

The Science Behind the Development of Rehabilitation Protocols

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Introduction

Physical therapy in human medicine is a field that continues to grow steadily due to the successes in this field of medicine over several decades. These successes are partially due to the advancements in the science behind rehabilitation. When the healing processes, necessary for quality rehabilitation, are better understood there is an increased chance that healing will be optimized.

Many terms can be used to describe this area of specialty, such as neuromuscular rehabilitation, therapeutic exercise or physical rehabilitation, to name just a few. The description of the process is the most important regardless of the term used.

In human physical therapy, therapeutic exercises are used in an individualized, systematic and planned manner to:

1. Repair, improve, restore or enhance physical function.
2. Prevent or reduce health-related risk factors.¹

It is important to note that physical therapy is not only used after injury or surgery, but is also a primary means to prevent injury and enhance performance. This is one reason that many of the exercises in physical therapy are similar to those used in sports. In addition, physical therapy actively deals with structural faults that resulted in the initial injury, or *could* lead to further injury. Compensatory issues are addressed as well, and many times are the initial area of focus of the rehabilitation plan.

In equine practice the active use of rehabilitation techniques has been an exciting advancement. However, if the science behind the concepts are not evaluated the outcomes may not be optimal. If one method or modality has some success, others jump on the bandwagon to participate as well. While this type of reaction is obviously not ideal, it is important to continue to reevaluate the current methods to see if a change in procedures or modalities can obtain better outcomes. So, how is one to determine the difference between a fad and an effective method or modality?

While scientific experiments can be flawed, this type of evaluation is still considered an excellent way to support the validity of a concept. Double-blind-large-sample-size studies are thought to be the gold standard. However, statistical evaluations are only valid and powerful when the sample sizes are large enough. Antidotal information in large numbers that has been gathered within specific parameters can also be useful to determine the merits of data.² Much valuable data is lost because

the practitioner may think that the successful outcome of their technique with a large number of horses is not useful information.

A review of both science-based and clinical-based information can assist the individual in determining if a new or improved rehabilitation procedure or product falls within the realm of reason. Therefore, the purpose of this presentation is to look at studies evaluating the development of protocols in the human field as well as to discuss specific schools of thought concerning protocol development and how this may apply to equine practice.

Rehabilitation Protocol Development History

A brief review of the development of protocol design in the human field can provide useful insights into the process as equine protocols begin to develop. Initially, human rehabilitation protocols consisted of general categories of rehabilitation guidelines for bone, ligament/tendon and muscle. From this general information grew specific protocols for each grade of each injury, including illustrations of specific exercises.

Injury grading was important to clarify the differences between rehabilitation protocols. Muscle, tendon and ligament injuries are most simply graded by the American Academy of Orthopaedic Surgeons as; Grade 1 - the tissue was overstretched with or without swelling, Grade 2 - the tissue had some torn fibers and swelling was present, and Grade 3 - rupture of the tissue.

The difference between the amount of stress and the resulting strain that the injured site can accept, the number of repetitions, and the rate of repetitions further helped to clarify the different rehabilitation protocols. For example, at certain times during the rehabilitation protocol, an increase in stress is appropriate, however an increase in the number of repetitions is not.

In the early years, rehabilitation models were only skeletons of information describing the procedures. However, this was an important beginning because the practitioners at least had some guidelines to systemically test. Over time, additions and subtractions were made to refine the details of the rehabilitation protocols.

The identification of compensatory pain, as an important part in the rehabilitation treatment protocol, was also introduced. A diagnosis is important and will locate the source of the structural fault. However, this specific site may not be the area of primary pain, or secondary structural faults may also exist. At times, this compensatory pain, or secondary structural fault, may need to be addressed before the correction of the major fault can begin.

Clinical prediction rules, which were an attempt to identify functional problems of the body that could predispose it to injury, soon followed. Large amounts of data were reviewed to determine if injuries could be predicted by a variety of measurements. For example, does a bow-legged person have a greater lifetime chance of having a tear of the anterior cruciate ligament.

