ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

THE EFFECTS OF A 6 WEEK EXERCISE PROGRAM ON GLENOHUMERAL STABILITY

[1]James Marchi, [2]Dimitra Blana [3]Ed Chadwick
[1]Department of Sport and Exercise Science, Aberystwyth University, UK
[2]Independent Researcher, UK.
[3] Institute for Science and Technology in Medicine, Keele University, Stoke-on-Trent, UK
Email: jam5@aber.ac.uk

INTRODUCTION

The human shoulder has been described as a compromise between mobility and stability [1], enabling the performance of a variety of day to day tasks and movements, particularly moving the hand. Due to the shallow glenoid, passive stability of the joint is limited and stability is maintained by coordinated activation of the muscles around the joint. However, the stability of the shoulder can be compromised by a number of conditions including nerve injury, rotator cuff tears, spinal cord injury and stroke.

A method of quantifying glenohumeral stability has previously been reported [2]. Upper limb kinematics and muscular activity during hand positioning tasks were measured, and glenohumeral reaction forces were estimated using a musculoskeletal model of the upper limb [3]. This method was found to show significant differences between previously dislocated and never injured shoulders [2]. This modelling approach has been used to study glenohumeral forces and stability by a number of previous authors under different conditions [4-6].

Previous research analysed the effect of an exercise program to improve stability in subjects with traumatic or atraumatic recurrent anterior, posterior, or multidirectional subluxation [7]. The exercises used were targeted at the rotator cuff, deltoid and trapezius muscles. Good or excellent results were found for 16% to 80% of subjects, dependent on direction and nature (traumatic or atraumatic) of the subluxation.

The aim of this study was to quantify the effects of that program on stability of the glenohumeral joint using the musculoskeletal modelling method described.

METHODS

Subjects

Twelve subjects with previous shoulder dislocation and no known rotator cuff tears were recruited. Subjects were randomly allocated to either an exercise intervention or control group. The exercise intervention group completed a 6 week exercise intervention. Exercises were taken from a previously used exercise program targeted at the rotator cuff and deltoid muscles [7]. The control group completed a 6-week whole body exercise program not aimed at the shoulder. Stability was measured pre- and post-intervention using the methods described.

Measurements of upper limb kinetics

A robotic arm (Haptic Master, Moog FCS, Nieuw Vennep, NL) was used to apply forces to the hand of the participant during upper limb postural stability tasks. A virtual reality environment (written in GameStudio) was used to present the task to the subject. An image of the subject's arm was presented on a computer screen, and a target appeared at a predetermined (but randomised) location. The participant was asked to move their hand to the target location and resist the force applied through the handle, attempting to keep the hand as close to the target as possible. Forces were applied at nine locations (the centre and corners of a 20cm cube directly in front of the participant), in two directions along three axes (push/pull, left/right and up/down) and at two levels (5 and 10N). This gave a total of 108 conditions, for which the order was randomised. The duration of force application was 5 seconds for each condition, with a 5 second rest before the next condition to allow for movement to the new location. The session was split into two minute trials, with two minutes of rest between each trial. The interaction force between the robot arm and the participant's hand was recorded throughout the trial at a frequency of 50Hz.

Surface electromyograms (EMG) of biceps brachii, triceps long head, anterior deltoid, middle deltoid, posterior deltoid, infraspinatus and pectoralis major were recorded (Biometrics Ltd., Newport, Wales, UK). Sensor placement was carried out according to SENIAM guidelines as far as possible. All EMG data were normalised to MVCs taken for each muscle prior to the recording of the trials. EMG data were recorded at 1000Hz using pre-amplifiers with 15 450Hz bandpass filters. EMG envelopes were subsequently calculated by rectifying and low pass filtering at 10Hz. EMG data were recorded simultaneously with kinematics and endpoint forces, and used to constrain the inverse-dynamic optimisation of muscle forces during the model-based estimation of glenohumeral forces.

Model-based estimation of GH forces

A large-scale model of the shoulder and elbow (Delft Shoulder and Elbow Model, DSEM) [3,8] was used to estimate the muscle and joint forces at the shoulder during the positioning tasks. The model comprises 3-DOF sternoclavicular, acromioclavicular and glenohumeral joints, 2-DOF at the elbow, and a scapulothoracic gliding plane describing the motion of the scapula over the thorax. The muscles of the upper limb are divided into 139 elements and wrapping objects such as spheres and cylinders are defined to model their lines of action. Solution of the load-sharing problem is achieved by minimisation of a cost function representing energy consumption in the muscles [9]. The muscle force optimisation wasc onstrained by requiring the relative force (estimated force divided by maximum isometric force at that length) to lie within 5% of the recorded EMG value, where that was present. The reaction force in the glenohumeral joint was subsequently calculated and the functional stability of the joint estimated by calculating the direction of the force vector in the glenoid during the performance of a range of tasks. The stability of the glenohumeral joint in this case was a function of the angle of the resultant force in the glenoid. The value is -1 when the force is in the centre of the glenoid and 0 at the maximum angle that can be reached before dislocation of the joint.

