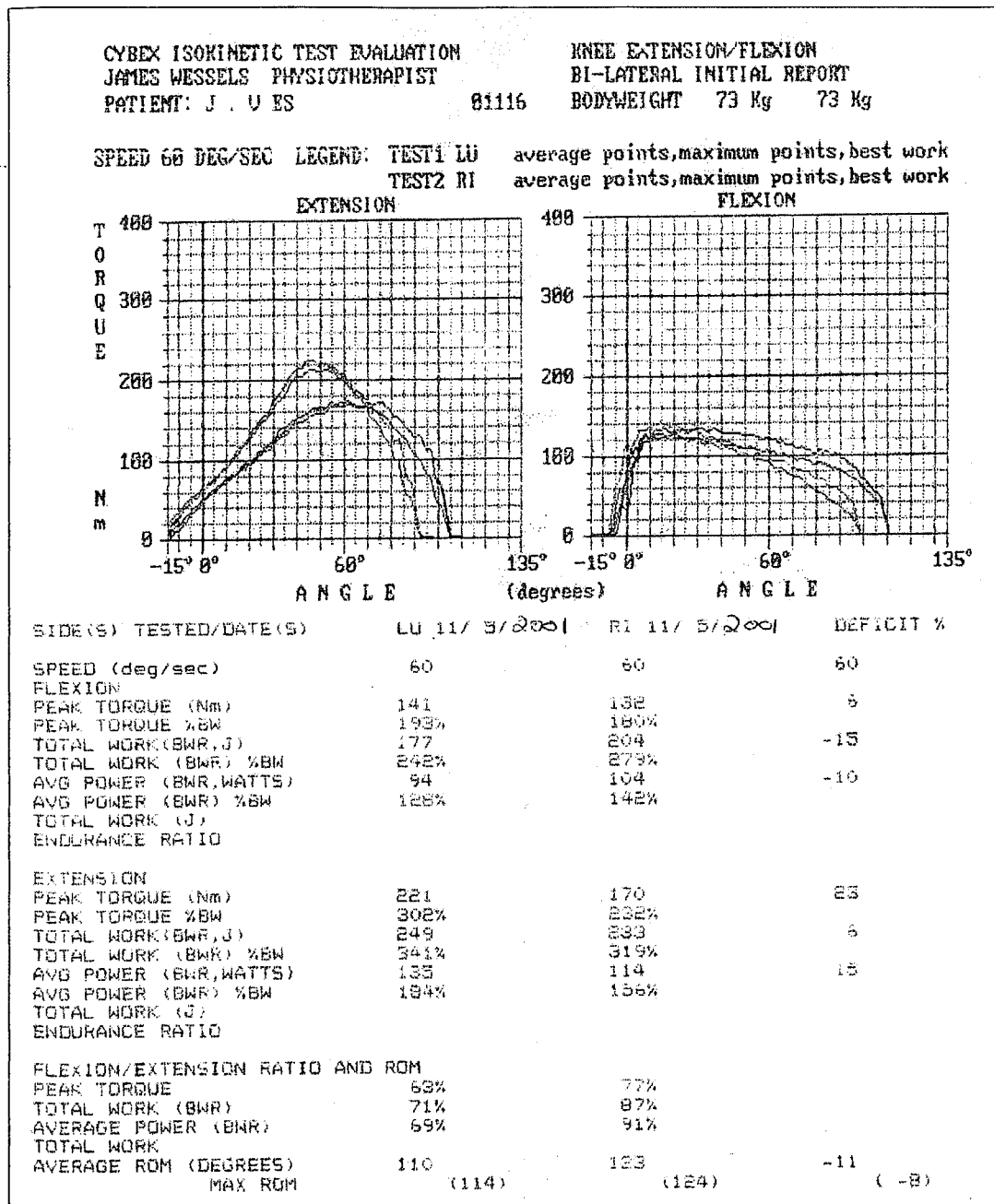
Surface EMG

Final Assessment

Examples

Figure A is a printout example of the Cybex Power Test that was conducted during the final assessment on Day 43. Figure B is an example of the Surface EMG printouts that were performed on Days 21, 28 and 43.

A: Cybex Evaluation



B: Surface EMG (SEMG)

- Electrodes were placed on the midpart of the *Vastus Lateralis Muscle* and on the midpart of the *Vastus Medialis Oblique Muscle*.
- Patients performed five repetitions on a Cybex Dynamometer with the Surface EMG electrodes in place.
- The EMG recordings were then taken when patients performed leg extensions on the Cybex Dynamometer.

