

# Physical rehabilitation of muscles, tendons and ligaments

## Abstract

The principles of physical medicine and rehabilitation for acute injuries of muscles, tendons and ligaments include following stages: healing of soft tissue, early mobilization after injury, and progressive tissue loading in order to return to the functional level. The aim is the control of pain and edema, restoration of normal range of motion, strength, endurance, and neuromuscular control to achieve the optimum functional level and return to activities. The management of tendonopathies includes eccentric exercises and stretches. Other factors, such as changes in exercise program, orthotics and other rehabilitation interventions can also reduce pain and improve functionality.

**Keywords:** Rehabilitation, Soft tissue, Physical modalities, Tendons, Muscles, Ligaments

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## Introduction

Many soft tissue injuries result in some degree of permanent disability and leave the subject with permanent pain and limitations in functionality. The days of long term immobilization regarding the treatment of soft tissue injuries belong to the past. Modern literature redefined rehabilitation goals, highlighting the many benefits of using physical modalities, early mobilization and the importance of properly organized rehabilitation programs.

In the largest proportion of cases the changes after any type of injury are more than the summary of clinical symptoms that the patient displays. To this end treatment should take into account all the changes after extensive clinical examination. Part of these changes include, a) clinical changes involving a cluster of clinical symptoms, b) structural changes involving a complex tissue injury and a tissue complex under increased loading, and c) physiological / mechanical changes involving a complex of functional biomechanical deficits and a complex of subclinical adaptations.<sup>1</sup> Specifically anatomical changes are involving a group of tissues that have a clinically apparent injury or a group of tissues that were exposed to stress and exhibit subclinical changes that either participate or worsen the problem. The physiological / mechanical changes are changes in flexibility, muscle strength and balance which modify the mechanical and efficient performance of the patient. The subclinical adaptations are group patterns of movements and activities which are used by the patient as a counterpart of the other changes that have occurred. The degree of involvement of each of these changes should be evaluated carefully.<sup>2</sup>

## The principles of rehabilitation for acute soft tissue injuries

Before analyzing the principles a question needs to be answered: If is preferable the immobilization or early mobilization in injuries

of soft tissue. This question had been previously answered in a pioneer publication of Pekka Kannus.<sup>3</sup> According to his article, the stages of healing after an acute injury of soft tissues are three: the phase of inflammation lasting until 7th day, the phase of propagation lasting from 7th to 21st day and finally the stage of maturation and remodeling after the 21st day. The stages of rehabilitation are also three: acute, recovery and maintenance.

A rehabilitation protocol after injury of soft tissues includes: mobilization techniques, use of physical modalities and muscle strengthening.<sup>4</sup> At the stage of acute inflammation the main events resulting in inflammation are ischemia, metabolic disturbance and destruction of the membrane of the cells. This inflammation is characterized by infiltration of tissues by inflammatory cells, tissue edema, wall thickening of capillaries, plasma leakage etc. Clinically inflammation is manifested as swelling, reddening, increased temperature, pain and loss of function. This process is time dependent and characterized by vascular, cellular and chemical events culminating in tissue repair (tissue building) or in some cases scarring.<sup>3</sup>

The acute rehabilitation phase primarily focuses on complex clinical symptoms and cluster of tissue injuries. Applying treatments need to reduce the symptoms of acute inflammation and injury, swelling and promote tissue healing. Anti-inflammatory drugs, suitable splints and possibly surgery could be applied. During this initial phase of acute inflammation, long term use of cryotherapy (mainly with ice) is considered the most effective treatment, as supported by many studies. Cryotherapy slows the progression of inflammation and has analgesic activity. The credibility problem regarding the use or not of ice was created because of poor methodology of the clinical studies which investigated the issue of cryotherapy. In these studies, randomization problems according to the exposure in cold were the issue and thus failure to achieve scores of 10 in Physiotherapy

Evidence Database (PEDro) scale. However, it was possible to achieve higher scores than 5. The quality assessment of randomized, controlled clinical studies is significant because studies' results with poor planning eventually are biased for or against the effectiveness of treatment (over- or underestimate). Despite the general acceptance of cryotherapy as an effective intervention, the elements which support it are limited. Strong randomized, controlled clinical trials are required in order to understand the actual effectiveness of cryotherapy.<sup>5</sup> The transcutaneous electrical nerve stimulation (Transcutaneous Electrical Nerve Stimulation - TENS and Electrical Muscle Stimulation - EMS) is also effective. The continuous passive motion (CPM) machine, which helps in clearing haemarthroses in the initial phase, is also helpful. In a period of 24 hours after trauma, less blood in the joint after application of a continuous passive motion CPM was found compared with immobilized joints, while at 48 hours at joints applied CPM, synovial fluid was clear, in contrast to the corresponding immobilized which remained bloody.<sup>4</sup> During the acute phase possible is also the application of specific maneuvers, aiming to accelerate the blood away from the joint, reducing the local spasm, swelling, pain and possible irritation of nerve branches.

