CHARLES UNIVERSITY IN PRAGUE

Faculty of Physical Education and Sport

BACHELOR THESIS

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FILIPPOS FILIPPAKOPOULOS

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Pre-surgical Rehabilitation of Patient with Full Rupture of Anterior Cruciate Ligament.

BACHELOR THESIS

Supervisor of the Bachelor's Thesis

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ABSTRACT

TITLE: Pre-surgical Rehabilitation of patient with Full Rupture of Anterior Cruciate Ligament

Objective: The goal of this bachelor thesis is to do a clinical study about the pre-surgical rehabilitation of a patient with full rupture of anterior cruciate ligament (ACL).

Materials: The patient is male 31 years old and he is working as a cardiologist to the military hospital of Prague. He is recreational skier and during this activity got ruptured his ACL. The injury took place at 13th December 2009 and then he was wearing a brace from 0-30 degrees.

Methods: The study lasted for a period of two weeks. During the initial meeting and evaluation of the patient, a rehabilitation plan has worked out and executed during the two weeks with all together 8 sessions. I performed PIR at every session for the relaxation of hypertonic muscles, proprioception and sensomotoric stimulation, stretching techniques to elongate the shortened muscles, mobilization of restricted joints and strengthening exercises of the weak muscles.

Results: after 8 therapeutic units I provided final kinesiologic examination and the results were really satisfying with 120 degrees active flexion at the knee joint and normal gaiting. The patient is functional again and anymore has free choice to discuss with the orthopedist if he will reconstruct the ruptured ligament or not.

Conclusion: the most important therapeutic aim for pre-surgical rehabilitation for patients with ACL deficiency is the strengthening of the muscles relating at the knee joint. Group muscles such as quadriceps and hamstrings play very important to maintain the knee stability as they have to cover the absence of ACL especially against forces which create anterior sliding of tibia on the femur.

KEY WORDS: Anterior Cruciate Ligament, Range of Motion, Gaiting pattern, Quadriceps, Hamstrings.

DECLARATION

I declare that this Bachelor Thesis is based on my own individual work during the two weeks of my clinical practice in the Vojenska Nemocnice in Prague, between the 11th and 22nd of January 2010. All the information which is used for the development of this Bachelor Thesis has been taken from the list of literature at the end of this project.

…………………………..

Filippos Filippakopoulos

DEDICATION

This Bachelor Thesis is dedicated to my parents that are always there for me.

It is also dedicated:

To Czech Republic, Charles University and its great teachers that they made me a better person.

To my supervisor Mgr. Klára Faladová-Hojkova that without her help and advices I wouldn't be able to create alone this Bachelor Thesis.

To the beautiful Greek city of Thessaloniki and the Aristotle University that I got my first bachelor in physical education and sports and made me strong enough to continue my studies.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Mgr. Klára Faladová-Hojkova, for her advice during the process of writing my bachelor thesis. A thank you to the patient I was assigned with; during the practice for his cooperation and patience with me during the 2 weeks that we worked together. I would like to thank also my supervisor at the Vojenska Nemocnice (military hospital of Prague), Peter Smejkal for the precious help that provided me with all the patients that I met during the two weeks of my clinical practice.

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1. INTRODUCTION

The anterior cruciate ligament (ACL) is one of the four major ligaments of the human knee. It is the most common knee ligament injury especially in athletes. By these 2 phrases arise questions such as: what causes the ACL injuries? Which factors are hidden behind? What can I do if it will happen to me? Will I be able to do sports again? What options do I have? How much time will need my cruciate ligament to be healed? Do I need surgery? How will be my rehabilitation? This Bachelor Thesis will answer all these questions and many more from the Anatomic, Biomechanic, Physiologic and physiotherapeutic point of view in two parts. The first part is the general-theoretical part and the second is the special-practical part.

The theoretical part describes the anatomy of the human knee including the bones, muscles and ligaments. The biomechanics and the loadings of the knee joint will be discussed with a special reference to the skiing activity that my patient injured by. Surgical options, treatments and the materials which are used for these kinds of operations will be discussed. Indicated and contraindicated sport activities will be referred.

The special part is a real study of a patient of mine with full rupture of ACL that I was responsible for his rehabilitation. This second part of my thesis will give in detail all my physiotherapeutic work from the first day that my patient came to military hospital and I examined him, the physiotherapeutic techniques that I used during the therapeutic units till the last therapeutic session that I provided to my patient the final kinesiologic examination. The results of the final kinesiologic examination shows that my patient is fully functional again, having anymore the free will to choose if he wants to proceed with surgical operation or not.

THEORETICAL PART

2.1 ANATOMY OF THE KNEE JOINT

2.1.1. BONES

The knee joint (articulation Genus in Latin) is one of the largest and strongest joints in the human body. It is commonly called a hinge joint. There are three bones that involved at the knee joint. On the upper part of the knee joint is the femur, on the lower part the tibia and the third is the largest sesamoid bone of the human body which is called patella (kneecap). When people who are not related with the area of medicine are using the word knee joint, they imagine that this joint is only one. Is that true? The answer is no. The knee joint is not what we can see out of the skin but what really exists inside of it. Under our skin that we are unable to see with simple eye, there are three joints within a synovial cavity which are connected together and give shape to the knee joint. So let's imagine that the knee joint is a puzzle that we have to build in three levels. Our materials will be the three bones (the femur, the tibia and the patella) and our target will be to create the three articulations of the knee joint.

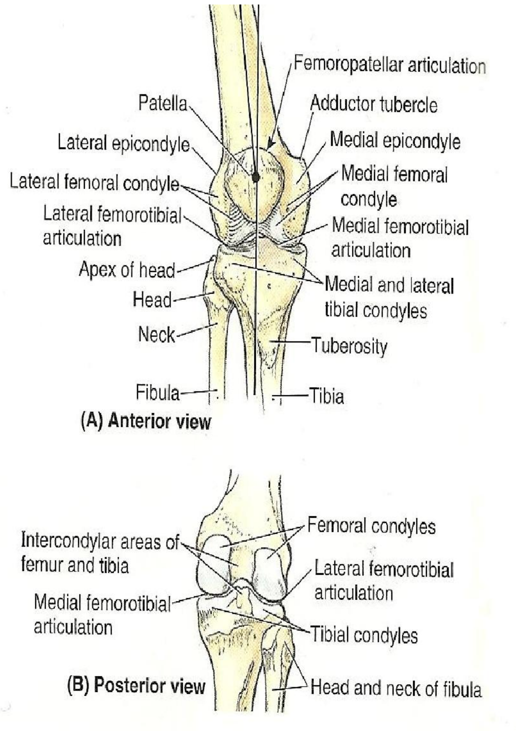


Figure 1. Bones and articulations of the knee joint. (1)

The first bone that we spoke about is the femur. Femur is the longest and heaviest bone of our body (1). If we observe the distal part of femur from the posterior view we will see two strong bone protrusions which are covered with joint cartilage and called medial and lateral condyles (knee joint - level I).

The second bone that we spoke about and the second longer of our body is the tibia. The proximal part of tibia is characterised also by two bone protrusions the medial and lateral condyles that they overhang the shaft medially, laterally, and posteriorly, forming a relatively superior articular surface which called tibia plateau [Level –II].

Patella is the third bone and lies anterior to the distal end of femur [Level III]. Summarizing (figure 1) the result of these three levels we create the three articulations of the knee: Level I (femur) and Level II (tibia) we have the first two femorotibial articulations of the knee between the medial and lateral condyles of the tibia and femur (in the middle there are menisci which we will talk about their role in the next chapters). Summarizing the level I (femur) with the Level III (patella) the result is the third articulation of the knee joint which is called patellofemoral joint. (3) As we can see the fibula does not participate in the three articulations of the knee joint. It is attached to the tibia posterolaterally by the tibiofibular syndesmosis. The main roles of fibula are to provide attachments for the muscles and to provide with stability the ankle joint. Fibula has no function in the weight bearing of our body. (1)

2.1.2. KNEE JOINT CAPSULE

When we are talking for a capsule we mean a structure which has the ability to enclose some kind of content. Considering this fact comes out the question of what the knee joint capsule encloses in. Before I will speak about that, I consider that is really important firstly to write about the synovial joints and their characteristics. So what the synovial joints are? Having already presented in the previous chapter the three knee joint articulations we have to think that these three bones are moving in relation to each other. By thinking the physical laws one thing comes in mind: how these bones are not destroyed by the friction in a healthy organism during movement? This is because the knee joint is a synovial joint and has a very unique characteristic to provide us with an auto-protection system against the friction between the bony surfaces.

This unique characteristic is not other than the presence of a space which we call it synovial (joint) cavity. This synovial area takes place between the bony surfaces that articulating to each other. Because synovial cavity is giving the advantage to a joint to be freely movable is classified as diarthroses. The articular bony surfaces in a synovial joint have a very important layer which is called articular cartilage. The articular cartilage provides the articulating bony surfaces with its slippery and smooth hyaline surface by not letting them to bind together resulting to auto-protect the joint from friction (figures 2 and 3). This incredible protection system against the friction is the content of the knee joint capsule which is called articular capsule.

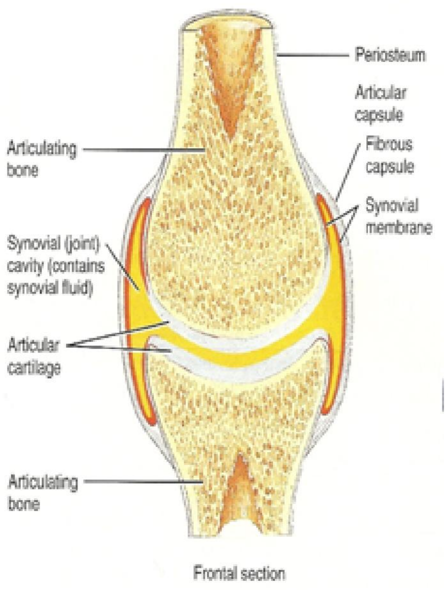


Figure 2- synovial joint (3)

The fibrous capsule consists mostly of collagen fibers which attach to the periosteum of the bones that articulate each other. The knee joint capsule is characterised by two layers, the outer fibrous capsule and the inner synovial membrane which is responsible for the production of the synovial fluid. The synovial fluid we could say that is the lubricant of the joints. Reduces the friction between articular surfaces within the capsule and has very important role to the joint shock absorption.

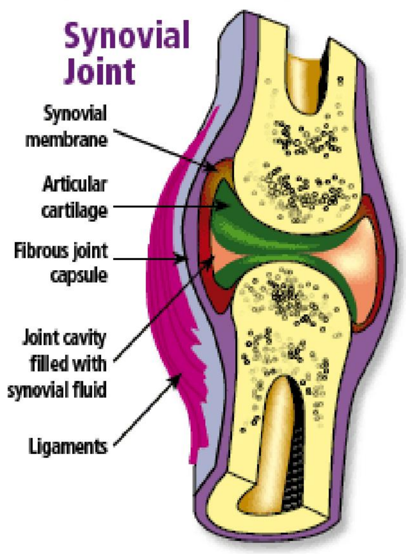


Figure 3 – Synovial joint (35)

The main function of the knee joint capsule is not only to enclose the structure of the synovial joint but also to be flexible by advantaging the joint with great range of motion but at the same time to resist to stretching and to prevent bone dislocations.

The articular capsule and the knee joint are receiving mechanical support by the ligaments that I will be referred in the next chapter. (3)

2.1.3 LIGAMENTS

As I have already written our knee joints are using the abilities and characteristics that the synovial joints are providing them in order to reduce the friction between the bony surfaces. The next factor that our joints have to fight against called stability. The human knee has every day to handle great pressures and forces while is in motion. The ligaments of the knee joint undertake this role. We could characterise them as “elastic clever ropes” which are in tension and are able to “feel” and “read” the forces which are applied to the knee joint keeping it in shape while we move. We divide the ligaments as extracapsular ligaments and intracapsular ligaments. (1)

EXTRACAPSULAR LIGAMENTS

Five extracapsular ligaments undertake the role to strengthen the anterior, posterior, lateral and medial aspects of the knee joint. These ligaments are the patellar ligament, the tibial collateral ligament, the fibular collateral ligament, the oblique popliteal ligament and the arcuate popliteal ligament (figure 4). The patellar tendon is visible in figure 5. (1)

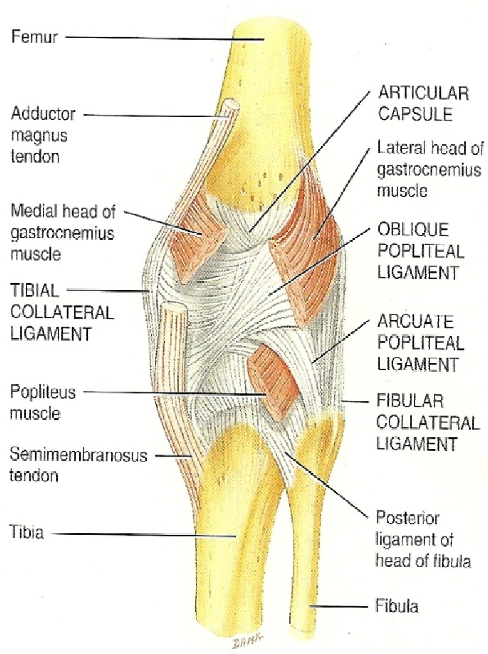


Figure 4. Extracapsular ligaments. Posterior view (3)

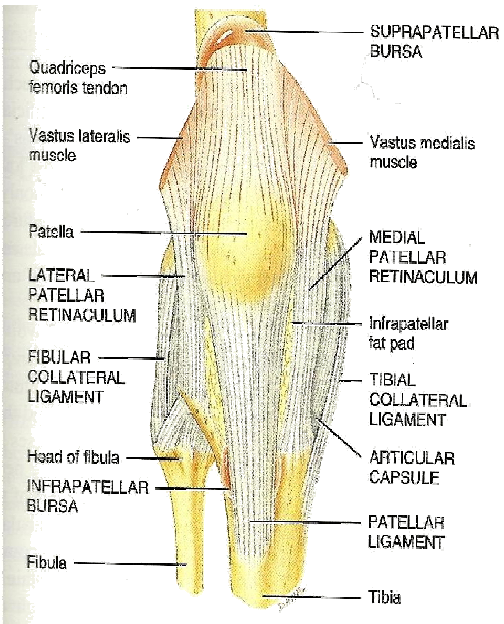


Figure 5. Extracapsular ligaments Anterior view (3)

The patellar ligament is the insertion of quadriceps femoris muscle. The tendon of quadriceps femoris is this which we call patellar ligament and takes place from the patella to the tibial tuberosity. The patellar ligament strengthens the anterior aspect of the knee joint.

The tibial collateral ligament connects two medial condyles, the medial condyle of the femur with the medial condyle of the tibia. It strengthens the medial surface of the knee joint.

The fibular collateral ligament we could say that is an extra strong ligament because it receives covering by the tendon of biceps femoris muscle. This ligament extends from the lateral femoral condyle to the lateral side of the fibular head and strengthens the lateral side of the joint (3).

The oblique popliteal ligament extends from the femoral intercondylar fossa to the head of the tibia. This ligament is responsible for the strengthening of the posterior part of the knee joint.

The arcuate popliteal ligament undertakes the role to strengthen the knee joint in its lower posterolateral aspect by extending from the lateral condyle of the femur to the styloid process of the fibular head (3).

INTRACAPSULAR LIGAMENTS

As I referred in the previous chapter (2.1.3) the human knee has every day to handle great pressures and forces while is in motion. These forces sometimes have the tendency to force the tibia to slide in the anterior or posterior direction in relation to the femur. The intracapsular ligaments undertake the role to resist to these forces and to prevent this sliding.

The intracapsular ligaments as their name declares are within the joint capsule and they connect the tibia with the femur. These ligaments are the cruciate ligaments, anterior cruciate ligament (ACL) and Posterior cruciate ligament (PCL) which they cross each other by shaping the letter X (figure 6 and 7), and the menisci (figure 8) which I will talk about in the next chapter. The point of crossing between the cruciate ligaments called also chiasm (by the Greek letter X which in Greek is spelled “hy”).