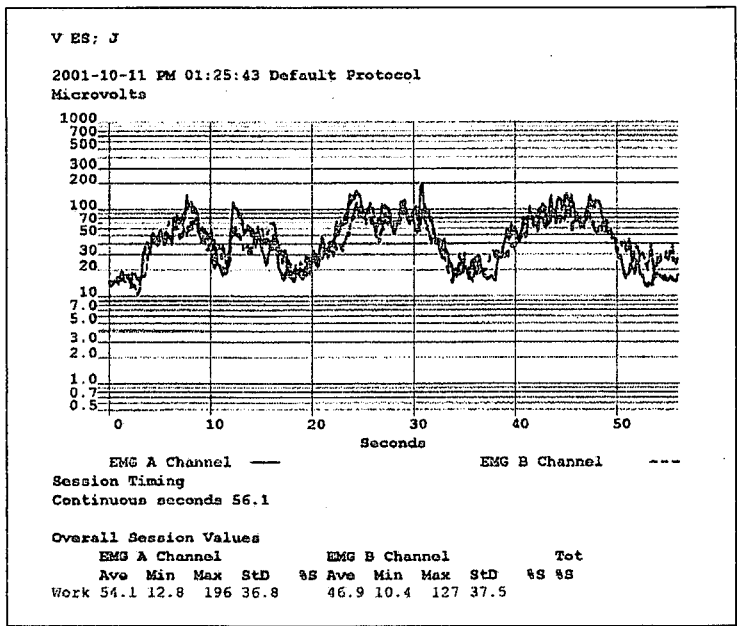


Figure 1: SEMG printout performed on Day 21.

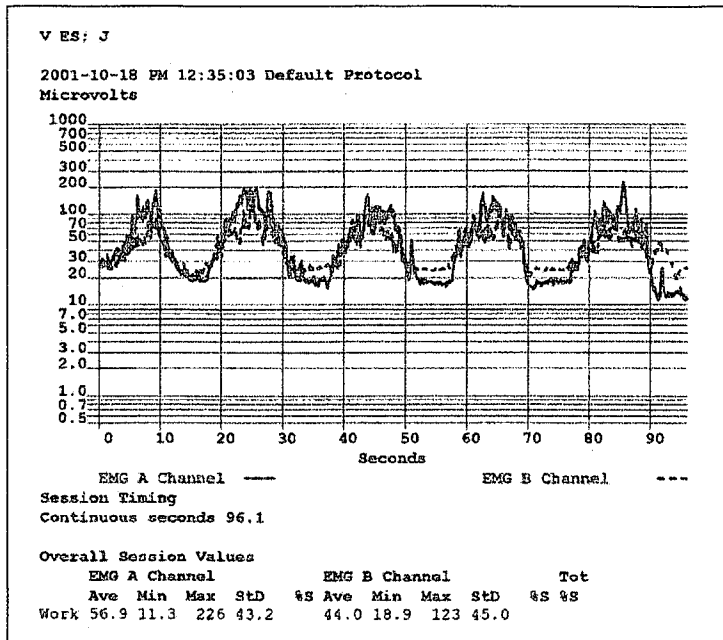


Figure 2: SEMG printout performed on Day 28.

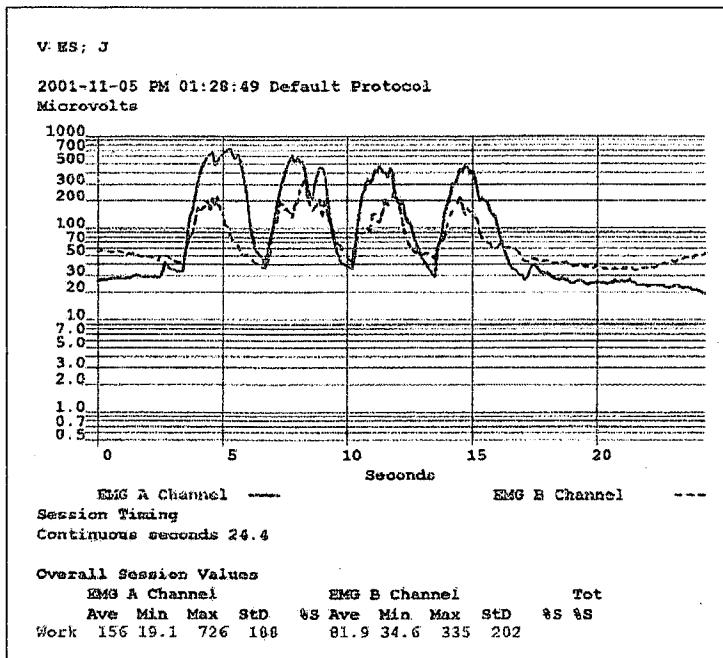


Figure 3: SEMG printout performed on Day 43.

