

Gastrocnemius Muscle Changes Following Hindlimb Tibial Osteotomy and External Coaptation in Goats

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INTRODUCTION: Joint immobilization often is indicated following orthopedic procedures to control motion, mechanical loading, and facilitate healing. However, joint immobilization can cause changes in muscle structural properties, such as mass and length, that affect muscle force-generating behavior. Such changes could impair mobility and other long-term musculoskeletal problems. Animal models have been used extensively to study the effects of orthopedic interventions on muscle structure and function. Although goats are a common model in orthopedic research, the effect of joint immobilization on muscle structure is sparse. The primary objective of our study was to quantify changes in the gastrocnemius muscle of goats having post-surgical hindlimb immobilization using fiberglass casts or rigid splint bandages.

METHODS: The study from which these muscles were derived was approved by the University of Tennessee, Knoxville IACUC. This study used adult Boer-cross goats as part of a larger study of bone regeneration. All goats in the study were female as this limited variability within small group sizes, and because of housing limitations. Each goat had a mid-diaphyseal segmental osteotomy followed by stabilization using a locking plate. The right hindlimb was immobilized from foot to femorotibial joint for approximately 4.5 months post-surgery, alternating between fiberglass casts and rigid splints. A subset of goats were removed at timepoints 3-, 6-, 9-, and 12-months post-surgery (minimum of 3 muscles per group and timepoint were collected) included in analysis of the gastrocnemius muscle. The gastrocnemius muscle was harvested from the right (operated) and left (non-operated) hindlimb, divided into lateral and medial heads, then fixed and stored in 10% neutral-buffered formalin. The following were measured from each muscle: mass (digital scale), cross sectional area (CSA), length (caliper), muscle fiber length (caliper), and sarcomere length (laser diffraction technique). Cellular infiltrates into the muscles were assessed by nuclei density as measured from randomized regions of histology sections stained with hematoxylin and eosin (H&E). A mixed-model nested fit was used to compare muscle properties (averaged across lateral and medial heads) among groups and timepoints. For the operated limb, Pearson's correlation coefficient (r) was computed to determine the correlation between each muscle property and compared to either bone mineral density (BMD) score or peak vertical force during walking (MF%BW), which were measured and reported previously.

RESULTS: No significant differences were found among groups across all timepoints and within limb muscle properties. However, for all muscle properties, there was a significant difference ($p < 0.05$) between operated and non-operated limbs at all timepoints. Gastrocnemius muscle mass and CSA were less on the operated side, suggesting muscle atrophy associated with disuse and immobilization [1]. Gastrocnemius length and optimal fiber length were less on the operated side, consistent with the muscle in the operated limb having been immobilized in a shortened position. The operated side had a greater nuclei density than the non-operated side ($p = 0.002$ for lateral, $p = 0.001$ for medial). Mass was positively correlated with BMD score ($r = 0.49$, $p = 0.001$) and MF%BW ($r = 0.48$, $p = 0.002$) on the operated side. Similarly, CSA was positively correlated with BMD score ($r = 0.48$, $p = 0.002$) and MF%BW ($r = 0.37$, $P = 0.0189$) on the operated side (Figure 1).

DISCUSSION: Based on the observed between-side differences in the goats, the gastrocnemius muscle in the operated limb experienced degenerative changes that are typical of reduced biomechanical loading and immobilization in a shortened position, including muscle atrophy and reduced optimal fiber length, respectively. Surprisingly, muscle properties did not recover over the 7-to-8-month period after removal of external coaptation. Promisingly, the correlation analysis results indicated that muscle properties were positively correlated with both bone healing and limb loading during gait. Although further research is needed, this suggests the use of physical rehabilitation to increase limb loading and improve bone healing.

SIGNIFICANCE: Orthopedic surgery and subsequent bandaging and casting are common in humans and animals and can alter biomechanics in several ways. Our study provides valuable new data on muscle properties following immobilization. The data may inform new strategies to maximize recovery while minimizing adverse effects.

IMAGES AND TABLES:

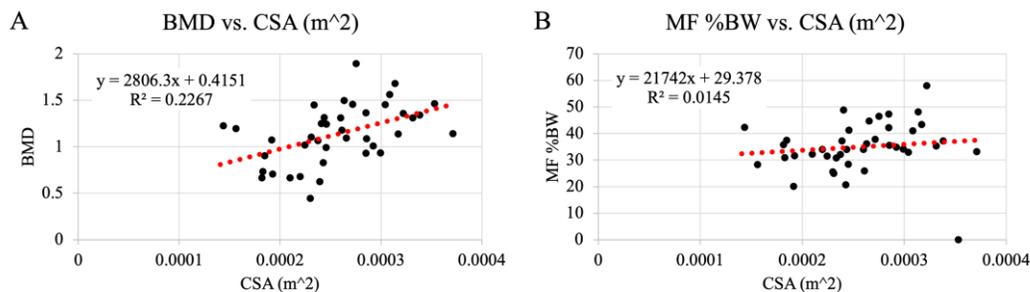


Figure 1: CSA was positively correlated with BMD score (A). CSA was positively correlated with MF%BW (B)

REFERENCES:

[1] R. L. Lieber, *Skeletal muscle structure, function & plasticity*. Philadelphia, Pa: J.B. Lippincott, 2002

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