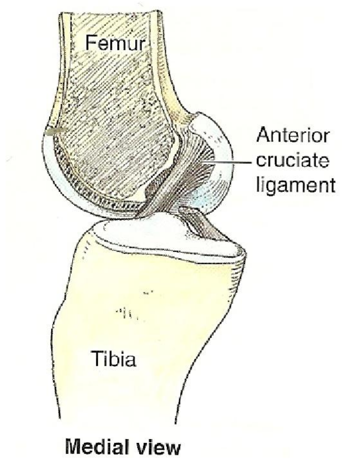


Figure 6-ACL medial view(3)

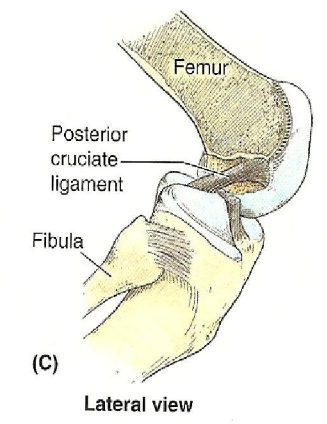


Figure 7-PCL lateral view (3)

The ACL from the two cruciate ligaments is the weaker and arises from the anterior intercondylar area of the tibia to the, just posterior, to the attachment of the medial meniscus (1). The main functions of ACL are to prevent the anterior sliding of the tibia on the femur, to limit and resist the hyperextension of the knee joint. ACL will be the main subject of interest in the next chapters.

The PCL which is the stronger of the two cruciate ligaments arises from the posterior intercondylar area of the tibia, passes superiorly and anteriorly of the ACL and attaches to the anterior part of the lateral surface of the medial condyle of the femur (1). The main function of PCL is to prevent the posterior sliding of the tibia (and the anterior of the femur in the relation to the tibia) in relation to the femur when the knee is flexed. This is a very important function especially when we are going down the stairs. (3)

2.1.4. MENISCI

Menisci (Figure 8) or articular discs (by the Greek word meniskos which means crescent) are "C" shaped plates of fibrocartilage on the articular surface of the tibia. The lateral meniscus appears to be more circular than the medial one. Because the femoral and the tibial condyles have different shape and cannot firm well menisci are compensating this connection by deepen the surfaces between these two bones, providing by this way the knee joint with extra stability. Another important function of menisci is to play important role in shock absorption.

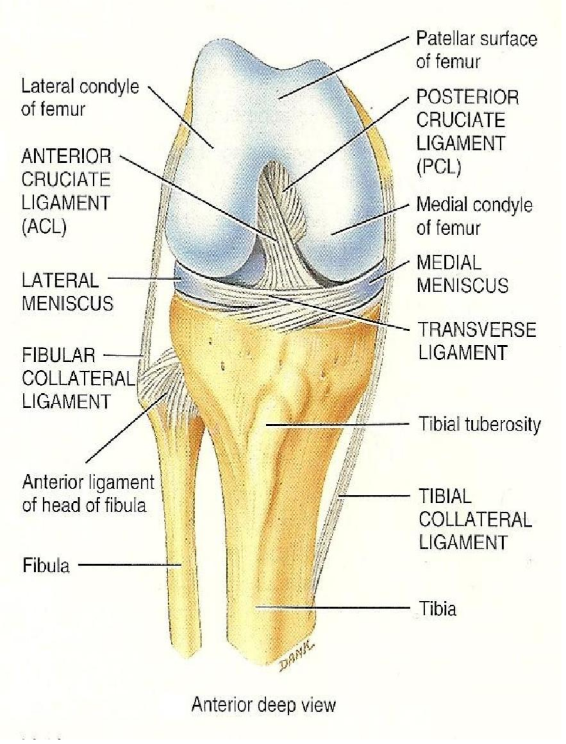


Figure 8- Menisci, extracapsular and intracapsular ligaments. (3)

The medial meniscus as we said is letter C shaped and its anterior end is attached to the anterior intercondylar area of the tibia, anterior to the attachment of the ACL (1). Its posterior end is attached to the posterior intercondylar area, anterior to the attachment of PCL.

The lateral meniscus is smaller with more circular shape and more movable than the medial one. Its anterior end is attached anteriorly to the intercondylar eminence of the tibia, and anteriorly to the posterior end of the medial meniscus (3). The role of connection between the two menisci (medial and lateral) is provided by the transverse ligament and the connection of menisci to the tibial head is provided by the coronary ligaments.

2.2 PHYSIOLOGY OF LIGAMENTS

2.2.1. THE STRUCTURE AND PHYSIOLOGY OF LIGAMENTS

As I wrote before, the ligaments are “clever elastic ropes” which are the employers for the stability of our knee, by resisting to the forces that are trying to change the shape of our knee joints. The location of the ligaments is a parameter that couldn’t stand alone in order to guarantee their well function. It is really important to see by what “materials” are composed and how these materials are organised.

The ligaments are dense bands of collagenous tissue that span a joint with their insertions to the bones at either end. They have different size, shape, orientation and location. The surface of the ligaments is covered by a more vascular overlying layer which is called “epiligament”. The epiligament is often indistinguishable from the actual ligament and merges into the periosteum of the bone around the attachment sites of the ligament. If we will remove the epiligament then will be exposed its fibrous architecture. The ligament is further organised hierarchically into groups of parallel fibres which are called bundles. These bundles are interconnected in a very special fashion which holds them together in a manner that is very difficult to separate them.

The epiligament is more vascular than ligament and and receives its blood supply from a branch of the superior medial geniculate artery. It is also more cellular with more sensory and proprioceptive nerves.

By examining the ligaments in microscopic level we will observe that ligaments appear to be even more complex. The cells which a ligament is composed called fibroblasts. The fibroblasts are surrounded by matrix. For the well observation of the ligament microstructure can be used polarized light which reveals that the collagen bundles are aligned along the long axis of the ligament. Observing even deeper we can see that these collagen bundles have a “spring nature” meaning that we can see “small waves” or crimp. The role of this crimp appears to be biomechanical. During the increased loading state of the ligaments some parts of the bundles are uncrimping allowing the ligament to elongate without sustaining damage.

Biochemically, the ligaments are approximately two-thirds water and one-third solid. The water is responsible for their cellular function and their viscoelastic behaviour. The solid components of ligaments are 85% of type I collagen, and the rest (approximately 75 % of their dry weight) are type III, VI, V, XI, XIV. Proteins that are part of ligaments composition are the proteoglycans (less than 1%), elastin, and other proteins and glycoproteins such as actin, laminin and the integrins. Many dry weight components have not been characterised and this remains a research focus for the physiologists.

If we will go to observe even deeper in ultra-structural level we will find that collagen fibers are actually composed of smaller fibrils. At the molecular level, we can see that the collagen is synthesized as procollagen molecules and these are secreted into the extracellular space through some structures of the cell which called microtubules. In the extracellular space takes place a procedure which called post-transitional modification (PTM). During PTM the triple collagen molecules line up and begin to form fibrils and then fibres. This step is promoted by the enzyme lyxyl oxidase which promotes the cross-links formation. This process involves the placement of stable cross-links within and between the molecules. This is a very critical and important step because gives to the collagen fibres this incredible strength.

During the growth and development these cross-links are soluble and relatively immature but with age they immature and become insoluble increasing with this way their strength (10).

2.2.2. THE STRUCTURE OF ACL

Everything have been already referred about the ligaments is valid also for the ACL. However, the ACL has some more structural characteristics that I must mention for the better understanding of its nature, function and growing.

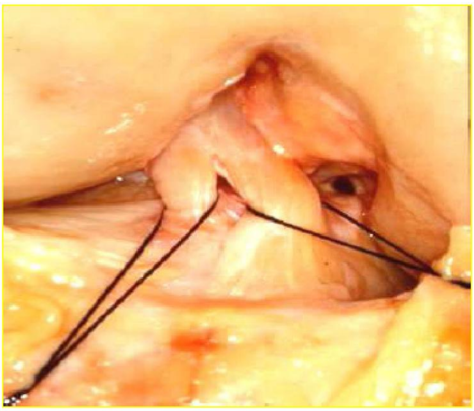
The ACL as a structure has three bundles, one anteromedial bundle (AM), one posterolateral (PL) and one intermediate (IM). The IM bundle is anatomically, physiologically and biomechanically very similar with AM bundle so in this chapter it will be considered as a part of the AM bundle.

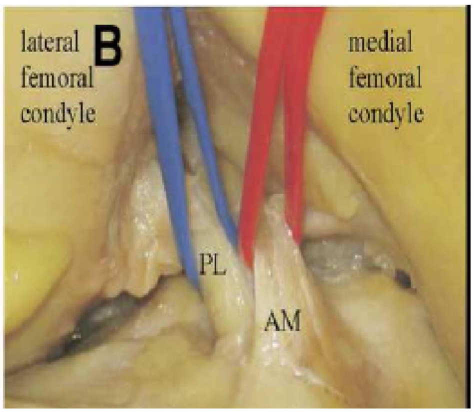
The ACL's composition includes numerous particles of dense connective tissue that undertake the role to connect the distal femur with the proximal tibia.

Histologically, there is a septum of vascularised connective tissue that separates the AM from the PL bundle. In addition, it has been shown that the histological properties of the ligament are variable at different stages in ACL development. At the time of ACL development, the ACL is observed to be hypercellular with circular, oval and fusiform-shaped cells. Later in the adulr ACL, the histology reveals a relatively hypocellular pattern with predominantly fibroblast cells with spindle-shaped nuclei (23), (7).

The ligament finds its origin on the medial surface of the lateral femoral condyle (LFC), runs an oblique course within the knee joint from lateral and posterior to medial and anterior, and inserts into a broad area of the central tibia plateau. The cross-sectional area of the ligament varies significantly throughout its course from approximately 44 mm^2 at the mid-substance to more than three times as much at both its origin and insertion. The total length of the ligament is approximately 31-38 mm and varies by as much as 10% throughout a normal range of motion.

The two distinct bundles of ACL are present and visible with arthroscopy, particularly, with the knee held in 90-120 degrees of flexion (after 16 weeks of gestation). All individuals with an intact ACL have both bundles of ligament (figures 9 and 10). (4)





Figures 9 and 10 – Anteromedial and Posterolatera bundles of ACL. (4)

2.2.3. LIGAMENT FUNCTION

There are three important functions of the ligaments and ACL of course couldn't be excluded. One of the main functions of ligaments is mechanical as they passively stabilize joints and help in guiding those joints through their normal range of motion when a tensile load is applied. Ligaments exhibit non linear anisotropic mechanical behaviour and under low loading conditions they are relatively compliant, perhaps due to recruitment of “crimped” collagen fibres as well as to viscoelastic behaviours and interactions of collagen and other matrix materials. Continued ligament loading results in increasing stiffness until a stage is reached where they exhibit nearly linear stiffness and beyond this, then, ligaments continue to absorb energy until tensile failure (disruption).

Another ligament function relates to its viscoelastic behaviour in helping to provide joint homeostasis. The term “load-relax” for ligaments means that loads/stresses decrease within the ligament if they are pulled to constant deformations. The term “creep” for ligaments is defined as the deformation (or elongation) under a constant or cyclically repetitive load. Creep is particularly important when considering joint injury or reconstructive surgery as excessive creep could result in laxity of the joint thus predisposing it to further injury.

A third function of the ligaments is their role in joint proprioception, which is referred to as the conscious perception of limb position in space. In joints such as the knee, proprioception is provided principally by joint, muscle and cutaneous receptors. When ligaments are strained, they invoke neurological feedback signals, and then activate muscular contraction and this appears to play a role in joint position sense. Although progress continues to be made to elucidate the role of proprioception in normal ligament function and during injury, more precise quantification is the subject of ongoing analysis. (10)

2.2.4. LIGAMENT RESPONSE TO INJURY AND HEALING

Ligaments are most often torn in traumatic joint injuries that can result in either partial or complete ligament discontinuities. Due to the title of this thesis I will focus on complete disruptions. The ligaments are healing by a process which includes three phases: haemorrhage with inflammation, matrix and cellular proliferation and finally, remodelling and maturation. Before we will describe the phases and how each of them is working, it is very important to refer that ACL is a special case. ACL has very poor healing capability, fact that will be explained later in this chapter. In case of ACL rupture the patient has to choose between the surgical or nonsurgical treatment but if the choice of treatment will be nonsurgical, then the patient will never have his cruciate ligament back.

The first phase involves retraction of the disrupted ligament ends, formation of a blood clot, which is subsequently reabsorbed, and replaced with a heavy cellular infiltrate. Subsequently, a considerable hypertrophic vascular response takes place in the gap between the disrupted ends and results in an increase in both vascularity and blood flow, both of which decrease with time.

The proliferative phase is defined as the production of "scar tissue" (dense, cellular, collagenous connective tissue matrix bridging the torn ends of the ligament) by hypertrophic fibroplastic cells. This scar tissue is initially quite disorganized with more defects (more blood vessels, fat cells, fibroblastic and inflammatory cells and loose connective tissue) identified histologically than normal ligament matrix. After a few weeks of healing the collagen becomes quite well aligned with the long axis of the ligament despite the fact that the types of collagen are abnormal (more type III in relation to type I and an increase in type V) and the collagen fibrils have smaller diameters in the proliferating tissue.

The third phase of ligament healing is matrix remodelling. Defects in the scar become filled in but although the matrix becomes more ligament-like with time, some major differences in composition, architecture and function persist. Differences which persist include altered proteoglycans (increased biglycan and decreased decorin protein and mRNA levels) and collagen types, failure of collagen crosslinks to mature, persistence of small collagen fibril diameters, altered cell connection, increased vascularity, abnormal innervation, increased cellularity and the incomplete resolution of matrix "flaws". The functional recovery of these ligament scars demonstrates a slow recovery of many properties.

During the remodelling phase, viscoelastic properties recover to within 10-20% of normal, implying that scars tend to stress-relax to a greater extend, therefore maintaining a load less efficiently than normal ligament. Ligament scars have also inferior creep properties, creeping twice as much as normal ligaments during cyclic and static loads that are only a fraction of their failure loads. Failure behaviours of healing ligaments do not recover with injured complexes being weaker (50% of normal failure loads), less stiff and absorbing less energy before failure than healthy ligaments.

Biomechanically, ligament recovery or healing in the long term may be dependent on a number of variables including the size of the initial gap, whether contact exists between the torn ligament ends and to what degree of joint movement they are subjected.

Many different strategies have been employed to heal ligaments back to their original properties and functions; some such as controlled joint motion, biochemical modulation, surgical repair, grafting, gene therapy and tissue engineering have assisted in our understanding of ligament healing, however, complete ligament healing continues to be elusive and will remain the continuing focus of future investigations (10).

2.2.5 ACL HEALING CAPABILITY

The clinical and experimental studies show that ACL's ability to heal itself is really poor. Healing potential is very limited and takes place only in case of complete mid-substance disruptions of the ACL. Several explanations have been given in order to explain the reasons of this poor healing.

First, although ACL is extra-synovial its disruptions occur very often simultaneously with its synovial surface layer. This has as a result to let free the ends exposed to the space relative vacuum of the joint cavity. This makes ACL to be deficient of any anatomic scaffolding or enclosure of torn ends, prevents the formation of an organizing hematoma and finally disrupts the initiation of the healing procedure. Even in case that a small number of connections will be formed, can be disrupted by the joint movement.

A second explanation refers to mechanical causes. The absence of ACL may destabilize the joint in the level beyond the healing is impossible. Forces on healing tissue may exceed the required limits that a scar is able to be formed.

A third possibility which suggested before many years but has not been proved yet is the potential inhibitory property of the synovial fluid. The torn ends of the ligament ends to the synovial fluid and there interfere with other factors that are important to begin the scar formation (for example blood clotting). However, it is important to make clear that there is big difference between the "no" healing response and the "some" healing response. After the disruption may appear "a kind of improvement". Several studies show that after a human ACL rupture may take place some signs of healing response. For example, has been observed by arthroscopy some fashion of ACL healing in which the torn ends of ACL reattached in a new place in the joint and this provide some stability to the knee. While the full ACL ruptures appear to be little, we can see that the respond of ACL to the partial ruptures appears to be higher. Experiments to the animals show that ACL may have some healing potential which can be facilitated by the presence of a synovial sheath around the healing area. However, the first choice of treatment for ACL ruptures is the reconstruction especially for young people and athletes. (6)

2.3 KINESIOLOGY AND BIOMECHANICS OF THE KNEE JOINT

2.3.1. RANGE OF MOTION

As we discussed in the chapters 2.3.1 and 2.3.2 the movements of the knee joint are flexion, extension, “axial” internal and external rotation. It is very important to answer the question about how much flexion or extension the knee joint does. The range of motion answers this question as it refers to the number of degrees that a joint is able to move. Physiotherapists combined the goniometry with ROM in order to create a diagnostic method which is able to evaluate in which level a joint is functional (by the use of goniometer). There are some standard degrees of freedom that we use to compare the ROM of joints with our measures (14). For the knee joint, the normal accepted ranges are the following ones:

Active flexion of the knee with the hip flexed is 140^0 and with the hip in extension 120^0, meaning that the total ROM of the knee joint is 0-140^0. The passive flexion of the knee joint is greater with 160^0 and can be achieved when the heel touches the buttock.

The knee extension is 0^0 considering the position of reference. However, can be achieved passively another 5-10^0.

