Biomechanical and Histological Effects of Augmented Soft Tissue Mobilization Therapy on Achilles Tendinopathy in a Rabbit Model

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Abstract

Objective: Augmented soft tissue mobilization (ASTM) has been used to treat Achilles tendinopathy and is thought to promote collagen fiber realignment and hasten tendon regeneration. The objective of this study was to evaluate the biomechanical and histological effects of ASTM therapy on rabbit Achilles tendons after enzymatically induced injury.

Methods: This study was a non-human bench controlled research study using a rabbit model. Both Achilles tendons of 12 rabbits were injected with collagenase to produce tendon injury simulating Achilles tendinopathy. One side was then randomly allocated to receive ASTM, while the other received no treatment (control). ASTM was performed on the Achilles tendon on postoperative days 21, 24, 28, 31, 35, and 38. Tendons were harvested 10 days after treatment and examined with dynamic viscoelasticity and light microscopy.

Results: Cross-sectional area in the treated tendons was significantly greater than in controls. Storage modulus tended to be lower in the treated tendons but elasticity was not significantly increased. Loss modulus was significantly lower in the treated tendons. There was no significant difference found in tangent delta (loss modulus/storage modulus). Microscopy of control tendons showed that the tendon fibers were wavy and type III collagen was well stained. The tendon fibers of the augmented soft tissue mobilization treated tendons were not wavy and type III collagen was not prevalent.

Conclusion: Biomechanical and histological findings showed that the Achilles tendons treated with ASTM had better recovery of biomechanical function than did control tendons. (J Manipulative Physiol Ther 2015;38:112-118)

Key Indexing Terms: *Achilles Tendon; Tendon Injuries; Tendinopathy; Massage*

Achilles tendinopathy is a common overuse syndrome, especially among runners.[1,2] In a cohort study with 11 years of follow-up, Kujala et al.[3] reported that 29% of 269 male orienteering runners and 4% of 188 controls had experienced an Achilles tendon overuse injury; the age-adjusted odds ratio was 10.0 in runners compared with controls. Achilles tendinopathy causes many patients to decrease their physical activity, with a potentially negative effect on their overall health and well-being.[4,5] Despite rest from sports activities and various conservative treatments, many patients continue to have symptoms. The need for surgery increases with patient age, duration of symptoms, and changes in tendinopathy.[6] The results of operative treatment for Achilles tendinopathy are usually good.[7–11] However, postoperative complications often contribute to impairment and delayed recovery.[9–11]

Massage is one of the oldest forms of therapy for musculoskeletal disorders. Several forms of massage or soft tissue mobilization techniques have been developed and used for chronic Achilles tendon overuse injuries. Augmented soft tissue mobilization (ASTM) is a modification

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Paper submitted May 15, 2014; in revised form December 3, 2014; accepted December 6, 2014.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2014.12.003

of traditional soft tissue mobilization. It uses specifically designed solid instruments to provide the contact force on the tendon. In the only published clinical trial of ASTM, Wilson et al.[12] compared ASTM with a traditional physical therapy regime for patellar tendinitis. ASTM treatment was superior (100% vs 60% symptom resolution). ASTM is commonly used for Achilles tendinitis although no clinical trials have been reported. It has been shown to result in morphologic changes in the tendon in at least 2 animal studies.[13,14] Davidson et al.[13] suggested that ASTM may promote healing via increased fibroblast recruitment. Gehlsen et al.[14] suggested that applying heavy pressure promotes the healing process to a degree greater than use of light or moderate pressure. Both studies showed that ASTM increased the number of fibroblasts and activated fibroblasts. Thus, ASTM theoretically increases the synthesis of collagen and might change the biomechanical properties of the tendon. However, there are no reports of the effect of ASTM on the biomechanical properties of injured Achilles tendons.

