Effects of Pulsed Electromagnetic Field Therapy on Healing in a Rat Achilles Tendon Partial Width Injury Model Without Immobilization

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Introduction

Partial tears of the Achilles tendon are typically treated conservatively[1], often with various noninvasive therapies such as ultrasound. An FDA-approved Pulsed Electromagnetic Field (PEMF) therapy (Physio-Stim®, Orthofix Inc., Lewisville,TX, USA) has been shown to improve outcomes in tendon-to-bone rotator cuff healing in a rat model[2,3]. However, for partial Achilles tendon tears, the effects of PEMF therapy on in vivo joint function and ex vivo tendon fatigue properties remain inconclusive[4], as the use of postoperative plantarflexion immobilization confounded results in an earlier study.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 (partial tear) in the absence of limb immobilization.We hypothesized that PEMF treatment would improve Achilles tendon healing compared to a non-PEMF group.

Methods

144 adult male Sprague-Dawley rats (400-450g) were anesthetized with isoflurane, and underwent a unilateral, full thickness, partial width (1.5mm biopsy punch) Achilles tendon injury through the center of the tendon (IACUC approved). All animals were allowed cage activity throughout the study. Animals were placed into 3 groups (n = 48/group): a control group receiving no PEMF treatment (non-PEMF), or a treatment group receiving either 1 or 3 hours of daily systemic PEMF (Physio-Stim®, 1HP and 3HP, respectively) therapy.Animals were sacrificed at 1, 3, or 6 weeks (n = 16 per group per time point). All animals in the 6 week groups underwent longitudinal in vivo ambulatory assessment and passive ankle joint mechanics testing at 2, 4, and 6 weeks post-injury[5,6]. At sacrifice, the Achilles-calcaneus complex was dissected out (n = 6 per group per time point) and processed for μCT scanning (21μm resolution) followed by decalcification and histological analysis. All other animals (n = 10 per group per time point) were frozen at -20°C and thawed for dissection prior to tendon cross-sectional area measurement using a custom laser device and mechanical testing using a load controlled fatigue testing protocol[7]. For all measures, the two treatment groups (1HP and 3HP) were compared to the control (non-PEMF) group at each time point using two-tailed, t-tests after checking for normality. Bonferroni post-hoc corrections were applied for multiple comparisons and significance was set at $p < 0.025$.

Results

Joint Range of Motion

No differences were observed between the PEMF treatment groups and the non-PEMF group at any time point (data not shown).

Ambulatory Assessment

Rats receiving 3 hours of PEMF treatment walked faster than non-PEMF animals 2 and 4 weeks post-injury. Rats receiving either 1 or 3 hours of PEMF treatment loaded their injured limbs faster than non-PEMF rats 2 weeks post-injury (Figure 1).

Histology

Tendons receiving 3 hours of PEMF were less cellular than control non-PEMF tendons at

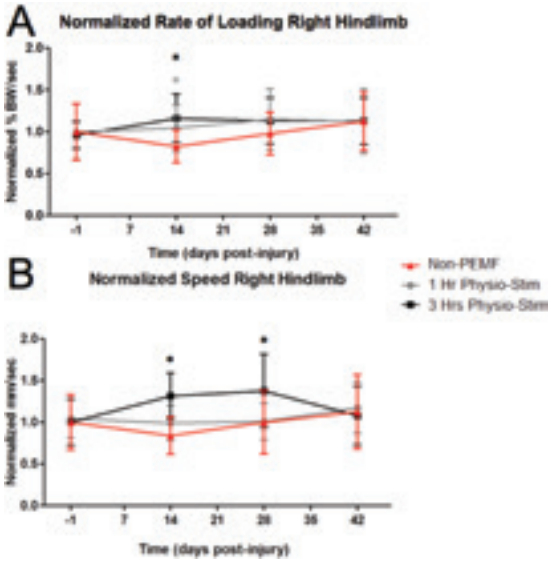

FIGURE 1. (A) Normalized rate of loading was increased in both PEMF treatment groups compared to non-PEMF animals 2 weeks after injury. **(B)** Normalized speed of the injured limb was increased in 3HP animals at 2 and 4 weeks after injury. Data are mean ± SD. Black asterisks indicate $p = 0.025$ comparing 3HP to NP. Gray asterisks indicate $p < 0.025$ comparing 1HP to NP.

