

THE IMPORTANCE OF ISOINERTIAL TRAINING AND EVALUATION FOR FUNCTIONAL RECOVERY IN ATHLETES WITH ACL INJURIES

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Abstract: This article presents the case of a high league soccer player with a traumatic injury to his left knee occurring during a match for which reconstructive surgery followed relatively quickly. After reconstruction intervention, a personalized rehabilitation intervention followed according to current guidelines. The functional protocol was individualized with an isoinertial training program. The isoinertial training is commonly used for athletes training and physical preparation. But, the principles of isoinertial training are also translated into the rehabilitation of athletes who want to return to sports activity as quickly as possible and without the risk of another injury.

This case illustrates also that clinical and functional assessment is a common language that can codify the terms and modalities of treatment applied. Specific tests can identify risk factors that modulate management protocols to optimize functional results and can be a common language between the therapists from different countries; this is also the particularity of this topic. Today, the principles of isoinertial training are also translated into the rehabilitation of athletes who want to return to sports activity as quickly as possible and without the risk of another injury.

Keywords: knee lesions, surgical intervention, functional evaluation, isoinertial training,

Introduction

Knee trauma among athletes who practice football for performance or as a leisure activity are frequent and a correct diagnosis and an early and complex intervention program can reduce the risk of recurrence and recovery time.

Trauma in football According to Maniar et al. (2022) in the last 20 years studies report an increase number of injuries to the knee joint. These problems can lead to long-term disability and delay the athlete's return to the field by causing knee instability, pain, and decreased functionality and on long term early onset of osteoarthritis, and a decrease in the quality of sports performance or giving up performance sports.

Beard et al. (2022) analyzing the two therapeutic possibilities: surgical reconstruction and rehabilitation management on a group of 316 subjects with chronic injuries of the anterior cruciate ligament (ACL) concluded that surgical reconstruction was clinically superior and more cost-effective.

From our point of view the two types of intervention should not be separated in practice and in discussions between specialists and between specialists and subject with ACL trauma when the stages of management treatment.

Urhausen et al. (2022) believe that there is a lack of evidence in the scientific literature to support the benefits of testing knee extensor and flexor strength in individuals with ACL and/or meniscus injuries. But although the rehabilitation intervention protocols and guidelines in the post-surgical period are known and their principles are applied by therapists, it seems that the evaluation and quantification is not as standardized worldwide, but isokinetic concentric resistance testing is recommended and that of isotonic resistance are good alternatives (Urhausen et al., 2022).

These tests are still a topic with a degree of subjectivity and are based on therapist's customization, results are considered reliable if evaluated with various devices that are sometimes not currently available in all physical therapy offices. A common language

in assessment is even more important when a patient is being treated in multiple locations by different therapists.

Culvenor et al. (2022), critically appraising the rehabilitation outcomes of subjects with traumatic knee injuries draws attention to the unsatisfactory level of evidence to underline intervention outcomes. It is possible that these conclusions are based on the use of evaluation methodologies that are not standardized as is the case with therapeutic protocols.

Training modalities that can improve players' physical performance and reduce muscular and motor asymmetries are desirable when the maximum performance and escape of injuries is the purpose.

Isoinertial training seems to be an addition that challenge the muscle fibers to adapt to resistance and individualized eccentric overload. (Fiorilli et al., 2020).

Isoinertial training allows the muscles to work with maximum force at any angle, engaging them at a very high level; it is carried out with devices that maintain a constant inertia (resistance created by the inertia of a wheel) throughout the movement, both in the effective contraction phase of the muscle. The device controls the process that generates movement regardless of the force of gravity. The movement of the subject is transformed into kinetic energy and subsequently dissipated in the eccentric phase, the greater the force applied by the athlete during the concentric movement, the faster the wheel will accelerate.

Compared to conventional training, isomertial overload and multidirectional movements can increase performance, stimulate the athlete's neural adaptations, improving his soccer skills. (Fiorilli, G. et al 2020).

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Anatomy and function of the anterior cruciate ligament (ACL)

This structure is exposed to strong mechanical forces during various types of sports activities

and tearing of these ligaments is a fairly common occurrence. Naturally, ACL injury (tears or ruptures) can occurs in contact sports such as football, volleyball, basketball, or traumatic injuries involving falls.