There are no published guidelines regarding the recommended dose of ASTM for Achilles tendinitis in humans. Proponents of ASTM have noted that an average of 8 treatments resulted in 77% excellent results (at least 90% symptom resolution) and 15% good results (80%-90% symptom resolution).[15] Histological changes have been reported in a rat model after 4 to 6 treatments[13,14] and the amount of pressure applied during treatment was noted to correlate with the amount of organized rough endoplasmic reticulum in the healing tendon (indicative of protein synthesis).[14]

During rehabilitation after Achilles tendon overuse injury, the tendon is subjected to both static and dynamic loads during walking, running, and jumping. Therefore, it is necessary to assess not only static but dynamic biomechanical properties. Studies assessing viscoelastic properties of soft tissues have primarily used static testing,[16–19] but we have not found reports assessing the biomechanical properties of Achilles tendon by dynamic viscoelastic testing. While creep[17] and stress-strain[20,21] have often been used as static viscoelastic tests, the rate of change with stress and strain is slow, and there are no reports of chronological change.

Dynamic mechanical analysis measures viscoelastic properties by repeatedly applying sine wave stress at various frequencies to a tendon sample while measuring the dynamic strain response. The storage modulus (E') is an indicator for the elastic component representing energy storage, while the loss modulus (E'') is an indicator for the viscous component of the tissue which dissipates the mechanical energy and converts it to heat. Tangent delta ($\tan \delta$) is calculated by dividing E'' by E'.[22,23] Thus, dynamic viscoelastic testing can ascertain the dynamic mechanical response of the Achilles tendon to mechanical perturbations that reflect activities of daily living.

The purpose of this study was to evaluate the effect of ASTM therapy on healing in a rabbit model of Achilles tendinopathy by quantifying dynamic biomechanical properties and examining histological features.

Methods

Both Achilles tendons of 12 male New Zealand white rabbits (mean weight 3.53 +/- 0.06 kg) were injected with collagenase to produce tendon injury simulating Achilles tendinopathy. One hind leg of each rabbit was randomly assigned to treatment with ASTM while the other served as a control. This protocol was approved by the Mayo Clinic Institutional Animal Care and Use Committee. All animals were monitored for adverse effects by animal care staff.

Achilles Tendon Injury Model

The Achilles tendons of the 12 rabbits were injected with collagenase to induce tendinopathy.[24,25] The direct injection of collagenase provided a good model of tendinosis because connective tissue natively contains collagen and levels of collagenase rise after injury. Prior to the injection, the animals were anesthetized intramuscularly with a cocktail solution of ketamine (70 mg/mL), acepromazine (2 mg/mL), and xylazine (10 mg/mL) at a dosage of 0.6 mL/kg of body mass. A longitudinal incision was made slightly medial to the outline of the Achilles tendon. The Achilles tendon was exposed 1 cm proximal to the calcaneal insertion. Under direct visualization, 30 μL of collagenase (10 mg/mL) were injected into the center of the tendon. The incision was closed with simple sutures. The rabbits were returned to cage activity after surgery. The surgical site was allowed to heal for 3 weeks before beginning treatment.

Although the treatment was expected to produce minimal if any discomfort, the animals were monitored for signs of pain before, during, and after the collagenase injection and throughout the study using published guidelines.[26]

Augmented Soft Tissue Mobilization

The animals underwent ASTM using a custom-made stainless steel instrument (Graston Technique, Indianapolis, Indiana) to apply mobilization force to the Achilles tendon. To administer ASTM, animals were placed in a prone position with the foot elevated to allow access to the Achilles tendon. An assistant gently held the animals body and steadied the lower limbs while the investigator applying the treatment held the foot of the side being treated to assure minimal movement of the animal. Prior to administering treatment, the treating person practiced consistently applying 1.5 N/mm^2 pressure to tendon as measured by a force sensor (K-Scan System sensor model 6900; Tekscan, Inc, South Boston, Massachusetts), with real-time feedback to help maintain the target contact force. The animals were