The axial rotation of the knee, as already mentioned, is possible only if the knee is flexed. The different ranges of knee flexion are able to change the results during measurement but the accepted average degrees are 30^0 (total range 0-30) for active internal rotation, and 40^0 (total range 0-40) for active external rotation (13). If our findings are lower from the numbers that mentioned above then the subject has hypo-mobility or limited ROM, if the ROM is higher than the normal numbers then the subject has hyper-mobility or excessive ROM of this joint. (14)

2.3.2 FLEXION AND EXTENSION OF THE KNEE JOINT

In this chapter we will define the main movements of the knee joint. Any movement that takes place in the human body can be characterised as active or passive according the source which comes from. Active is a movement that is produced by the muscular system of an individual and passive movement is caused by external forces such as the therapist. Before I will write about the definitions of extension and flexion is really important to write about the reference position. This position is necessary because the human knee is able to provide knee flexion, extension and rotation from different positions such as in standing position, in supine position, prone position, side lying position and sitting and this fact could make difficult to define the flexion and extension without having a common axis of reference.

Reference position is the one that we use as physiotherapists when we provide postural examination by lateral view with the patient standing.

Extension is defined the movement that takes away the posterior aspect of the leg from the posterior aspect of the thigh. A small expansion of this movement called hyperextension and it is the result of another five to ten degrees motion from the reference position.

The active extension very rarely is able to go beyond the position of reference and if so, only slightly can be performed. In active extension the knee is dependent by position of the hip.

Relative extension is defined as the full extension which resulted after knee flexion. This takes place during gaiting when the lower extremity touches the ground in order to prepare the next step.

Flexion can be defined as the movement which brings the posterior part of leg close to the posterior part of femur. (13)

2.3.3 AXIAL ROTATION OF THE KNEE JOINT

The rotation of the leg can only take place with the knee being in flexion. In order to measure active axial rotation the patient will sit in the edge of the table with the legs hanging down with the toes being slightly outwards (figure 11).

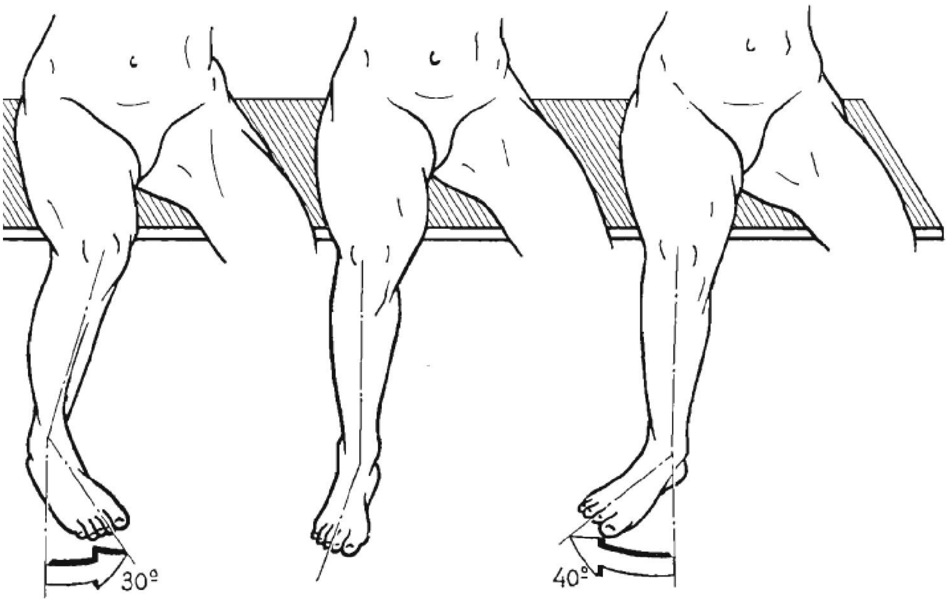


Figure 11 – Axial rotation of the knee (13)

The active internal rotation is the movement that brings the big toes to face each other (medially) and has important role in adduction of the foot.

The active external rotation is the movement that brings the calcanei of each foot to face each other resulting to face the toes of each foot laterally and has important role in abduction of the foot.

The passive internal rotation has only one way to be measured and this is when the patient is prone with the knees flexed. The therapist grasps the patient's foot with both hands and turns it in the way that the toes will face medially for passive internal rotation and laterally for passive external rotation.

There is one more type of axial rotation and called automatic. The automatic axial rotation while is active can not be controlled by the individual and is connected with the beginning of flexion and the ending of extension of the knee. When the knee is extended the leg turns to external rotation and when the knee is flexed the knee turns to internal rotation.

The range of motion (ROM) of the knee joint will be referred in the next chapter. (13)

2.3.4. MUSCLES ACTING AT THE KNEE JOINT

As already mentioned the motions of the knee joint are flexion, extension, medial and lateral rotation. In this chapter we will define which muscles are responsible to produce these motions of the knee joint.

The responsible muscle for the extension of the knee is quadriceps femoris. This muscle counteracts the effect of gravity and this makes quadriceps to be three times more powerful than the knee flexors. When the knee is locked quadriceps does not undertake the role to maintain the erect posture but undertakes the role to prevent a possible fall after knee flexion. The name of this muscle defines its structure as quadriceps has four “heads” (in Greek called “tetrakefalos” meaning four head muscle) which are sharing the same common tendon which is inserted in the tibial tuberosity. The three “heads” are monoarticular are medially the vastus medialis, laterally the vastus lateralis and in the middle the vastus intermedius. The fourth “head is biarticular and called rectus femoris.

Six muscles are responsible for flexion of the knee joint.The three of them called hamstrings and are the biceps femoris, semitendinosus, semimembranosus and the other three are gracilis, sartorius and popliteus. All these muscles are biarticular except the short head of biceps and the popliteus.

The knee flexors undertake also the role of rotation of the knee. We can characterise them in two groups according to their insertion. The biceps femoris and tensor fascia latae (has the role of knee flexor and external rotator only when the knee is flexed), are attached laterally and as a result they serve as external rotators. Sartorius, semitendinosus, semimembranosus, gracilis and popliteus are medially attached and as a result they serve as internal rotators. The following table contains an overview of all the muscles that are acting at the knee joint (1).

Movement	Degrees Possible	Primary Muscles Producing Movement	Secondary Muscles Producing Movement	Comments
Extension		Quadriceps femoris	Weakly: tensor of fascia lata	Ability of quadriceps to produce extension is most effective when hip joint is extended; flexion diminishes its efficiency.
Flexion	120 (hip extended) 140 (hip flexed) 160 passively	Hamstrings (semitendinosus, semimembranosus, long and short head of biceps)	Gracilis, sartorius, gastrocnemius, popliteus	Normally, role of gastrocnemius is minimal, but in presence of a supracondylar fracture it rotates (flexes) distal fragment of femur.
Medial Rotation	10 with knee flexed 5 with knee extended	Semitendinosus and semimembranosus when knee is flexed; popliteus when non bearing knee is extended	Gracilis, sartorius	When extended knee is bearing weight, action of popliteus is laterally rotates femur; when not bearing weight, popliteus rotates patella medially.
Lateral Rotation	30	Biceps femoris when knee is flexed		At end of rotation, with no opposition, tensor of fascia lata can assist in maintaining position

Table 1. Overview of muscles acting at the knee joint. (1)

2.3.5. LOADS OF THE KNEE JOINT

The knee joint interconnects the two longest levers of the human body, the femur and the tibia. These two bony-levers create a very high potential for the torque development in the knee and in combination with its weight bearing role and the muscles acting on it, results to the great loads that our knee joints have to handle through daily activities. This chapter will present an analysis about the loads which act on the knee during extension, flexion and rotation.

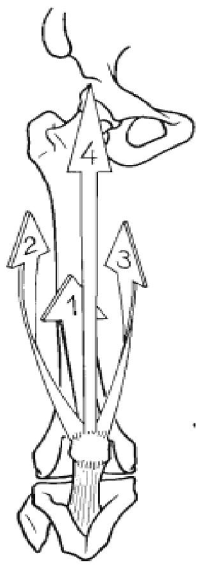


Figure 12 The muscle bellies of Quadriceps (13)

As already mentioned the quadriceps muscle has three monoarticular bellies, the vastus intermedius (1), the vastus lateralis (2) the vastus medialis (3), and a fourth biarticular the rectus femoris (4) (Figure 12). The three monoarticular vasti bellies while act only as extensors they exert a component of force sideways. The vastus medialis is more distally than lateralis but lateralis is more powerful than the medialis and this leads to check lateral dislocation of the patella. If these vasti muscles are well balanced during a contraction the result will be an upward force along the axis of the femur but if medialis is deficient then cannot compete the forces that are produced by lateralis and this mechanism explains why the dislocations of patella occurs always laterally. However, the strengthening of vastus medialis can fix this imbalance.

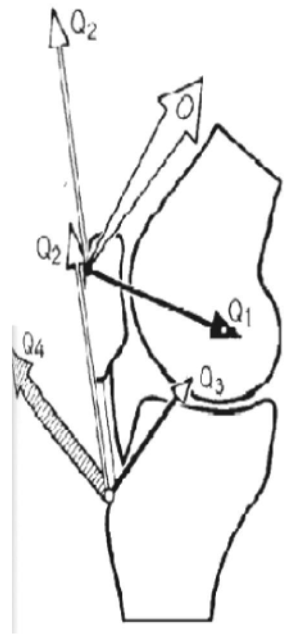


Figure 13 - Forces acting at the patella (27)

The patella is under the extensor tendon of the knee and undertakes the very important function to increase the effectiveness of the quadriceps muscle by shifting the line of action of its muscular pull. This can be better understandable if we will analyze the figure 13. The force Q is produced by the quadriceps muscle and be analyzed to the vectors Q_1 and Q_2. The vector Q_1 represents the force which acts towards the axis of flexion and extension resulting to press the patella against the femur. The vector Q_2 represents the force represents the force which acts along the line of the patellar ligament. The force Q2 is applied on the tibial tuberosity and can be analyzed further to the forces Q_3 and Q_4 which are perpendicular. The force Q_3 is applied towards the axis of flexion and extension and results to keep the femur and tibia together. The vector Q_4 represents the force, which is the effective component in extension and results to move the tibia in anterior direction underneath the femur. (13)

When the knee is in extension the compressive forces are small because the tension in the group of muscles act close and perpendicular to the joint. As the knee flexes more the compressive forces increase because the orientation of the forces changes and the tension requirement of quadriceps in order to keep the body position increases. During the stance phase of gait the compressive forces acting in the tibiofemoral joint are about three times greater than the body weight and are increased up to four times our body weight during stair climbing. During the stance phase the medial tibia plateau is responsible to bear most of this load especially when the knee is in extension. The lateral tibia plateau undertakes to bear the loads during the swing phase which are much smaller. This is logic if we think that the surface area of the medial plateau is about sixty percentage more than the lateral one and the tibial plateau has three times thicker articular cartilage. (27)

2.3.6. LOADS OF THE ANTERIOR CRUCIATE LIGAMENT

As already have been referred the ACL is composed by two bundles, the anteromedial (AM) and the posterolateral (PL). The AM bundle has length around 38mm.The PL bundle is not so well studied as the AM bundle but the measurements in fifty cadavers gave an average of 17,8mm. The two bundles have similar diameter and their alignment changes during the knee movement from extension to flexion. When the knee is in zero degrees the two bundles are oriented parallel (figure 14) with their femoral insertions been oriented vertically (figure 15). When the knee is moving into 90 degrees of flexion, the site of AM bundle which is inserted on the femur rotates posteriorly and inferiorly. The femoral insertion of PL bundle rotates anteriorly and superiorly in contrast to the AM bundle.

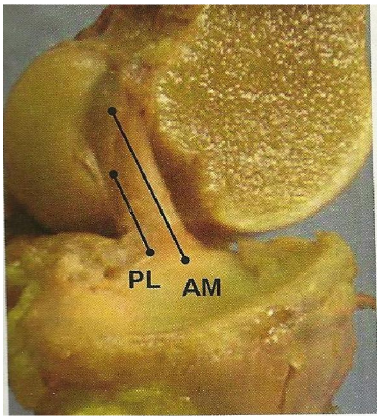


Figure 14 -Anteromedial and Posterolateral ACL bundles. (4)

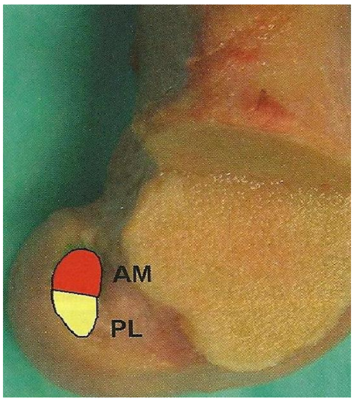


Figure 15-The femoral insertion sites of ACL are oriented vertically

This change in alignment of the insertion sites leads to a horizontal plane of insertions for the ACL bundles when the knee is in 90 degrees of flexion (figure 16). It also causes also the crossing pattern of the ACL bundles which means that the AM and PL bundles twist around each other and become crossed (figure 16). This twisting pattern in combination with the different length between the two bundles has implications for the tensioning pattern of the overall ligament and each individual bundle.

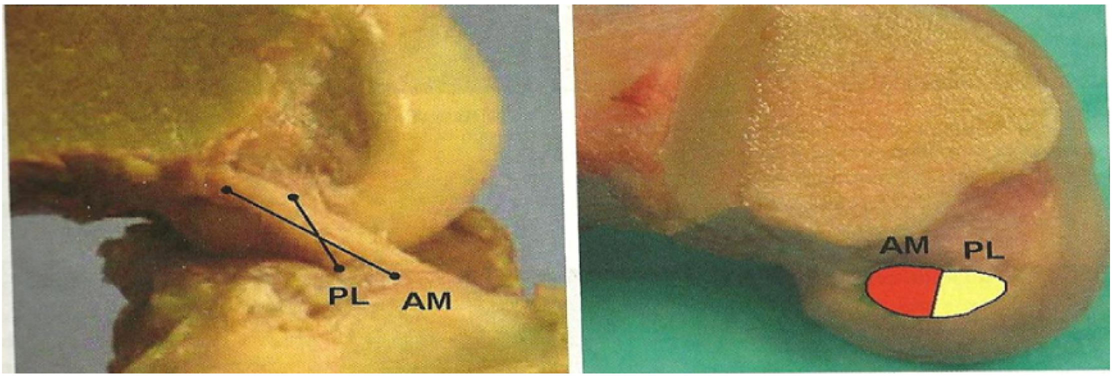


Figure 16-crossing pattern of ACL bundles during 90 degrees knee flexion. The insertion sites are oriented horizontally. (4)

Gabriel et al with their study measured forces in each bundle during an anterior load of 134N over several flexion angles and as well for combined rotator load of 10Nm valgus and 5Nm tibial torque. The result appears the PL bundle to be tightest in extension (in situ force of approximately 67N) and then relaxes as the knee becomes flexed. The AM bundle is more relax in extension in comparison to the PL bundle and the maximum AM bundle tightness appears to be when the knee approaches the 60 degrees of flexion (in situ forces around 90N). The PL bundle becomes also tighten when external and internal rotation takes place.

The first biomechanical studies mainly focused about how the ACL is functioning in order to resist the anterior tibial translation. When was applied a 110N anterior tibial load, the ACL demonstrated high in situ forces between 0 and 30 degrees flexion and the maximum result occurred when the angle was at 15 degrees. Between 60 and 90 degrees in situ forces were at their lowest point with the 90 degrees angle been the minimum amount. (29)

Recent studies focused more to the evaluation of each ACL bundle individually in anterior-posterior translation. The given results shows that the AM bundle has relatively constant levels of in situ forces during knee flexion, where the PL bundle is more unpredictable with high in situ forces at 0, 15 and 30 degrees of flexion but quickly decreasing in situ forces beyond this angle. (22)

The AM and the PL bundles contribute to the rotation stability of the knee at specific angles. Gabriel et al (9), analyzed in his study a combined rotator load of 10 Nm valgus and 5Nm internal tibial torque at 15 and 30 degrees of flexion. The situ forces in PL bundles at 15 degrees angle were 21N and at 30 degrees angle were 14N. The AM bundle at 15 degrees flexion showed in situ forces 30N and at 30 degrees flexion 35N.

The last studies in the field of ACL biomechanics focused to the rotational stability in the ACL during low and high demand activities such as walking, running and cutting. Studies in the living organisms compare normal and ACL deficient subjects during four phases of walking. The result shows that the ACL deficient knee has different positioning than a normal knee. The healthy ACL maintains a balance of rotation during the interval of swing phase to heel strike. The ACL deficient knee appears to have increased internal rotation during these phases of walking which is sustained through the stance phase.

