

ROBOTIC OUTCOMES IN PERSONS WITH ROTATOR CUFF TEARS

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INTRODUCTION

Rotator cuff tears are one of the most common causes of pain and disability of the upper extremity[1]. Impaired motor control and biomechanics of the shoulder girdle with concomitant instability often exists prior to any surgical procedure. In this patient population clinical measures are limited, with questionable reliability and validity[2].

The MIT-MANUS robotic device has been found to be a reliable tool for of a patient's self generated motions, quantifying different features of motor performance (e.g. accuracy, speed, coordination, smoothness, etc) [3,4,5]. Robot generated outcome measures have demonstrated the ability to detect significant improvements in motor performance even when the clinical measures revealed only small changes[4,5]. The device can provide means to quantify aspects that have traditionally relied exclusively on qualitative observation, such as smoothness of movement[5]. Therefore, robotic measurement of patient unconstrained movements could be employed as the primary outcome in patients with rotator cuff tears. The purpose of this study was to evaluate the capability of the MIT-MANUS to detect movement differences between extremities with a rotator cuff and without tears. A secondary purpose was to determine if a relationship exists between self-reported functional outcomes, clinical motion measures and robotic generated variables.

METHODS

Twelve individuals (age=58.9±7.9yrs) with physician diagnosed rotator cuff tears completed the self-report functional status measures of the Shoulder Pain and Disability Index (SPADI) and the American Shoulder and Elbow Surgeons

Standardized Assessment (ASES) followed by performance of a planar reaching robotic evaluation with their involved extremity followed by their non-involved limb. The evaluations were performed on the highly-backdriveable low friction MIT-MANUS[6]. Backdriveable robots have low endpoint impedance insuring a gently compliant behavior of the robot when interacting with the subject. Therefore, the machine does not interfere with motion and allows the individual to move freely. The robot reaching evaluation required the subject to reach from the center target to eight peripheral targets evenly distributed on a circle with radius of 14cm and moving clockwise, without movement assistance. For all robot tasks the subjects were seated in a chair, centered in front of the robot support table. A waist strap with vertical straps anterior-medial the shoulders was applied during all training and evaluation sessions to limit/prevent forward trunk compensation without impeding scapular motions.

Outcome variables assessed for the reaching task were aiming error (mean absolute angle between actual direction and a straight line between start and target), mean speed (total displacement traveled over total movement duration), peak speed, mean-to-peak speed ratio (mean speed divided by the peak speed is a metric of movement smoothness⁵ and movement duration.

Paired t-tests evaluated if a difference could be detected between involved and uninvolved extremities ($p \leq 0.05$) while Pearson correlation evaluated the relationship between the robotic outcomes and the self-report functional scales ($p \leq 0.05$). Correlation was defined as moderate ($r = 0.50 - 0.69$), high ($r = 0.70 - 0.89$) or as very high ($r > 0.90$).

RESULTS

The MIT-MANUS detected a difference in mean speed ($p=0.026$), movement smoothness ($p=0.003$), and movement duration ($p=0.031$) between involved and uninvolved extremities in persons with rotator cuff tears (Table 1).

Significant moderate correlation were found between the ASES total and robotic outcomes of mean speed ($r=0.58$, $p=0.05$). Mean speed also had significant moderate correlation to SPADI pain ($r = -0.69$, $p = 0.014$), SPADI disability ($r = -0.63$, $p=0.028$) and SPADI total ($r = 0.67$, $p = 0.016$). High correlation was found between movement duration and SPADI pain ($r = 0.81$, $p = 0.001$), SPADI disability ($r = -0.72$, $p = 0.009$) and SPADI total ($r = 0.78$, $p = 0.003$).

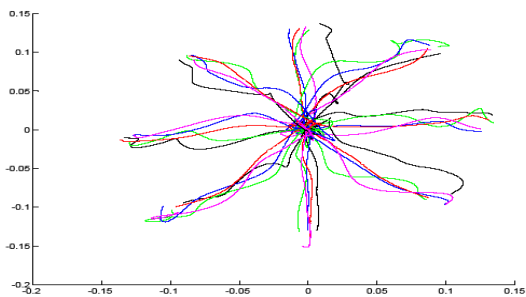


Figure 1: Reaching task output from a representative participant with rotator cuff tear.

CONCLUSIONS

This study provides the first evidence that planar robot outcomes may provide objective measures of motor control in patients with shoulder impairments

quantifying biomechanical profiles and perhaps provide insights into recovery more distinctly than clinical measures. Goal-directed, quantifiable rehabilitation outcomes measuring redevelopment of function through improved range of motion, strength and motor control are lacking in patients with musculoskeletal impairments. A moderate to strong relationship exists among the SPADI self-report functional outcome and speed and duration of movement on the planar robot evaluation. The MIT-MANUS derived robotic metrics are sensitive to bilateral differences and, therefore, potentially able to determine changes, potentially in advance of clinical measures. Since the clinical scales for orthopedic impairments are limited and these robot outcome measures are shown to be reliable and sensitive, they can be utilized in future investigations as primary outcomes to evaluate patients with orthopedic conditions.

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Table 1: Robotic outcomes in involved and uninvolved extremities (mean, std error).

* indicates significant difference between extremities

	Involved limb	Uninvolved limb	p-value
Aiming Error (rad)	2.02 (0.04)	1.95 (0.05)	0.402
Mean speed (m/sec)	0.10(0.01)	0.12(0.01)	0.026*
Peak speed (m/sec)	0.23(0.02)	0.26(0.01)	0.165
Smoothness (mean speed:peak speed)	0.45 (0.01)	0.47(0.01)	0.003*
Movement duration (sec)	1.81(0.15)	1.48(0.07)	0.015*