**“Having success and making a
difference – The one is as important as
the other”**

Bertus Pretorius

SUMMARY

Rehabilitation is recognized as a critical component in the treatment of sports injuries, and has been the subject of intense research over the past decade. As a result, sound scientific principles have been applied to the realm of rehabilitation data and results. Life in the world as we know it is fast becoming a flustering playground that also affects rehabilitation as such, and especially the cost and time of the rehabilitation programs prescribed. By developing ways to minimize time-consuming efforts and at the same time optimize the efficiency of a rehabilitation program, we will be able to keep up with our constant changing world.

As a result of the aforementioned, significant evidence has been found for a *Change-Point* model using rehabilitation data. A statistical method for analyzing rehabilitation data/sequences containing a *Change-Point* is therefore proposed. The methods may be extended in many directions. By calculating a patients' *Change-Point* during his rehabilitation process, one will be able to either take a more aggressive, or a more conservative approach when adjusting the exercise prescription of a patient during the different phases of the rehabilitation process. Evidence suggests that *Change-Point* analysis may be a completely new direction in rehabilitation as we know it.

In order to implement the use of *Change-Point* analysis on rehabilitation data, one needs to identify an injury(s) along with the treatment used for it. *Patello Femoral* disorders, especially the *Patello Femoral Pain Syndrome (PFPS)* is a well-known problem in all

age groups. This disorder is a very common complaint amongst the general population. Conservative treatment will always be the first option with regard to rehabilitation of this disorder. If, however, this method fails, the surgeon will opt for a surgical procedure, in this case a procedure known as and *arthroscopy*. An *arthroscopy* is a minimally invasive surgical procedure that can be performed for the purpose of diagnosing and the following treatment of problems within the internal structure of joints. Over the past decade, it has become one of the most frequently used procedures for the diagnosis and treatment of knee injuries.

In addition, various rehabilitation or treatment modalities are proposed after a patient underwent a knee *arthroscopy*. One of these modalities is *isokinetic exercise*. *Isokinetic exercise* is a popular dimension in the field of resistive exercise and muscle evaluation. It is made possible by an electro-mechanical device that keeps limb motion at a constant, predetermined velocity. Many competitive and recreational athletes perform resistance training as a part of their conditioning program. Resistance training in addition to increasing muscular strength and hypertrophy may also aid in the prevention of injuries. Research indicates that resistance training promotes growth and/or increases in the strength of ligaments, tendons, tendon to bone and ligament to bone junction strength, joint cartilage and the connective tissue sheaths within muscle. Studies involving humans and animal models also demonstrate resistance training can cause increased bone mineral content and therefore may aid in the prevention of skeletal injuries.

SUMMARY

Change-Point analysis can therefore be of high value to the Biokineticist in helping him/her to evaluate the progress of rehabilitation more successfully. Because of our rapid changing world, it is imperative that new methods of analyzing and interpreting rehabilitation data are developed and created. This will aid in our understanding thereof and it will have a significant effect on the cost, time and outcome of a prescribed, rehabilitation program. Only then, will we as Biokineticists truly fulfill the mission of our profession, which is to improve the quality of life of our fellow human beings.

Key words and phrases: Change-Points, Patello Femoral Pain Syndrome, Arthroscopy, Isokinetic Test Design, Bayesian Statistics.

OPSOMMING

Rehabilitasie word erken as 'n kritiese komponent in die behandeling van sportbeserings en was die onderwerp van intensiewe navorsing tydens die afgelope dekade. Gevolglik is gegronde wetenskaplike beginsels op die terrein van rehabilitasiedata en -resultate toegepas. Die lewe van vandag word gekenmerk deur 'n hoë tempo wat ook rehabilitasie as sodanig, en veral die koste en tyd van die programme, beïnvloed. Deur maniere te ontwikkel wat tydrowende pogings minimaliseer en terselfdertyd die effektiwiteit van programme optimaliseer, word ons in staat gestel om in pas te bly met ons veranderende wêreld.

