New Concepts in Managing Non-Insertional Achilles Injuries:

Why Improving Tendon Pressure Dynamics and Interfascicular Sliding Are Essential for Recovery.

By Tom Michaud, DC

- *New research shows heavy-resistance long-duration isometric contractions accelerate tendon repair by increasing the outflow of fluid from the center of the Achilles tendon.*
- *The gliding of neighboring individual fibers of the Achilles tendon against one another also stimulates tendon remodeling, and this is best accomplished with bent knee heel raises.*
- *For best outcomes, it is important to reduce stress on the Achilles tendon by strengthening its synergists. Flexor hallucis longus is particularly effective at offloading the Achilles tendon.*

The Achilles tendon is a remarkable structure that has the ability to store and return nearly 90% of the energy it takes to stretch it (1). Because different fibers of the Achilles tendon rotate between 26° and 136° before attaching to the calcaneus (2), they function like coiled springs, absorbing and returning 10 times more energy than the neighboring gastrocnemius and soleus muscles (Fig. 1).

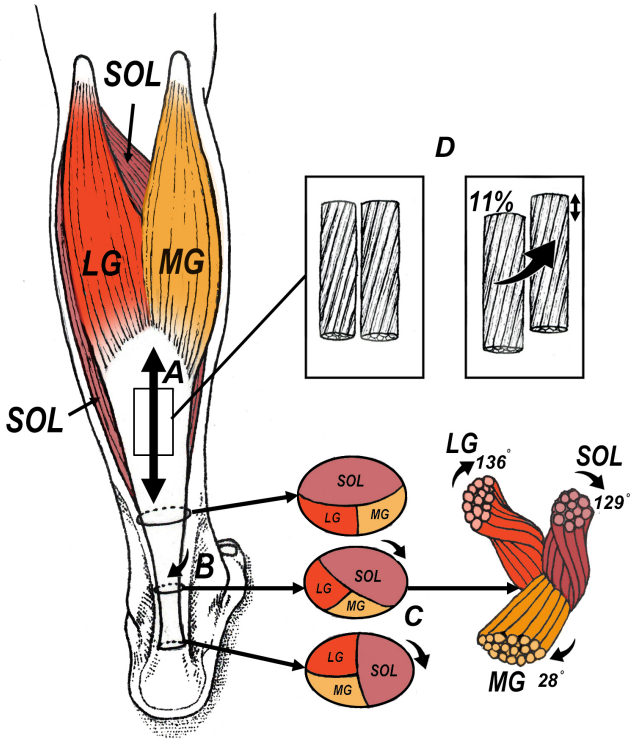


Fig. 1. As the Achilles tendon lengthens while walking and running (A), fibers from the corresponding muscles rotate 90° (B and C), and neighboring fibers in the Achilles tendon can separate by more than 11% (D). The combination of tendon fiber twisting and sliding allows the Achilles tendon to store and return 10 times more energy than the gastroc and soleus muscles and twice as much energy as the arch (25). Notice how tendon fibers originating from the lateral gastrocnemius and soleus muscles rotate significantly more than fibers from the medial gastrocnemius. The greater degree of tendon twisting in the lateral gastroc and soleus makes these muscles more important with storing and returning energy, while the medial gastroc plays a significant role in rapid force production, explaining the high prevalence of tears in the medial gastroc with jumping sports. **Abbreviations: LG**: lateral gastrocnemius; **MG**: medial gastrocnemius; **SOL**: soleus.

The free energy supplied by this elastic recoil significantly reduces the metabolic cost of locomotion and has played a huge role in our success as bipeds (3). Unfortunately, despite its size and significant strength, the Achilles tendon is injured with surprising regularity, especially in running athletes. In any given year, nearly 10% of runners develop Achilles tendinopathy, and the lifetime prevalence of Achilles injuries in middle and long distance runners is nearly 50% (4). Although occasionally injured at the insertion point on the calcaneus, the vast majority of Achilles injuries occur at the midportion of the Achilles tendon and are referred to as non-insertional tendinopathies. The higher frequency of non-insertional injuries is the result of the naturally impaired circulation present in the midsection of the Achilles tendon. While the limited number of blood vessels allows the midsection to tolerate extremely high forces, it also results in impaired cellular remodeling following trauma.

