Eccentric Exercise Interventions for Tendinopathies

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SUMMARY
TENDON INJURIES OR TENDINOPATHIES ARE A CHALLENGING AND PERPLEXING CONDITION FOR STRENGTH AND CONDITIONING PROFESSIONALS. TENDON INJURIES CAN BE DEBILITATING AND RESULT IN LOST TIME FROM SPORTS PARTICIPATION. IF LEFT UNTREATED, TENDON INJURIES CAN PROGRESS TO AFFECT DAILY FUNCTION. FURTHERMORE, TENDON INJURIES AFFLICT ALL AGES AND SKILL LEVELS. IN THE PAST 10 YEARS, ECCENTRIC EXERCISE HAS GAINED SUPPORT IN THE LITERATURE AS AN EFFECTIVE NONSURGICAL NONPHARMACOLOGICAL INTERVENTION TO TREAT THESE INJURIES. THE PURPOSE OF THIS REVIEW IS TO DISCUSS THE RELEVANT TERMINOLOGY AS WELL AS THE ANATOMY AND PHYSIOLOGY OF TENDONS AND TENDON INJURY. ADDITIONALLY, THE CONCEPT OF ECCENTRIC EXERCISE IN TREATING TENDINOPATHIES WILL BE DISCUSSED, AND EXERCISE INTERVENTIONS WILL BE PROVIDED FOR COMMON TENDINOPATHIES.

INTRODUCTION
Tendon injuries account for 30–50% of injuries in sports (16). Specifically, chronic problems caused by overuse of tendons have resulted in 30% of all running-related injuries, and elbow tendon injuries can be as high as 40% in tennis players (26). People of all ages and skill levels, as well as nonathletes can be afflicted by these conditions. Tendon pathologies can not only lead to lost time in sports but also can result in long-term damage to tendons that can even affect daily function and let alone sports performance. There is discrepancy in the literature about how to manage these injuries as well as the proper terminology to use when referring to them. The term “tendonitis” is often used as a catchall term for tendon injuries. Histological studies have shown that oftentimes, no inflammation exists (20,21). The suffix “itis” indicates that an inflammatory process is present. Leadbetter (19) has previously defined tendonitis as a symptomatic degeneration of a tendon with vascular disruption and inflammatory repair. More recently, the term “tendinopathy” has been used as an all-encompassing term for tendon injuries, whereas the term “tendinosis” has been used to describe chronic tendon issues. Leadbetter (19) has also defined tendinosis to be a focal area of noninflammatory degeneration that may be asymptomatic. The suffix “osis” implies that a degenerative process is present. Complicating this matter further is that there are significant differences in the physiological healing responses of acutely and chronically diseased tendons (15).

Strength and conditioning professionals often have to develop training programs to accommodate the athletes who have these conditions throughout the training cycle and during the competitive season. Being able to recognize an “itis” or an “osis” is a crucial step because the management of the athlete’s training is vastly different. An inflamed “itis” often has sharp localized pain with activity and in the morning or after periods of long rest. Pain may actually decrease during activity but worsens at rest. On the contrary, a chronic “osis” has fairly constant pain that is more of a dull ache and poorly localized. Usually, a chronic degenerative tendon gets worse with activity. A comprehensive review by Nirschl (22) about stages of tendon injury has been published previously in the Table.

Within the past few years, eccentric exercise has shown promise in multiple studies as a potential nonoperative and effective training modality for tendinopathies. The purpose of this review is 3-fold. First, a brief discussion about tendon anatomy and physiology will set the foundation for discussing why eccentric exercise is of physiologic benefit to tendons. Second, a review of the causes of tendinopathies will be briefly discussed. Finally, exercise interventions will be provided for common tendinopathies as well as a framework for how to implement them effectively.

KEY WORDS:
tendon; tendonitis; tendinopathy; tendinosis; eccentric exercise
ANATOMY

Tendons transmit force generated by muscle to bone and act as a buffer by absorbing external forces to limit muscle damage (27). Tendons themselves are relatively avascular but get their innervations and vascular supply from the paratenon, the sheath around the tendon proper. Tendons are composed of 30% type I collagen, glycosaminoglycans, elastin, and 68% water (23). Collagen’s role is to resist tensile forces, whereas elastin functions to increase the flexibility of tendons. The structure of tendons reveals that they have a wavelike appearance at rest, indicating that it is susceptible to and allow stretch.