RESULTS AND DISCUSSION

Pilot data for 2 subjects (with traumatic shoulder dislocations) in the exercise intervention group are presented.

Mean stability values were compared pre- and post-intervention for each direction of force applied to the subjects (Tab. 1). Stability values decreased, suggesting greater shoulder stability, for subject 2 in all force direction conditions, except the pull condition which showed no change following the intervention. Subject 1 showed improved stability values in only the push condition, with stability values in other force conditions staying the same or increasing.

Previous research found the exercise intervention used in this study provides an excellent outcome in only 16% of subjects with traumatic shoulder dislocations [7]. This may explain the lack of change in stability values for subject 1 following the intervention. By quantifying the change in stability it is possible that we can assess the improvement in stability more precisely, validating or disproving the previous studies findings of a 16% excellent outcome rate.

Direction of force	Pre-Intervention	Post-Intervention
Subject 1		
Push	-0.84 (0.13)	-0.88 (0.10)
Pull	-0.95 (0.00)	-0.87 (0.09)
Right	-0.92 (0.06)	-0.83 (0.08)
Left	-0.95 (0.06)	-0.91 (0.90)
Up	-0.86 (0.14)	-0.86 (0.07)
Down	-0.92 (0.08)	-0.90 (0.07)
Subject 2		
Push	-0.87 (0.13)	-0.93 (0.05)
Pull	-0.95 (0.04)	-0.95 (0.06)
Right	-0.96 (0.03)	-0.97 (0.03)
Left	-0.95 (0.05)	-0.97 (0.03)
Up	-0.92 (0.05)	-0.97 (0.02)
Down	-0.97 (0.04)	-0.99 (0.02)

Table 1. The effect of force direction on mean stability values, pre- and post-intervention, standard deviation in brackets

Changes in scapular kinematics (Tab. 2) and muscle model-predicted muscle forces (Fig. 1.) are presented.

Scapula variable	Pre-intervention	Post-intervention
Protraction/retraction	22.98 (1.1)	23.71 (4.0)
Elevation	3.95 (0.7)	-1.57 (3.9)
Posterior tilt	-7.11 (0.5)	-8.00 (1.5)

Table 2: Average scapular kinematics (degrees), during a single force direction condition (push) for subject 2, standard deviation in brackets.

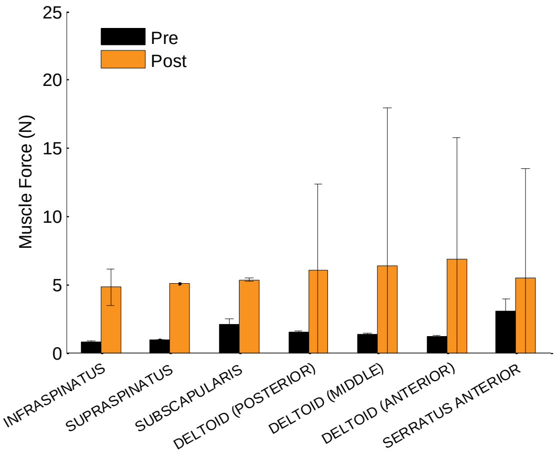

Figure 1: Mean model predicted muscle force for both subjects in a single force direction condition (push).

Mean model predicted muscle force was found to increase for rotator cuff and deltoid muscles. As the exercise intervention targeted these muscles this result could be expected. Scapula elevation decreased for subject 2 following the exercise intervention.

CONCLUSIONS

A method of analysing the effects of a previously used exercise intervention on shoulder stability, muscle activation and scapular kinematics has been described and pilot results presented. It is expected that this study will improve understanding of the effects of this intervention on scapular kinematics, muscle forces and shoulder stability. It is also hoped that significant differences will be found between subjects that respond well and those that do not, in terms of scapular kinematics and muscular activations allowing us to predict response rates for individual subjects in future or suggest possible modifications to improve the current exercise intervention.

REFERENCES

1. Veeger HEJ and van der Helm FCT. *J Biomech*, **40**:2119–29, 2007.
2. Marchi J et al. *ISG conference*, 2012.
3. van der Helm FCT. *J Biomech*, **27**:551–69, 1994.
4. Chadwick EKJ et al. *Clin Biomech (Bristol, Avon)*, **19**:906-12, 2004.
5. van Drongelen S et al. *Arch Phys Med*, **86**:1434-40, 2005.
6. Steenbrink, F et al. *J Biomech*, **42**:1740-5, 2009.
7. Burkhead Jr WZ and Rockwood Jr CA. J Bone *Joint Surg Am*, **74**:890-6, 1992
8. Nikooyan AA et al. *Hum Mov* Sci, **31**:429-47, 2012
9. Praagman M et al. *J Biomech*, **39**:758-65, 2006