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Short communication

The effects of a rotator cuff tear on activities of daily living in older adults: A kinematic analysis

Meghan E. Vidt [a,*], Anthony C. Santago II [b,c], Anthony P. Marsh [d], Eric J. Hegedus [e], Christopher J. Tuohy [f], Gary G. Poehling [f], Michael T. Freehill [f], Michael E. Miller [g], Katherine R. Saul [c]

[a] Exercise Science and Health Promotion, Arizona State University, Phoenix, AZ, USA
[b] Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences, Winston-Salem, NC, USA
[c] Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC, USA
[d] Department of Health and Exercise Science, Wake Forest University, Winston-Salem, NC, USA
[e] Department of Physical Therapy, High Point University, High Point, NC, USA
[f] Department of Orthopaedic Surgery, Wake Forest School of Medicine, Winston-Salem, NC, USA
[g] Department of Biostatistical Sciences, Wake Forest School of Medicine, Winston-Salem, NC, USA

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ABSTRACT

Rotator cuff tears (RCT) in older individuals may compound age-associated physiological changes and impact their ability to perform daily functional tasks. Our objective was to quantify thoracohumeral kinematics for functional tasks in 18 older adults (mean age $=63.3 \pm 2.2$), and compare findings from nine with a RCT to nine matched controls. Motion capture was used to record kinematics for 7 tasks (axilla wash, forward reach, functional pull, hair comb, perineal care, upward reach to 90°, upward reach to 105°) spanning the upper limb workspace. Maximum and minimum joint angles and motion excursion for the three thoracohumeral degrees of freedom (elevation plane, elevation, axial rotation) were identified for each task and compared between groups. The RCT group used greater minimum elevation angles for axilla wash and functional pull ($p \leq 0.0124$) and a smaller motion excursion for functional pull ($p = 0.0032$) compared to the control group. The RCT group also used a more internally rotated maximum axial rotation angle than controls for functional reach, functional pull, hair comb, and upward reach to 105° ($p \leq 0.0494$). The most differences between groups were observed for axial rotation, with the RCT group using greater internal rotation to complete functional tasks, and significant differences between groups were identified for all three thoracohumeral degrees of freedom for functional pull. We conclude that older adults with RCT used more internal rotation to perform functional tasks than controls. The kinematic differences identified in this study may have consequences for progression of shoulder damage and further functional impairment in older adults with RCT.

1. Introduction

Sarcopenia and reduced strength are well-known sequelae of aging contributing to functional declines older adults experience (Clark and Manini, 2010). Presence of a shoulder injury, like a rotator cuff tear (RCT), can further reduce an individual's ability to perform functional tasks (Lin et al., 2008; van Schaardenburg et al., 1994). RCT is a common musculoskeletal injury for older adults, with prevalence increasing from 25.6% to 50.0% for adults in their sixties and eighties, respectively (Yamamoto et al., 2010). Shoulder injury may result in adaptive movements caused by muscle weakness or force imbalance (Lippitt and Matsen, 1993; Lippitt et al., 1993; Magarey and Jones, 2003; Phadke et al., 2009), or used as a pain avoidance strategy (Hall et al., 2011; Mell et al., 2005). In addition to limiting functionality, altered kinematics may expose the glenohumeral joint to new contact force scenarios, which could lead to further joint damage (Hsu et al., 2003; Vidt, 2014).

The upper limb is critical for daily functional tasks, including eating and personal hygiene (Katz et al., 1963). Studies evaluating upper limb functional task performance have primarily focused on younger or uninjured individuals (Magermans et al., 2005; Safaee-Rad et al., 1990; van Andel et al., 2008). Little work has focused on older adults (Hall et al., 2011) or investigated functional task performance in those with RCT. Therefore, our objective was to quantify thoracohumeral kinematics for a group of older adults

* Corresponding author at: Exercise Science and Health Promotion, Arizona State University, 550 North 3rd Street, Phoenix, AZ 85004, USA. Tel.: +1 602 827 2280; fax: +1 602 827 2253.
E-mail address: mvidt@asu.edu (M.E. Vidt).

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with and without RCT during performance of functional tasks spanning the upper limb workspace. Kinematics for three thoracohumeral degrees of freedom were compared between groups. The null hypothesis was that task kinematics for RCT and control groups would not be different.

2. Methods

2.1. Participants

Eighteen older individuals (mean age$=63.3\pm2.2$) participated (Table 1); 9 participants (4F/5M) had RCT of the supraspinatus tendon; 9 were age- and sex-matched controls. RCT participants had an MRI-confirmed supraspinatus tendon tear ($\geq 50\%$ tendon thickness) and were recruited from our institution's orthopedic clinic, where they sought treatment for RCT symptoms. Controls were recruited from the local community, had no history of shoulder pain or injury, and were screened for shoulder pain and weakness using a modified lateral Jobe's test (Gillooly et al., 2010), whereby manual resistance was applied to arms elevated 90° in the scapular plane with neutral axial rotation. RCT participants' injured arm was studied and the dominant arm was investigated for controls. Wake Forest Health Sciences Institutional Review Board approved this study; all participants provided written informed consent prior to participation.