Inside the knee joint are two ligaments that have the role of creating stability by joining the tibia and femur making the so-called "a *central pivot*" being the center of rotation of the joint. To create these biomechanical effects these ligaments have a special arrangement, cross in the center of the joint and are divided into anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL). Surgical and rehabilitation treatment offered immediately post-intervention does not decrease the risk of a new ligament injury. A function score below a maximum appears to be associated with new knee injuries. (Hietamo et al., 2023).

Symptoms and diagnosis of ACL injuries

Symptoms of ACL injuries can vary significantly from patient to patient. The typical post-traumatic immediate clinical picture is characterized by intense pain, marked edema that occurs rapidly, and a sensation of giving way or instability with a significant degree or total functional limitation.

Diagnosis is based on clinical examination that uses tests to assess the passive stability of the knee. Magnetic resonance imaging identifies all joint injuries and is decessive for the therapeutic intervention to restore knee functional stability.

The functional assessment (for example using scales and simples-low costs) allows obtaining information regarding the adaptation and individualization of a rehabilitation process, tracking the fulfillment of treatment objectives and therapeutic progress. Just the range of motion and a muscular force cannot predict the future of the joints in the kinetic chains activities.

Treatment following knee injury

1. Surgical reconstruction of the ACL

Great advances have been made in the techniques of surgical reconstruction of the ACL, which is recommended especially for the young people and athletes in the hope of returning to pre-injury sports activity.

Without this type of treatment, the subject with ACL is advised to refrain from sports or heavy work/recreational activities, which by accumulating new trauma and can cause early onset of knee osteoarthritis.

2. Post-operative ACL rehabilitation

After the surgical ligament reconstruction the physical therapy intervention goes through several stages and is based on therapeutic protocols that must adapt to each individual case.

Although it is a high promotion for preserving or increasing muscle trophism and mass in the presurgical period, Culvenor et al. (2022) point out that postoperative evaluations verifying preoperative exercise physiotherapy intervention show no differences in definite improvement in physical or self-reported functioning. We consider more important the motivation of the subject to perform and to follow the indications of treatment.

Post-operatively, the purpose of a rehabilitation program is to recover stability, mobility, strength, flexibility and restore the ability to repeat certain technical gestures, trying to bring the functionality of the injured limb to values very similar, if not identical, from the pre-injury period.

Hietamo et al. (2023) recommended neuromuscular training to be included in regular training athletes with previous ACL lesions in order to prevent reinjury (Hietamo et al., 2023)

Arundale et al (2023) updated the knee and anterior cruciate ligament injury prevention guideline which can help therapists apply an evidence-based treatment.

The physical therapy management guidelines propose 5 therapeutic phases after postoperative and emphasize the importance of restoring **strength and neuromuscular control** through exercises to replace the loss of muscle mass and flexibility due to ACL injuries.

In subjects with ACL reconstruction Garrison et al (2015), discuss factors that should be assessed such as strength and power, balance that must be alike for the both lower limbs in order to decrease the risk of future injury.

An important factor that can have a key role is the period that occurs from the point zero (the

moment of injury and the degree of functionality and training) and the surgical intervention moment. If the subject is active or practice intensively a sport and if the surgery restore the ligament very quickly the risk of disturb functionality is lower.

Also the level of pain felt post-surgically by the subject is different and if the pain is great and causes discomfort it will slow down the rate at which the exercises progress and the recovery of muscle mass and stability.

Method

Case presentation

We would like to present the rehabilitation results for a football player, who plays as a side defender or side midfielder for a Romanian football team and in the Romanian SuperLiga. The subject of this study has been a sportsman since the age of 15, currently he is 31 years old, which emphasizes his physical preparation prior to the knee injury he suffered in November 2022.

The injury occurred during a match, he complained of sharp sudden pain in the left knee area, he was diagnosed with ACL, being operated on November 16, 2022 (2 days after injury).

From the medical history of the subject we underline the fact that he suffered a left tibial bone fracture 9 years ago treated by implanting a tibial rod. This was a contraindication to bone-tendon segment harvesting for ACL reconstructions. The surgical reconstruction was made with a fragment of the semitendinosus. This type of intervention requires a longer recovery and rehabilitation period.

At 72 hours postoperatively in the orthopedic clinic, Kinetec was applied for 4 hours a day: in the 1st day the knee extension was performed from 0 to 60°; and the next 2 days the knee extension performed was from 0 to 90°.

