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Distal radius fractures result in alterations in scapular kinematics: A three-dimensional motion analysis

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ABSTRACT

Background: Scapular motion is closely integrated with arm motion. Injury to a distal segment requires compensatory changes in the proximal segments leading to alterations in scapular motion. Since the effects of distal injuries on scapular kinematics remain unknown, in the present study we investigated the influences on scapular motion in patients with distal injuries.

Methods: Sixteen subjects with a history of distal radius fracture and 20 asymptomatic healthy subjects (controls) participated in the study. Three-dimensional scapular and humeral kinematic data were collected on all 3 planes of shoulder elevation: frontal, sagittal, and scapular. All testing was performed in a single session; therefore, the sensors remained attached to the participants for all testing. The position and orientation data of the scapula at 30°, 60°, 90°, and 120° humerothoracic elevation and 120°, 90°, 60°, and 30° lowering were used for statistical comparisons. Independent samples *t*-test was used to compare the scapular internal/external rotation, upward/downward rotation, and anterior/posterior tilt between the affected side of subjects with a distal radius fracture and the dominant side of asymptomatic subjects at the same stage of humerothoracic elevation.

Findings: Scapular internal rotation was significantly increased at 30° elevation ($P = 0.01$), 90° elevation ($P = 0.03$), and 30° lowering ($P = 0.03$), and upward rotation was increased at 30° and 60° elevation ($P < 0.001$) on the affected side during frontal plane elevation. Scapular upward rotation and anterior tilt were significantly increased during 30° lowering on both the scapular ($P = 0.002$ and 0.02, respectively) and sagittal planes ($P = 0.01$ and 0.02. respectively).

Interpretation: Patients with distal radius fractures exhibit altered scapular kinematics, which may further contribute to the development of secondary musculoskeletal pathologies.

1. Introduction

Optimal positioning of the scapula is essential for enhancing the quality of arm movement when fine motor control is required to achieve goal-directed activities (Kibler, 1998; Paine and Voight, 2013). Scapular motion provides optimal muscle length–tension ratios for accurate movement patterns and promotes muscular energy conservation during arm motion (Escamilla and Andrews, 2009; Kibler, 1998). In particular, the scapulothoracic joint creates a functional bridge between the upper extremity and the trunk segment, where 51% of the kinetic energy is sequentially transferred to distal segments (Kibler, 1998).

Because the scapula acts as a linkage between the trunk and the upper extremity, it is more vulnerable to the deleterious effects of distal injuries on its position and motion. Compensatory motions at proximal segments following a distal injury have been reported in previous studies (Ayhan et al., 2014; Bulthaup et al., 1999; Carey et al., 2008). Clinical findings have also confirmed postural alterations and musculoskeletal dysfunction in more proximal segments; in particular, a considerable amount of patients complain of shoulder pain. Our previous study suggested that patients with distal injuries mainly use compensations with a greater range of glenohumeral motion (Ayhan et al., 2014). This finding corresponds to the results of several studies suggesting excessive loading on the shoulder complex following limited distal movement (Carey et al., 2008; de Groot et al., 2011; King et al., 2003; Lack et al., 1991; O'Neill et al., 1992; Pereira et al., 2012). Because scapular motion is closely integrated with shoulder motion, additional stress on the shoulder joint may impair the scapulothoracic rhythm.

Monitoring the scapulothoracic rhythm throughout the rehabilitation period is important for clinicians in terms of providing the desired scapular function. There is a growing body of literature investigating the associations between shoulder pathologies and scapular kinematics. Many researchers have reported alterations in scapular motion following dysfunction of the shoulder and trunk segments (Borstad and Ludewig, 2005; Fayad et al., 2008a, 2008b; Hung et al., 2010; Lack et al., 1991; Lin et al., 2006; Ludewig and Reynolds, 2009; Matsumura

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et al., 2010; McCully et al., 2006; Rundquist, 2007; Timmons et al., 2012); however, the effects of distal injuries on scapular kinematics remain unknown.

Understanding alterations in the scapulothoracic rhythm may help clinicians to select appropriate therapeutic exercises when planning a rehabilitation program for patients with a distal injury. However, at present, there are no studies determining how a distal injury impacts the scapular kinematics. Distal injuries such as carpal/metacarpal/phalanx fractures, carpal instabilities, TFCC lesions, soft tissue injuries, and nerve lesions affect the use of both extremities adversely due to pain, immobilization, or abnormal postural habits. The purpose of this study was to investigate the influences on scapular motion in patients with distal injuries. To standardize the patient population with distal injuries, the study was performed on patients with a distal radius fracture, which is one of the most common injuries seen by physicians (Handoll et al., 2006, 2007). We hypothesized that a distal injury impairs the scapulothoracic rhythm, leading to alterations in scapular motion.