2.2. Functional tasks

Participants completed 7 functional tasks spanning the upper limb workspace: forward reach, functional pull, upward reach to a shelf at shoulder height (upward reach 90°) and 15° above horizontal (upward reach 105°), axilla wash, perineal care, and hair comb. All tasks were completed while seated (chair height$=0.53$ m) at a table (height$=0.775$ m). Descriptions of each task and associated loads, selected to mimic typical loads in daily performance, are described in Table 2. Participants were given instructions on start and finish hand positions for each task, but could freely choose their joint postures and speed during each movement. Task order was randomized; three trials of each task were recorded before proceeding to the next task. Participants were provided 60 s rest between trials and 2 min rest between tasks. Participants were instructed to stop a task if they experienced any pain or discomfort (see below). The second trial of each task for each participant was used for analysis.

Positions of twelve 1 cm retro-reflective markers placed on the upper limb and torso (Fig. 1) were tracked at 200 Hz (60 Hz for 3 participants) using 7 Hawk motion capture cameras (Motion Analysis Corporation, Santa Rosa, CA). Marker data was post-processed and smoothed with a 6 Hz Butterworth filter using Cortex software (Motion Analysis Corporation).

2.3. Kinematic calculations

A dynamic upper limb model (Saul et al., 2015) was implemented in OpenSim (v.3.1) (Delp et al., 2007). The model was scaled to each participant using marker locations from one static trial. Following scaling, the inverse kinematics tool calculated joint kinematics for each task. Kinematic trajectories were filtered with a zero-phase filter using a custom Matlab program (The Mathworks, Natick, MA). Consistent with ISB standards describing thoracohumeral motion (Wu et al., 2005), joint angles were decomposed by applying *Y*–*X*–*Y* rotation order, corresponding to elevation plane, elevation, and axial rotation, using axes defined from anatomical landmarks. Elevation in 0° elevation plane is abduction; elevation in 90° elevation plane is forward flexion; positive axial rotation is internal rotation; negative axial rotation is external rotation. Maximum and minimum angles were calculated for each degree of freedom (Fig. 1). Motion excursion was calculated by subtracting the minimum angle from the maximum angle. To compare across participants, kinematics were normalized by task completion time and are presented as a percentage of total movement time.

2.4. Statistical analysis

Mixed model ANCOVA, using random effects to represent matched pairs and adjusting for hand dominance, was used to separately evaluate differences between RCT and control groups for maximum angle, minimum angle, and motion excursion of each degree of freedom for each task (v.9.3, SAS Institute, Inc., Cary, NC). Significance was set at $p\leq0.05$. We did not adjust for type I error due to the exploratory nature of these analyses.

3. Results

Six RCT participants had full-thickness supraspinatus tear. Tears extended into infraspinatus in 7 participants and subscapularis in 5 participants. Three RCT participants did not complete all tasks due to pain: one could not complete perineal care and hair comb; one could not complete hair comb; one could not complete upward reach 105°. RCT participants completed several tasks with different kinematics than controls (Fig. 2; Supplement 1, 2). Elevation plane was similar between groups for most tasks, but RCT participants used a smaller (closer to abduction plane) maximum elevation plane for forward reach ($p=0.0300$) and functional pull ($p=0.0020$) (Fig. 2; Table 3). Minimum elevation angle for RCT participants was greater (more elevated) for axilla wash

Table 1
Participant characteristics.

Subject	Age (years)	Height (cm)	Body mass (kg)	Dominant arm	Injured arm
RF01	65	149.9	53.5	Right	Left
RF02	63	160	73.5	Right	Right
RF03	60	180.3	122.5	Right	Right
RF04	65	162.6	65.8	Right	Left
RM01	61	167.6	83.9	Right	Left
RM02	64	177.8	108	Left	Left
RM03	64	182.9	88.5	Right	Left
RM04	62	177.8	95.3	Left	Left
RM05	66	168.9	87.1	Right	Left
CF01	67	172.7	70.8	Right	N/A
CF02	65	162.6	65.8	Right	N/A
CF03	60	157.5	79.4	Right	N/A
CF04	64	160	60.3	Right	N/A
CM01	61	177.8	99.8	Right	N/A
CM02	64	182.9	86.2	Right	N/A
CM03	62	172.7	73.5	Right	N/A
CM04	61	175.3	70.3	Right	N/A
CM05	66	182.9	83.9	Right	N/A
RCT mean ± SD	63.3 ± 2.0	169.8 ± 11.0	86.4 ± 21.0		
Control mean ± SD	63.3 ± 2.4	171.6 ± 9.5	76.7 ± 12.0		

R: rotator cuff tear subject
C: control subject
F: female subject
M: male subject
N/A: not applicable