After the surgical intervention, 7 days postoperatively, he started a physical therapy (PT) complex program in Romania with a frequency of 5 times a week; figure 1 shows synthetically how the intervention was carried out. Motivated by the desire to return to the field at maximum capacity, the athlete decided to intensively follow the recovery

program, which for him was similar to a daily training program.

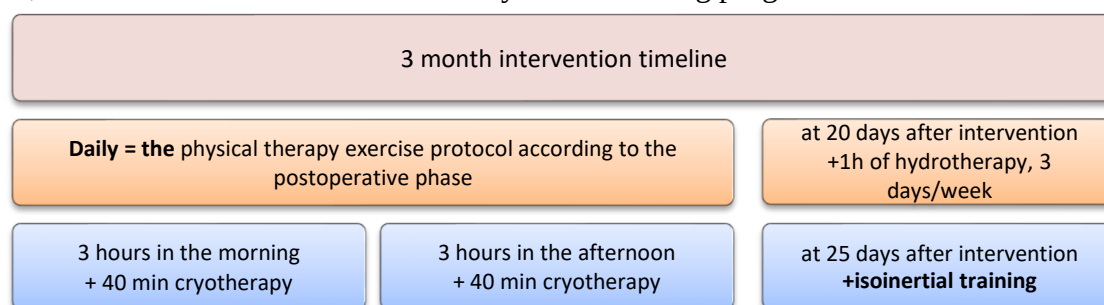


Figure 1. Synthesis of the rehabilitation program applied after the intervention for 3 months

The subject wore an orthosis outside of the recovery program, followed the therapists' instructions. The PT sessions took place over a period of approximately 8 hours daily (3+3 hours exercise program and 45+45 minutes cryotherapy), respecting the values of the pain scores reported by the subject and the principle of progression. For a successful therapy, it was considered that the correct execution is more important than the number of repetitions, at least in the first phase of the therapy for the protection and healing of the graft and the scars. *The PT objectives of the intervention* respected the postoperative stages and progression and are systematized in table 1.

Pain, Edema and swelling management was carried out at the end of each therapy session for a period of 45 minutes cryotherapy using the *Game Ready Knee Ice Machine Cold & Compression Package*.

Table 1. The physical therapy objectives of the intervention

Intervention stages	Therapeutic program objectives
1. The first stage (first 20 -25 days)	- Graft protection -Reduction of painful and inflammatory symptoms (edema) at the level of the joint at rest and in motion, -Extension to 0° of the left knee and flexion to 90° of the left knee - Patella mobility - Correct movement patterns
2. Second stage (20 days)	Objectives of the previous period + - Improving muscle strength/preventing injuries related with the surgical intervention - Improving proprioception - Restoring the stability of the left knee joint to obtain a functionality equivalent to the pre-injury period - Restore Posture + Balance + Correct and pain-free gait with weight bearing on both lower limbs equally
3. Third stage	Consolidation of previous objectives + Returning to competitive sport at a level of effort similar to the pre-injury

The education of the subject was mainly about explanation and teaching him how to manage pain symptoms at home and for the period when he did not do the physical therapy treatment:

First and second stage

- Knee pain and knee swelling can be used like a "*guide*" that can indicate the tolerance to effort and activity and the therapist should educate the subject to recognize the signs.
- Eliminate swelling and risk of swelling by using PRICE protocol (protection

/compression =orthesis, rest = after exercises, ice aplication, elevation)

- Straighten the knee and keep it straight as much as possible for example 20-30 minutes of supine posture for left knee extension repeated 3 times daily.

- Avoid activities that produce pain or increase the level of pain and swelling, graft protection.

- Avoiding keeping the knee in a same position for long periods of time (more than 1 hour during the day)

In the last stage

Control of posture and weight berring in orthostatic position

Control of gait with low speed and correct distribution of weight during stepping, avoiding instability, promoting proper movement patterns

The therapeutic program (table 2) followed the principles and phases recommended by the available guidelines, adapted to the case particularity (a good fitness level preinjury, motivation to perform an intensive and complex and long-time daily rehabilitation program etc). In the first week, a work rhythm was set by the subject that learn to manage the rith according to the pain level, it was desired to *obtain a correct execution rather than a large number of repetitions.*