In a case of a muscle injury a short period of rest is useful, but should be limited to the first few days. This period allows the scar tissue to connect smoothly to remaining injured muscle, so that muscles regain the necessary strength to withstand the loads of the forthcoming generated contractions without the risk of a new rupture. Moreover, reducing the immobilization only in the first days reduces to a minimum the side effects of immobilization period. Some of the adverse clinical effects of immobilization are the substantial atrophy of healthy muscle, excessive deposition of connective tissue in the muscle tissue and a significant delay in the return of the injured muscle strength. If immobilization extends beyond the acute phase (first few days) the destructive effects muscle regeneration will occur also in degeneration and rehabilitation phases. It has been tested in the 10th day after injury in experimental models (mice) that tension in the healthy part of the muscle showed failure, indicating that the tension force of the scar tissue of the connective tissue becomes greater than the muscle tissue in that time. As result, the injured muscle activity must start before this time [6]. Immobilization has shown positive results in the early phase of muscle regeneration and experimentally has been shown, although paradoxically, that placing the injured muscle at rest in the first days extensive scarring and recurrence / relapse ruptures the wound section can be prevented with best way. As mentioned above, immobilization gives the new-formed tissue a necessary tensile strength to withstand the forces caused by muscle contractions.

The beginning of active mobilization after a short rest period (as supported by experimental data) prospers penetration of muscle fibers through the scar connective tissue, reduces the size of the permanent scar, facilitates the proper assembly of emerging muscle fibers and helps in regaining dynamic voltage of the injured muscle. If the acute phase of injury has passed without further complications and recovery seems to evolve smoothly, after 3-5 days the active mobilization of the muscle should be gradually start. Moving on to the second stage of healing (lasting from 7<sup>th</sup> to 21<sup>st</sup> day), the inflammatory cells remove tissue debris by phagocytosis, the fibroblasts proliferate and increase significantly the production of collagen (primarily type collagen 3 and then type 1) and other components of the extracellular matrix. Finally in the third stage the content of the matrix of the newly-formed joint or tendon is reduced in water and proteoglycans, while collagen fibers type 1 acquire physiological orientation. Approximately 6-8

weeks after injury, the new tissue is able to withstand loading forces, although the completion of maturation of the joint or tendon may require up to 6-12 months.<sup>3,4</sup>

The recovery phase is the longest and the phase in which rehabilitation medicine has the greatest participation and contribution. This phase includes the lysis of tissue injury complexes and restoration of tissue overload complexes and the functional and biomechanical deficits. The emphasis at this stage is shifted from the clinical symptoms to functioning. The anti-inflammatory therapeutic agents are much less used and have only supported role. During this phase, proper loading of the tissues is the most important therapeutic agent. As Dr. James Cyriax supports, action at this early stage allows the collagen fibers to be arranged in the longitudinal axis of the link, acquiring a normal orientation and preventing their abnormal attachment.<sup>7</sup>

## The rehabilitation program

We know that the aim of rehabilitation is to maintain the functionality of soft tissues, so that the patient may again become fully operational by performing movements free from pain, with full power, strength and range of motion. To achieve this during rehabilitation of the treated tissue functional loading should be applied. If one limb remains immobilized throughout the duration of rehabilitation, the tissue will heal but would be poorly adapted to the functional requirements with low adaptation probability especially if the immobilization period was long. The mobilization techniques should be applied throughout the duration of the propagation and remodeling phases to ensure the correct tissue adaptation. The mobilization must be carried out based on pain levels in patients, starting with controlled passive mobilization, which continues until the maximum range of motion succeeds. It is also essential to preserve the remaining parts of the body in good physical condition. Progress criteria from the acute phase to the next phase will be the control of pain, tissue repair to enable appropriate loading of the joint and range of motion of the joints to be painless in about two thirds of normal.<sup>7</sup>

The Deep Transverse Friction Massage (DTFM) is a technique introduced by Dr. James Cyriax to relieve pain and inflammation in musculoskeletal problems.<sup>8</sup> This technique aims to reduce uneven fiber synapses and make scar tissue more flexible in sub acute and chronic phase of inflammation through realignment of healthy fibers of the soft tissue. Furthermore, it has been found that DTFM additionally promotes normal recovery preventing the formation of abnormal scar. Finally, the mechanical action causes hyperemia with increased blood flow to the area.<sup>9,10</sup> The DTFM benefit was supported in a study in which one group of patients received two sessions-DTMF, ultrasound and placebo ointment, while the control group only ultrasound and placebo ointment. Patients in the DTFM treated group regained good functionality and were able to participate successfully in endurance programs with statistical significance.<sup>11</sup>

