

# Disruption of The Anterosuperior Rotator Cuff Leads to Ambulatory and Grip Strength Deficits in a Rat Model

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**Disclosures:** Courtney Nuss (N), Rebecca Betts (N), Jeremy Eekhoff (N), Louis J. Soslowsky (N), Andrew F. Kuntz (5 – FX Shoulder USA, Integra Life Sciences, Orthofix; 9 – American Board of Orthopaedic Surgery, American Shoulder and Elbow Surgeons)

**INTRODUCTION:** Rotator cuff tears are a highly prevalent condition, with tears involving the subscapularis tendon now more frequently recognized.<sup>1</sup> Subscapularis tears disrupt the anterior aspect of the rotator cuff force couple and often occur in association with supraspinatus tears.<sup>2</sup> However, prior studies that investigated joint damage caused by rotator cuff injuries did not include tears of the subscapularis and focused largely on post-mortem experimentation.<sup>3</sup> Additionally, although we previously assessed rat gait following an isolated supraspinatus injury with and without repair, longitudinal *in-vivo* diagnostics for tears involving the subscapularis tendon have not been evaluated in a rat model.<sup>3,4</sup> Therefore, the objective of this study was to determine the impact of a combined subscapularis and supraspinatus tear on gait and grip strength in a rat rotator cuff model. We hypothesized that there would be a loss in medial-lateral shoulder kinematics and kinetics, changes in stride length and speed, and a decrease in grip strength post-injury.

**METHODS:** Adult male Sprague-Dawley rats (400-450g) were used in this IACUC approved study. Animals were acclimated and trained to use our custom ambulatory<sup>5</sup> and grip devices<sup>6</sup>, which assess shoulder joint function and reflexive grip strength, respectively. Baseline gait and grip measurements were obtained at 7, 4, and 1 days prior to surgery. In the right shoulder of each animal, the supraspinatus and subscapularis tendons were sharply detached at the insertion sites and biceps tenotomy was performed (n=5). Animals were administered one dose of extended-release buprenorphine at the time of injury, which provided 72 hours of analgesia. Forelimb gait and ground reaction forces as well as grip strength were recorded with our custom devices longitudinally at 2, 4, 7, 14, 20, 27, 41, 55, and 82 days after injury (n=5/timepoint). Gait kinematics were measured by tracking paw positions over time and measuring stance, stride speed, stride length, and stride width. Gait kinetics were assessed using 6 degree-of-freedom load cells to determine lateral force, propulsion force, normal force, braking force, and rate of loading<sup>5</sup>. Reflexive grip strength was measured using a custom grip strength device with independent grip bars and load cells for each limb, allowing for simultaneous measurements from both forelimbs.<sup>6</sup> Six trials were completed for each time point, with average values across all trials reported. One rat was excluded from grip strength data because of mild injury to the left forepaw. Statistical comparisons were made using two-way ANOVAs with main effects of time, limb, and their interaction. Multiple comparison post hoc tests between limbs were performed where appropriate based on significance of main effects. Significance was set at p<0.05 for all comparisons and trends at p<0.10.