MRI based Studies in vivo kinematics focused on the normal ACL during weight bearing knee flexion. As the flexion increases the twisting of ACL increases as well. When the full extension takes place ACL twists internally by approximately 10 degrees. When the knee moves to 30 degrees flexion the ACL twisting increases to approximately 20 degrees and when the knee is flexed in angles 60 to 90 degrees the ACL twisting increases to approximately 40 degrees. A second very important fact is that when the flexion angle increases the same does the lateral angulation of the ACL. In summary the ACL bundles are in cooperation to each other during low and high demand activities, resulting to help the knee joint to maintain the normal position of the tibiofemoral contact against the tensile loads that are applied during the movement. (4)

2.3.7. MECHANISMS OF ACL INJURIES AND SKIING.

The ACL injury is the second most common injury to the knee for skiers. Beginners and generally recreational skiers belong to high risk category of the persons that may experience an ACL rupture. However, the expert skiers appear to be in a lower risk group due to their increased skills, technique and fitness that recreational skiers have not. But why the skiing activity produces so great loads at the knee joints? Before we will analyze the injury mechanics this must be clear. The danger for skiers is the boot which is locked into the ski. The ankle joint inside the boot has very restricted motion and this fact loads the knee as it becomes responsible to provide most of the motions of the lower extremities. Beginners usually set the bindings not very tight and this decreases the damage to ACL but the more advanced skiers in order to be able to perform more aggressive skiing use tighter bindings and this puts the knee at greater risk. The ACL is at highest risk when the knee is in hyperextension or by an accident that makes the foot to point inward such as when the skis get caught in the snow or a tree root, forcing the forward tip of the ski to rotate inward. Even if the ski pops off, the motion of the body will continue forward causing a sudden hyperextension at the knee. This can also caused by a fall during a hard turning or during a collision with another skier. The ACL becomes tight with a quick internal rotation and if will be combined with a sudden jolt can often cause an injury. All these reasons that are written above, we can characterise them as “visible causes of ACL injury” but the real mechanisms that cause these injuries are not visible and takes place within the joint space. (24)

The first injury mechanism is hyperxtension: this can happen after a blow on the anterior aspect of the extended leg which forces the knee into hyperextension. If this force is strong enough it will stretch and will make weaker the posterior capsule leading to be frayed a few of the fibbers of PCL, and then the major injury will occur with rupture of the ACL.

The second injury mechanism is with abduction, flexion and internal rotation: the force that acts here is a kind of subluxating force and usually can take place in football and skiing injuries. The body weight is thrown inward; the femur is in medial rotation and the foot fixed by the ski boot, body weight or some obstruction. This mechanism as a first “step” stretches or tears partially the long superficial and direct deep fibbers of the tibial collateral ligament followed by the second “step” which ruptures the ACL or frays some of its fibbers near the superior insertion, as it becomes stretched over the medial border of lateral femoral condyle that is shifted medially. This mechanism can also cause compression fracture of the lateral tibial condyle but in this case this fracture may be considered as an advantage as the ligaments usually will not be severely damaged.

A third mechanism injury is in adduction, external rotation and flexion: these kinds of injury are not very common but can be seen sporadically in football, motorcycle and skiing accidents. The force is applied near the knee joint to the medial side with the foot been fixed. A pure adduction subluxation injury may result from trauma to the extended knee. If the knee is flexed, the element of lateral rotation may also be present. In this mechanism the fibular collateral ligament gives up first and shortly follows the ACL often followed by the tendon of popliteus muscle. (17)

Coming back to the injuries caused during skiing must be referred that the better the skier knows the technique the lower the risk of the injury will be. Balance exercises and stepping with the skis decreases the danger. Prevention is another parameter that lowers the risks, for example the skier must be aware of the forces that may applied during a fall and how he is able to transform this fall into a safe one. This can be better understandable if we will see the figure 17 below.

Figure 17 – Isolated tear of anterior cruciate ligament during skiing. (24)

This is a classical example (figure 17) of a wrong fall. It’s a possible mechanism that causes an isolated tear of the ACL. The tibia is in internal rotation on the femur. The applied forces are highly increased considering the weight and speed of skier in combination with the two longest levers of human body the femur and the tibia. In this scenario the ACL may be disrupted by avulsion of bone from its femoral or tibial attachment or by a rupture in its mid-region.

The most detailed analysis of the mechanism of ACL injury has been in alpine skiing, where recorder video analysis revealed two potential mechanisms of injury. The most common is the “phantom foot mechanism” that occurs when the skier falls or sits backwards, catching the inside edge of the tail of the ski and this results in internal rotation of the tibia with the knee flexed well beyond 90 degrees. Another common ski injury mechanism occurs with a hard off- balance landing. In this scene the skier's boot pushes the tibia anteriorly on landing and this increases the load on ACL. (24)

2.4 THE PHYSIOTHERAPEUTIC APPROACH

2.4.1 NON OPERATIVE TREATMENT OF ACL

As already mentioned the knee joint has everyday to handle great loads. Before I will write about the management is really important to analyze what exactly is happening after an ACL rupture and how our organism responds to it. The rupture of ACL causes the destabilization of the knee joint, and this fact makes the deficient ACL knee to be an "easier victim" of repeated subluxations. These repeated subluxations may cause to the joint other secondary damages. As a result the dynamic stabilization through the quadriceps and hamstrings is very essential for the protection of the ACL deficient knee. The ACL has not only mechanical role but also has sensory function due to the mechanoreceptors within its substance.

The quadriceps muscle after the ACL rupture is affected to a greater level for the following reasons: firstly, there is post-injury neural inhibition due to the loss of afferent feedback from ACL to gamma motor neurons. Secondly, there is adaptation which leads the quadriceps to avoid the normal pattern of gait in order to prevent anterior subluxation. This adaptation unloads the injured lower extremity and is possibly the most important reason that causes weakness of quadriceps in ACL deficient patients. In contrast, evidences have shown that the hamstrings muscles are recruited in weight-bearing subconsciously in order to resist the anterior forces (25). This neural inhibition of quadriceps in combination with the poor coordination activation within the hamstrings explains the neural aspects of mechanical output abnormality. The marked weakness of the quadriceps reduces the functional ability of the muscle during walking and prevents the knee from its normal function.

Now that is clear the organism response to ACL injury we must think about the answers that the therapist must give, in order to help the patient. Exercises in ACL deficient patient are aiming to the improvement many different aspects of muscle properties including coordination with other muscles, strength, reflexes and endurance. The main role of training program consists of functional exercises that are able to re-educate the neuromuscular coordination combined with compensatory muscle activation strategies which will help the patient during the loading of the injured knee. It is clinically proved that patients with greater than normal strength are able to reduce the abnormalities caused by the ACL rupture during low and high demand activities, in a higher level than patients with low or normal strength (20).

The increase of hamstrings strength plays also very important role and this can be done by functional exercises including strengthening, stretching, plyometric drills paralleled a decrease in peak landing forces and hence safer landing. Our aim is not only to train the group of hamstring muscle group but also to increase the hamstring (H) quadriceps (Q) strength ratio (H:Q) in order to boost the dynamic control of the ACL deficient knee. This improvement is very closely connected to bring back the patient to physical activity after the ACL injury and the strength of both muscle groups of the thigh has very important functional role. (21)

The general goals of the rehabilitation program include the good functional stability, the optimization of the functional level, sensory-motoric stimulation training and to minimize the chances of re-injury. The well organization of the rehabilitation plan is very important. There are three major phases that the therapist has to work according to gain the best possible results. The first phase called acute phase. This phase must be focused on pain management to relief the patients symptoms, range of motion, regaining ambulation, and retarding atrophy.

The second phase is the advanced phase, which is focused to increase patient’s strength and endurance and the third and final phase, called “the return to play phase” in which the final neuromuscular optimization of the knee function takes place (5)

Considering our rehabilitation plan we must mention that a complete rehabilitation program must focus also to the healthy side. This is very important because the majority of the patients who choose the conservative approach as treatment follow a more conservative lifestyle mostly due to the fear of injury. This reduction of physical activity affects and the healthy side of the body and the come back to high demand activities is not easy. Our therapeutic answer to that is by applying to the patient close kinetic chain exercises with great hip flexion angles. This is an evidence based method which re-educates coordination and physiological properties with safety and can be combined with open chain single joint exercise for more specific effects.

Reinforcement of synergists such as tibialis anterior, soleus and muscles of the deep posterior compartment muscle group is a choice that will help hamstring muscle group to control the knee instability as they have the potential to control the anterior translation and tibial medial rotation. (18)

2.4.2 PREOPERATIVE REHABILITATION

This chapter refers to the patient that decides to reach the surgical approach and how the physiotherapist can prepare the patient in the pre-surgical period. The first 72 hours after the injury there is an immediate inflammatory response. The symptoms of this acute inflammatory phase include redness, swelling, pain and loss of function. The physiotherapeutic intervention during this phase aims to:

- Reduce pain
- Limit and reduce inflammatory exudates
- Reduce the metabolic demands of tissue
- Protect newly damaged tissue from further injury
- Protect the newly forming tissue from disruption
- Promote new tissue growth and fibbers realignment
- Maintain general levels of cardiovascular and musculoskeletal activity.

In order to achieve all these aims referred above, we may use the PRICE principle.

Protection: the aim is to protect the tissues from further mechanical damage and this can be achieved by the use or protective modalities such as crutches, slings and braces.

Rest: in the very early stage 0-48 hours after the injury the patient must be encouraged to rest the injured area completely in order to prevent increased bleeding and further inflammatory response.

Ice: the use of cryotherapy is to cool the affected tissues and reduce the metabolic demands of the neighbouring cells. This helps more cells to survive the ischemic phase and this fact minimizes secondary tissue damage. Maximum effect is obtained with a tissue reduction approximately 10-15 degrees, duration 20-30 minutes every 2 hours.

Compression: will be used to the affected tissue and adjacent areas in order to reduce exudates, protect tissues and possibly reduce pain. The theory behind this therapeutic step is that the hydrostatic pressure of the interstitial fluid is raised, thus pushing fluid back into the lyph vessels and capillaries reducing the amount of fluid that can seep out into surrounding tissues. Compression can be used in combination with cryotherapy by using an ice compression device such as cryocuff which allows cooling and compression, simultaneously.

Elevation: this step aims to reduce bleeding and swelling and suggests the elevation of the injured area above the level of the heart. Because the elevation of the injured lower extremity is not so easy the patient is advised to elevate the affected limb intermittent during the day when possible and to remove compression at this time. The affected lower extremity must be supported adequately with the use of pillows or a sling.

The PRICE treatment lasts for 7-10 days or can be continued and combined with non steroid inflammatory drugs such as ibuprofen.

The next therapeutic step is that the therapist has to apply preoperative rehabilitation protocols. This is a very important step considering that one of the most common complications following ACL reconstruction is the loss of motion, especially the loss of extension. This happens due to weakness of the quadriceps muscle, anterior knee pain and neural inhibition which is caused by the lost mechanoreceptors of the ruptured ACL and results to lock the knee in a specific angle of flexion. The time that the surgery will take place has crucial meaning because the timing of ACL surgery has a significant influence on the development of postoperative knee stiffness. Before many decades was believed that the best possible timing for surgery was by the first two weeks post-injury but nowadays studies show that the best possible option for the ACL injured patient is firstly to participate to a pre-surgical rehabilitation program and then to go operative. The highest common incidence of knee stiffness occurs if the ACL reconstruction is performed when the knee is swollen, painful and has a limited ROM. This fact makes even more important the preoperative rehabilitation phase that a physiotherapist must plan for his patient. The “ACL reconstruction preoperative plan” has the following goals:

- Control pain and swelling
- Restore normal range of motion
- Develop muscle strength sufficient for normal Gait and ADL
- Improve the gait pattern to be normal or at least near to it
- Mentally prepare and educate the patient for surgery

The following guidelines will be applied in order to prepare the knee for surgery and to achieve the goals that I mentioned above:

Immobilize the knee: braces and crunches will be used until the patient regains a good neuromuscular control of the affected lower extremity. The patient must be encouraged to bear as much weight on the leg as is comfortable.

Control pain and swelling: cryotherapy combined with compression and anti-inflammatory drugs help to achieve this goal.

Restore normal ROM: the therapist must apply exercises which will result to regain the lost ROM our patient and must begin as quickly as possible. Exercises such as passive knee extension and flexion, heel slides or prone hang exercise may be used.

Develop muscle strength: this therapeutic step may begin when our patient has already approximately 90-100 degrees of flexion. A stationary bicycle is a good choice and can be applied two times a day for 10-20 minutes to help increase muscular strength, endurance and to maintain the achieved ROM. Swimming and theraband exercises may also be applied.

Mental preparation and education: this step includes the patient's education of what to expect from the surgery, to arrange with the physical therapist the postoperative rehabilitation units, to arrange with family and friends how to help the patient after the operation and also to help the patient understand the rehabilitation phases after the surgery. (31)

2.4.3 PREOPERATIVE TIPS FOR PATIENTS

The role of physiotherapist is not only to help the patient to be healed again but also to guide the patient about how to do his ADL activities easier and safer during this "injured phase" of his life. Some of the following tips can make the patient's life easier until to become fully functional again and also to prevent further injuries of the already affected limb or other parts of the body. The therapist may advise or teach the patient to:

- Put a plastic chair into shower to sit when bathing
- When bathing keep also 1-2 towels that can be used on the floor. Crunches can slip and cause further damage to your affected limb or other part of the body. Anti-slip carpets may be a good solution.

- If you have to do any different task such as to change a lamp or to reach something that is high enough, ask the help of someone else.
- Keep and ACL journal to help keep you motivated and see your progress.
- If you live alone make copies for your home keys and give to trusted persons such as good friends and family and have always a mobile phone close to you.
- If you sleep with someone else such as your wife use the side of the bed that will keep your injured extremity out of contact with the other person.
- Teach the patient about how to climb up and down the stairs by using crunches and also advise fim to be always close to the lateral part of the stairs so in case of lose balance to be able to hold and avoid the fall.

It is also possible that some patients become psychologically tired of this "inactive way of life" until to be fully functional again. The therapist must find ways to boost their psychology and keep them motivated. (33)

2.5 DIAGNOSTICS AND SURGICAL APPROACH

2.5.1 DIAGNOSTICS

The majority of orthopedists usually have the necessary skills in the diagnosis of ACL injuries. Some diagnostics that are commonly used are the Lachman testing which considers the most accurate physical exam for ACL tear and can be used to a non anesthetized patient. KT-1000 in the hands of experienced doctors is a high diagnostic accurate method of ACL tear examination. Magnetic resonance imaging (MRI) is also a good test but is not as accurate as it is commonly thought, as it is difficult to distinguish the partial from complete tears. Very high diagnostic accuracy can be obtained by the synthesis of anamnesis, the physical examination, MRI and examination under anesthesia. Arthroscopic surgery can also be used as it is an operative method that uses and endoscope which permits the doctor to evaluate the damage in the joint. However, my aim in this chapter will be to present from physiotherapeutic point of view a great number of manual clinical tests for the musculoskeletal system that are suitable for ACL evaluation.