Different rehabilitation concepts are constantly being tried and tested in the human field. A couple examples of these concepts includes; hypermobilization as a

predictor of pain, and the use of micro rather than macro movement during rehabilitation. These techniques started as alternatives to the original thought process of an ideal protocol and over time moved into mainstream usage.³

General Rehabilitation Protocol Guidelines

The knowledge of healing rates for different structures is the basis for rehabilitation protocols. Muscle tissue is rehabilitated differently than tendon and ligament tissue.⁴ However, if there is an injury to the tendon and/or ligament, there will be an associated injury to the muscle. Therefore, it can be difficult to single out one tissue for rehabilitation without keeping in mind the rehabilitation necessary for the associated tissues.³ This necessity of combining different tissue healing processes in rehabilitation could be one of the reasons rehabilitation plans may vary. Seemly different plans can have both successes and failures and gleening out the differences between the types of injuries and the best healing plan can be daunting.

Figure 1 illustrates the overlap of the general healing processes of a Grade 3 muscle injury and a Grade 3 tendon/ligament injury. Each injury should be viewed as an individualized case, and this guideline provides only a generalized tool. Guidelines such as this can prove helpful to implement the appropriate rehabilitation plan at the optimal time.

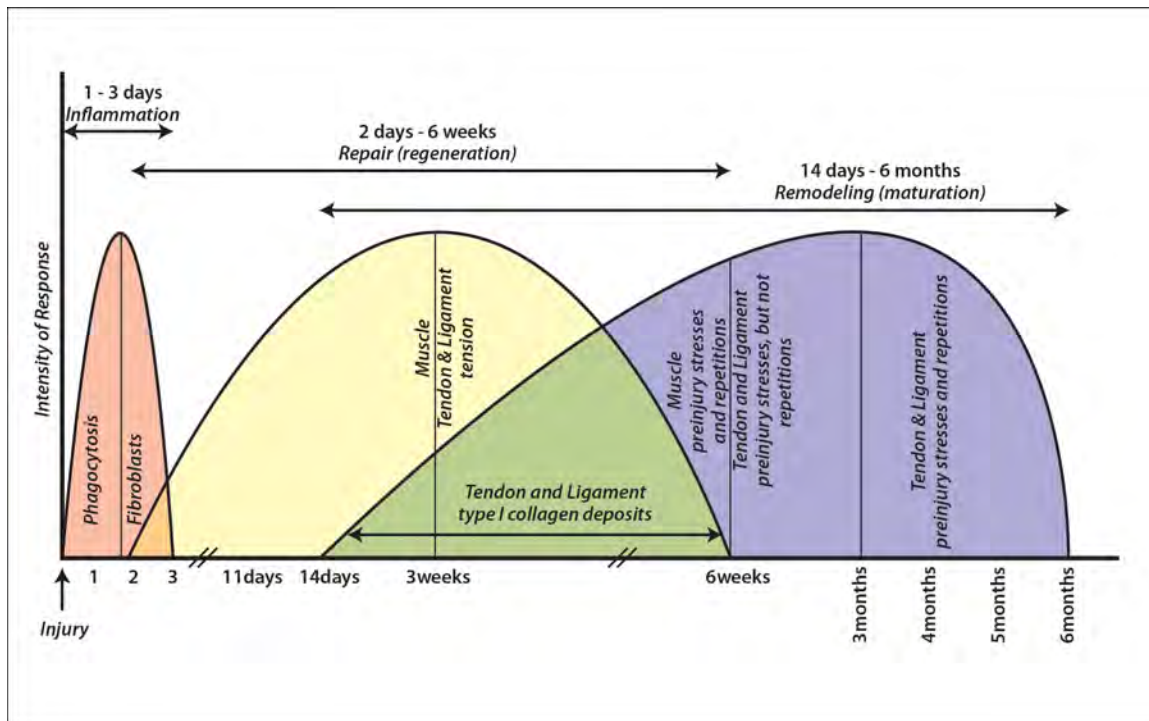


Figure 1. Healing rates of Grade 3 muscle, tendon and ligament injuries.

Muscle Rehabilitation

The majority of muscle problems in humans involve two-joint muscles, probably because of the synchronization of contraction and relaxation.^{5,6} Muscle injury is most often attributed to three factors:

1. Inadequate muscle length or strength.
2. Muscle fatigue.
3. Inadequate muscle skills.

Skeletal muscle can change relatively quickly in its composition and functional characteristics to adapt to different types and levels of stresses.^{7,8} Unfortunately, this ability to rapidly adjust can be positive or negative during recovery from injury. For example, immobilization can quickly produce significant changes at the muscular level.