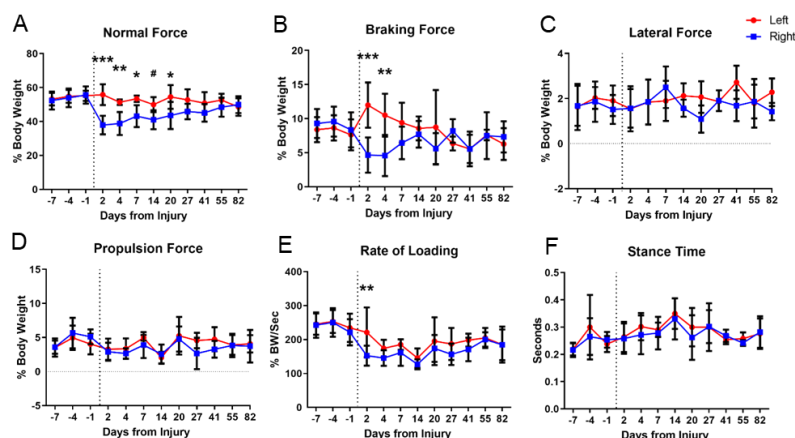
**RESULTS:** *Gait Analysis:* A decrease in normal force in the injured limb compared to contralateral was observed after injury at 2, 4, 7, and 20 days with a trend at day 14 (Fig.1A). Braking force was also decreased in the injured limb compared to contralateral 2 and 4 days after injury (Fig.1B). Furthermore, there was a decreased rate of loading in the injured limb at 2 days after injury (Fig.1E). Propulsion force, lateral force, and stance time (Fig.1C,D,F) were not different between limbs at any time point. In contrast to several of the kinetic measures that did show differences, kinematic gait measures (i.e., speed, stride length, and stride width) showed no difference due to injury (data not shown). *Grip Strength:* The reflexive grip strength force was decreased in the injured limb compared to contralateral at 2, 4, and 7 days after injury, and this difference resolved at 14 days after injury and all subsequent time points (Fig.2).

**DISCUSSION:** The purpose of this study was to evaluate the utility of gait analysis and grip strength assays after a large anterosuperior rotator cuff injury in a rat model. Results demonstrated that functional deficits were detectable post-injury using these assays. We observed changes in gait kinetics after injury which gradually resolved over the course of ~20 days post-injury; however, no changes were observed in temporal gait kinematic data. This greater sensitivity of gait kinetics in comparison to kinematics is consistent with prior studies,<sup>7</sup> and highlights the importance of the increased sensitivity of load measures during gait analysis experiments. Similar to gait data, reflexive grip strength demonstrated functional deficits in the injured limb post-injury, while this deficit resolved between 7 and 14 days post-injury. The differences between limbs in both gait and grip strength highlight the importance of early post-injury time points to capture functional deficits post-injury and their temporal changes after a rotator cuff injury, especially with less severe injuries that would be expected to produce more subtle changes than observed here. While this study confirmed the presence of functional deficits post-injury, it remains unclear how pain, or lack of pain, contributes to the observed changes in gait and grip strength when pain relievers are introduced. Future work will investigate pain as a factor through the use of analgesics.

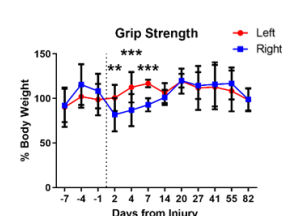
**SIGNIFICANCE/CLINICAL RELEVANCE:** The ability to quantify longitudinal functional deficits in animal models is essential for minimizing animal use and informing translation to the clinic. Results from this study illustrate changes in upper limb function that result from rotator cuff tears involving the subscapularis and supraspinatus.

**REFERENCES:**[1] Denard PJ and Burkhart SS, Arthrosc Tech, Oct 2013. [2] Barth J et al. Ortho and Trauma Dec 2012. [3] Reuther KE et al. J Orthop Res, May 2014. [4] Reuther KE et al. J Shoulder Elbow Surg, Mar 2015. [5] Sarver JJ et al. J Biomech, Mar 2011.[6] Reiter A et al. J Biomech Eng, Apr 2019. [7] Hsu JE et al. JOR Feb 2011.

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**Figure 1.** A decrease in normal force in the injured limb compared to contralateral was observed after injury at 2, 4, 7, and 20 days, and is trending at day 14 (Fig.1A). Braking force was decreased in the injured limb compared to contralateral 2 and 4 days after injury (Fig.2B). A decreased rate of loading in the injured limb was observed 2 days after injury (Fig.1E). Lateral force, propulsion force, and stance time (Fig.1C,D,F) were not different between limbs at any time point. (#p<0.10, \*p<0.05, \*\*p<0.01, \*\*\*p<0.001).



**Figure 2.** Reflexive grip strength force was decreased in the injured limb compared to contralateral at 2, 4, and 7 days after injury, and is resolved by 14 days after injury. (\*\*p<0.01, \*\*\*p<0.001).