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Technical and measurement report

Characterization of humeral head displacements during dynamic glenohumeral neuromuscular control exercises using quantitative ultrasound imaging: A feasibility study

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ABSTRACT

The objectives of the present study were to test the feasibility of measuring humeral head displacements using quantitative ultrasound imaging during the performance of two different dynamic glenohumeral neuromuscular control exercises and to investigate the influence of these exercises on the acromiohumeral distance (AHD) and anterior-posterior distance (APD). Ten individuals who have no history of shoulder injury at the non-dominant shoulder completed three repetitions of an active humeral head lowering exercise and three repetitions of a posteriorisation exercise in a random order in a seated position. The AHD and the APD of the humeral head relative to the glenoid cavity were measured continuously using an ultrasound imaging system during each exercise. Variations in AHD and APD, defined as the difference between the distance obtained before the exercise and the maximal distance reached during the exercise, were compared for each exercises. The active humeral head lowering exercise significantly increased the AHD by 0.94 ± 0.28 mm (relative: + 11.4%), but had no significant effect on the APD. The active humeral head posteriorisation exercise significantly increased the AHD by 0.65 ± 0.41 mm (relative: + 6.3%) and the APD by 1.51 ± 0.51 mm (relative: + 13.8%). The use of quantitative ultrasound imaging allows physiotherapists to quantify inferior and posterior humeral head displacements during dynamic glenohumeral neuromuscular control exercises. These measures, confirming favourable inferior and posterior humeral head displacements at the shoulder, may become useful when studying the effectiveness of rehabilitation programs incorporating dynamic glenohumeral neuromuscular control exercises.

1. Introduction

Rotator cuff tendinopathies can yield pain, restrict mobility, and decrease muscular strength at the shoulder, and are one of the most common reasons for consultation in physiotherapy (Beaudreuil et al., 2011; Seitz et al., 2011). Rotator cuff tendinopathies may result from multiple possible causes (Mackenzie et al., 2015). Among those, a mechanical impingement between the tendons and the subacromial arch during dynamic movements, with the supraspinatus tendon being the most commonly affected tendon (Braman et al., 2013; Mackenzie et al., 2015). One of the possible causes of this dynamic impingement, linked in part to the narrowing of the subacromial space, is an inadequate dynamic glenohumeral neuromuscular control that causes anterior-superior displacement of the humeral head in the glenoid cavity during arm elevation (Desmeules et al., 2004; Ludewig and Cook, 2002; McCreesh et al., 2015). Variations of the subacromial space can be measured using the acromiohumeral distance (Desmeules et al., 2004). In fact, Graichen et al. (1999) demonstrated an average AHD reduction of 68% at the symptomatic shoulder compared to the asymptomatic shoulder in individuals with impingement syndrome during quasi-static muscle contraction in shoulder elevation positions. This reduced AHD may favour impingement of the

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rotator cuff tendons and yield degenerative changes over time (Seitz and Michener, 2011). Moreover, an anteriorly positioned humeral head relative to the glenoid cavity and an increased anterior translation of the humeral head during arm elevation has been observed in individuals with impingement syndrome (Ludewig and Cook, 2002).

Physiotherapists frequently incorporate dynamic glenohumeral neuromuscular control exercises into rehabilitation programs (Beaudreuil et al., 2015; Beaudreuil et al., 2011). These exercises target active lowering and posteriorisation of the humeral head relative to the glenoid cavity in an attempt to maintain the AHD and the anterior-posterior distance (APD). The APD represents the relationship between the center of rotation of the humeral head and the glenoid fossa (Iannotti et al., 1992; Beaudreuil et al,. 2011) demonstrated a significant reduction in pain after 3 months of treatment in a group of participants with impingement syndrome who practiced dynamic glenohumeral neuromuscular control exercises compared to a group receiving a control intervention. In a follow-up study, the same authors showed that the pain-free range of motion also increased in the group prescribed dynamic glenohumeral neuromuscular control exercises (Beaudreuil et al., 2015). Although these exercises seemed to be a treatment modality that helped in reducing impairments from rotator cuff disease, no objective information on the actual arthrokinematic displacement induced by the exercises is available in the literature. Gaining additional insight into the effects of various dynamic glenohumeral neuromuscular control exercises on humeral head displacements may strengthen decision-making in clinical practice.