Tendon injuries can happen essentially at 2 locations. Tendon injury can be midsubstance or in the body of the tendon proper. There is also potential for injury at the enthesis, which is the attachment of a tendon, ligament, or joint capsule to the bone (28). Injury at the enthesis is commonly referred to “insertional” tendinopathy. Regardless of location, management is very similar and eccentric exercise can be used. Tendons are prone to injury because of a “tendon paradox” that exists. Oxygen consumption is 7.5 x lower in tendons and ligaments than skeletal muscle (33). To minimize the risk of ischemia, which is a decrease in blood supply, a low metabolic rate and anaerobic generating capacity in tendons are needed to carry loads and maintain tension for long periods. In the case of tendons, risk of inadequate or deficient blood supply is reduced because of the lower metabolic rate. The lower metabolic rate indicates that there is less need for oxygen for tendons during functional tasks. However, the low metabolic rate in tendons results in slow healing after injuries. Thus, this may explain why tendon injuries persist or develop chronic issues (32).

If an athlete does not rest from the aggravating stimulus or provide the correct environment for regeneration, the tendon will be in a perpetual state of breakdown and attempted but failed healing. The end result is pain, dysfunction, and, for the athlete, lost time from sport.

CAUSES OF TENDON INJURIES

Tendons respond to repetitive overload beyond the physiological threshold by inflammation of their sheath, degeneration of their body, or a combination of both (27). There are a host of reasons that tendon injuries occur, but the etiology remains unclear, and many causes have been theorized (27). Typically, there are 2 main types of injury mechanisms that have several potential sources in each category (5). Intrinsic causes are factors contributed to an athlete’s makeup. Intrinsic risk factors include, but are not limited to such things as anatomical abnormalities or malalignments (i.e., genu valgum, or “knock kneed”, and leg length discrepancies), age, gender, flexibility, joint laxity, muscle weakness, biomechanics/
sport technique, fatigue, and psychological factors. Intrinsic causes may or may not be adjusted or changed and may be something that the athlete must learn to live with or possibly make modifications in training or equipment. The other causes are due to extrinsic factors. Unlike intrinsic factors, extrinsic factors can usually be easily changed and modified to help the athlete. The 2 main extrinsic causes of injury to tendons are overuse and training errors (3–6,9,20). Considerations under the umbrella of extrinsic causes include, but are not limited to, faulty equipment, playing surfaces, and shoe wear. Training errors can include a number of factors that the strength and conditioning professional can significantly contribute to either positively or negatively. Doing “too much too soon” or having intensity/volume/load too high; progressions too fast; improper rest and recovery; and repetitive, asymmetric, specialized training are all things that put an athlete at risk. A properly designed program with progressive overload helps minimize risk from these factors.

THE CASE FOR ECCENTRIC EXERCISE

As stated previously, the current paradigm is shifting in favor of eccentric exercise in the treatment of tendinopathies. Khan and Scott (17) have discussed the role of mechanotransduction as a mechanism for healing in eccentric exercise. Mechanotransduction is the process by which the body converts mechanical loading into cellular responses (17). These cellular responses lead to cell signaling, an informational network of proteins, lipids, and ion channels that are part of a physiologic cascade. Mechanotransduction is broken down into 3 steps (17). Mechanocoupling is when a physical load (i.e., tension or shear) causes a physical perturbation of cells that make up a tissue. These forces elicit a deformation of the cell that triggers a series of events depending on the type, load, duration, and magnitude of loading. The second step is cell-cell communication. In this step, stimulus in one location leads to changes in distant cells, even though the distal cell did not receive the mechanical stimulus directly. Mechanotransduction closes with the effector cell response. Here, the mechanical stimulus on the outside of the cell promotes intracellular processes, leading to matrix remodeling through alterations in biochemical pathways and gene expression. In the case of tendons, load-induced responses via mechanotransduction have shown an upregulation of insulin-like growth factor (IGF-I), which has been associated with cellular proliferation and matrix remodeling (17).

In shortening of a muscle, the faster it contracts, the smaller the tension it can exert (10). Tension is considerably greater in muscle fibers when lengthened than when shortened (19–21). During negative work (eccentrics), the oxygen consumption rarely rises to more than twice the resting value (1,2,12,31,32). Studies have shown previously that when a muscle is stretched, the energy requirement falls substantially because ATP breakdown and heat production are both slowed (8,31,32). Clearly, the decreased energy and oxygen requirements needed are of benefit to tendon metabolism based on the above discussion regarding the “tendon paradox.” Furthermore, with increased heat generation during concentric/positive work, there is a concurrent increase in cellular metabolism. Thus, more waste products will be generated, leading to chemical irritation of nerves and eventually pain. Abbott and Bigland (1) did a study measuring oxygen uptake in subjects using a bicycle ergometer. Positive work (concentrics) always resulted in more oxygen consumption than negative work. Abbott et al. (2) did a follow-up study examining the relationship between oxygen consumption and work. Results of the study showed that oxygen consumption is many times larger at great force and low speed than at small force and high speed. Lastly, Bigland-Ritchie and Woods (7) found that less muscle activity is required to maintain the same force during negative work, fewer muscle fibers are required to exert a given force, and there is a substantial reduction in oxygen uptake when fibers are stretched. The above studies show that eccentric exercise results in less oxygen consumption, more force production, and less energy requirement than concentric exercise. Put simply, “you get much more bang for your physiological buck” with eccentric exercise, both for the muscle and for the tendon.