Table 2: Summary of rehabilitation program applied to the subject

TREATMENT PHASES	
PHASE I: INTERMEDIATE POST-OP (1-5 WEEKS AFTER SURGERY)	
A. Manual therapy to improve AAROM and AROM performed by the physical therapist to increase patellar mobilization (medial and lateral) and to maintain the vascularization – 20 minutes B. From supine 1. Knee extension and hip abduction – bilateral 2. Heel slides on the support surface with knee flexed and extended – bilateral. The extension and flexion should be performed without additional pain in the beginning. 3. Quadriceps strength - push the heel into the support surface, with muscle contracting The push should be firm but not to cause additional pain. 4. Straight leg raises for quadriceps strength development from supine and ventral decubitus 5. Hip abduction from side lying – bilateral C. Cryotherapy	In the first week 2 sets of 10 repetitions (1 set in the morning + 1 set in the afternoon) Then 1 set of 20 repetitions x 2 times/day Then movement is allowed with the increase of 1 or 2 number of the pain value.
PHASE II: LATE POST-OP (6-8 WEEKS AFTER SURGERY)*	
A. Manual therapy – 10 minutes B. From supine – like before C. Orthostatic position 1. Wall slide while standing against a wall with feet apart at the shoulder line, heels at around 30 cm from the wall. Hold the position for 3-4-5 seconds, slowly return to the starting position. The flexion of the knee at around 60°. 2. Partial squat exercises 3. Balance and proprioception - bilaterally 4. Cycloergometer – pedal for 50 minutes (25 min session x 2 time daily) to stimulate blood circulation, improve muscle strength and coordination, without loading in the beguining	2 sets of 20 repetitions x 2 times/day (1 set in the morning + 1 set in the afternoon)

**5. Isoinertial training	
C. Cryotherapy	
PHASE III: TRANSITIONAL (9-12 WEEKS AFTER SURGERY)*	
A. Manual therapy – 10 minutes B. Orthostatic position (for the both lower limbs) 1. Single leg standing balance with a good technique and control of the joints alignment, in front of a mirror 2. Lateral Lunges bilaterally in slow pattern with the importance for correct execution and NOT the number of execution. The number of executions with the same pain level. 3. Romanian Deadlift 4. Single leg squat - bilaterally 5. Calf raises with support- bilaterally 6. Standing hip extensions – for the left lower limb, with support on a stable surface, 10 repetitions in 2 sets. I repeat 10 times without and with a resistance. 7. Plyometric Program (high of a jump at 25 cm and lower) D. Isoinertial training** (Fig 1. The suspension for the isoinertial knee training)	Maintaining the same pain level during the execution If the pain was increased it was recommended to pause or decrease the execution rhythm It was important to obtain the weight control on the lower limbs and with posture control, without trunk rotation.
AROM: Active Range of Motion, AAROM: Active-Assisted Range of Motion	

**PAIN modulates the train intensity. The exercise load was increased progressively throughout the training program according to the subject feedback (ie self-perception and ability) and muscle strength response. For example once the patient could perform 11th repetition with the same level of pain or symptoms the load and repetitions was increased in the next set or training session.*

**** Isoinertial training**

There are many protocols of isoinertial training; a recent study looked at three ways to produce resistance with eccentric overload in trained and untrained subjects, the conclusions being that they all produce similar neuromuscular changes. (Maroto-Izquierdo et al 2022).

Madruga-Parera et al. (2022), evaluated the effects of 8 weeks of isoinertial vs. cable-resistance training on motor skills performance and interlimb asymmetries in handball players and found greater physical improvements and reduction of interlimb

asymmetries in the group using a portable flywheel device.

The quantitative summary comparing isoinertial and elastic resistance exercises by Aboodarda et al. (2016), highlights relatively equal results from the two types of training provided that equal external resistance is used between the two exercises.

This type of training can generate multiple changes in motor unit recruitment, strength and power or neuromuscular and tendon function. (Yáñez, C. A. et al 2022).

From the point of view of the type of effort, isoinertial training involves the development of a concentric and an eccentric effort at the same time, regrouping as many muscle fibers as possible to achieve joint movements.

A Kinett device was used, the support was made on the right lower limb, with the suspension at the level of the left calf. The protocol of the isoinertial treatment applied from the 25th day post-surgical, at the end of the physical therapy session, was progressively applied as follows:

From day 25

- Big butt
- ischigambier

From day 35

- iliac psoas
- quadriceps

From day 40

- Hip abduction and adduction



Fig 1. The suspension for the isoinertial knee training

The advantage of isoinertial training in the case of this subject rehabilitation program was that the athlete previously used this type of exercises for athletic training, so he was familiar with the requests and their execution.