Far and away the most popular exercise prescription for managing non-insertional Achilles injuries is the eccentric training protocol originally described by Alfredsson et al. (5) more than 25 years ago. This routine consists of having the patient perform 3 sets of 15 repetitions of both straight and bent knee exercises twice daily (Fig. 2). Patients are told to exercise through discomfort, and the exercises are done 7 days per week. Unfortunately, despite its widespread use for almost 3 decades, the Alfredson protocol has been proven to be only moderately effective at reducing long-term symptoms associated with Achilles tendinopathy, as nearly 60% of people treated with this intervention report pain and continued discomfort 5 years later (6).

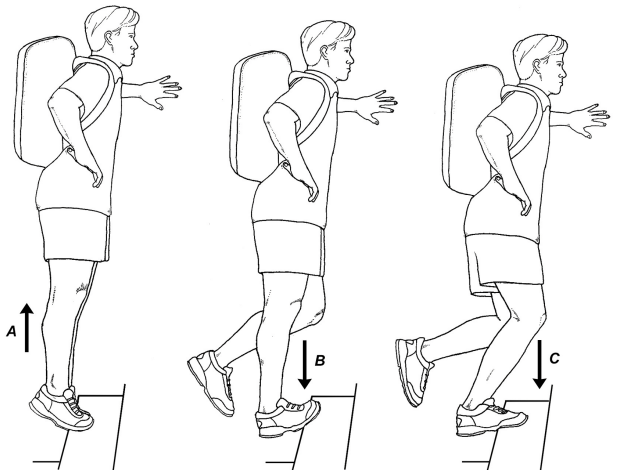


Fig. 2. The Alfredson protocol. This popular exercise routine involves having the patient perform heavy-resistance eccentric exercises by going up with 2 legs (**A**) and down with one leg (**B**). The exercise is repeated with the knee bent (**C**), and 3 sets of 15 repetitions are performed twice daily.

In an attempt to improve outcomes associated with exercise therapy, researchers have realized that it is important to understand the exact mechanism in which exercise stimulates recovery. To that end, some interesting new research out of Australia shows that fluid flow dynamics within the Achilles tendon may play a key role in accelerating recovery (9). These authors cite numerous studies showing when a healthy tendon is exercised, there is a significant flow of fluid away from the core of the tendon, and the shear stress from this fluid flow creates a tensile strain that stimulates tenocyte remodeling (10-12) (Fig. 3). This outflow of fluid is absent in tendinopathic tendons. To identify which exercises most effectively stimulate intratendinous fluid flow, the authors used 3-dimensional ultrasonography to monitor flow dynamics as participants performed isometric contractions at intensities that varied from 35 to 75% full effort, with load durations ranging from 2 to 8 seconds. Upon completion of the study, the authors determined the subjects performing the heavy-load, long-duration exercises had a 13% reduction in tendon volume, which was far and away greater than any other treatment group. As a result, the authors state that in order to accelerate tendon repair, “the applied load must be heavy and sustained for long-duration.”

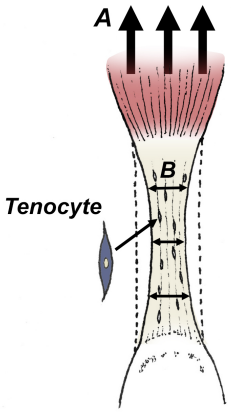
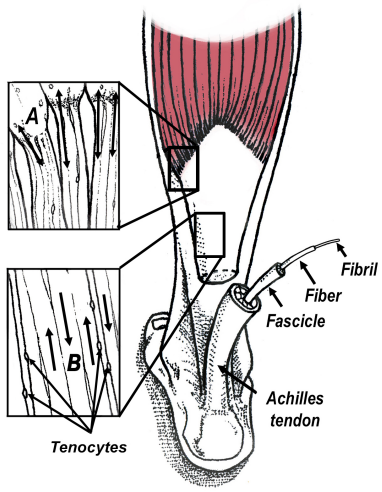


Fig. 3. Because tendons are made of nearly 70% water, muscle contraction (A)creates an internal force that squeezes fluid from the tendon (B), comparable to twisting a wet towel. Movement of the fluid stimulates specialized cells called tenocytes to accelerate tendon remodeling.