One of the ways to improve the outcome of the healing process is through the use of early mobilization. Much of the current research has found that mobilization should be started as soon as possible to; properly align the regenerating muscle fibers, limit the extent of connective tissue fibrosis, regain flexibility, and prevent further injury and inflammation.^{9,10,11} Even in cases of severe injury to the muscle, active mobilization is begun within the first week.¹⁰

Human studies have found that with 4 to 6 wks of bed rest there was a decrease of up to 40% in muscle strength, and even after 6 months of weight-bearing activity, losses in bone mass had not fully recovered.¹² After 3 days of bed rest, peak-power output declined 10-14%.¹³

The effects of 7 weeks of cast immobilization have been studied on the healthy forelimbs of horses. Even after 8 weeks of forced exercise after cast removal, the limbs did not return to their pre-immobilized musculoskeletal state.^{14,15}

Conversely, if mobilization happens too early after injury the repair process may be inhibited. Inflammation is not all bad and phagocytosis has been shown to be necessary to stimulate healing.^{16,17} In addition, overloading during the early stages of rehabilitation can be detrimental and may lead to increased connective tissue formation.^{18,19} The appropriate amount of mobilization is necessary so that the healing process is stimulated, but not over stressed.

So, when should mobilization begin? Most practitioners agree that for a Grade 3 muscle tear, mobilization can begin between 1 and 3 days after the initial inflammation period is over. After approximately 6 to 8 weeks, the new muscle tissue can accept near preinjury stress and preinjury repetitions, and protection is no longer needed.¹⁹ In less severe Grade 1 injuries, mobilization can occur immediately after trauma. (Figure 1, Table 1)

The activation of both synergistic and antagonist muscles is also important to quality healing. Without that activation, maturation of the injured muscle does not occur due to the lack of contractile activity.²⁰ Flexion and extension movements are

equally important when developing a rehabilitation protocol to help retain the balance of the injured site. At times, certain exercises are emphasized and this varies during the treatment protocol. However, the balance and symmetry of the body mechanics is always the end goal of a quality rehabilitation program. (Table 1)

MUSCLE REHABILITATION PROTOCOL					
	Onset of injury	Day 3	Week 1	Week 2	Week 3
Grade 1	IC* and F	F	F	S and F	S and F
Grade 2	IC and F	F	S and F	S and F	S and F
Grade 3	RIC*	S (light)	S and F (light)	S and F	S and F
TENDON/ LIGAMENT REHABILITATION PROTOCOL					
	Onset of injury	Day 3	Week 1	Week 2	Week 3
Grade 1	IC and F	F	F	S and F	S and F
Grade 2	IC and F	F	S and F	S and F	S and F
Grade 3	RIC	S (light)	S and F (light)	S and F (light)	S and F

F = Flexibility exercises
 S = Strengthening exercises
 *IC = Ice, Compression
 *RIC = Rest, Ice, Compression

Table 1. Early mobilization techniques for muscle, tendon and ligament

Tendon and Ligament Rehabilitation

In general, ligaments and tendons are soft connective tissues that stabilize and guide the motion of joints and transmit forces from bone to bone and muscle to bone.²¹ There are differences between ligament and tendon structures, but in rehabilitation they are viewed in similar ways.^{22,23} Of course, certain tendon and ligament structures will need individualized rehabilitation plans, especially when the injury is severe. However, generally these structures are rehabilitated in a similar way.

Ligament and tendon injury is most often attributed to three factors:

1. Pathological rotation.
2. Overloading.
3. Excessive, repetitive loading.^{24,25}

In addition, ligament and tendon injuries almost always affect several different structural components, rather than just one.²⁶

Immediately after injury the ligament or tendon is filled with inflammatory cells. Within 24 hours, phagocytosis is removing debris and necrotic cells. At about day 2, the macrophages are gradually replaced by fibroblasts, and the lay down of type III collagen scar tissue begins. Between 3 and 6 weeks, the turnover begins, and type I collagen begins to predominate.²⁷ At 6 weeks, the tendons and ligaments can

withstand preinjury stresses, but not at preinjury repetitions. (Figure 1) This level of work is recommended due to the fact that human tendons during exercise have been found to have stresses of 25-33% of their maximum strength.²⁸

When should mobilization occur for tendon and ligament damage? If the early stages of repair are not emphasized, opportunities are missed that can optimize tissue healing. With Grade 1 and 2 injuries, early mobilization can begin within 3 days. With Grade 3 injuries, active mobilization should occur after 3 weeks, although passive mobilization can begin within 3 days after injury. The previous standard of 6 weeks of immobilization is not frequently recommended.²² (Table 1)