2. Methods

2.1. Participants

Sixteen subjects with a history of distal radius fracture treated with internal fixation participated in the study [8 females, 8 males; age, 43.6 (10.8) years; height, 170.8 (10.7) m; body mass, 74.4 (15.5) kg]. Eight patients had injured right side and eight had injured left side. All patients had right hand dominancy. Patients were recruited at 6–8 weeks postoperatively. The participants' wrist pain level was 3.64 (2.4), and their Disabilities of the Arm, Shoulder and Hand (DASH) score was 40.1 (24.6).

The inclusion criteria for participation were no limitation in the shoulder range of motion, no acute pain, no signs of non/mal-union of the fracture, and treated with the same procedure after injury (casting and rehabilitation for at least 6 weeks). Subjects were excluded if they had multiple joint injuries, had reflex sympathetic dystrophy, had any known systemic or neurological disorders, performed repetitive shoulder movements related to occupational or sports activities on a regular basis, or had a history of shoulder pain before distal injury.

Because the uninvolved extremity may also have been adversely affected following an injury (Ayhan et al., 2014), we included a control group to perform group comparisons. Twenty healthy subjects [20 males; age, 23.8 (0.9) years; height, 1.76 (0.5) m; mass, 73.8 (8.5) kg; 19 right handed, 1 left handed] without a history of shoulder pathology or pain in both the shoulders participated in the study. Scapular kinematic data of the study group were compared with those of the healthy subjects.

The Hacettepe University Institutional Review Board approved the protocol for this study, and all the subjects were informed of the nature of the study and signed a consent form.

2.2. Instrumentation

Three-dimensional (3D) kinematic data for the scapula and humerus were collected via the Flock of Birds (Ascension Technologies Inc, Burlington, VT) electromagnetic tracking device. This system consists of an electronics unit, a standard range transmitter, 5 sensors (25.4 mm × 25.4 mm × 20.3 mm), and 1 digitizer and was interfaced with the Motion Monitor software program (Innovative Sports Training Inc, Chicago, IL, USA). Data collected using this electromagnetic tracking system are reliable, with previously reported trial-to-trial, within-day, without-removal-of-sensors correlation coefficient values ranging from .88 to .97 and a standard error of measurement values ranging from 1.35° to 1.74°(Thigpen et al., 2005). In addition, this method of measuring 3D scapular kinematics has previously been validated by comparing data obtained from skin sensors with those obtained from acromion-fixed sensors, which were similar, particularly below 120° of elevation (Karduna et al., 2001). Data were collected at a rate of 100 Hz per sensor and subsequently filtered using the system's Butterworth filter software with a 6-Hz low-pass cutoff frequency.

For data collection, 5 sensors were directly applied to the skin of the participants with 2-sided adhesive tape and further secured with non-elastic tape (Fig. 1). The thoracic sensor was located over the C7 spinous process. The scapular sensor was applied to each scapula over the flattest aspect of the posterolateral aspect of the acromion in an attempt to reduce artifact produced by skin movement (Ludewig and Cook, 2000). The humeral sensor, for each arm, was applied over the posterior aspect of the humerus distal to the triceps muscle belly (Fig. 1).

The transmitter mounted on a rigid wooden base provided a global coordinate system. Area of the sensors must be a minimum of 1 m^2 from the transmitter (Fig. 1). Participants stood with their arms relaxed, while specific bony landmarks on the thorax (C7, T8, T12, jugular notch, and xyphoid process), scapula (trigonum spine scapula, inferior angle, posterior acromial angle, and coracoid process), and humerus (lateral and medial epicondyle) were digitized to create an anatomically based local coordinate system. The method suggested by Meskers (Meskers et al., 1998) was used to define the rotation center of the glenohumeral joint. The International Society of Biomechanics standard protocol was followed for defining segmental axes and converting the local coordinate system into angular rotations using the Euler angle sequence (Wu et al., 2005). Scapular rotations were represented using the Y–X'–Z'' sequence, in which first rotation defined the amount of internal/external rotation, the second defined the amount of upward/downward rotation, and the last defined the amount of anterior/posterior tilt. Humeral rotations were represented using the Y–X'–Y'' sequence of humerothoracic elevation, in which the first rotation defined the plane of elevation, the second defined the amount of humerothoracic elevation, and the third defined the amount of axial rotation.

Fig. 1. Setup for testing and sensor placement.