Research Experience for Teachers

Older adults with rotator cuff tears use muscle compensation to perform a loaded axilla wash: A model-based study

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Introduction

- Rotator cuff tears (RCT) commonly occur among older adults and reduce function[1,2].
- Previous work shows that increasing rotator cuff tear severity impacts the magnitude of the glenohumeral joint contact force during task completion[3].
- The combined effect of external load, tear severity, and sex on muscle compensation and glenohumeral joint contact force for older adults has not been studied.

__Objective:__ **Determine the combined effect of external load, rotator cuff tear severity, and sex on muscle force compensation, glenohumeral joint contact force, and hand deviation during a functional task using a computational model.**

Methods

- Older adult female (OAF) and older adult male (OAM) models[4,5] were used in OpenSim (v 3.3)[6].
- Tear severity was modeled by decreasing peak isometric force for rotator cuff muscle actuators (Table 1).
- Kinematics from older adults from a previous study[7] performing an axilla wash task (Figure 1) were input into the Computed Muscle Control algorithm in OpenSim to predict individual muscle forces.
- Predicted muscle forces were normalized by tear severity specific peak isometric force.
- The joint reaction tool in OpenSim was used to predict the magnitude of the glenohumeral joint contact force (JCF).
- Point kinematics was performed to measure the hand deviation from the input kinematics.

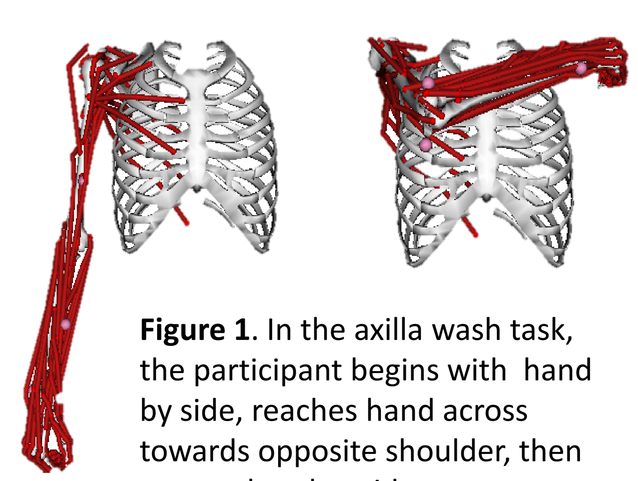

Figure 1. In the axilla wash task, the participant begins with hand by side, reaches hand across towards opposite shoulder, then returns hand to side.

Analyses

- 3-way ANOVA (external load, tear severity, sex) was used to examine differences in muscle force for each of the 13 muscles paths crossing the shoulder using custom MATLAB (The MathWorks, Inc, Natick, MA) script.
- Maximum JCF was calculated using custom MATLAB script
- Hand deviation was quantified by root mean squared error (RMSE) calculated using a custom MATLAB script.

Table 1. RCT modeled by reducing peak isometric force to a percentage of the no tear model.

	Tear Severity			
Muscle	No Tear	Partial Tear	Full Tear	Massive Tear
Supraspinatus	100%	50%	0%	0%
Infraspinatus	100%	100%	75%	25%
Subscapularis	100%	100%	100%	50%

Results

Muscle Force and External Load with Massive Tear Severity

Muscles increased force with increasing external load for massive tear severity:

- Anterior deltoid by 30.2% for OAF and 24.5% for OAM ($p<0.0001$).
- Middle deltoid by 40.9% for OAF and 4.4% for OAM ($p=0.002$) .
- Posterior deltoid by 43.7% for OAF and 32.1% for OAM ($p<0.0001$).
- Infraspinatus by 3.9% for OAF and 50.7% for OAM ($p<0.0001$).
- Subscapularis by 139.8% for OAF and 38.1% for OAM ($p=0.0005$).
- Teres minor by 37.0% for OAF and 38.1% for OAM ($p<0.0001$).
- Superior pectoralis by 65.9% for OAF and 16.8% for OAM ($p<0.0001$).

