Effect of Pulsed Electromagnetic Field Therapy on Healing in a Rat Achilles Tendon Partial Tear Model

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Introduction

Partial tears of the Achilles tendon are relatively common and are typically treated conservatively[1]. To this end, a variety of nonoperative, noninvasive therapies exist for the treatment of these tears. It has been previously shown that Pulsed Electromagnetic Field (PEMF) therapy improves supraspinatus tendon-to-bone healing as well as full-thickness Achilles tendon healing in rat models[2, 3]. However, the effects of an FDA- approved PEMF therapy (Physio-Stim®, Orthofix Inc., Lewisville, TX, USA) on in vivo joint function and ex vivo tendon fatigue properties after a partial Achilles injury remain unknown. Therefore, the objective of this study was to quantify the effects of this FDA-approved PEMF therapy on joint and tendon level properties after a partial width, full thickness injury. We hypothesized that PEMF treatment would improve Achilles tendon healing compared to a non- PEMF group.

Methods

This IACUC-approved study consisted of 160 adult male Sprague-Dawley rats. Anesthetized with isoflurane, 144 animals underwent a unilateral, full thickness, partial width (1.5mm) Achilles tendon injury. All animals were cast immobilized in plantarflexion for 1 week following injury. These animals were then placed into 3 groups (n=48/group): 1 group received no PEMF treatment (NP) while the other 2 groups received 1 and 3 hours of PEMF treatment daily (Physio-Stim®, 1HP and 3HP, respectively). The final 16 rats were not injured, received no PEMF treatment, and were sacrificed at 3 weeks, following 1 week of initial cast immobilization. PEMF treatment was administered systemically via custom modules surrounding the rat cages. At 2, 3, and 6 weeks post injury, animals were evaluated for ankle joint function using a joint range of motion measuring device[4]. Ambulatory measurements were collected at 3 and 6 weeks post injury using an instrumented walkway[5]. Animals were sacrificed at 1, 3, or 6 weeks. For histology, the injured Achilles tendon and gastrocnemius/soleus muscle complex was dissected at time of sacrifice (n=6 per group). Specimens were sectioned and stained with hematoxylin and eosin and graded for cellularity and cell shape[2]. Circular standard deviation was measured to ascertain collagen alignment. For mechanical testing, the Achilles tendon and foot complex were dissected at time of sacrifice (n=10 per group) and the calcaneus was potted in Poly(methyl methacrylate). While immersed in 37°C phosphate-buffered saline and in a physiologic orientation, the Achilles tendons were gripped and subjected to a mechanical loading protocol consisting of: preloading, stress relaxation at 6% strain, dynamic frequency sweeps, and fatigue cycling under load control until specimen failure[6]. For all outcome measures, the two treatment groups (1HP and 3HP) were compared to the control (NP) group at each time point using two-tailed, Student t-tests after checking for normality. Bonferroni post-hoc corrections were applied to account for multiple comparisons.

Results

Joint Range of Motion: After 6 weeks, both PEMF treatment groups exhibited decreased joint range of motion compared to the NP group (Fig 1A). *Ambulatory Assessment:* No differences were observed between the PEMF treatment groups and the NP group at any time point (not shown). *Histology:* Decreased cellularity was observed in the 1HP group 3 weeks post injury compared to the NP control group (not shown). *Mechanical Testing:* At 3 weeks post injury, 1HP specimens exhibited increased stiffness and modulus compared to the NP tendons making them behave more like the uninjured control tendons (Fig 1B, Fig 1C). At 1 week post injury, 3HP tendons demonstrated the same increases (Fig 1B, Fig 1C). During fatigue testing, the 1 week, 3HP tendons and 3 week, 1HP tendons survived more cycles than the NP controls (Fig 2A). Throughout the fatigue life, 1 week, 3HP tendons and 3 week, 1HP tendons exhibited increased stiffness compared to NP tendons (not shown). At 6 weeks after injury, 3HP tendons exhibited decreased laxity and decreased peak strain compared to NP tendons (Fig 2B). Finally, K2, a measure of how quickly tendons exhibit increased strain during fatigue testing, was decreased in the 3HP tendons 6 weeks post-injury (not shown).

Discussion

The aim of this study was to determine the effects of non-invasive PEMF treatment on rat

