J Shoulder Elbow Surg (2014) 23, e140-e148

ELSEVIER

JOURNAL OF
SHOULDER AND
ELBOW
SURGERY

www.elsevier.com/locate/ymse

Electromyographic activity in the shoulder musculature during resistance training exercises of the ipsilateral upper limb while wearing a shoulder orthosis

Talia Alenabi, MD[a,*], Monique Jackson, PhD[a], Patrice Tétreault, MD[b], Mickaël Begon, PhD[a]

[a]*Laboratoire de Simulation et Modélisation du Mouvement, Département de Kinésiologie, Université de Montréal, Laval, Canada*
[b]*Hôpital Notre-Dame, Centre hospitalier de l'Université de Montréal (CHUM), Montreal, PQ, Canada*

Background: Resistance training is usually postponed until 3 months after rotator cuff surgery to prevent the damaging effects of high muscle stress on the repaired tendon. After upper limb immobilization, non-injured muscles as well as the repaired muscles are affected by long-term inactivity. Exercises with minimal cuff activity may be appropriate in the early postoperative period, so we aimed to quantify the effect of resistance exercises on the muscle activity of a semi-immobilized upper limb.
Method: Fifteen shoulder muscles of the dominant limb of 14 healthy subjects were evaluated by electromyography, with 11 surface electrodes and 4 fine-wire electrodes in the rotator cuff muscles. While wearing an orthosis, the subjects completed resistance tests including elbow and wrist flexion/extension with 3 loads, maximal squeezing, and shoulder adduction against 3 different foams. The peak activity of each muscle was normalized to maximal voluntary contraction (% MVC).
Results: Shoulder muscles were activated less than 20% MVC during elbow and wrist flexion/extension with 2-lb (907-g) and 4-lb (1814-g) loads. In the maximal squeezing test, rotator cuff activity exceeded 20% MVC in some cases. During shoulder adduction tests, subscapularis, latissimus dorsi, triceps, and pectoralis major had the highest activation levels; supraspinatus and infraspinatus were minimally activated.
Conclusion: Supported elbow and wrist flexion/extension in the horizontal plane, with weights of up to 4 lb (1814 g), minimally activates the rotator cuff muscles while potentially preventing muscle disuse of other upper limb musculature. Resisted shoulder adduction cannot be considered safe for all rotator cuff injuries.
Level of evidence: Basic Science Study, Electromyography.

Keywords: Electromyography; orthosis; resistance training; rotator cuff; shoulder; rehabilitation

The study was approved by the university research ethics committee (Comité d'éthique de la recherche des sciences de la santé, certificate number CÉRSS-2010-1013-P) and the subjects signed a consent form before involvement in the study.

*Reprint requests: Talia Alenabi, MD, Laboratoire de Simulation et Modélisation du Mouvement, Département de Kinésiologie, Université de Montréal, 1700, rue Jacques-Tétreault, H7N 0B6, Laval, Canada.
E-mail address: seyedeh.talia.alenabi@umontreal.ca (T. Alenabi).

1058-2746/$ - see front matter © 2014 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2013.08.024

Recovery of shoulder strength after rotator cuff surgery is an important part of all rehabilitation protocols. For the first 6 weeks after surgery, the shoulder is generally immobilized, and exercises that generate high rotator cuff activity are usually avoided. During this time, rehabilitation involves passive exercises that minimize loads across the repair.[13,34] From 6 weeks postoperatively, active range of motion exercises are gradually introduced; and from 3 months after surgery, strength training usually starts with isometric exercises at first, then resistance exercises with an elastic band.[34,38] Hence, not only the rotator cuff muscles but all the shoulder muscles are in a largely inactive condition for at least the first 3 months after surgery. Considering that shoulder orthoses often also immobilize the elbow and wrist joints, the same assumption can be made for all the upper limb muscles. Studies have shown that neural activation and muscle strength can be impaired after just 2 to 5 weeks of joint immobilization,[16,20] so strength loss can be expected for all of the upper limb muscles after 6 weeks of immobilization. In addition, strength is diminished with disuse[23,29]; therefore, the further 6 weeks of low muscle activity can be expected at least to maintain the strength loss if not to exacerbate it.