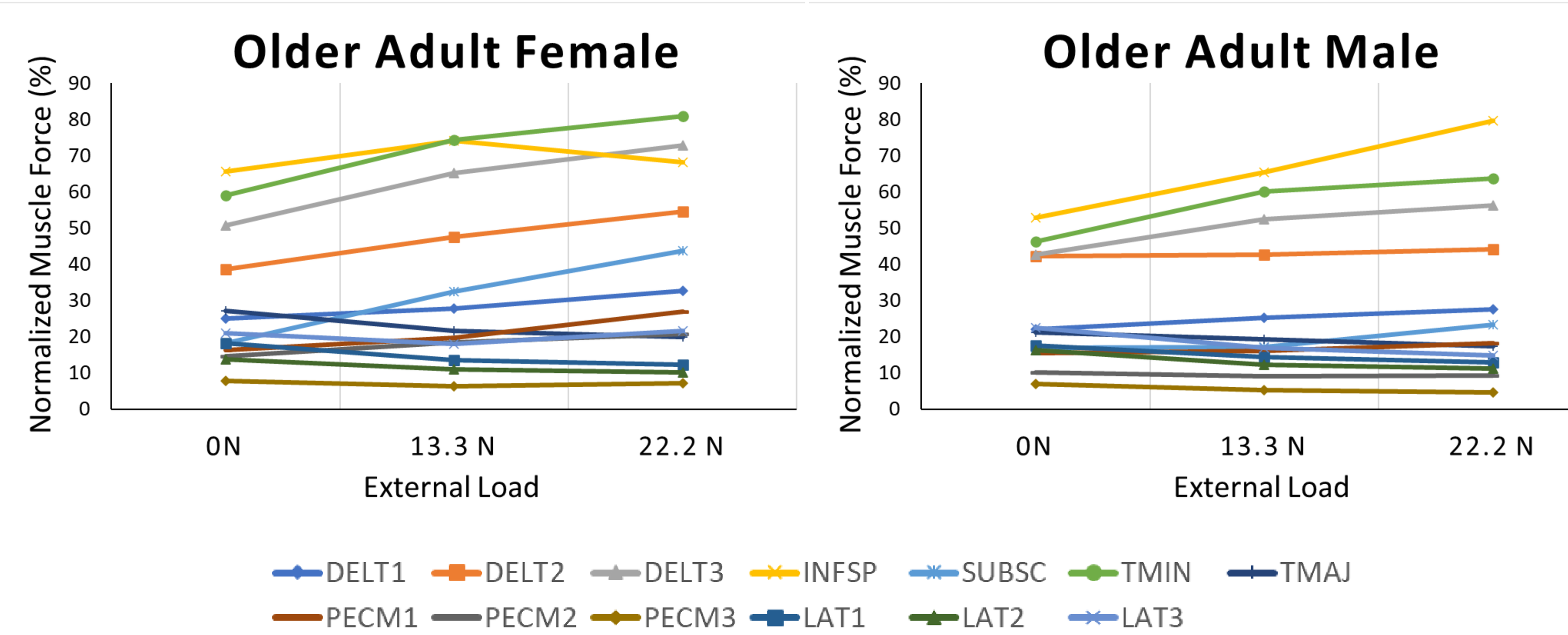

Figure 2. Normalized muscle force across the 13 muscle paths crossing the shoulder at each external load on OAF and OAM models with massive tear severity.

Muscle Force and Rotator Cuff Tear Severity with 22.2 N Load

Muscles increased force with increasing tear severity for a 22.2N external load:

- Middle deltoid by 39.6% for OAF and 18.8% for OAM ($p=0.0171$).
- Posterior deltoid by 34.3% for OAF and 10.8% for OAM ($p=0.0001$).
- Infraspinatus by 20.0% for OAF and 20.6% for OAM ($p=0.0001$).
- Teres minor by 61.1% for OAF and 22.3% for OAM ($p<0.0001$).