Lachman test (Figure 18): we ask the patient to lie down in supine position; the knee joint must be flexed 15-30 degrees. Therapist's cranial hand stabilizes the distal part of femur and the caudal hand pulls the proximal part of tibia to anterior direction while the knee flexor muscles and the quadriceps are fully relaxed. During the performance of this test we evaluate the presence of end point during the tibial anterior pulling. If appears hard end point within 3mm then the ACL is present and if the hard stop appears between 3-5mm the ACL is relatively stable. If there is no end point or exists but is very soft then the test is positive and the therapist is sure for the damaged ACL. (15)

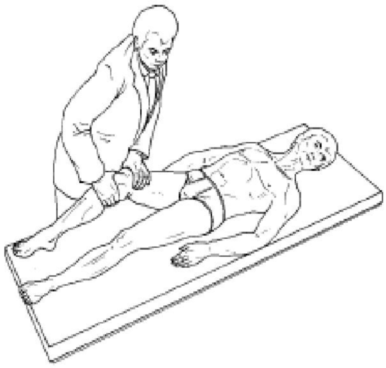


Figure 18 –Lachman test (15)

Prone Lachman test (fig 19): As the name of this test declares the patient is in prone position. The therapist is on the side of the healthy lower extremity and uses the cranial hand to grasp the distal part of femur. The caudal hand is on the proximal part of tibia and the patient's ankle is stabilized in the therapist's axilla. The therapist stabilizes the thigh and presses the tibia to anterior direction in relation to the femur. The assessment is the same with the previous Lachman test. (15)

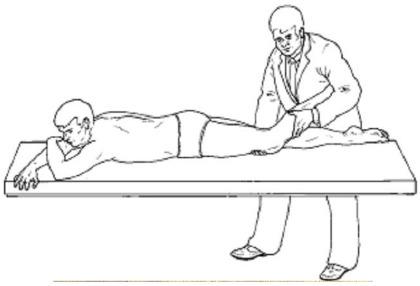


Figure 19 -Prone lachman test (15)

No touch Lachman test (fig 20): in this test the therapist is only observer and the actions should be taken by the patient. The patient is supine and grasps the thigh of the suspected ACL insufficient lower extremity with both hands. Then the patient is told by the examiner to provide a slight knee flexion and to raise the extremity off the table keeping the same flexion angle. The therapist observes during the movement and if there is significant anterior displacement of the tibial tuberosity then the ACLand the MCL are not intact. (15)

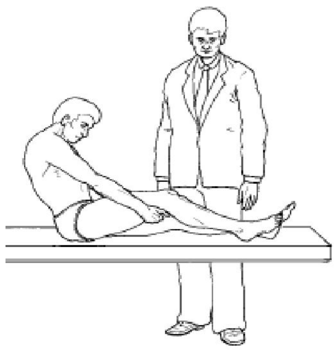


Figure 20 – No touch lachman test (15)

Active Lachman test: the patient is supine. The therapist places the cranial hand in such a way that will create a slight flexion to the injured extremity and to touch the distal part of femur to the healthy extremity. The patient then is told to raise the ankle of the injured extremity by providing knee extension. During the assessment the examiner observes the migration of the tibial head between the healthy and injured extremity. If ACL is intact then migration will be slight, if it is significant the difference then the ACL no longer limits the displacement which is produced by the quadriceps and the test is positive. (15)

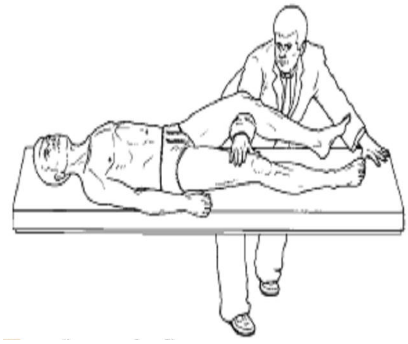


Figure 21 – active Lachman test (15)

Anterior Drawer test in 90 degrees flexion: This is a passive test with the patient in supine position, hip flexion 45 degrees and knee flexion 90 degrees as the name of the test declares. The therapist sits on the end of the table in a way that patients foot is stabilized under examiner buttocks. The examiner grasps the tibial head with both hands, asks the patient to relax the knee flexors and then pulls the head of tibia anteriorly in relation to femur. If the knee is with 15 degrees external rotation the examiner is able to evaluate the anterior and medial stability of the knee and with the knee with 30 degrees internal rotation is able to evaluate the anterolateral stability of the knee. We evaluate the anterior tibial displacement and if exists a soft end point or not this means that the test is positive. (15)

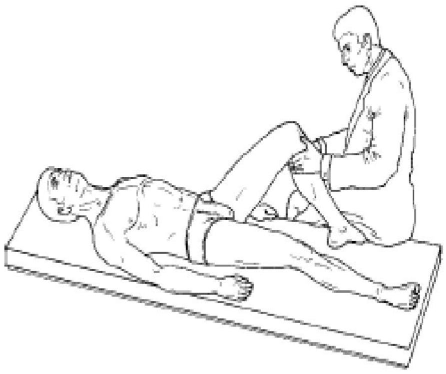


Figure 22 – Anterior drawer test (15)

Jakob maximum drawer test: the patient is supine in the same position with active Lachman test but the knee is more flexed approximately 50-60 degrees. The examiner's position is the same and the principle of the test is the same of anterior drawer test. The difference is that the examiner will cause maximum anterior subluxation to the tibial head by using his forearm.

Figure 23- Jakob maximum drawer test (15)

The assessment is exactly the same with the anterior drawer test in 90 degrees flexion. (15)

Pivot Shift test: the patient is supine and the examiner on the side of the injured lower extremity. The cranial hand immobilizes the patient's lateral femoral condyle in a way that its thumb been able to palpate the proximal part of tibia or fibula. The therapist's caudal hand holds the patient's lower leg in internal rotation and abduction in order to create valgus stress. The evaluation takes place when the extremity is moved from extension into flexion from this starting position and in case that the test is positive then the valgus stress will cause tibial subluxation anteriorly with the knee still is in extension. (15)

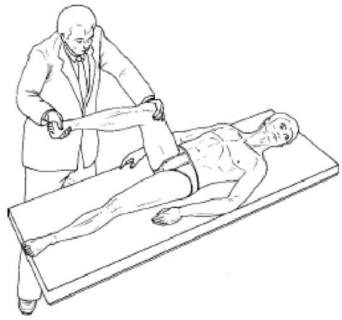


Figure 24-Pivot shift test (15)

Jakob graded pivot shift test: the procedure is similar with the previous test. The difference here is that the examiner's cranial hand will be placed in the proximal part of tibia. The instability of the lower leg will be evaluated not only in internal rotation but also in the neutral position and in external rotation. The evaluation of this test has four grades. Grade I is only when the test is positive in maximum internal rotation. Grade II is assessed when the result is negative in external rotation but position in internal rotation and neutral position. Grade III is assessed when the test is positive particularly in external rotation and clearly positive in neutral position. Grade IV is when the posteromedial and lateral structures are damaged in addition to ACL, so all the motions will appear positive signs. (15)

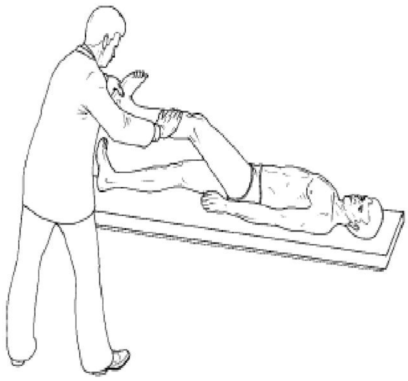


Figure 25 – Jakob graded pivot shift test (15)

Medial shift test: patient is supine and the therapist is standing on the side of the injured extremity. The examiner's caudal hand is placed slightly distal to the medial joint cavity and the cranial hand on the lateral side of the thigh. The examiner uses the caudal hand in a way to apply valgus stress to the knee and presses medially with the cranial hand. If there is tear of ACL the tibia will be displaced medially till the

Figure 26 – Medial shift test (15)

moment that the intercondylar eminence becomes in contact with the medial condyle of the femur. (15)

Soft pivot test: Patient is in supine position with the hip in abduction and the foot in neutral or external rotation. The examiner's caudal hand grasps the patient's foot and the cranial hand the calf. The therapist provides 3-5 cycles of normal flexion and extension in the knee joint in order to reduce the reflexive muscle tension. After these cycles the cranial hand applies a mild anterior stress. The test is positive if the mild anterior stress will cause slight subluxation when the knee approaches extension. (15)

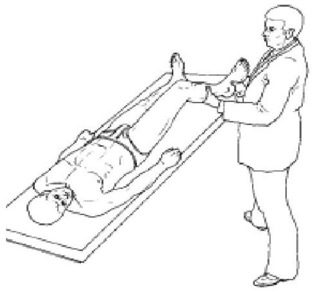


Figure 27 – soft pivot test (15)

Loose test: patient in supine and the therapist stands on the injured side. The examiner's cranial hand grasps the knee from the lateral side with the thumb posterior to the head of fibula and the rest fingers resting on the patella. The caudal hand grasps the ankle from the proximal part and medially. The examiner causes slight external rotation to the lower leg and the test is positive if there is visible and palpable anterior subluxation of the tibial head when the knee is extended from 40-50 degrees of flexion. (15)

Figure 28 – Loose test (15)

Slocum test: the patient is in side lying position on the healthy side with the hip and knee in flexion to hold the injured upper extremity in a slight internal rotation with the foot to the most possible extension. This position creates a slight valgus stress. The examiner stands at the back of the patient and grasps the patient's thigh with the cranial hand and perpendicular places the caudal hand in a way that the index fingers to palpate the head of fibula. When the knee approaches extension of there is ACL tear the lateral tibial head will subluxate anteriorly. (15)

Figure 29 - Slocum test (15)

Arnold crossover test: the patient is in standing position and crosses the healthy leg over the injured one. The examiner places his ankle in patient's injured foot in order to immobilize it. The test is positive if the patient will report a very unpleasant feeling and will give the description that the knee is going to dislocate.
This test is considered very accurate for muscular patients. (15)

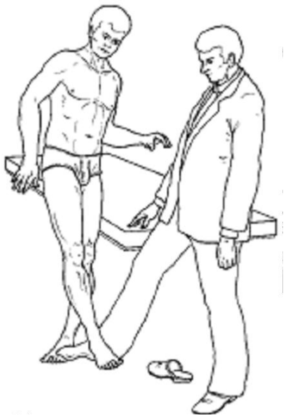


Figure 30 – Arnold crossover test (15)

2.5.3 GRAFTS

As already mentioned the ruptured ACL has very poor healing capability and in case of rupture needs to be replaced. This replacement is called ACL reconstruction and the surgeon is using a graft to replace the destroyed ACL. The material which is used for this transplantation is an autograft or an allograft. Autograft is defined as transplanted healthy tissue from one part of the body to another in the same individual. Allograft is the transplant of an organ or tissue from one individual to another of the same species with a different genotype (genetic constitution – genome of a cell). Allografts account for many human transplants such as those from cadaveric, living related or leaving unrelated donors. In the mid of 80s were very popular the synthetic grafts. These synthetic grafts were made from materials such as polyester and carbon fibres but the problem was not only that their failure was very high, but also other significant issues such as biocompatibility, for example septic arthritis caused by Gor-Tex synthetic graft, or the organism could recognize carbon fibre grafts as a "foreign body-attacker" leading to a severe sterile synovitis that resembled a septic arthritis.

Nowadays the choices are between autograft and allograft with the autograft been more resistant against forces that are acting on it. The most important factor to choose the correct graft is the graft strength. The surgeons anymore are able to use grafts which have greater strength than the initial ACL. The strongest available grafts are the four-strand hamstring autografts, tibialis, quadriceps tendon, BPTB (bone-patellar tendon-bone) and Achilles tendon. (4)

2.5.4 THE SURGICAL APPROACH

Before one decade there were two types of surgery, open and arthroscopic. Nowadays, the arthroscopic surgery is the best option. The surgical procedure has two aims:

- Harvesting in which the graft will be taken from the patient's body and then
- The ACL reconstruction in which the surgeon will attach the graft to the points which the ACL was attached before the rupture.

The arthroscopic surgery uses a pen shaped arthroscope to which a tiny video camera is attached. It contains optical fibers, a light source and lenses that can magnify images 25 to 30 times. The camera attached to the end of arthroscope sends images to a video screen. The surgeon looks at the screen and is able to get an exceptionally clear view of the inside of the joint. Because the procedure can be done using an arthroscope, and using small specialized instruments without big incisions and excessive trauma to the tissues, it is really well suited to be an outpatient procedure (one that does not require an overnight stay at the hospital). Most ACL reconstructions are commonly performed as outpatient procedures. However, many doctors prefer to keep patients overnight in the hospital following surgery. Before actually reconstructing the torn ligament, the surgeon uses the arthroscope to carefully survey the whole joint, looking at and evaluating each key structure. During this portion of the procedure, any additional damage to any of the other knee structures can be identified, and where appropriate, is corrected surgically.

Each of the available ACL graft tissue choices requires a unique harvesting technique. Furthermore, there are usually different methods used for fixing the grafts in the bone tunnels, depending on the characteristics and properties of the tissue selected. Because of these differences in graft techniques, the type of surgery chosen is frequently made by the surgeon based on his or her experience and comfort level with the chosen technique. The common steps of harvesting are:

- The surgeon creates the appropriate incisions
- Tendon exposition
- Tendon release
- Stripping of the tendon
- Preparation of the graft (sizing)

The steps of surgery reconstruction are:

- The surgeon inserts the arthroscope
- Creation of tibial tunnels (transtibial technique)
- Creation of femoral tunnels
- Graft fashioning
- Graft placement
- Graft tensioning and fixation

There is one case, that the patient has to be treated surgically but there is no need of a new graft to be placed. This case is very rare and refers to the case of avulsion fracture. This means that the ACL has no tearing but the small bone point which connects the ACL ligament with the bone has been torn away. The surgeon has to reattach (fixation) this small piece of bone that after its torn away remains connected with the ACL.

After all the surgical principles that I mentioned I will describe two common ACL surgical procedures in order to connect the theory with the practice.

Central Quadriceps Free Tendon (CQFT) for ACLR:

The middle third of quadriceps tendon has been used for more than 25 years. This kind of graft has three very good advantages: Firstly, it has very good stability results; secondly the patients experience less pain than other alternative surgical options and finally the patient may start the rehabilitation program earlier compared to other grafts. The procedure starts with the CQFT harvesting. To harvest the CQFT needs a small incision 1.5-2 inches which takes place above the middle and proximal part of patella (Figure 31). It is preferred that the graft will be taken from the medial part of the quadriceps tendon. Then second incision is placed in the place 9 to 11 cm laterally to the first incision at the level of proximal patella. After these two incisions, the tip of a haemostat (a surgical instrument that stops bleeding by clamping a blood vessel) is placed in the desire depth under the CQFT. The haemostat spreads to separate the CQFT posterior fibbers within the substance of the quadriceps tendon. After this separation the

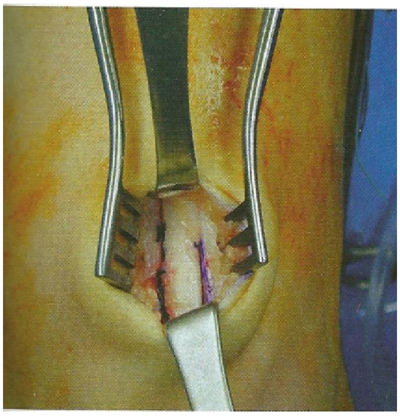


Figure 31 – Exposure for quadriceps tendon graft harvest (4)

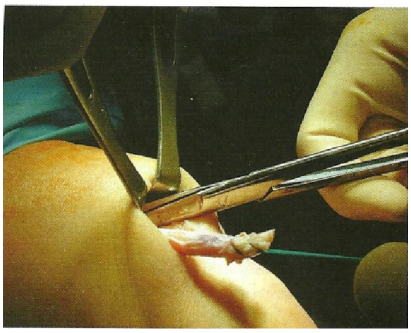


Figure 32 – Release of the proximal end of the quadriceps tendon graft (4)

surgeon will use scissor to dissect the tip of the graft at its insertion into the patella and release carefully by keeping intact the surrounding quadriceps tendon. The graft must be released proximally 7 to 8 cm from distal end (Figure 32).