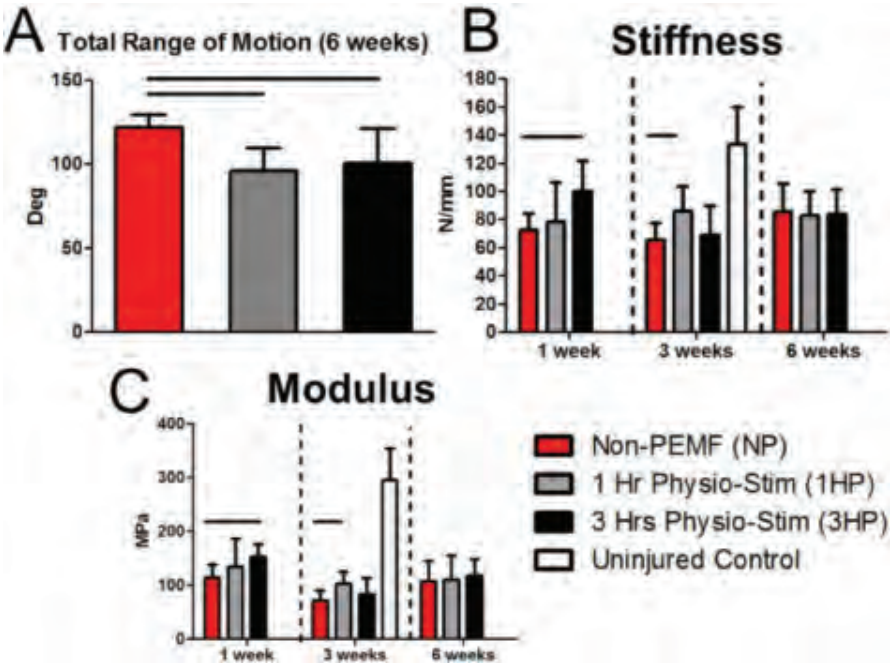

Figure 1. (A) Total ankle joint range of motion was decreased in PEMF treated animals compared to non-PEMF animals at 6 weeks. **(B)** Stiffness during mechanical testing was increased in 1 week, 3HP tendons and 3 week, 1HP tendons. **(C)** Modulus was increased in 1 week 3 HP tendons and 3 week, 1 HP tendons. Data are mean + SD. Markers indicate $p < 0.025$.

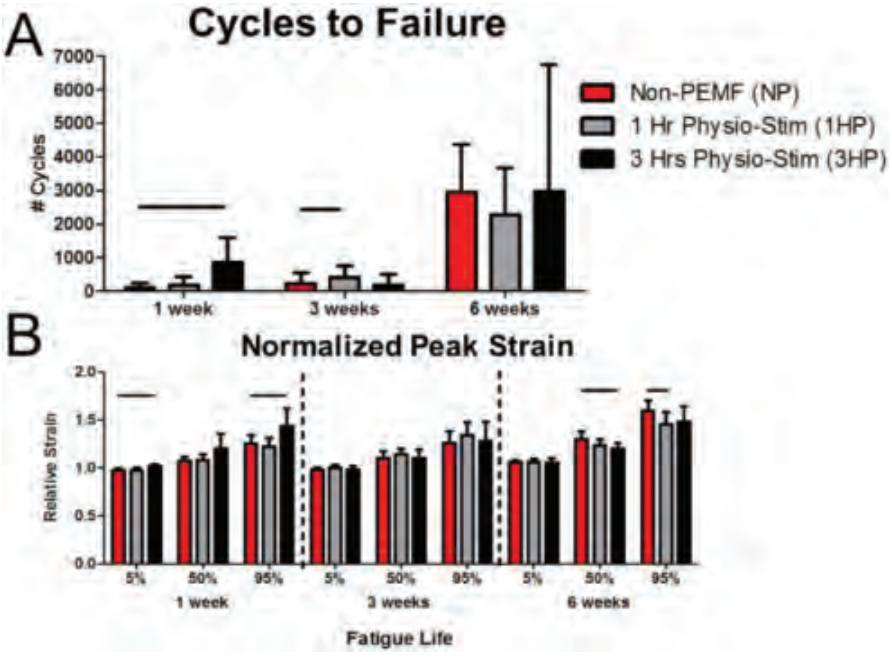

Figure 2. (A) Cycles to failure were increased in 1 week, 3HP tendons and 3 week, 1 HP tendons than non-PEMF control tendons at the same respective time points. **(B)** Normalized peak strain was increased in 3 HP tendons at 1 week compared to non-PEMF tendons. At 6 weeks, both PEMF treatment groups resulted in decreased strain. Data are mean + SD. Markers indicate $p < 0.025$.

Achilles tendons following partial tendon injury. We hypothesized that PEMF treatment would result in improved healing compared to control tendons. Although no differences in joint function were observed via ambulatory assessment, PEMF-treated joints exhibited decreased range of motion 6 weeks post injury. This observation was corroborated by the findings of decreased peak strain and increased K2 in the 6 week tendons during mechanical testing. In general, PEMF-treated tendons exhibited increased stiffness and decreased laxity during this fatigue protocol. It is unclear if this increase in both tendon and joint level stiffness is beneficial for healing. However, uninjured control tendons exhibit greater stiffness than the PEMF tendons at 3 weeks post injury suggesting that this increased stiffness may be beneficial (Fig 1B). Ultimately, while no change was detected in several measured parameters, it appears that PEMF treatment may aide in early tendon healing following partial width, full thickness Achilles injury in rats. Additional study is underway to understand the role of immobilization in tendon properties in this model. Further study may be necessary to understand the long-term effect of the decreased ankle joint range of motion and decreased tendon strain observed at our final time point.

Significance

This study shows that early tendon healing in a rat model may be improved by the use of PEMF treatment. This study is the first to investigate this nonoperative, noninvasive therapy to accelerate tendon healing in an Achilles tendon partial tear model.

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