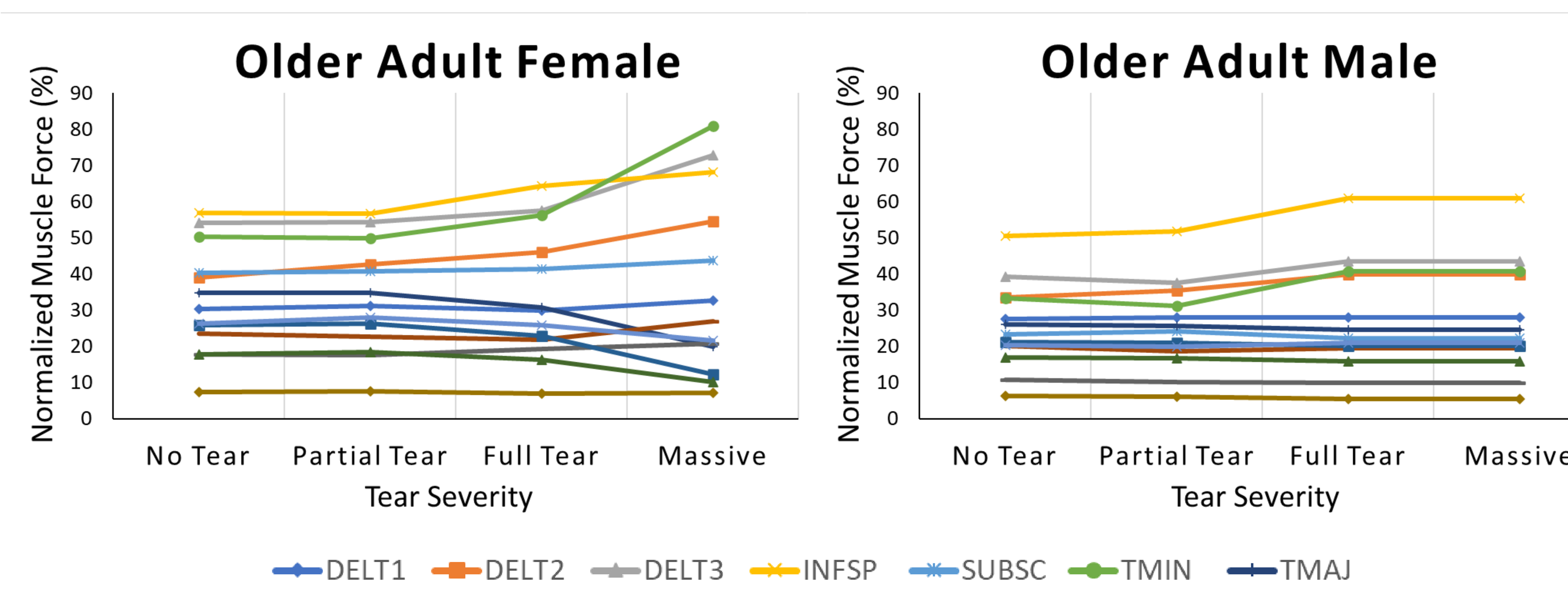

Figure 3. Normalized muscle force across the 13 shoulder muscles paths crossing the shoulder at each tear severity on OAF and OAM models with 22.2 N external load.

Results

Glenohumeral Joint Contact Force (JCF)

- OAM show greater JCF across all loads and severities.
- JCF increases when external load increases from 0 N to 22.2 N for OAF (18.27%) while OAM show little change (0.21%).
- JCF decreases as tear severity increases in OAF and OAM.