Now that the CQFT graft is out the surgeon will place on it whipstitches in each end and then will determine the size of graft and tunnels by using sizing canulas. The tunnels will be drilled in the tibia and femur. The graft now will be marked at the point that will end the femoral socket; preferably an endobutton will be applied on the femoral end (Figure 33). (4)

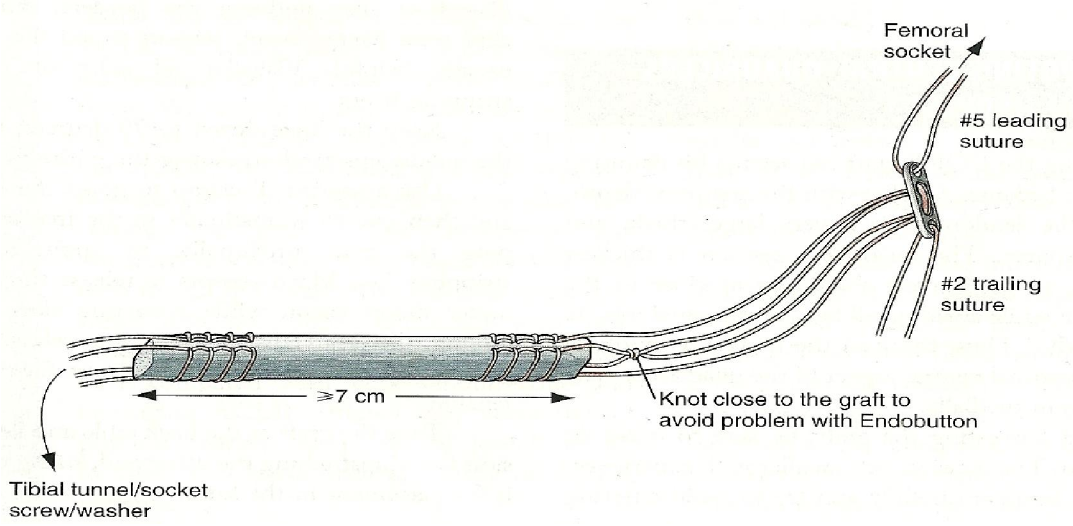


Figure 33- Quadriceps Tendon with Endobutton. (4)

The surgeon has now to tie the sutures with an endobutton with the knot just adjacent to the tendon graft. The graft is pulled into the femoral and tibial tunnels. Tibial size needs fixation to be stable and this will be provided by a bio-interference screw that is one size larger than the tunnel size. When the whole graft is in the knee and keeping its tension the surgeon flexes the patient’s knee 20 degrees and inserts the bio-interference screw over a guide-wire that is held in place just anterior to the graft in the tibial tunnel. Extra fixation can be obtained with an extra button over the tibial tunnel (figure 34). (4)

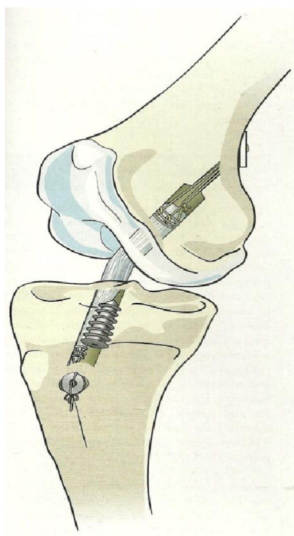


Figure 34 – Central quadriceps free tendon reconstruction. (4)

Hamstring ACLR with a Quadrupled or tripled semitendinosus tendon graft:

The patient is in supine position under general or spinal anaesthesia. The knee is fixed at 90 degrees of flexion and a tourniquet will be used to control venous and arterial circulation of the extremity. The surgeon is ready to harvest the graft by providing a 5cm vertical incision below the medial joint line. When the graft is out the arthroscopy will be used for the reconstruction. One anterolateral incision is provided for the arthroscope. The principle of this technique is the same with CQFT. Femoral and tibial tunnels will be created. The tibial tunnel is in 70 degrees inclination and the femoral tunnel is drilled for a right knee in the 10:30 position. The femoral fixation will take place with the use of endobutton which will be connected to the graft and the tibial fixation will be obtained by an 8mm titanium Fastlok device which will also be connected to the graft with a quadrupled polyester tape. A bone block will be pressed to fit in the tibia tunnel (figure 35). (4)

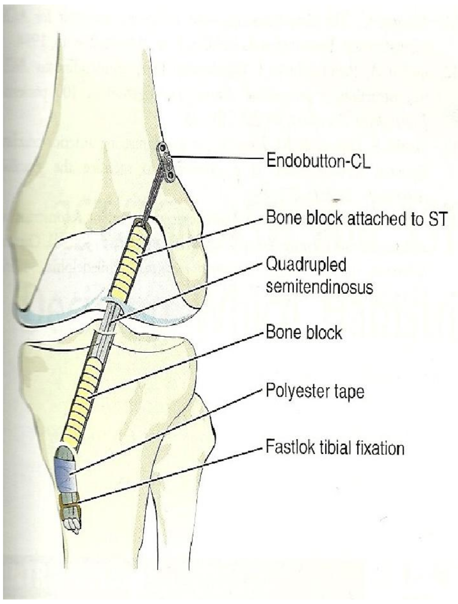


Figure 35 – Diagram of quadrupled semitendinosus with bone anterior cruciate ligament reconstruction. (4)

2.5.5 COMPLICATIONS

After an ACLR may the patients will experience some complications. Some of them will be referred in this chapter. It is very important to be noted that the major reason that may causes all the following complications usually is due to a technical error

Contamination is possible to take place in the operative site cause by the use of inadequately sterilized instruments or implantation of contaminated grafts. Contaminated in-flow cannulas have also been found to be the source of infection. Instrumental sets that were sterilized found to be contaminated with coagulase-negative staphylococcus. However, the rate of such these cases is pretty low (1 in 400 cases).

Biofilm formation: this is a key mechanism for persistence or recurrence of infection. The biofilm is an aggregation of microbial colonies enclosed within an extracellular polysaccharide matrix (glycocalyx) that adheres on the surface of implants or devitalized tissue. During an ACL reconstruction the presence of an avascular graft and metal fixation devices may create condition conducive to biofilm development if the postoperative infection will not be treated early and adequately. The role of biofilm is to protect the organism from antibiotics and host defence mechanisms, such as the antibody formation and phagocytosis. As a consequence may exist infection in a sub-clinical state and eventually recur. In chronic musculoskeletal infections, removal of the biofilm by removal of implants and debridement of devitalized tissue are necessary for the successful treatment of infection.

Infrapatellar Contracture syndrome represents an abnormal fibrosclerotic healing response through the anterior retinaculum, patellomeniscal ligaments and fat pad tissues, which entraps the patella and leads to loss of extension and flexion of the knee. In advanced stages may lead to patellofemoral arthrosis. This syndrome is more often seen after ACLR due to errors in the surgical technique or rehabilitation. The syndrome has three stages. Stage I (2-8 weeks) presents periarticular inflammation and edema, immobility of the knee and quadriceps weakness and lag. Stage II, (6-20 weeks) patella appears to have limited mobility and anterior tilt (shelf sign) and the patient is able to walk only with bent knee. Stage III (after 8^{th} month) the patellar mobility is improved but the knee develops patella baja and degenerative changes in the patellofemoral joint. Early diagnosis of this process and avoidance of forced motions is very important, otherwise this syndrome may lead to further inflammation and fibrosis.

Leg numbness due to nerve damage is a considerable complication and usually takes place when the BPTB (bone –patellar tendon –bone) and Medial hamstring tendons grafts are used. The patients describe uncomfortable symptoms especially when are falling on their knees. The BPTB harvesting includes the risk of damaging nerves and causes sensory disturbances.

Arthrosis: following the ACL reconstruction there are further factors that may play an additional role in the development of arthrosis. It has been shown that pretensioning the graft can cause changes in the biomechanics of the joint that may lead to arthrosis in long term. Shortening of the patellar tendon may occur after patellar tendon autograft, which has been shown to lead to patellofemoral arthrosis and a worse functional outcome, both of which are directly associated with the degree of shortening of the patellar tendon. Clearly, a spectrum of joint changes exists, with many patients demonstrating minimal radiographic change and few clinical symptoms; although unfortunately a minority will go on to have symptomatic arthrosis. The key to avoid is the fast decision making as it is well recognized that the untreated ACL deficient knee has an increased risk of developing degenerative change. (4)

2.6 INTERNATIONAL KNEE COMITEE OF ACL

2.6.1 RISK FACTORS OF NON CONTACT ACL INJURY

The risk factors can be classified as environmental, anatomical, hormonal and neuromuscular.

Environmental factors include the weather and playing conditions, shoe-surface interaction, footwear and bracing. These variables are really important as they represent potentially avoidable risk factors. Basic physics describes static and kinetic frictional forces between two bodies. Energy is dissipated once the frictional force is conquered allowing movement. This is called sliding and causes a shift from static to kinetic frictional force that is more readily overcome. It is logical to assume that during foot plant, characteristics that increase static frictional force between the foot and ground will create higher energy forces in the lower extremity. Certain studies examined the relation between ACL injuries and synthetic floors versus traditional parquet floors. This study made by Torg et al (31) and they found that the increased friction of the synthetic floors is a factor that increases the possibility of ACL injury. Orchard et al in their study (19) compared weather conditions and temperature and they found that higher rainfall and cooler temperatures were related to decrease ACL injuries and theorized that dry and hot weather conditions increases the frictional forces on the playing field and as a consequence the injury rates are higher.

Braces are commonly prescribed following ACL injury or reconstruction. However, while their use is excessive there is little evidence that supports their physiological or biomechanical efficacy. Many studies have been done but the results are so different that are not letting us to have a safe conclusion. Swirtum et al with their study found that patients have initial sense of increased stability, but these investigators were unable to find objective benefits (28). In contrast, Kocher et al (16) studied the use of braces in 180 ACL deficient alpine skiers and found re-injury occurred in only 2% of the braced skiers compared with 13% of the un-braced skiers. It has been theorized that damage to the ACL can disrupt mechanoreceptors in the knee leading to decreased proprioception. Birminham et al (2) in their study that to use brace may help this deficit somehow, but the benefits will not be carried over demanding tasks. Although, most results show that braces are ineffective in protection of the ACL deficient or reconstructed athletic knee, many patients still wish for a brace due to psychological reasons as they report that the brace increases their confidence during sport participation. (4)

Anatomical Risk Factors: anatomical risk factors include increased Q angle (Quadriceps femoris angle) ligamentous laxity in apparent knee valgus, femoral notch size, ACL geometry, subtalar joint pronation and body mass index (BMI).

The Q angle typically ranges from 12 to 15 degrees, and is formed by the intersection of two lines, one from the anterior superior iliac spine to the midpoint of the patella and the other one from the tibial tubercle to the same patellar point of reference. Females have been reported that due to their wider pelvis have larger Q angles than their male counterparts. It has been proposed that an increased Q angle may be associated with an increased risk of knee injury due to the excessive lateral forces that may influence negatively the knee's mechanical alignment. However, many studies appeared different results so we could say that this is a proposed theory which has not been proved yet. Structural characteristics of the distal femur and femoral intercondylar notch as well as ACL geometry and its relationship to the intercondylar notch have been implicated as anthropometric factors that are associated with ACL injury rate independent if it is referred to males or females. It has been postulated that a smaller notch which is called notch stenosis may causes ACL impingement and this may increase the risk of injury. (4)

Hormonal risk factors: perhaps sex hormones may influence ACL injuries not by a direct effect on the mechanical properties of the ligament but on other injury associated parameters such as balance, muscle response time, mood and focus. Estogen and progesterone have been found to influence the cardiovascular system, blood pressure, heart rate, minute ventilation, substrate metabolism, thermal regulation and other factors. (11)

Neuromuscular factors: these factors are met very often during sport activities. The recreational athlete has not the required coordination level to perform the technique correct and this may result to injuries including ACL rupture. Another fact is that the individual has weakness of one or more muscles that are responsible for the stability of the knee and he is unaware of that. This results that the patient is low resistant to the forces which are responsible for an ACL rupture. (4)

2.6.2 INDICATED AND CONTRAINDICATED SPORT ACTIVITIES

This chapter will suggest the indicated and contraindicated activities that a patient will be able to participate. This will be focused in two cases. Firstly, to the patient that chooses to not reconstruct his ACL and he is after a successful rehabilitation and secondly to the patient that choose the surgical approach of reconstruction and is already after rehabilitation.

The "reconstructed ACL patient": returns to activities of normal daily living within a few weeks and can start doing sports by six months post surgery. When the patient has regained power greater than 75% of the unaffected leg, strength training is intensified and he may begin activities such as straight-line jogging and more sports-specific type training at low intensity. When the affected lower extremity becomes almost equal with the healthy extremity the patient is any more able to increase intensity and is free to follow any sport activity prefers. (36) The use of a brace may help.

The ACL deficient patient: the situation here is more complicated. There is no free choice for the patient about what sports he can do even if he or she feels ready. Specifically, the following four activity levels are based on the International Knee Documentation Committee:

Level I: includes sports that involves jumping, pivoting and hard cutting such as basketball, volleyball, gymnastics and soccer.

Level II: includes heavy manual work or side to side sports such as table tennis (only in recreational level).

Level III: includes light manual work and non-cutting sports such as running,cycling and weightlifting.

Level IV: is sedentary activity without sports.

Unfortunately, the patients who don't prefer the ACL reconstruction treatment they have to modify their lifestyle and participate in the activities of the III and IV level so automatically the indicated sports for them are the level III ones, running, cycling and weightlifting. (34)

2.6.3 PREVENTION IN SPORTS – EQUIPMENT AND INJURY PREVENTION PROGRAMS

Braces may used to avoid ACL injury or re-injury. The results have not proved yet that bracing can minimize the loadings that are applied on the ACL but many people reports that they feel safer and the psychological factor cannot be ignored.

Injury prevention programs: this principle works with the logic that the training of each sportsman should be modified not only according to increase performance but also to prevent injuries. A neuromuscular training program that will be able to modulate the athletic technique must be planned and applied. This intervention program will be geared to change player technique, teach safer landings, strengthen the related muscles and increase special deceleration patterns such as a multistep stop during cutting. Attention must be given at the end of a sport activity, where there is neuromuscular fatigue and this result to affect biomechanically the technique of the athlete increasing the risk of injury. These prevention injury training programs consists of warm-up, stretching, strengthening, plyometrics and sport specific agilities to address potential deficits in the strength and coordination of the stabilizing muscles around the knee joint. (4)

3. SPECIAL PART

3.1 METHODOLOGY

3.1.1 SPECIFICATION OF STUDY

Clinical study of patient with full rupture of anterior cruciate ligament. The patient is male born in 1979. The diagnosis confirms full rupture of ACL of the right knee.

3.1.2 TIME AND PLACE

UVN (Ustav Vojenske Nemocnice), Prague. The duration was from 11th January to 22nd January 2010.

3.1.3 DIAGNOSTIC METHODS

-Aspection
-Postural examination
-Muscle palpation
-Gait examination
-Transfer and ADL examination
-Lachman Test for ACL
-Arnold crossover test for ACL
-ROM examination, Active and Passive
-Manual Muscle Testing by Kendall (14)
-Anthropometric measurement
-Joint play examination by Lewit
-Proprioception

3.1.4 THERAPEUTIC METHODS

-Soft tissue techniques
-Passive movements
-Active movement
-Strengthening exercises with open kinetic chain

-Strengthening exercises with close kinetic chain

-Balance exercises

-Stretching exercises

-Post Isometric Relaxation (PIR) by Lewit

-PNF by Kabat

-Joint play mobilization by Lewit

-Senso-motoric stimulation

3.1.5 DIAGNOSTIC TOOLS

-Plumb line

-Goniometer

-Measuring tape

3.1.6 THERAPEUTIC TOOLS

-Soft balls (sponge material)

-Theraband

-Wobble board (Balance plates)

-Posturomed

-Bosu

-Nailmat (soft-spike carpet for walking)

-Aquatherapy (Vodolecba)

3.2 ANAMNESIS

<u>Personal Information</u>

Patient: M.H.

Date of birth: 1979

Diagnosis: S83.5 Rupture of ACL of the right knee

Chef complain: Decrease ROM of the right knee, Difficulty to flex the right knee with pain, swelling of the right knee, Low back pain in the Lumbar segment. All these symptoms began after the Rupture of ACL. Low back pain started after walking with the brace.

History of Present Problem

The patient was in Livingo (Italy) for vacation. At 13th December 2009 while he was skiing, the patient tried to change direction and lost his balance. He heard a "klik" sound from his right knee and then fall down. Snow patrol came to pick him. They examined him and they said that must be a knee distortion. Next day the knee appeared with a very big swelling and haematoma. Patient came back to Czech Republic and spoke with his insurance to arrange diagnosis and treatment. They provided arthrocentesis to remove the blood from the joint and then MRI (Magnetic Resonance Imaging). The MRI showed a complete rupture of ACL. After the patient used a brace from 0-30 degrees for two weeks and then for one week used a brace from 30-50 degrees.

Family Anamnesis

His father has hypertension.

Previous operations

No previous operations

Pharmacological Anamnesis

Painkillers and NSAID (Non sterorid anti-inflammatory drugs)

Personal Anamnesis

He lives in a block of flats, 12th floor in a building with elevator.

Professional Anamnesis

He is working as a cardiologist to the Military Hospital in Prague (UVN).

Physical Activities

Ski, Squash, cycling.

Abuses

Just small amounts of alcohol when he is going out at weekends mostly.

Allergies

None

Precious rehabilitation

PRICE treatment for three weeks after injury.

3.3 STATEMENT FROM PATIENTS MEDICAL DOCUMENTATION

MRI diagnosis which confirmed full rupture of anterior cruciate ligament.

3.4 ORTHOPEDIC DOCTORS INDICATION FOR REHABILITATION

The prescription by the orthopaedist included the following:

- Control Pain and Swelling
- Increase Range of Motion for the right knee joint
- Increase muscle strength of quadriceps with respect to right side
- Increase muscle strength of hamstrings with respect to right side
- Balance exercises
- Aquatherapy

3.5 PRESENT STATE AT INITIAL KINESIOLOGIC EXAMINATION

Date: 11th January 2010

Height: 1,95m

Weight: 80kg

BMI: 21.0

BP: 120/70

Hb/min: 70

3.6 INITIAL KINESIOLOGIC EXAMINATION

Date: 11/1/2010

3.6.1 ASPECTION

- There is swelling of the right knee
- The right knee is "locked" in a semi-flex position approximately 20 degrees.

Conclusion: The right knee is swollen and locked in 20 degrees of semi-flexion.