Results

The evaluations were done at the beginning of the therapeutic program and after 2 month. The results obtained from the functional evaluations are presented in table 3.

Table 3: Summary of evaluation of rehabilitation progression.

First evaluation 28.12. 2022	Evaluation of therapy progression on 21.02.2023
Clinical evaluation	
Knee = periarticular significant edema, increased temperature Thigh = bilateral insensible difference in muscle volume Gastrocnemius = no bilateral differences in muscle volume are evident	Knee= no significant periarticular edema Thigh = a bilateral difference in muscle volume is evident Gastrocnemius = no bilateral differences in muscle volume are evident
Explanations. Periarticular edema is a sign of reduced inflammation and represents a favorable evolution. The differences regarding the muscle volume at thigh level was not very obvious immediately after the intervention (Craiova evaluation) due to the fact that the subject was sporty, trained, with a significant muscle mass.	
PAIN Level (evaluated with Visual Analogue Scale- VAS)	
6-7 at rest 8-10 when performing the mobilization and evaluation tests	0 at rest 0 when performing the evaluation tests
Monopod stability. Assesses the body's ability to stabilize when supported weight on one lower limb, during movements. The value deficit represents the differences between the two lower limbs. (figure 2)	
DIFFICULTIES IN MONOPODAL STABILIZATION ON LEFT LIMB	NO DIFFICULTIES STABILIZING MONOPOD ON LOWER LIMBS
Proprioception and balance allow the assessment of stability capacity in monopodal support in various directions. This parameter is a functional indicator in the evaluation of functional recovery and the risk of re-injury and it was performed through Y Balance test. The deficit value represents the difference between the two lower MIs.	
Anterior = bilateral deficit Posterior medial = bilateral deficit Lateral posterior = bilateral deficit	Anterior = bilateral deficit Posterior medial = no bilateral deficit Lateral posterior = no bilateral deficit

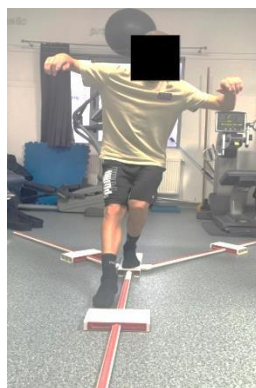


Figure 2. The functional assessment using Y Balance test platform

Discussion and conclusions

The rehabilitation of sports injuries is based on multiple knowledge, from several medical area, which are based on clinical studies that present solid results with the ultimate goal the returning to the field and competition. Sometimes this goal is difficult to achieve, and different percentages of success are reported, depending on the sport and the age of the athletes.

ACL injury alters the longevity of performing a sport, with other long-term consequences, such as speeding up the onset of future knee osteoarthritis. (Buerba, R.A., et al 2021).

Garrison, J.C. et al (2015) felt that there is little information regarding the outcomes of early rehabilitation and the achievement of functional and performance indices to ensure a safe return to sport.

The differences regarding the muscle volume at thigh level was not obvious immediately after the intervention, due to the fact that the subject was high level athlete, trained, with an important muscle mass and the intervention was done relatively quickly, before the appearance of the atrophies that are characteristic of immobilization.

We cannot draw general conclusions regarding the future sports evolution and return to performance sports practice or to a high level of effort without the risk of a new injury. The muscle deficits captured by the tests are mentioned and help the therapist to shape and individualize the proposed exercise program as best as possible.

But, we can underline the fact that the athlete motivation and previous training level is a key factor that enhance adherence. Different studies show different percentages of return to sports activity, but they are lower than we might expect and are influenced by different factors (Webster & Feller, 2019; Buerba et al 2021, Garrison et al., 2015), consider that balance and the equal muscular properties for the lower limbs are some of them.

Also, this case proves that functional tests and evaluations should be common language between therapists from different countries who dealt with the treatment of sport injuries subject. The therapists need less sophisticated and sport-specific skill screening tools and time-saving tools and costs (Hietamo et al., 2023). Because expensive or complicated testing equipment are rarely available and will not be currently applied to commun subjects.

Functionality assessment scales (such as the Y Balance test) can be also a step in introducing appropriate injury prevention strategies especially for lessions where the studies present the known future risks.

Knee trauma among athletes who practice football for performance or as a leisure activity are frequent and a correct diagnosis and an early and complex intervention program can reduce the risk of recurrence and recovery time.

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