Many studies in the past 10 years have substantiated eccentric exercise as a treatment for tendinopathies. In 1998,
Alfredson performed, to the author’s knowledge, the first study investigating eccentric exercise on diseased tendons, and the protocol used in that study has been used in most studies on eccentric training (4). In a prospective study of 15 athletes with chronic Achilles tendinosis, subjects performed 3 sets of 15 repetitions of bent knee and straight knee calf raises, twice a day, 7 days per week over 12 weeks. Subjects were told to work through pain, only ceasing exercise if pain became disabling. Load was increased in 5 kg increments with use of a backpack that carried the weight once body weight was pain free. Researchers found that all 15 patients returned to preinjury levels of activity. Additionally, they had a significant decrease in pain with a significant increase in strength.

Shalabi et al. (25) evaluated 25 patients with chronic Achilles tendinopathy measured before and after an eccentric program using the protocol of Alfredson et al. via magnetic resonance imaging for tendon volume and intratendinous signal. Eccentric training resulted in decreased tendon volume and decreased intratendinous signal, which correlated to improved clinical outcomes. Reduction in fluid content within the tendon may suggest increased collagen deposition. The increase in collagen is a possible effect because Langberg et al. (18) found that type I collagen synthesis increased after eccentric training in a group of 12 soccer players with unilateral Achilles tendinosis. Ohberg et al. (24) also found that in a group of subjects with chronic Achilles tendinosis training with the eccentric calf protocol of Alfredson et al. resulted in a decrease in tendon thickness and normalized tendon structure in most patients, both correlated with less pain.

Jonsson and Alfredson (11) did a prospective study of athletes with jumper’s knee randomized into either an eccentric or a concentric group for 12 weeks. In the eccentric group, 9 of 10 subjects were pleased with treatment, whereas 10 of 10 in the concentric group were not. At mean follow-up of 32 months,
the eccentric group was still satisfied and sports active, but all in the concentric group had surgery or sclerosing injections. In another study including athletes with patellar tendinopathy, Young et al. (34) used 2 different eccentric programs in elite volleyball players using the protocol of Alfredson et al. but with different exercises. One group did decline squats, whereas the other did a single-leg step down. Results of the study showed that both groups improved from baseline at 12 weeks and 12 months.

Systematic reviews of literature by Wasielewski and Kotsko (30) and Kingma et al. (14) examined the effects of eccentrics in reducing pain and improving strength in those with lower extremity tendinosis and chronic Achilles tendinopathy, respectively. The systematic reviews revealed that eccentric exercise may reduce pain and improve strength in lower extremity tendinopathies, but whether it is better than other forms of rehabilitation has yet to be determined and the magnitude of the effects are equivocal.

**IMPLEMENTATION OF ECCENTRICS**

Kibler et al. (13) has previously stated that the goal of rehabilitation in tendinopathies is relief of the symptoms from the "itis" to the restoration of function that is lost with the "osis." The previous studies have shown great potential in using eccentrics to restore function. From an exercise standpoint, regardless of body part, load and volume should be progressed gradually and should be dictated by the amount of pain the athlete experiences. Because the athlete is recovering from injury, it is advised that load used not be determined by a 1 repetition maximum (RM). Furthermore, some of the exercises are for targeted muscle groups (elbow extensors for elbow injury), and determining a 1 RM is not practical or advised. The protocol of Alfredson et al. has been used in previous studies and appears to be a safe and effective method to implement the eccentric training program.
Curwin (9) has previously proposed a method to determine training load in eccentric training for tendon injuries that is based on repetitions completed and the amount of pain experienced. One significant difference between Curwin’s program and Alfredson’s program is that the athlete performs both the concentric and eccentric portions of the exercise, with the eccentric portion being performed at a faster rate. In their protocol, they suggest that the athlete should experience pain and fatigue between 20 and 30 repetitions at a given load, performing 3 sets of 10 repetitions. Pain felt before that range is generally accompanied by worsening of symptoms and either load or speed is decreased. If there is no pain after 30 repetitions, the stimulus is inadequate. Either load is increased or the speed of exercise performance is increased but not both. Pain experienced during the exercise protocol should be similar to the pain experienced during the athlete’s functional activity with an acceptable moderate increase from that point. If it is the athlete’s first session, load is increased until symptoms appear. After a general warm-up (bike, upper-body ergometer), the athlete performs two 30-second stretches of the involved muscle group. The athlete then completes the above exercise protocol.

