

# The Effect of Manual Wheelchair Push Rim Positioning on Rotator Cuff Tendon Compression During Propulsion

Gaura Saini<sup>1</sup>, Aaron Hellem<sup>1</sup>, Cyrus Rezvanifar<sup>1</sup>, Amanuel Nigatu<sup>1</sup>, Denzel Godwin<sup>1</sup>, Teresa Bisson<sup>1</sup>, Arin Ellingson<sup>1</sup>, John Looft<sup>1,2</sup>, Andrew Hansen<sup>1,2</sup>, Paula Ludewig<sup>1</sup>  
<sup>1</sup>University of Minnesota, Minneapolis, MN, <sup>2</sup>Minneapolis VA Medical Center, Minneapolis, MN  
saini041@umn.edu

**Disclosures:** None

**INTRODUCTION:** Individuals using manual wheelchairs (MWCs) as their primary form of mobility have a high prevalence of shoulder pain.<sup>1,2</sup> Propulsion requires repetitive shoulder motion within the range of motion thought to pose the greatest risk of rotator cuff compression from the coracoacromial (CA) arch.<sup>3,4</sup> There is also increasing evidence that the rotator cuff tendons are obstructed by the glenoid during motion,<sup>5</sup> though this effect has not been evaluated during MWC propulsion. A modeling study determined that the theoretical optimal position for MWC push rims is with the center of the push rims anterior to the shoulder to minimize muscle stress, co-contraction, and metabolic cost.<sup>6</sup> A novel MWC was designed separating the push rims from the drive wheels, allowing the rims to be anteriorly positioned without affecting chair stability. This pilot study assessed the distances between 1) the CA arch and the rotator cuff tendon bony insertions and 2) the glenoid and the rotator cuff tendon bony insertions during MWC propulsion to test the *in vivo* compression risk of an anterior push rim position as compared to the standard position (push rim axis below the shoulder joint). We hypothesized that the theoretical position would result in increased distances between the insertions and the CA arch and glenoid compared to the standard position during the push phase of propulsion.

**METHODS:** This study was approved by the UMN Institutional Review Board. Six full-time MWC users with spinal cord injuries of thoracic level 1 (T1) and lower (ensuring full upper extremity function) were tested after providing informed consent to participate. Humeral and scapular motion was assessed using biplane video radiography. A custom MWC simulator allowed independent push rim positioning and simultaneous capture of propulsion kinematics within the x-ray field of view. Data were collected while participants propelled the simulator in 1) standard position, with the center of the push rim aligned with the shoulder joint and 2) anterior position, with the center of the push rim 10° anterior to the shoulder joint using a goniometer. MRIs or CT scans were obtained to create participant-specific 3D models of the humerus and scapula. The bone models were projected onto the video x-rays to obtain 3D kinematics (2D/3D shape-matching), and humeral kinematics were described with respect to the scapula (glenohumeral (GH) kinematics). The bony insertions of the supraspinatus, infraspinatus, and subscapularis were identified on the humerus as were the CA arch and glenoid on the scapula. Kinematic data and insertion-to-CA arch and insertion-to-glenoid minimum distance were extracted using KinematicsToolbox.<sup>7</sup> Data were analyzed descriptively.

**RESULTS:** No notable differences in minimum distances based on push rim position were observed (Table 1). Minimum distances between the supraspinatus (Figure 1, left) and subscapularis insertions and CA arch and glenoid occurred near the end of the push phase (maximum GH elevation (Figure 1, right)). Minimum distances between the infraspinatus insertion and the CA arch and glenoid occurred during the recovery phase.