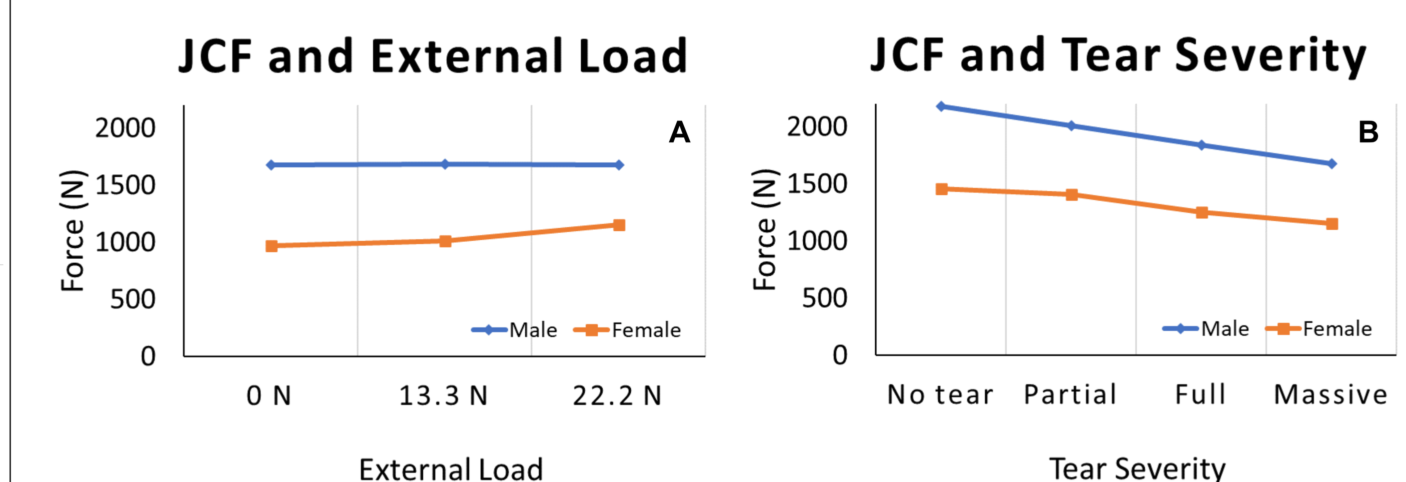

Figure 4. A) Resultant Joint Contact Force at each external load for massive tear severity. B) Resultant Joint Contact Force at each tear severity using 22.2 N external load.

Hand Deviation

- Hand deviation increases with tear severity and external load for both OAF and OAM (Table 2).
- OAF show increased hand deviation compared to OAM.

Table 2. Average resultant RMSE (±SD) for OAF and OAM models for no load, no tear and highest load, massive tear models.

	Hand Deviation (cm)	
	Older Adult Female	Older Adult Male
No Tear 0N Load	8.88 ± 3.19	7.12 ± 3.94
Massive Tear 22.2N Load	10.59 ± 3.51	10.31 ± 2.73

Discussion

- OAF are showing more muscle compensation than OAM with increased external load and tear severity.
- OAF may compensate more to enable successful task performance due to lower muscle volumes and force generating capacity than OAM.
- Although not significant, there may be an emerging trend toward sex-based differences in JCF that could impact exposure to secondary injury.
- Increased hand deviation with increasing load and tear severity is consistent with increased muscle compensation and force.

References

[1] Lin JC. et al., J Am Med Dir Assoc. 2008;9(9):626-32
[2] Yamamoto A. et al., J. Shoulder Elbow Surg. 2010;19(1):116-120
[3] Pataky J. et al., Clin Biomech. 2021;90:105494
[4] Vidt ME. et al., J Biomech. 2012;45:334-341
[5] Saul KR. et al., Comput Methods Biomech Biomed Eng. 2015;18(13):1445-58
[6] Delp SL. et al., IEEE Trans Biomed Eng. 2007;54(11):1940-50
[7] Vidt ME. et al., J Biomech. 2016;49:611-17

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