The author of this article suggests that once the athlete can complete 15 repetitions over all 4 sets, resistance should be increased to perform sets of 8 repetitions with the eighth repetition being close to failure. The athlete uses that load and builds up to 15 repetitions before increasing load again. Anecdotally, the author has found this method to be progressive yet safe, with less overall volume to help enhance recovery. Additionally, 3–4 sessions per week is advocated instead of everyday.

The author proposes that “heavy load” is a misnomer in the study of Alfredson et al. because the volume of exercise is rather high and the load is low given the amount of exercise that is tolerated by the athlete. Ultimately, however, dosing will be based on tendon...
reactivity. Load should be reduced at least 10% if the athlete has increased pain or worsening of symptoms, particularly with activities of daily living. Depending on their symptoms, introducing concentric exercise should be based on whether or not they have pain with nonsporting activities. Concentrics can be attempted once nonsport activities, like walking and stair climbing, are pain free. As with eccentrics, the concentric portion of exercise should involve a gradual progression. Once concentrics are pain free, then the athlete can begin jogging or more sport-specific activities. A progression from individual drills to team activities is a methodical way to reintroduce the athlete to sport. If the athlete has pain, they should regress to the previous regimen until pain free. In the author’s experience, a cooldown activity (i.e., recumbent bike) followed by stretching of involved muscles should follow the program. Although Thacker et al. (29) found that there is insufficient evidence to support pre- or postexercise stretching, lack of flexibility is a common finding in chronic tendinopathies (9) and should be a part of the program. Ice to the affected area is advised to limit postexercise pain and potential inflammation. Athletes should be warned that eccentric exercise may make them sore initially, and this is to be expected. As a general rule, athletes are instructed to perform eccentrics by actively doing the eccentric portion of the muscle/joint in question while returning to the start position passively or with assistance of the other limb, instead of actively doing the concentric portion.

**ACHILLES TENDINOPATHIES**

The athlete could begin with calf raises on flat ground, plantar flexing with both legs, and going down with the involved muscles only. Once these are pain free, the athlete can be progressed to leaning calf raises with the use of a physioball (Figure 1). In the leaning position, there is more ankle dorsiflexion, which induces a greater stretch to the Achilles and thus more force is needed to plantar flex. Next, the athlete
can progress to a staircase. A nice compliment to these exercises is using a leg press machine as a "supine calf raise" fashion (Figure 2). Depending on how much pain the athlete is experiencing, the supine position may be a more appropriate starting point because the weight can be adjusted to be less than body weight. A very functional addition to the Achilles program would be an anterior step down (Figure 3). The athlete leads with the uninvolved muscle, attempting to keep the involved heel on the step. As the reader can see, the ankle is in a dorsiflexed position, thereby placing the Achilles on stretch because it controls the motion. In this position, the soleus muscle is targeted in its role as a decelerator of the tibia anteriorly during gait during the end of stance phase to limit excessive dorsiflexion. To progress, the step can be increased or the athlete can hold dumbbells.

**PATELLAR TENDINOPATHIES**

It is suggested that an athlete begins using the leg press because the weight can be adjusted to be less than body weight if the athlete cannot tolerate body weight due to pain (Figure 4). Other means include decline squats (Figure 5) or eccentric step downs (Figure 6). The athlete should be reminded to perform the concentric portion with both legs and the lowering phase with just the involved muscles. When using the decline board or step, they should only get back on the step using the uninvolved limb.

**TENNIS ELBOW**

Tennis elbow, or lateral epicondylitis, is an irritation of the common extensor tendon from its attachment on the lateral epicondyle of the humerus. On the extensor surface, the supinator muscle is also implicated. Therefore, it should be included as part of a program. The athlete can do "eccentric wrist extension" (Figure 7). Here, the weight is raised by the uninvolved limb and then lowered by the involved muscles. A hammer or similar device with a long lever arm to do eccentric radial deviation (Figure 8) and eccentric supination (Figure 9) are additional exercises. Again, it must be reinforced that the athlete cannot raise the weight back to the starting position concentrically. Although cumbersome to reach across to the involved limb to raise it back to the starting position, it must be done initially to prevent further flares. Athletes can be progressed by increasing the lever arm or adding weight. Conversely, if they cannot tolerate a weight at a longer lever arm position, it can be moved to shorten the lever arm, which may make the exercise tolerable (Figure 10).

**CONCLUSION**

Eccentric exercise is showing promise as an effective means to treat tendon injuries. It is so promising because the basis for it is centered on muscle and tendon physiology, not a theory. It should be a part of a comprehensive program that involves collaboration of the health care team and the athlete’s coaches to ensure that all intrinsic and extrinsic risk factors have been addressed as well as other complimentary pain alleviating modalities. It is hoped that more research will surface further, advocating the use of eccentric exercise.

Dan Lorenz is a sports medicine specialist at Providence Medical Center and an adjunct faculty member at Rockhurst University in Kansas City, Missouri.

**REFERENCES**