3.6.2 PALPATION

Table 2- muscle palpation – Red color pathological findings

Muscle	Muscle Tone Left	Muscle Tone Right	Trigger points
Gluteus maximus	Normal	Hypo	No
Gluteus medius, minimus	Normal	Normal	No
Quadriceps	Normal	Hypo	No
Hamstrings	Normal	Hyper with spasms	Yes - Right
Gastrocnemius	Normal	Hyper	No
Quadratus lumborum *	Normal	Hyper	Yes

*I provided palpation of Quadratus Lumborum because I found during the posture and gaiting examination that the patient was contracting this muscle to elevate the pelvis in order to unload the right injured lower extremity.

Note: Palpation of iliac crests took place in the 3rd therapeutic unit that my patient was able to provide full knee extension. The result was without pathologic influence of the patient's posture.

- Spina Iliaca Anterior superior left 2cm higher than the right one.
- Spina Iliaca Posterior superior left 2 cm higher than the left one.

3.6.3 ANTHROPOMETRICS

The measurement of circumferences took place in the 1st therapeutic unit. The measurement of leg length provided during the 3rd therapeutic unit because the patient in the first two therapeutic units was unable to provide full knee extension of the right side. The results:

Table 3 – Anthropometric measurements –Red color pathological findings

Measurements	Left	Right
Anatomical leg length	110cm	108cm
Functional leg length	107cm	105cm
Circumference of Thigh (thicker part)	52cm	46cm
Circumference of Calf (thicker part)	35cm	38cm

Conclusion: The patient's left lower extremity is 2cm longer than the right one. The patient was aware of this fact and he referred that he uses a 2 cm heel-pad in his right shoe.

3.6.4 POSTURE

For all posture examinations I used plumb line as a point of reference.

Table 4 – Posture examination lateral view –Red color pathological findings

Segment	Left Lateral view	Right Lateral View
Head	Neutral Position	Neutral Position
Cervical spine	Normal curve slightly anterior	Normal curve slightly anterior
Sholders	Normal	Normal
Thoracic spine	Normal curve slightly posterior	Normal curve slightly anterior
Lumbar spine	Hyperextended –Lordosis	Hyperextended –Lordosis
Pelvis	Anterior tilt	Anterior tilt
Hip Joint	Slightly flexed	Flexed - 30
Knee Joint	Slightly hyperextended	Flexed - 30 degrees
Ankle Joint	Slightly plantar flexed	Dorsiflexion – 15 degrees

Conclusion: the lateral view from the right side shows how the injury influences the patient's posture. With the red letters we can see the pathological findings. Considering the normal findings of the healthy left side the patient has a lordotic posture.

Table 5 – Posture examination Posterior and Anterior view –Red color pathological findings

Segment	Left side	Right side
Head	Neutral Position Neutral Position	
Cervical spine	Straight with the plumb line	
Shoulders	Normal	Slight elevation compare to left
Lumbar spine **Thoracic spine**	Straight (referred to plumb line) Straight (referred to plumb line)	
Pelvis	Spina iliaca posterior superior in the same transverse level* Spina iliaca anterior superior both in the same transverse level but lower than both spina iliaca posterior superior (anterior tilt due to lordotic posture)	
Hip Joint	Neutral position	Flexed with slight internal rotation compare to left side
Knee Joint	Slight external rotation	Internal rotation
Ankle Joint	Neutral position	Dorsiflexion with inversion

Note: I used the same table for anterior and posterior views because the findings were the same and I wanted to make easier the comparison between spina iliaca anterior superior and spina iliaca posterior superior. The very interesting fact is that when the patient had the pathologic posture the iliac crests were in the same line. When the posture seemed normal after the 3rd therapeutic unit the iliac crests of the right side were 2 cm lower than the ones from the left side.

Conslusion: the right knee appears to be in internal rotation and the ankle in dorsiflexion to compensate weight bearing. Only the toes are touching the ground on the right side.

3.6.5 GAIT EXAMINATION

Table 6 – Gait examination (red color pathologic findings).

Factor	Left Side	Right Side
Stance phase (how long feet are apart)	23 cm, contact is pathological with the entire foot touching the ground.	0 cm patient walks and the injured right side never initiate a step. The Patient touches the ground only with toes. There is persisted semiflexion approximately 20 degrees.
Swing phase	There is very small swing phase, almost none. The extremity is locked in hyperextension and seems to be landed on the ground with every step in order to not load the right side. There is no knee flexion.	There is visible inability to bear the weight to the injured side. This causes the injured extremity to provide a very small swing phase. There is a small pelvis elevation during this phase to unload more the lower extremity.
Symmetry	NO	
Stability	Sufficient	Very Poor
Feet raising from the ground	Very low – almost none	Very low-almost none
Leg stiffness	No	Yes
Degree of knee bending	The fault gait pattern results to a very small flexion approximately 10-20 degrees	The right knee is locked approximately 30 degrees flexion.
Arm swing	Yes - Normal	No. The right extremity is fixed during walking.
Speed	Almost normal	Faster than normal –to avoid the loading of the injured extremity
Difficulty to initiate or stop gait	No	Yes

Conclusion: there is altered gait pattern. The patient has fear to load the right extremity and prevents any movement of the right knee while walking. The left side is disturb also which takes all the load in order to compensate pain.

3.6.6 ROM EXAMINATION

Table 7 – Rom examination of the lower extremities (Red color pathological findings)

Joint-Motion	Left		Right		Normal (Average)
	Active	Passive	Active	Passive	
Hip extension	10	15	10	12-13	10
Hip Flexion with flexed knee	125	128	100, provided with knee in 40 degrees flexion	105	125
Hip Abduction	45	50	45	50	45
Hip Adduction	10	12	10	12	10
Hip lateral Rotation	45	47	42-43	45	45
Hip Medial Rotation	45	45	35	40	45
Knee Extension	0	0	-20	-20	0
Knee Flexion	140	145	50	55 with pain	140
Ankle Pantarflexion	45	47	35	40	45
Ankle Dorsiflexion	20	22	20	22	20
Foot Inversion	40	42	40	42	40
Foot Eversion	20	22	20	22	20

Conclusion: There is 20 degrees limited ROM in the right knee extension but the knee flexion is very significant limited. The knee flexion at the right side that the ACL injury took place is almost 1/3 of the normal ROM and the left side.

3.6.7 MANUAL MUSCLE TESTING by Kendall

Table 8 – Manual Muscle Testing Examination (weak muscles with red)

Muscle	Left Holds against pressure	Right Holds against pressure
Quadriceps	moderate to strong 4+	Gravity 2+
Hamstrings	Strong pressure 5	Gravity 2+
Hip flexors*	moderate to strong 4+	moderate to strong 4+
Hip extensors*	Moderate 4	Just holds test position 3
Abductors	Moderate 4	Moderate 4
Adductors	moderate to strong 4+	moderate to strong 4+
Triceps Surae	moderate to strong 4+	Moderate 4

* Hip flexors: Iliopsoas, sarorius, tensor fasciae latae, rectus femoris

* Hip extensors: Gluteus maximus and hamstrings.

Conclusion: there is significant weakness of the muscles which remained inactive due to injury of the right side, Quadriceps, Hamstrings and Hip extensors must be strengthened. The hip extensions of the right side is very influenced by the weakness of hamstrings and while the right gluteus maximus looks strong the inability of weak hamstrings to help makes the patient able only to hold the test position (appeared tremor after 4-5 sec by keeping this position).

3.6.8 JOINT PLAY EXAMINATION by Lewit

Table 9 – Joint play examination

Joint Play examination	LEFT	RIGHT
Patella into medial direction	No restriction	No restriction
Patella into lateral direction	No restriction	Restricted

Conclusion: there is restriction of patella into lateral direction of the right knee.

3.6.9 SPECIAL TESTS

Two scales test:

- Left lower extremity 48 kg
- Right lower extremity 32 kg

Conclusion: patient's weight bearing is 60% on the healthy side.

Anterior drawer test for (right knee joint) ACL: positive with tibial displacement. Arnold's crossover test for (right knee joint) ACL: positive with the patient reported an uncomfortable feeling of dislocation.

Conclusion: The MRI diagnosis is confirmed also by these two special tests.

3.7 DIFFERENTIAL DIAGNOSIS

The goals which are prescribed by the orthopaedist are my primary goal. However there are plenty of things that must be considered from the physiotherapeutic point of view. The patient after the moment of injury applied PRICE treatment expecting that when the swelling and pain will be reduced, he will be functional again. Muscle groups which are really important for the knee stability such as quadriceps and hamstrings are weak. This didn't happen and the patient started to use altered gait patterns in order to compensate the pain. This is translated with the knee in a semi-flex position during walking. With this compensate pattern the patient contracts the right quadratus lumborum to extra unload the injured extremity causing the low back pain. The left lower extremity is all the time extended to take up more weight and prevent any pain or unstable feeling of the patient's deficient ACL knee.

The physiotherapeutic aim will be focused to bring back the knee stability by strengthening the related muscle groups (quadriceps, hamstrings) and to make the knee functional again by increasing the limited ROMs. Then my patient will be ready to re-educate him all the altered movement patterns that he changed and primary gaiting. When the patient will be functional again will be able to discuss with his orthopaedist the surgical option or not according to the lifestyle that his wants to follow.

3.8 SHORT TERM AND LONG TERM REHABILITATION PLAN

Short term plan

- Control Pain and Swelling of the right knee.
- Treat PIR trigger points of Quadratus lumborum (right side)
- Increase Range of Motion for the right knee joint flexion to at least 100 degrees.
- Increase Range of Motion for the right knee joint extension to 180 degrees.
- Increase muscle strength quadriceps (right side).
- Increase muscle strength of hamstrings (right side).
- Improve proprioception
- Improve balance

Long term plan

- Improve right knee stability
- Improve posture
- Improve gait pattern
- Prepare mentally and educate the patient for the possible following surgery and arrange his rehabilitation after.

3.9 DAY TO DAY THERAPY

3.9.1 FIRST THERAPEUTIC UNIT

Date: 11/1/2010

Pain today from scale 0-10: 7

Goals of today's therapeutic unit

- Anamnesis and initial kinesiologic examination
- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Strengthening of quadriceps
- Strengthening of hamstrings
- Release trigger points of quadratus lumborum (right)
- Hyperaemia and myorelaxation

Therapeutic procedure

Ø Anamnesis and initial kinesiologic examination of the patient

Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin

Ø Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.

Ø Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 40-50 degrees angle of flexion.

- Ø Active movement for knee flexion and extension in prone position. Barrier is at the same angle close to 50 degrees. There is tremor of hamstrings during extension. Patient performed the exercise 15 times.
- Ø Passive movement for knee flexion in prone position facilitated by "breathe out and relax" when barrier is met. Performed 15 times.
- Ø Positioning with prone hang exercise to facilitate knee extension. The patient is prone with the legs hanging off the edge of the table. Patient allows the legs to sag into full extension. Breathing out and relax helps the knee extension. Performed for approximately one minute.
- Ø Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 2 sets X 15 repeats (between each set was 1 minute free to rest).
- Ø Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 2 sets X 15 repeats (rest 1 minute).
- Ø Release of right quadratus lumborum. I applied PIR with a small modification and the isometric relaxation took place in sitting position because the patient was unable to provide it in standing position due to pathological posture. I provided fixation and support at the back of the patient to avoid lumbar extension. Then I told the patient to provide left lateral flexion, and at the barrier breathed in and hold for 10 seconds. Then breathed out and relaxed. PIR took place 4 times.
- Ø Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes.

Results:

- Soft tissues techniques provided pain relief to my patient and helped him to relax and gain more ROM with passive movements.
- Passive knee flexion in combination with breathing facilitation let the patient to achieve another 5 degrees passive flexion of the right knee.

- Prone hang exercise improved knee extension approximately 3-5 degrees.
- Quadratus lumborum is less painful than before the treatment but trigger points still exist.
- Aquatherapy was beneficial by giving the patient pain relief and relaxation.

Self therapy

- Ø I taught patient how and then I advised him to apply PIR of the right quadratus lumborum as we provided and to gain fixation by a chair, 3 times.
- Ø Theraband exercises for quadriceps and hamstrings.
- Ø Prone hang exercise

3.9.2 SECOND THERAPEUTIC UNIT

Date: 12/1/2010
Pain today from scale 0-10: 6

Goals of today's therapeutic unit

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Strengthening of quadriceps
- Strengthening of hamstrings
- Release trigger points of quadratus lumborum (right)
- Hyperaemia and myorelaxation

Therapeutic procedure

- Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin

- Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 40-50 degrees angle of flexion.
- Active movement for knee flexion and extension in prone position. Barrier is at the same angle close to 50 degrees. There is tremor of hamstrings during extension. Patient performed the exercise 15 times.
- Passive movement for knee flexion in prone position facilitated by “breathe out and relax” when barrier is met. Performed 15 times.
- Positioning with prone hang exercise to facilitate knee extension. The patient is prone with the legs hanging off the edge of the table. Patient allows the legs to sag into full extension. Breathing out and relax helps the knee extension. Performed for approximately one minute.
- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 2 sets X 15 repeats (between each set was 1 minute free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 2 sets X 15 repeats (rest 1 minute).
- Release of right quadratus lumborum. I applied PIR with a small modification and the isometric relaxation took place in sitting position because the patient was unable to provide it in standing position due to pathological posture. I provided fixation and support at the back of the patient to avoid lumbar extension. Then I told the patient to provide left lateral flexion, and at the barrier breathed in and hold for 10 seconds. Then breathed out and relaxed. PIR took place 4 times.

- Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes.

Results:

- Soft tissues techniques provided pain relief to my patient and helped him to relax and gain more ROM with passive movements.
- Passive knee flexion in combination with breathing facilitation let the patient to achieve another 5 degrees passive flexion of the right knee.
- Prone hang exercise improved knee extension approximately 3-5 degrees.
- Quadratus lumborum is less painful than before the treatment but trigger points still exist.
- Aquatherapy was beneficial by giving the patient pain relief and relaxation.

Self therapy

- I advised patient to apply PIR of the right quadratus lumborum as we provided and to gain fixation by a chair, 3 times.
- Theraband exercises for quadriceps and hamstrings.
- Prone hang exercise

3.9.3 THIRD THERAPEUTIC UNIT

Date: 13/1/2010

Pain today from scale 0-10: 5

Goals of today's therapeutic unit

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion

- Increase ROM of the right knee extension
- Strengthening of quadriceps
- Strengthening of hamstrings
- Release trigger points of quadratus lumborum (right)
- Hyperaemia and myorelaxation

<u>Therapeutic procedure</u>

- Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin
- Ø Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Ø Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 40-50 degrees angle of flexion.
- Ø Active movement for knee flexion and extension in prone position. Barrier is at the same angle close to 50 degrees. There is tremor of hamstrings during extension. Patient performed the exercise 15 times.
- Ø Passive movement for knee flexion in prone position facilitated by "breathe out and relax" when barrier is met. Performed 15 times.
- Ø Positioning with prone hang exercise to facilitate knee extension. The patient is prone with the legs hanging off the edge of the table. Patient allows the legs to sag into full extension. Breathing out and relax helps the knee extension. Performed for approximately one minute.

- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 2 sets X 15 repeats (between each set was 1 minute free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 2 sets X 15 repeats (rest 1 minute).
- Release of right quadratus lumborum. I applied PIR with a small modification and the isometric relaxation took place in sitting position because the patient was unable to provide it in standing position due to pathological posture. I provided fixation and support at the back of the patient to avoid lumbar extension. Then I told the patient to provide left lateral flexion, and at the barrier breathed in and hold for 10 seconds. Then breathed out and relaxed. PIR took place 4 times.
- Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes.

Results:

- Soft tissues techniques provided pain relief to my patient and helped him to relax and gain more ROM with passive movements.
- Passive knee flexion in combination with breathing facilitation let the patient to achieve another 5 degrees passive flexion of the right knee.
- Prone hang exercise improved knee extension approximately 3-5 degrees.
- Quadratus lumborum is released without tension trigger point and pain.
- Aquatherapy was beneficial by giving the patient pain relief and relaxation.

Self therapy

- Theraband exercises for quadriceps and hamstrings.
- Prone hang exercise

3.9.4 FOURTH THERAPEUTIC UNIT

Date: 15/1/2010

Pain today from scale 0-10: 4

Goals of today's therapeutic unit

- Release soft tissues and relief pain.
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Strengthening of quadriceps
- Strengthening of hamstrings
- Hyperaemia and myorelaxation

Therapeutic procedure

- Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin
- Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 40-50 degrees angle of flexion.
- Active movement for knee flexion and extension in prone position. Barrier is at the same angle close to 50 degrees. There is tremor of hamstrings during extension. Patient performed the exercise 15 times.