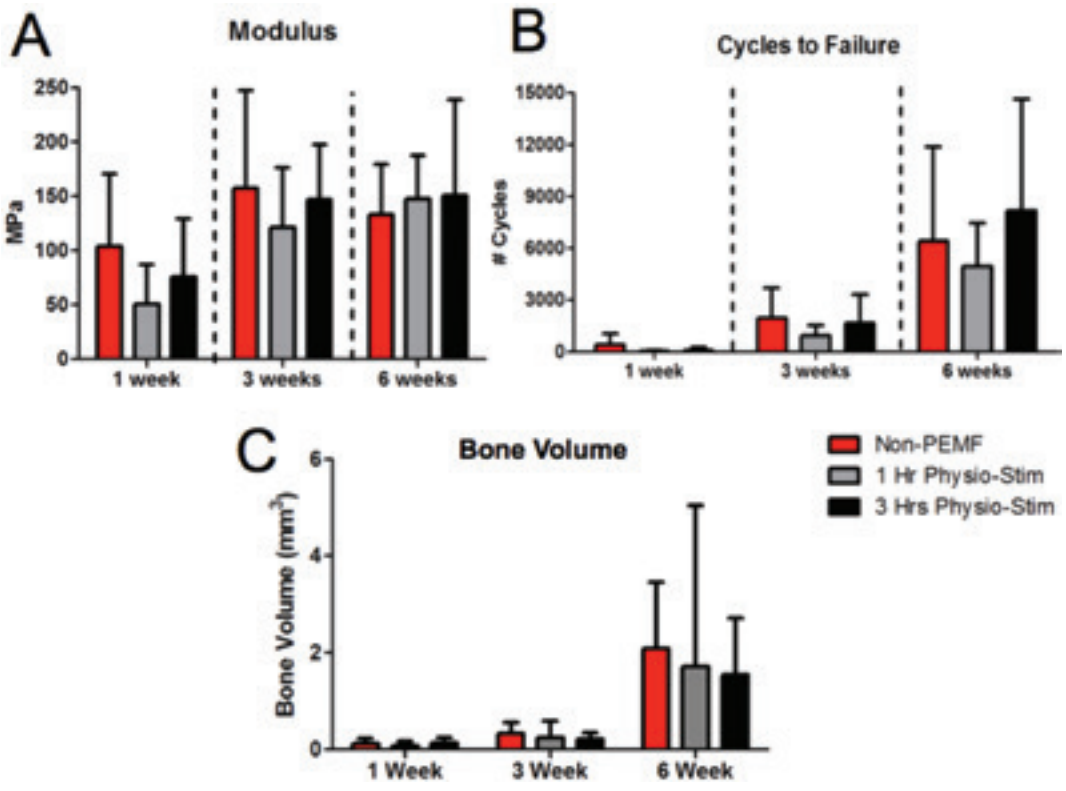

FIGURE 2. (A) Modulus values during mechanical testing were no different between PEMF treatment groups and control tendons. **(B)** Cycles to failure were no different between PEMF treatment groups and control tendons. **(C)** Bone volume was no different between treatment groups and NP control tendons but did appear to increase over time. Data are mean ± SD.

3 weeks, and exhibited greater collagen organization than control non-PEMF tendons at 6 weeks (data not shown).

Mechanical Testing

No differences were observed between PEMF treated tendons and non-PEMF control tendons at any time point (Figures 2A & 2B).

µCT

Heterotopic bone formation in the injured Achilles tendons was observed in all groups including the non-PEMF control, and at 6 weeks post-injury all scanned tendons contained bone. No differences were observed in bone volume or bone mineral density between the PEMF treated tendons and the non-PEMF control tendons at any time point (Figure 2C).

Discussion

The aim of this study was to determine the effects of an FDA-approved, non-invasive PEMF treatment on rat Achilles tendons following injury without immobilization. We hypothesized that, in the absence of immobilization, PEMF treatment would result in improved healing compared to control tendons. However, no differences were observed in mechanical testing outcome measures generally associated with tendon function and healing. While some scattered differences were observed in ambulatory measures, the lack of corresponding changes in mechanical properties suggests that these are more likely the result of animal variations than they are the result of improved tendon function. While not different between treatment groups, the observed bone formation in this Achilles tendon injury model remains interesting and appeared to increase over time. It should be noted that heterotopic bone formation has been observed clinically as well. Ultimately, it appears that PEMF treatment does not improve tendon healing in this partial width, full thickness injury model without immobilization. Surprisingly, ambulatory and joint range of motion assessments detected very little loss of function following this injury model without immobilization. These results indicate that immobilization may be detrimental in this model. Additional comparisons are being performed to quantify this effect. Conversely, a previous study demonstrated that the same PEMF treatment had a positive effect on rat rotator cuff healing suggesting site-specific efficacy[3]. Overall, it is possible that this specific injury model is too conservative to measure potential therapeutic effects in the context of rapid baseline healing in these otherwise healthy Sprague-Dawley rats.

This study shows that healing of a rat partial Achilles tendon injury is not improved by the use of PEMF therapy. Our previous study led to inconclusive results when immobilization was applied after injury[4]. This study provides clarity in the context of the earlier study and provides novel insight into the severity and complexity of this particular injury model.

References

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