Conversely, aggressive mobilization during the first 3 weeks may be detrimental to collagen orientation, leading to gap formation and/or repair failure.^{29,30} Studies found that for severe ligament damage, collagen remodeling is the best with the use of site immobilization for up to 3 weeks followed by mobilization.³¹ However, the clients were not bed rested and mobilization of the associated tissues was important in the healing process. In addition, some research has shown that during nerve regeneration, mobilization during the first 3 weeks may delay revascularization and encourage more scar formation.³²

The majority of the past research on tendon and ligament healing has focused on collagen type. As research progress, the understanding of the role of the proteoglycan matrix and other non-collagenous cells in healing will further assist the development of rehabilitation techniques.³³⁻³⁶

Reinjury

Reinjury is common and is unavoidable to a certain extent because no rehabilitation protocol can be 100% effective. Many times another injury will occur to the structures associated to the primary injury. Sometimes this can be due to the disruption of the whole horse mechanics when the primary injury occurs. Therefore, the compensatory faults, if not corrected, could be what eventually leads to the overall failure of the body rather than the primary injury.

However, trying to reduce injury is not a completely lost cause. Working with the whole body mechanics during rehabilitation of a primary injury can be of great help in reducing reinjury, but this approach is time consuming. Research has shown that when isolated rehabilitation of acute hamstring strains emphasized only stretching and strengthening of that specific muscle group, 54% of the athletes reinjured. When hamstring specific exercises were combined with early movement and pelvis and trunk muscle exercises, the reinjury rate was zero.⁹

To heal injuries and prevent reinjury, flexibility training is extensively used.³⁷⁻⁴⁰ Controlled stretching can increase collagen synthesis and improve fiber alignment leading to improved strength.²¹ However, too much flexibility can also prove detrimental, and both hyper and hypo flexibility were found to increase injury.⁴¹

Equine Rehabilitation Protocol Development

Current rehabilitation practices replace immobilization with specific exercises to improve muscle and joint movement, and reduce pain. These exercises focus on balancing the changes in the load, the number of repetitions and the rate of repetitions several times a day. A balance between strength and flexibility is emphasized.⁴² Table 1 outlines the progression of techniques in human rehabilitation and approximately when either strengthening or flexibility exercises should begin.

It is useful to note that in human athletes, Grade 1 and 2 injuries almost always have some pain after the initial trauma. In Grade 2 injuries, the athlete typically cannot continue to perform. In a Grade 3 ruptures, there is severe pain when the trauma occurs, but there may be little pain soon after. Many times because there is no severe pain, the athlete will then continue to perform which leads to even more severe damage.²²

When atrophy is present, strengthening of the muscles is primary. Slow twitch muscle fibers tends to atrophy faster than fast twitch fibers and the level of connective tissue is increased in atrophied muscle.⁴³ Research has shown that after joint damage there may be selective inhibition of motor units, which could explain why atrophy many times occurs after joint injury.⁴⁴

Flexibility exercises should be incorporated into the mobilization programs as early as possible.⁴⁵⁻⁴⁷ Many times the flexibility exercises are much more difficult for the client to perform, but the addition of flexibility during almost all stages of rehabilitation must be emphasized.^{48,49}

Range of motion (ROM) is related to the level of flexibility, and normal ranges of motion in most joints have been established for humans. These ranges are used to determine the flexibility exercises needed, as well as guide the progress of the rehabilitation program.⁵⁰⁻⁵² However, simply evaluating the joint angle obtained during ROM activities can be misleading. A large ROM of a specific joint may be due to the client utilizing other associated joints to increase the targeted joint's movement and therefore may not be reflective of the ROM of the joint under observation. For example, the client can increase the ROM of the knee joint by rounding the lower back to repositioning the pelvis, thus giving the impression of a greater knee extension than is possible with the neutral positioning of the pelvis.³

A direct relationship between the level of pain and the level of inflexibility has not been found. Muscle inflexibility may be as severe in the later pain-free stages of rehabilitation as it is in the early more painful stages of injury. Therefore, pain is not always the best guide in determining muscle flexion limitations.^{53,54} In addition, a very small amount of joint effusion can reduce muscle flexion, therefore joint stiffness is typically related to the level of flexibility.^{55,56}

The load applied during mobilization is specific to the injury and the species tested, and a high stretching force during rehabilitation is not necessarily better. Low forces (5 N) have been found to produce as much improvement in strength and reduction in stiffness as higher forces (17N), when used on canine flexor tendons.³⁰

In addition, tendons that are under high tensile loads should not be stressed during flexion to the level of tendons at lower tensile loads. Therefore, the specific type of stretching is more important to healing than the degree of the stretch, where more is not necessarily better. The first few degrees of movement are considered to be the most important means to change muscle memory.³

A working rehabilitation protocol for muscle, tendon and ligament is listed in Table 2 illustrating the differences between; Strains (Grade 1), Sprains (Grade 2) and Tears (Grade 3). The protocol makes a distinction between the times for increased stress, increased repetitions and increased rate of repetitions, due to the different tissue responses to each of these parameters.^{30,44,45} Serial ultrasounds will aid in determining the progress of the protocol, and if healing is not progressing as desired, then the protocol can be altered.