As the tissues regain their integrity gradually isometric and isotonic strength training and flexibility exercises are applied. At this point active assisted motion can be implementing, and as the wound is recovering and the tissue is adapted, the patient can gradually perform active movement with resistance. The program continues with strengthening using specific resistance exercises. The above sequence is the optimal for the recovery of the maximum force of the patient. The mobilization has an important role in restoring injured soft tissue and benefits include: increased strength and flexibility of treatable tissue, limitation of the extent of formed scar and adhesions,

enhancing the nutrition of cartilage, and reduction of re-injury frequency. Attention should be drawn not only in pain but mostly in the area of tissue which would be overloaded. Deficits in flexibility and muscle strength should be trained and corrected and restoration of muscle balance is needed. Emphasis is placed on concentric and eccentric muscle contraction. The program includes initially closed chain exercises and is later enriched with open chain exercises. Criteria to continue from this point are to achieve complete healing of tissue, lack of pain, range of motion between 80%-85% and muscular strength equal to 75% of the opposite side.<sup>3,4</sup>

The plyometrics, i.e. eccentric contractions exercises that increase muscle length, were first described in 1984. Plyometrics have a role in treatment of tendonopathies as they normalize the concentrations of glycosaminoglycans and arrangement of collagen fibers resulting in reduced tendon thickness, while increasing the passive ROM, the length of the muscle-tendon unit and the tendon strain force through the progressive charging. Especially in the third phase of maturation and remodeling, plyometrics contribute to collagen deposition and enhance muscle-tendon contribution and strength of connective tissue, while sarcoplasm network and sarcolemma level increase their resilience, reduce induced calcium damage and the efflux proteins of myofibrils. The guidelines for the use of eccentric exercises in rehabilitation medicine recommend gradually increase of resistance, strain and load (load force at 120% -150% of the maximum voluntary isometric contraction), speed of the exercise and continuity of the program (over 6 -12 months) till full return in functioning.<sup>12</sup> Moreover, hyperbaric oxygen therapy may assist in the late onset of pain management after closed trauma of soft tissue.<sup>13</sup>

An important goal of rehabilitation is to achieve satisfactory motor function, as expressed by the range of motion index (ROM). Limitations of this indicator are related with barriers in activities of daily living. One of the factors limiting ROM is the development of contractures as a result from changes in soft tissues such as muscles and skin. Techniques aimed at improving the ROM include passive stretching to prevent shortening of muscles and physical modalities for improving muscle plasticity.<sup>14,15</sup>

According to physical modalities in the context of the rehabilitation program, it is expected to improve muscle and joint movement, relax muscle tone and increase muscle's and tendon's elasticity. More particularly, thermotherapy has been found to be effective in prolonging the muscles, with an additional benefit of increasing the flexibility of the collagen fibers. The results in the increase of fiber length are better when combined with stretching. Ultrasound, a widely used form of thermotherapy, which manages to penetrate deep into tissues, have been proven more effective in improving the ROM compared to superficial thermotherapy, when applied as continuous thermal waves with intensity 1.0-2.5 W/cm<sup>2</sup>.<sup>16</sup> The maintenance phase is the final phase of the rehabilitation program. In this phase, the patient should be ready to return in activity (sometimes with restrictions or protection). During maintenance phase subclinical adjustments and biomechanical functional deficits need to be trained. Emphasis is given on functional improvement based on normal mechanical activity or improvement in biomechanics when required. This activity should be supervised and the risk of mechanical failures should be properly assessed. Several studies have attempted to determine the optimal time for mobilization and return to activity. This is an important task as to ensure enough time for the formation of a sufficient amount of collagen in the muscle-tendon unit able to withstand the strains-loadings and generate torque in the joint, without to be detrimental in final mobility.<sup>17</sup>

In a study of two rehabilitation programs considering recovery time after rupture of the hamstring a group of 11 athletes followed protocol consisting of static stretching and resistance exercises of hamstring and cryotherapy was compared to a group of 13 athletes, followed protocol with agility exercises, balance of the body and cryotherapy. Time of returning in sports activities was significantly shorter for the second group, which may suggest that the first group was followed rather a relatively poor program. It is unclear which neuromuscular factors are responsible for the promising clinical results and reduce of injury frequency in 2<sup>nd</sup> group. The authors describe 2 hypotheses to explain this result. The 1<sup>st</sup> one suggests an improved neuromuscular control of lumbosacral region allows hamstrings to operate in secure elongations and strains during sport activities, reducing the risk while the 2<sup>nd</sup> one that the early use of sub maximal loads reduces residual side effects of scar tissue that had been created during the reconstruction process.<sup>18</sup>

Protective equipment such as elbow, ankle or knee braces may be used at this stage for faster return to activity. However, in most cases the use of braces is temporary and braces must be removed as quickly as possible. Criteria of a fully return to sport activity should be strict and include: an end of all vicious circles complexes, complete mobility, muscle strength equal to the opposite side, balance of power within the required limits for the activity and completion of operational progress activities.