The main reason for postponing strength training after rotator cuff surgery is that high muscle activity can damage the repaired tendon.[36] However, if resistance training can be shown to activate the shoulder and upper limb muscles independently or with minimal activation of the rotator cuff, it can be assumed that such training may be implemented in the postoperative period without harming the repaired tendon. For instance, Smith et al[40] found that isolated scapular depression and protraction motions could maintain low levels of electromyographic activity in the supraspinatus and infraspinatus muscles while producing levels of electromyographic activity sufficient for strengthening of the serratus anterior and trapezius muscles. It was also suggested that selected kinetic chain exercises could potentially be implemented during periods of shoulder immobilization.[41] However, these studies investigated only a limited range of activities, and therefore further research of the effect of resistance training exercises on the immobilized shoulder musculature is required. Alenabi et al[1] found that unresisted elbow, wrist, and finger movements minimally activated the rotator cuff muscles and therefore could be considered potentially safe during the postoperative period. Thus it is of interest to determine if these same activities could be safely performed with resistance.

The purpose of this study was to identify resistance training exercises of the ipsilateral upper limb that could be safely performed during postoperative immobilization. Furthermore, we intended to quantify the effect of different loads on shoulder muscle activity. We hypothesized that training exercises such as resisted elbow and wrist flexion/extension, maximal gripping, and restricted shoulder abduction would minimally activate the rotator cuff muscles while effectively activating other upper limb musculature.

Methods

The dominant shoulders of 14 healthy volunteers (10 men, 4 women; 12 right handed, 2 left handed; mean age, 25 ± 4 years; mean weight, 73.4 ± 9.5 kg; mean height,1.74 ± 0.08 m) were evaluated by electromyography (EMG). All subjects were free from shoulder and neck pain or disability as determined by the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire[22] and exhibited full pain-free shoulder range of motion.

Rectangular silver–silver chloride bipolar surface electrodes (20-mm interelectrode distance; CareFusion, San Diego, CA, USA) and standard placement techniques[6,8,12,39] were used to record EMG signals from shoulder muscles of the dominant limb, including the deltoid (anterior, middle, and posterior), trapezius (upper, lower, and middle), biceps, triceps, latissimus dorsi, pectoralis major (sternal), and serratus anterior. Fine-wire intramuscular electrodes (30 mm, 27 gauge; CareFusion, San Diego, CA, USA) were used to record EMG signals from the rotator cuff. Specifically, the electrodes were inserted into the supraspinatus, infraspinatus, and teres minor as described by Perotto and Delagi[37] and into the lower subscapularis as described by Kadaba et al[25] with standard aseptic techniques. The ground electrode was placed on the nondominant clavicle. To check electrode placement, the subjects were asked to perform submaximal isometric contractions in specific positions that were expected to generate high EMG activity, and the EMG signals were evaluated. Finally, the subjects performed maximal voluntary contraction (MVC) tests following the protocol outlined in our previous study[1] to determine the MVC for each of the 15 muscles.

Immobilization

The dominant shoulder was immobilized with two orthoses, both of which elevated the arm in the scapular plane.

1. Type 1 (Fig. 1). This custom orthosis (Laboratoire Orthopédique Médicus, Montréal, Canada) was a pre-production prototype and has not yet been tested on a patient population. The orthosis was fixed to the waist with a belt and supported the forearm between the elbow and wrist. The length of the support bar between the elbow and the waist could be adjusted to abduct the shoulder while supporting the forearm. The subject could flex and extend the elbow in the horizontal plane, flex and extend and rotate the wrist, and move the fingers while wearing the orthosis.
2. Type 2 (Fig. 2, *A*). This standard orthosis (Otto Bock HealthCare GmbH, Duderstadt, Germany) was fixed to the waist and the contralateral shoulder by two belts. The ipsilateral shoulder was immobilized in abduction with a removable wedge; the elbow and wrist were also immobilized. During the tests, the rigid wedge was replaced by wedge-shaped foams of 3 different densities, keeping the shoulder in 42° of abduction (Fig. 2, *B*). Appendix 1 explains how the foam densities were compared and highlights the differences between the foams.

Tests

While wearing the shoulder orthosis, the subjects completed a number of tests using the ipsilateral upper limb. The tests are