In perhaps the most interesting recent research on the underlying causes of Achilles tendinopathy, researchers from Finland show that when people with healthy Achilles tendons exercise, different portions of the gastrocnemius and soleus muscles pull on their corresponding tendon fibers, creating a nonuniform pattern of interfascicular sliding within the Achilles tendon (13). The nonuniform sliding of one tendon fiber against another mechanically stimulates tenocytes to accelerate tendon remodeling (Fig. 4). In contrast to healthy tendons, individuals with damaged Achilles tendons show a more uniform pattern with limited variation in interfascicular sliding. The clinical significance of this paper is huge, as it confirms that in order for the Achilles tendon to be effectively rehabilitated, all fibers of the different calf muscles must participate in force generation, as activity in each muscle gets transferred into the tendon promoting the nonuniform pattern of fascicle sliding present in healthy tendons.

Fig. 4. Because muscle fibers (A) attach to corresponding tendon fibers (B), when individual muscle fibers contract, their respective tendon fibers slide over one another, generating a mechanical shear force that stimulates tendon sites to remodel.



To identify exactly which exercises increase the amount of interfascicular sliding, Handsfield et al. (14) evaluated tendon fiber sliding patterns as people performed different calf exercises. Of all the exercises studied, the bent knee heel drop exercise that specifically targets the soleus muscle produced the greatest increase in interfascicular sliding while simultaneously placing the least stress on the tendon. The authors claim that this exercise will have "a major role in the future of tendon rehabilitation." The outcome of this paper is consistent with recent research showing that weakness of the soleus is the single best predictor of non-insertional Achilles injury (24). Because the soleus possesses 50% more muscle mass than the

neighboring gastrocnemius muscles, failure of the soleus to generate force would significantly impair interfascicular tendon sliding, which could be corrected with bent knee heel drop exercises.

To be consistent with the latest research, the ideal exercise prescription for managing Achilles injuries should include bent knee heel drops to enhance intratendinous fascicle sliding, and heavy-load long-duration isometric contractions to increase fluid outflow from the tendon. I typically recommend 4 sets of 24 repetitions of the exercises illustrated in figure 5, as the 4x24 protocol produces the same increase in muscle volume as heavy-load resistance training (15). Notice that at the end of each set, a 30-second isometric contraction is performed to enhance the outflow of fluid from the tendon. In my opinion, the isometric component of this exercise is the key to tendon recovery. In addition to improving fluid dynamics, Keith Baar (16) states that when a damaged tendon is forced to undergo a prolonged isometric contraction, the healthy fibers slowly slide over one another, exposing the stiffer damaged fibers to the mechanical stress necessary to remodel. Dr. Baar and others (17) measured the most important enzymes responsible for creating the cross-links associated with tendon repair, such as lysal oxidase and ERK1/2, and showed that after the first 10 minutes of isometric contractions, the levels of these important enzymes dropped significantly and became inactive for a full 6 hours. The clinical implication of this research is that the isometric components of these exercises can be performed twice per day, at 6 hour intervals. In contrast, the strengthening component should be performed just once a day.