Some conclusions for the rehabilitation program can be drawn from a systematic review of rehabilitation after correction of the rupture anterior cruciate, which reached the following conclusions: 1) Early weight lifting has proved useful with an additional benefit of reducing the Patellofemoral pain. 2) Early mobilization was safe and effective in preventing fibrosis and stiffening of the joint. 3) The CPM has deterrent costs compared to the potential benefit. 4) Use of a knee splint postoperatively seemed to be particularly effective. 5) Rehabilitation in an outpatient setting can be applied to selected patients without increasing the risk of serious complications. 6) The neuromuscular electrical stimulation (NES) has proved essential for patients and early introduction of the postoperative treatment is highly recommended. 7) The application of accelerated rehabilitation programs after five or six months had positive results. 8) Finally hydrotherapy, the use of inclined treadmill and stairs can provide some variety in rehabilitation program.<sup>19</sup>

Regarding the rehabilitation of tendons knowledge is based on surveys limited to the hand, shoulder, anterior cruciate ligament, patellar and Achilles tendon. We are aware of sequence of events leading to injury: after a period of repetitive strain of the tendon and subclinical episode of adaptation failure to required loading, progressively pain appears that would lead a person to seek medical assistance and further rehabilitation.

The challenge is to find the optimal time during rehabilitation period in which the person can return to athletic activity, in order to ensure sufficient rest period without any atrophy of adjacent muscles and joints. Specialized rehabilitation programs are therefore required, which must take into account the specific mechanical and physiological requirements of tendons. However, the ideal combination of exercises, physical modalities, drugs and surgical interventions has not yet been determined.<sup>20</sup>

In particular for an objective assessment of Achilles tendon rupture, the assessment of the impact of symptoms (pain, stiffness, fatigue, weakness) during physical activity of the patients and monitoring rehabilitation program, the Achilles Tendon Rupture Score (ATRS)

system is proposed, which is friendly to the patient and the physician and can be completed easily by answering ten questions, providing a reliable picture of the clinical situation.<sup>21</sup>

Rehabilitation methods include cryotherapy, electrotherapy (which stimulates collagen synthesis in laboratory conditions, however this is not supported by good clinical studies), acupuncture with analgesic activity, orthotics systems (i.e. heel lifts, elbow braces etc.) which allow the unloading of the region, possibly by redistributing the forces to a larger surface area, while changing the direction of traction of the tendon, and improve proprioception, and finally the specific strength programs, which stimulate tendon's cells to collagen synthesis with eccentric loading.

## Clinical examples

We will present below two clinical examples in order our theoretical approach to be understood in the rehabilitation of these structures: 1) Intennis elbow or *lateral epicondylitis*, clinical symptoms include pain and tenderness on the outside of the elbow and the surface of the annular ligament. Injured tissues include the origin of extensor carpi radialis brevis (chronic degenerative changes) and shin splints, but also muscles of the shoulder, supinators and biceps muscles. The functional biomechanical deficit refers to an inefficient pattern or movement of extension of the elbow, pronation and supination of forearm and reduced power to extent the wrist. Subclinical adaptations include improper technique on hitting the ball allowing for power in a swing to rotate through and around the wrist-creating a moment on that joint instead of the elbow joint or rotator cuff which leads to reduced performance or injuries risk. 2) In the case of plantar fasciitis the complex of clinical symptoms includes local tenderness over the origin of the plantar fascia on the heel, which is aggravated in the morning, after running and the seat bottom. The tissue complex with injury involves the plantar fascia in her origin and calcaneal spur. The tissue complex with increased loading comprises plantar fascia and calf muscles. The functional biomechanical deficit refers to stiffness and muscle weakness of calf muscles and reduced flexibility in ankle dorsiflexion. Subclinical adaptations are decreased stride length, toe/heel landing pattern in stance and reduced stance phase on walking cycle on the affected side.

## Conclusion

It is important to be realized that the clinical symptoms often play a smaller role in the total presentation of an injury problem. Although the patient focuses on the clinical symptoms, functional rehabilitation should be the goal of the therapeutic process. The rehabilitation of injuries should be based on the healing process of tissues and restoration of functional ability. The objectives of rehabilitation include tissue integrity, maintenance of other components of fitness, analysis of all cycle injury complexes and specific functional criteria in order to return to an athletic activity.

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## Conflicts of interest

None.

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