The present study had two objectives: 1) to test the feasibility of measuring humeral head displacements using quantitative ultrasound imaging during the performance of two different dynamic glenohumeral neuromuscular control exercises and 2) to investigate the influence of those exercises on the AHD and APD. It was hypothesized that quantitative ultrasound imaging would be a useful tool to measure humeral head displacement and that performing these dynamic glenohumeral neuromuscular control exercises would significantly and meaningfully increase the AHD and decrease the APD.

2. Methods

2.1. Participants

A convenience sample of ten asymptomatic adults was recruited for the current experiment (Table 1). Potential participants were excluded if they had shoulder pain in the past 6 months, corticosteroid injections in the last 30 days or a history of fracture, subluxation or surgery at the non-dominant shoulder. All participants were screened by a licensed physiotherapist who completed an upper quadrant assessment to confirm normal shoulder passive and active range of motion, negative shoulder impingement tests (Neer, Hawkins-Kennedy and Yocum tests), and normal cervical function (Tennent et al., 2003). Participants were also screened to ensure no posterior shoulder tightness and no laxity or instability at the non-dominant shoulder using criteria set out by previous authors, namely: a bilateral discrepancy of 5° in passive horizontal adduction was used to assess for tight posterior shoulder structures (Tyler et al., 1999); to determine glenohumeral laxity the anterior and posterior drawer tests were applied in supine (Levy et al., 1999); shoulder instability was determined with the sulcus sign in neutral and 90°, as well as with anterior apprehension and Jobe's relocation tests (Lo et al., 2004). Ethical approval was obtained from the Research Ethics Committee of the Center for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR-968-0514). Participants reviewed and signed an informed consent form prior to enrolling in the study.

2.2. Dynamic glenohumeral neuromuscular control exercises

Participants were taught active humeral head lowering and posteriorisation exercises in a seated position with their shoulder in a neutral position and the hand resting prone on their thigh. For the lowering exercises, participants were instructed to gradually co-contract their large thoracohumeral muscles (pectorialis major and latissimus dorsi) to lower the humeral head while maintaining the scapula in place (Beaudreuil et al., 2011). For the posteriorisation exercises, participants were instructed to gradually contract their subscapularis and latissimus to bring the humerus back while limiting scapula movement (Beaudreuil et al., 2011). These exercises were taught by and performed under the direct supervision of a physiotherapist (GD) who gave specific verbal and tactile feedback to ensure adequate performance of the exercises. The physiotherapist (GD) also recorded all ultrasound video sequences during the exercises. Verbal feedback given by the physiotherapist guided participants with regards to the movement strategies and the muscle contractions needed to perform the exercises. Tactile feedback provided by the physiotherapist aimed to passively facilitate or actively assist the performance of the exercise on the participants' shoulder until he or she was able to successfully perform the exercise. Following this 5-min familiarisation period, each participant completed three active humeral head lowering exercise and three posteriorisation exercise at the non-dominant shoulder that consisted of 5-s isometric contractions in a random order.

2.3. Ultrasound imaging

During the above-described exercises, the active humeral head displacement was continuously recorded (10-s video sequence) by a single physiotherapist (GD) separately for each trial of the two exercises tested, to minimize measurement error. All video sequences were recorded using an ultrasound imaging system (Philips HD11XE, Phillips Medical Systems, Bothell, WA) set in a brightness mode (B-mode) and equipped with a 50 mm wide 5–12 MHz linear transducer. The physiotherapist (GD) had previously received 20 h of practical training in musculoskeletal ultrasound examination of the shoulder region from two experienced physiotherapists (FD and DG) prior to initiating the study. The linear transducer was kept in placed during the performance of each exercise allowing the physiotherapist to continuously record ultrasound images either of the humeral head and acromion or of the humeral head and posterior glenoid rim, depending on the exercise being performed. All ultrasound parameters (depth = 5 cm, gain = 75) remained constant across participants so that each ultrasound image (UI) can be fragmented into a similar number of micro pixels of 0.087 mm^2 (height = 0.29 mm * width = 0.29 mm; image definition). To measure the AHD, the linear transducer was placed parallel to the long axis of the humerus, 1 cm posterior to the anterior angle of the acromion (Fig. 1a).

Table 1
Mean (1 SD) characteristics of participants. Abbreviations: kg: kilograms, m: meters, M: Male, F: Female, R: Right, L: Left.

Age (years)	25.1 (3.0)
Weight (kg)	68.6 (12.8)
Height (m)	1.7 (0.1)
Gender (M:F)	7:3
Dominance (R:L)	9:1