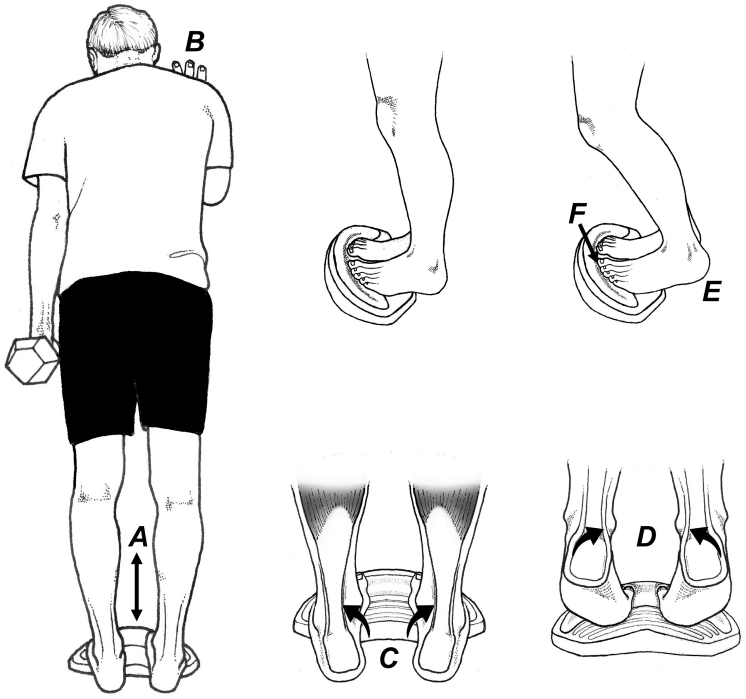


Fig. 5. Home exercise protocol for non-insertional Achilles injuries. Place the ToePro next to a wall and perform 4 sets of 24 repetitions going through a full range of motion (**A**). You should perform 2 sets with your knees straight and 2 sets with knees bent. You should contact the wall to maintain balance (**B**) and if necessary, hold onto a weight to ensure that you're fatigued by the 24th repetition. If you are unable to do 24 repetitions, perform the exercise next to a table so you can push down with your hands to offload your calves. While doing this exercise routine, you should move your feet from full inversion to full eversion (**C-D**) and after completing each set, you should perform a 30-second isometric contraction with your heels position just slightly off the floor (**E**). If you are extremely strong, you can do the isometric contraction on one leg at a time. To strengthen important synergists to the Achilles tendon, make sure you push down vigorously with your toes while performing these exercises (**F**).

Although these exercises can be performed on a stairway or an angled foam platform, I typically have the patient perform the exercises while standing on a ToePro. The main advantage to using the ToePro is that it markedly increases activity of the flexor hallucis and flexor digitorum longus muscles, which have long lever arms to the ankle axis and are capable of significantly offloading the Achilles tendon during recovery (Fig. 6). By exercising the toe muscles in a lengthened position, strength gains are increased nearly fourfold compared to conventional exercises (18). It's not just toe muscles that respond to exercising in lengthened positions. A growing body of research is showing that exercising all muscles in their lengthened positions accelerates muscle remodeling (19-21), and results in greater transference to dynamic performance (22).

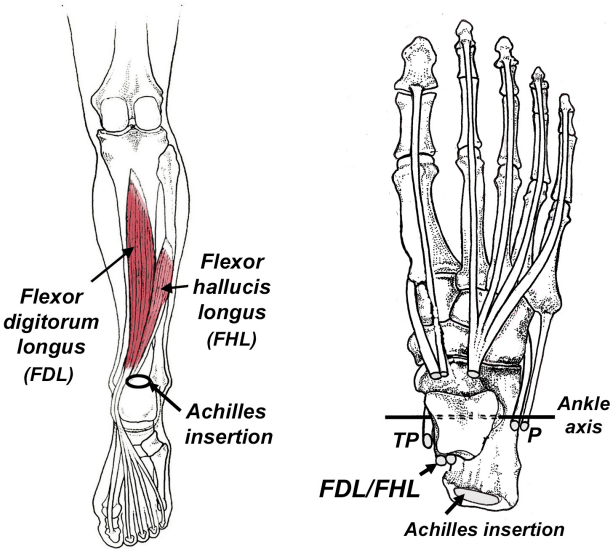


Fig. 6. Synergist to the Achilles tendon. Notice the long digital flexors have significantly longer lever arms to the ankle axis of motion than tibialis posterior (**TP**) and the peroneals (**P**). The long lever arms afforded these muscles explains why MRI studies show that people with Achilles tendinopathy present with compensatory hypertrophy of the flexor hallucis longus muscle (26).

I've been using this exercise protocol for almost 2 years now, and in my experience, it definitely produces better outcomes than the Alfredson protocol, especially in elite athletes. Although it requires a fair amount of commitment to perform these exercises daily, some recent research shows that even people who perform their Achilles exercise routine with reduced intensity and for a shorter period of time still get good outcomes (23). Because the ideal exercise frequency has yet to be determined, I base the frequency prescription on the individuals' level of fitness: extremely fit people should perform these exercises daily, with the isometric contractions performed twice a day, and less fit and/or older individuals should perform them 3 times a week, with the isometric components performed just once a day. The reduced frequency definitely increases compliance, which also increases the probability of a successful long-term outcome.

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