- Ø Passive movement for knee flexion in prone position facilitated by "breathe out and relax" when barrier is met. Performed 15 times.
- Ø Positioning with prone hang exercise to facilitate knee extension. The patient is prone with the legs hanging off the edge of the table. Patient allows the legs to sag into full extension. Breathing out and relax helps the knee extension. Performed for approximately one minute.
- Ø Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 2 sets X 15 repeats (between each set was 1 minute free to rest).
- Ø Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 2 sets X 15 repeats (rest 1 minute).
- Ø Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes.

Results:

- Soft tissues techniques provided pain relief to my patient and helped him to relax and gain more ROM with passive movements.
- Passive knee flexion in combination with breathing facilitation let the patient to achieve another 5 degrees passive flexion of the right knee.
- Prone hang exercise improved knee extension approximately 3-5 degrees.
- Aquatherapy was beneficial by giving the patient pain relief and relaxation.

<u>Self therapy</u>

- Ø Theraband exercises for quadriceps and hamstrings.
- Ø Prone hang exercise

Note: I provided a fast examination and I found that patient has ROM of right knee flexion 80 degrees (+25 degrees improvement), full ROM in knee extension (0 degrees and was -20), improved posture and gait. There is no swelling of the right knee. The patient looks adapted to the previous therapeutic units and I considered that for the next therapeutic units I must increase the training efforts and to induce balance exercises, sensomotoric stimulation, neuromuscular coordination exercises and to train gait. The restriction of patella is still restricted to lateral direction but now I am able to apply joint play of the patella as the patient anymore is able to rest the right knee in full extension. ADL activities looks easier with the patient started already driving his car.

3.9.5 FIFTH THERAPEUTIC UNIT

Date: 18/1/2010

Pain today from scale 0-10: 4

Goals of today's therapeutic unit

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Mobilization of patella
- Neuromuscular training of the right lower extremity
- Strengthening of quadriceps
- Strengthening of hamstrings
- Balance training
- Gait training
- Hyperaemia and myorelaxation.

Therapeutic procedure

- Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin

- Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 80 degrees angle of flexion.
- Active movement for knee flexion and extension in prone position. Barrier is approximately 80 degrees. Patient performed the exercise, 2set x20 times.
- Passive movement for knee flexion in prone position facilitated by "breathe out and relax" when barrier is met. Performed 20 times.
- Joint play for mobilization of right patella. The patient was in prone position and the knee in extension but not "locked". I provided mobilization of patella into lateral, medial, caudal and cranial direction.
- PNF 1st diagonal flexion with knee extension. The patient is in supine position and the starting position is: toes in flexion and adduction, foot and ankle in plantarflexion and eversion, knee joint in flexion and the hip in extension, abduction and internal rotation. The pattern provided 3 times very slowly to teach the patient and then 3 times with my resistance "guiding him".
- PNF 2nd diagonal extension with knee flexion. Patient supine and the starting position is: toes in extension and abduction, foot and ankle in dorsiflexion and eversion, knee in extension and the hip in flexion, abduction and internal rotation.
- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 3 sets X 20 repeats (between each set was 30 seconds free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 3 sets X 20 repeats (rest 30 seconds).
- Balance exercises with bosu. Patient keeps balance a few seconds on one leg. Then changes.

- Ø Same exercise on balance plates (wobble board)
- Ø Balance on posturomed.
- Ø Stationary Bicycle without resistance
- Ø Gait training. I correct the patient step by step re-educating the optimal pattern of gait. Emphasis was given to re-educate the flexion of the right injured extremity and the correct heel contact.
- Ø Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes

Results:

- Rom of right knee joint flexion increased approximately 5 degrees, barrier is at 85 degrees.
- Restriction of patella improved
- Balance improved
- Posture has been significantly improved.
- Gait pattern improved

3.9.6 SIXTH THERAPEUTIC UNIT

Date: 19/1/2010

Pain today from scale 0-10: 3

<u>Goals of today's therapeutic unit</u>

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Mobilization of patella
- Neuromuscular training of the right lower extremity
- Strengthening of quadriceps
- Strengthening of hamstrings
- Balance training

- Gait training
- Hyperaemia and myorelaxation.

Therapeutic procedure

- Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin
- Ø Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Ø Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 80 degrees angle of flexion.
- Ø Active movement for knee flexion and extension in prone position. Barrier is approximately 80 degrees. Patient performed the exercise, 2set x20 times.
- Ø Passive movement for knee flexion in prone position facilitated by “breathe out and relax” when barrier is met. Performed 20 times.
- Ø Joint play for mobilization of right patella. The patient was in prone position and the knee in extension but not “locked”. I provided mobilization of patella into lateral, medial, caudal and cranial direction.
- Ø PNF 1st diagonal flexion with knee extension. The patient is in supine position and the starting position is: toes in flexion and adduction, foot and ankle in plantarflexion and eversion, knee joint in flexion and the hip in extension, abduction and internal rotation. The pattern provided 3 times very slowly to teach the patient and then 3 times with my resistance “guiding him”.
- Ø PNF 2nd diagonal extension with knee flexion. Patient supine and the starting position is: toes in extension and abduction, foot and ankle in dorsiflexion and

eversion, knee in extension and the hip in flexion, abduction and internal rotation.

- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 3 sets X 20 repeats (between each set was 30 seconds free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 3 sets X 20 repeats (rest 30 seconds).
- Balance exercises with bosu. Patient keeps balance a few seconds on one leg. Then changes.
- Same exercise on balance plates (wobble board)
- Balance on posturomed.
- Stationary Bicycle without resistance
- Gait training. I correct the patient step by step re-educating the optimal pattern of gait. Emphasis was given to re-educate the flexion of the right injured extremity and the correct heel contact.
- Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes

Results:

- Rom of right knee joint flexion increased approximately 5 degrees, barrier is at 90 degrees.
- Restriction of patella improved
- Balance improved
- Posture has been significantly improved.
- Gait pattern improved

3.9.7 SEVENTH THERAPEUTIC UNIT

Date: 20/1/2010

Pain today from scale 0-10: 2

Goals of today's therapeutic unit

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Mobilization of patella
- Neuromuscular training of the right lower extremity
- Strengthening of quadriceps
- Strengthening of hamstrings
- Balance training
- Gait training
- Hyperaemia and myorelaxation.

Therapeutic procedure

- Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin
- Ø Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.
- Ø Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 80 degrees angle of flexion.

- Active movement for knee flexion and extension in prone position. Barrier is approximately 80 degrees. Patient performed the exercise, 2set x20 times.
- Passive movement for knee flexion in prone position facilitated by "breathe out and relax" when barrier is met. Performed 20 times.
- Joint play for mobilization of right patella. The patient was in prone position and the knee in extension but not "locked". I provided mobilization of patella into lateral, medial, caudal and cranial direction.
- PNF 1st diagonal flexion with knee extension. The patient is in supine position and the starting position is: toes in flexion and adduction, foot and ankle in plantarflexion and eversion, knee joint in flexion and the hip in extension, abduction and internal rotation. The pattern provided 3 times very slowly to teach the patient and then 3 times with my resistance "guiding him".
- PNF 2nd diagonal extension with knee flexion. Patient supine and the starting position is: toes in extension and abduction, foot and ankle in dorsiflexion and eversion, knee in extension and the hip in flexion, abduction and internal rotation.
- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 3 sets X 20 repeats (between each set was 30 seconds free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 3 sets X 20 repeats (rest 30 seconds).
- Balance exercises with bosu. Patient keeps balance a few seconds on one leg. Then changes.
- Same exercise on balance plates (wobble board)
- Balance on posturomed.
- Stationary Bicycle without resistance
- Gait training. I correct the patient step by step re-educating the optimal pattern of gait. Emphasis was given to re-educate the flexion of the right injured extremity and the correct heel contact.
- Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes

Results:

- Rom of right knee joint flexion increased approximately 5 degrees, barrier is at 95 degrees.
- Restriction of patella improved
- Balance improved
- Posture has been significantly improved.
- Gait pattern improved

3.9.8 EIGHTH THERAPEUTIC UNIT

Date: 22/1/2010

Pain today from scale 0-10: 1-2

Goals of today's therapeutic unit

- Release soft tissues and relief pain
- Increase ROM of the right knee flexion
- Increase ROM of the right knee extension
- Mobilization of patella
- Neuromuscular training of the right lower extremity
- Strengthening of quadriceps
- Strengthening of hamstrings
- Balance training
- Gait training
- Hyperaemia and myorelaxation.

Therapeutic procedure

- Ø Soft tissue techniques. The patient was in supine position and his knee was almost extended and rested on a small pillow. I used one small sponge ball massaging around patella. Then I created small folds (waves) from above patella into cranial direction close to quadriceps origin
- Ø Soft tissue techniques with the patient in prone position and support by a small pillow under the knee and along tibia and fibula (patient was not able to rest

the right knee in full extension). I provided soft tissues techniques creating and keeping a small fold along hamstrings muscle group from 5 cm above insertion into cranial direction close to origin.

- Passive movements into flexion for the right knee with passive hip flexion. My arms were supporting and assisting the movement under the calf of the patient been rested to my forearm. Patient is completely relaxed in supine position and feels pain in the barrier which is approximately 80 degrees angle of flexion.
- Active movement for knee flexion and extension in prone position. Barrier is approximately 80 degrees. Patient performed the exercise, 2set x20 times.
- Passive movement for knee flexion in prone position facilitated by “breathe out and relax” when barrier is met. Performed 20 times.
- Joint play for mobilization of right patella. The patient was in prone position and the knee in extension but not “locked”. I provided mobilization of patella into lateral, medial, caudal and cranial direction.
- PNF 1st diagonal flexion with knee extension. The patient is in supine position and the starting position is: toes in flexion and adduction, foot and ankle in plantarflexion and eversion, knee joint in flexion and the hip in extension, abduction and internal rotation. The pattern provided 3 times very slowly to teach the patient and then 3 times with my resistance “guiding him”.
- PNF 2nd diagonal extension with knee flexion. Patient supine and the starting position is: toes in extension and abduction, foot and ankle in dorsiflexion and eversion, knee in extension and the hip in flexion, abduction and internal rotation.
- Strengthening exercise of quadriceps with use of theraband. The patient is prone and provides knee extension against theraband resistance. Performed 3 sets X 20 repeats (between each set was 30 seconds free to rest).
- Strengthening exercise of hamstring muscle group. The patient was prone and provided right knee repetitive flexions against theraband resistance. Performed 3 sets X 20 repeats (rest 30 seconds).
- Balance exercises with bosu. Patient keeps balance a few seconds on one leg. Then changes.
- Same exercise on balance plates (wobble board)
- Balance on posturomed.

- Stationary Bicycle without resistance
- Gait training. I correct the patient step by step re-educating the optimal pattern of gait. Emphasis was given to re-educate the flexion of the right injured extremity and the correct heel contact.
- Aquatherapy, the patient was sitting with the affected lower extremity in a small whirlpool. The water temperature was 37^0 C, and there was water pressure massaging the right injured lower extremity. Duration 15 minutes

Results:

- Rom of right knee joint flexion increased approximately 5 degrees, barrier is at 100 degrees.
- Restriction of patella improved
- Balance improved
- Posture has been significantly improved.
- Gait pattern improved

3.10 FINAL KINESIOLOGIC EXAMINATION

At the end of the last treatment I provided final kinesiologic examination to see the effect of my therapy. For the easier and better comparison the following table summarizes the pathological findings of the initial kinesiologic examination with the results that I found at the final kinesiologic examination:

Table 10 – Initial vs Final kinesiologic examination findings

Pathological Finding	Initial Kinesiologic examination	Final Kinesiologic examination
Aspection	Swelling of right knee	No visible swelling
Aspection	Right knee approximately locked 20-30 degrees	Right knee is at normal extension position
Palpation of right gluteus maximus	Hypo-tonus	Normal tonus
Palpation of right quadriceps	Hypo-tonus	Normal tonus

Palpation of right hamstrings	Hyper-tone with spasm and trigger point	No trigger point No spasm
Palpation of right gastrocnemius	Hyper-tone	Normal tonus
Palpation of right quadratus lumborum	Hyper-tone with trigger point	Normal tonus No trigger point
Circumference of right thigh	46cm (-6cm from left)	50 cm (-2cm from left)
Posture Lateral view	Right hip flexed 30 degrees	0 degrees
Posture Lateral view	Right knee flexed 30 degrees	Slight hyperextension
Posture Lateral view	Right ankle joint dorsiflexion 15 degrees	Slightly plantar flexed
Posture Posterior view	Right shoulder slight elevation	Remains – right shoulder slight elevation
Posture anterior view	Knee joint internal rotation	Slight external rotation
Posture anterior view	Dorsiflexion with inversion	Neutral position
Gait examination	Altered gait pattern through all phases	Almost normal (needs to flex a little more the knee of the left healthy side)
ROM examination	Right hip flexion 100 degrees	125 degrees
ROM examination	Right hip medial rotation 35 degrees	45 degrees
ROM examination	Right knee extension -20 degrees	0 degrees
ROM examination	Right knee flexion 55 degrees	110 degrees
ROM examination	Right ankle plantarflexion 35 degrees	45 degrees
Manual Muscle Testing	Quadriceps right 2+	4-
Manual Muscle Testing	Hamstrings right 2+	4
Manual Muscle Testing	Hip extensors right 3	4-

Joint play examination	Right patella restricted into lateral direction		No restriction	
Two scales test	Left 48	Right 32	Left 42	Right 38

3.11 PROGNOSIS

Prognosis for this case of patient has two faces according to what option the patient will choose. At first prognosis is good, the patient is already almost fully functional and can perform work and ADL activities without any problem. On the other hand my patient is young and a very active person who likes sports. If he will not choose the surgical approach to reconstruct his ACL and will try to start again his sport activities such as skiing then prognosis is not good as this may result to further damage in the structure of the right knee joint and as a consequence to cause further injuries or arthrosis.

3.12 RESULTS – THERAPY EFFECT EVALUATION

After 8 therapeutic sessions, my patient has significantly improved. Starting from his posture which any more is not pathological as the weight bearing any more is almost equal to both lower extremities. The two scales test confirms that, as before the beginning of our rehabilitation plan there was a difference of 16kg between left and injured right lower extremity which anymore is only 4kg. There is no more "locking" in semi-flexion of the right knee joint and the patient has no fear to load the affected limb. The strengthening exercises with theraband seem to be really effective, as the patient can be double trained even home alone with their use. The results of MMT can confirm my observation about the strengthening effect of this kind of treatment as the MMT that I provided with the final kinesiologic examination appeared that quadriceps of the right side is 4- (was 2+), the hamstrings muscle group now is 4 (was 2+), and these muscles are the ones that undertake the role of the whole stability of the knee for ACL deficient patients.

Soft tissue techniques were very pleasurable for my patient and helped to release the skin tissues of the "injured area".

PIR is a guaranteed physiotherapeutic approach for muscles been in tension and after only 3 therapeutic units the quadratus lumborum and its trigger points released and my patient did not complain any more for low back pain.
PNF which I applied helped not only for strengthening of the lower extremity but also I consider that played important role to increase the neuromuscular coordination level of my patient. I observed that to train gait after PNF strengthening techniques by the means of slow reversal does the gait training more effective.
Joint play mobilisation had very fast effect against the restriction of patella into lateral direction.

4. CONCLUSION

These 8 therapeutic units were a great experience for me. It helped me to understand about the "physiotherapeutic thinking" and I understood how must be applied an initial examination, according to the findings how to create a rehabilitation and plan, then how to combine all the physiotherapeutic techniques to is with respect to disease and findings and finally how to evaluate the success of my plan through the final kinesiologic examination. During these 2 weeks I had also the opportunity to work with patients with other problems as well which also gave me experience about how to approach them.
Speaking specifically for this case of my patient the experience show me that primary aim for patients with ACL deficiency is to strengthen the muscles which undertakes the role to stabilize the knee joint (quadriceps and hamstrings) as the ACL is missing and to correct the altered movement patterns that created after injury in order to compensate pain.

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8. LIST OF ABBREVIATIONS

ACL – Anterior Cruciate Ligament

ACLR – Anterior Cruciate Ligament Reconstruction

ADL – Activities of Daily Living

AM – AnteroMedial

BPTB – Bone – Patellar Tendon – Bone

DF – Dorsal Flexion

E – Extension

ER- External Rotation

F – Flexion

FCL – Lateral Collateral Ligament

IM -InterMediate

IR – Internal Rotation

LFC – Lateral Femoral Condyle

TCL – Medial Collateral Ligament

MM – Medin Modular

OA – OsteoArthritis

PCL – Posterior Cruciate Ligament

PIR – Post Isometric Relaxation

PL- Posterolateral Bundle

PRICE – Protection, Rest, Ice, Compression, Elevation

PTM –Post Transitional Modification

RA – Rheumatoid Arthritis

ROM – Range of Motion

TFL – Tensor Fascia Latae