As gevolg van die bogenoemde, is betekenisvolle bewyse gevind vir 'n *Draai-punt* model waar rehabilitasiedata gebruik kan word. 'n Statistiese metode waarmee rehabilitasiedata wat 'n *Draai-punt* bevat geanaliseer word, word in die studie voorgestel. Die metodes kan in verskeie rigtings uitgebrei word. Deur 'n pasiënt se *Draai-punt* te bepaal gedurende die verloop van die rehabilitasie-proses, kan die Biokinetikus duidelik sien of daar 'n meer aggressiewe of meer konserwatiewe benadering gevolg moet word wanneer die oefenprogram-voorskrif aangepas word. Op grond van die studie kom dit voor asof *Draai-punt* analise 'n splinternuwe dimensie aan tradisionele rehabilitasie kan verleen.

Ten einde die gebruik van 'n *Draai-punt* model geassosieer met rehabilitasiedata, te implementeer, is dit nodig om 'n besering(s) en die betrokke behandeling te identifiseer. *Patello Femorale* afwykings, en meer spesifiek *Patello Femorale Pyn Sindroom (PFPS)*,

is 'n bekende toestand in alle ouderdomsgroepe en ook 'n gereelde klagte onder die algemene populasie. Konserwatiewe behandeling is altyd die eerste opsie tov die rehabilitasie van die probleem. Indien dit nie slaag nie, sal die chirurg 'n operatiewe prosedure oorweeg, in hierdie geval 'n *atroskopie*. 'n *Atroskopie* is 'n prosedure wat minimale skending veroorsaak en word uitgevoer om diagnoses te bevestig binne bepaalde gewigte. Gedurende die afgelope dekade is *atroskopie* gereeld gebruik vir die diagnose en behandeling van kniebeseerings.

Verder word daar verskeie rahabilitasie- en behandelings-modaliteite voorgestel nadat 'n pasiënt 'n *atroskopie* ondergaan het. Een van hierdie modaliteite is *isokinetiese oefening*. *Isokinetiese oefening* is 'n populêre dimensie binne die terrein van weerstands-oefening en die evaluasie van spierverhoudings. Hierdie tipe oefening word moontlik gemaak deur 'n elektro-meganiese apparaat wat ledemate teen 'n konstante, voorafbepaalde snelheid laat beweeg. Verskeie kompeterende sowel as rekreasie atlete sluit weerstands-oefeninge by hul kondisionerings-program in. Die beoefening van weerstands-oefeninge ten einde spierkrag en hipertrofie te verhoog, kan ook 'n bydrae lewer ter voorkoming van beseerings. Navorsing beaam dat weerstands-oefeninge groei en / of die sterkte van ligamente, tendons, tendon – been en ligament – been aanhegtings en gewrigs-kraakbeen bevorder. Studies wat op beide mense en diere uitgevoer is, dui aan dat weerstands-oefening tot 'n verhoging in die mineraal-inhoud van bene kan lei. Dit kan help met die voorkoming van skeletale beseerings.

Samevattend kan gestel word dat *Draai-punt* analise van onskatbare waarde vir die Biokinetikus kan wees aangesien dit hom/haar kan help om die vordering van die rehabilitasie-proses meer suksesvol te meet. Vanweë ons snel veranderende wêreld, is dit noodsaaklik dat nuwe metodes geskep en ontwikkel word wat ons in staat stel om rehabilitasiedata te analiseer en te interpreteer. Hierdie metodes sal 'n betekenisvolle invloed hê op die uitkoms, koste en tyd van die voorgeskrewe rehabilitasieprogram. Deur die lewenskwaliteit van medemense te verbeter, sal Biokinetici eers werklik die opdrag van hul profesie volbring.

Sleutelwoorde en frases: Draai-punte, Patello Femorale Pyn Sindroom, Atroskopie, Isokinetiese Toets-ontwerp, Bayesian Statistiek.

When you do the common things in life in an uncommon way, you will command the attention of the world.

George Washington Carver (1864-1943)

Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.

Antoine de Saint Exupery

I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.

Albert Einstein (1879-1955)

Ones best success comes after their greatest disappointments.

Henry Ward Beecher

I have often regretted my speech, never my silence.

Xenocrates (396-314 B.C.)



PERSISTENCE

After I'm dead, I'd rather have people ask why I have no monument than why I have one.

Cato the Elder (234-149 BC, AKA Marcus Porcius Cato)

Whether you think that you can, or that you can't, you are usually right.

Henry Ford (1863-1947)

The graveyards are full of indispensable men.

Charles de Gaulle (1890-1970)

The true measure of a man is how he treats someone who can do him absolutely no good.

Samuel Johnson (1709-1784)

I am neither especially clever nor especially gifted. I am only very, very curious

Albert Einstein (1879-1955)

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