**DISCUSSION:** The anterior push rim position did not consistently change rotator cuff insertion proximity to the CA arch or glenoid. Rather, proximities appear to be more closely related to GH kinematics, which did not consistently change between the two push rim positions. For all participants, the supraspinatus insertion distance to the CA arch was smaller in the push rim position that resulted in greater GH elevation. GH elevation was higher in the standard position for half of the participants and higher in the anterior position for the remaining half. Given the average thickness of the rotator cuff tendons (4.9 mm supraspinatus and infraspinatus, 5.5 mm subscapularis<sup>8</sup>), the only compression risk appears to be the supraspinatus from the CA arch, and it seems that compression may occur in 4/6 participants regardless of push rim position. These findings parallel existing evidence that the supraspinatus tendon is the most frequently torn of the rotator cuff.<sup>9</sup> However, these analyses were done using distances to the bony insertion of the tendon on the humerus without accounting for participant-specific tendon anatomy. Ongoing research is assessing tendon proximities directly. These preliminary results suggest that a theoretically optimal anterior push rim position may alter GH kinematics in some participants which may result in changes in rotator cuff insertion proximities to the CA arch and glenoid. Individual tendon anatomy must be considered in order to determine how meaningful these changes might be.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Individuals who use MWCs rely on repetitive motion at their shoulders for mobility, therefore it is critical to understand shoulder biomechanics during MWC propulsion given the high prevalence of shoulder pain in this population. Adjusting the push rims to minimize muscle stress may not consistently alter rotator cuff proximity to surrounding structures, so in determining the efficacy of the novel anterior push rim wheelchair design, other factors should be considered, including evaluating tendons directly beyond bone-to-bone distances.

**REFERENCES:** 1) Soo Hoo JA. PMR 2022. 2) Kentar Y. Spinal Cord 2018. 3) Mozingo JD. J Electromyogr Kinesiol 2022. 4) Lawrence RL. J Orthop Res 2017. 5) Saini G. Orthop J Sports Med 2021. 6) Slowik JS. Clin Biomech 2013. 7) Lawrence RL. KinematicsToolbox 2023. 8) Sessions WC. Iowa Orthop 2017. 9) Barreto RPG. J Shoulder Elbow Surg 2019.

Table 1: Rotator Cuff Insertion Proximities in the Standard and Anterior Push Rim Positions				
	Minimum Distance to CA Arch		Minimum Distance to Glenoid	
	Standard	Anterior	Standard	Anterior
Supraspinatus	1.8-7.6 (4.2±2.4)	1.5-8.0 (4.4±2.6)	12.3-27.6 (20.6±5.9)	13.3-26.8 (22.5±5.2)
Infraspinatus	6.8-13.4 (9.1±2.7)	6.4-12.6 (9.0±2.7)	23.3-32.3 (27.8±3.9)	22.1-33.1 (27.6±4.2)
Subscapularis	7.9-14.5 (10.4±2.3)	6.9-13.2 (9.8±2.2)	8.3-20.9 (13.6±5.6)	10.3-22.1 (15.4±5.5)

Data are presented as the range (mean ± standard deviation) in mm

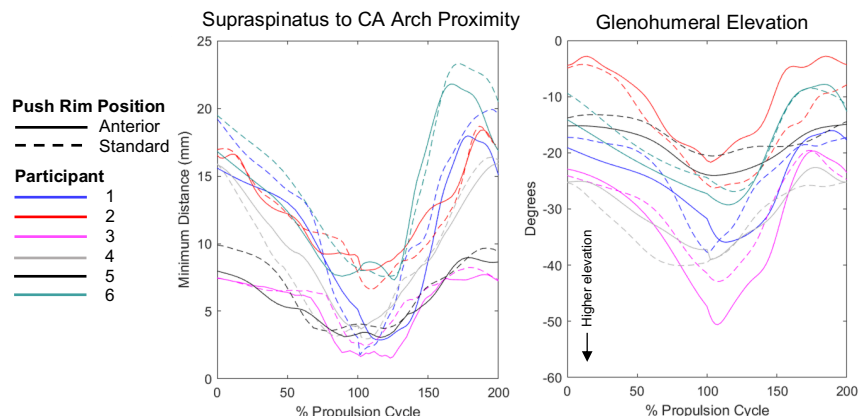


Figure 1. Supraspinatus insertion to CA arch minimum distance across the propulsion cycle (left). Glenohumeral elevation angle across propulsion cycle (right) in which higher elevations are represented by more negative values. The push phase of the propulsion cycle is represented by 0-100%, and the recovery phase is represented by 100-200%.