Neuromuscular electrical stimulation is utilized in most human rehabilitation protocols, and studies have supported its use to improve both motor recruitment and strength.^{3,57-59} Functional electrical stimulation (FES) can be used to activate the stretch reflex in tissue at increasing intensities. Initially, FES can be used to provide the tension and stress required for early mobilization, while keeping ground reaction forces low.

	Onset of injury	Day 3	Week 1	Week 2	Week 3 (Type I collagen turnover)
Grade 1 (strain)	Ice/Compression FES 10% flexion	Ice/Compression FES 25% flexion Hand walking 15-20 min	Ice/Compression FES 50% flexion Hand walking 20-30 min (with increase in speed) Trotting 5 min continuous	FES 100% flexion Hand walking 30-45 min Trotting 5 min cont x 2 (with increase in speed) Cantering 5 min continuous	FES 100% flexion Trotting 10 min cont x2 Cantering 5 min cont x 2-3 (with increase in speed)
Grade 2 (sprain)	Ice/Compression FES <10% flexion	Ice/Compression FES 10% flexion Hand walking 10-20 min	Ice/Compression FES 25% flexion Hand walking 15-30 min (with increase in speed)	Ice/Compression FES 50% flexion Hand walking 20-30 min Trotting 5 min continuous	FES 100% flexion Hand walking 30-45 min Trotting 5 min cont x 2 (with increase in speed) Cantering 5 min continuous
Grade 3 (tear)	Rest/Ice/Compression	Ice/Compression FES <10% flexion	Ice/Compression FES 10% flexion Hand walking 10-20 min	Ice/Compression FES 25% flexion Hand walking 15-30 min (with increase in speed)	Ice/Compression FES 50% flexion Hand walking 20-30 min Trotting 5 min continuous

Table 2. Protocols for different grades of muscle, tendon and ligament injuries.

Summary

It is easy to focus on the area of the diagnosis to determine the rehabilitation protocol. However, only when the whole horse is evaluated, and secondary as well as primary issues are addressed, can the rehabilitation protocol have a good chance of long-term success.

Human rehabilitation protocols for muscle, tendon and ligament injuries have been used for decades to improve the quality of healing and decrease rehabilitation time.

During this time, an understanding of the response of tissues to mobilization has led to a refinement of rehabilitation techniques. In human clinical practice, immobilization is avoided if at all possible.^{43,45}

A review of human physical rehabilitation programs shows that protocols must be specifically designed for each joint and each type of injury. The injury should be graded and this classification will assist in determining the direction of the rehabilitation protocol. The exercises selected for a rehabilitation protocol focus on a combination of; the level of stress, number of repetitions, and rate of repetitions of the stress.

Site-specific as well as site-complimentary exercises should both be included in the rehabilitation protocol. Too much stress to the injured tissue can harm the repair process as much as too little stress. Balance is the key to quality rehabilitation, and the practitioner's knowledge in physical therapy is important when establishing the appropriate program.⁶⁰ Poor quality rehabilitation is a vicious cycle of immobilization, muscle stiffness, joint stiffness and joint damage, leading to muscle wasting.^{21,43,45}

Generally, with severe injuries, stabilization is the first priority and this is obtained through muscle strengthening. However, if the strengthening phase lasts too long, flexibility can be hampered. Flexibility exercises are the most commonly overlooked part of the rehabilitation process, and are incorrectly thought to be secondary in importance to strengthening. Strength and flexibility exercises are combined at the proper levels and times to maximize the healing process.

The evidence is compelling that guidelines extrapolated from human rehabilitation for use in equine practice may be productive. Protocols will need to be refined from the large body of equine antidotal information that exists, and human techniques will need to be modified to suit the specific needs of equine rehabilitation.⁶¹ This process has begun, and the refinement of equine rehabilitation protocols will help improve the overall outcome for the injured horse.

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