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Recording scapular motion using an acromion marker cluster

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ABSTRACT

Disorders of the shoulder complex can be accompanied by changes in the movement pattern of the scapula. However, scapular motion is difficult to measure. A possible non-invasive method for dynamic three-dimensional kinematic measurement of the human scapula is the use of a marker cluster placed on the flat part of the acromion. A small light-weight acromion marker cluster (AMC) is presented in this study. In order to assess validity, kinematics obtained with the AMC were compared to simultaneous scapula locator (SL) recordings in a series of postures. The test/retest variability of replacement of the AMC, was also assessed. Measurement errors appeared to be sensitive for the plane of movement, the degree of humerus elevation, and replacement of the AMC. The AMC generally under-estimated scapula motion, compared to the SL. Some significant differences were found between the two methods, although the absolute differences were small (maximum mean difference 8.4° in extreme position). In humerus forward flexion and abduction the maximum mean differences were 6° or lower. In conclusion, the AMC is a valid method of measuring scapular movement during arm elevation that could be used in shoulder pathologies. Placement and planes of movement should be carefully considered and elevation of the humerus should not exceed 100°.

1. Introduction

Scapular movement is an essential component in arm elevation. The position of the scapula serves as an adaptive base of support for the humerus. Abnormal scapular kinematics are believed to contribute to shoulder pain and pathology, i.e. frozen shoulder [1], impingement [2], glenohumeral instability [3] and in joint replacement results [4]. Knowledge of the contribution of scapula motion to the humero-thoracic motion may benefit certain aspects of current clinical practice, such as physical examination, reconstructive surgery and rehabilitation programs. A recent study demonstrated the importance of recognizing the presence of scapular hypoplasia, elevation and rotation deformity before deciding on a treatment plan for persistent internal rotation due to internal rotation contracture in patients with obstetric brachial plexus injury [5].

When using motion capture technology, it is difficult to track the movement of the scapula during dynamic shoulder function, because of its broad, flat shape, substantial soft-tissue covering, and significant skin motion over it. Several methods have been developed for accurate registration of scapular movement. The insertion of bone pins into the scapula of living subjects, combined with a motion capture system, such as an electromagnetic one is obviously the most accurate [6,7]. Despite its high accuracy, such an invasive method is not feasible in clinical practice unless very important decisions depend on it. For diagnostic or evaluation research a number of non-invasive possibilities, based on electromagnetic or optical tracking devices, have been developed to measure scapular movements. These possibilities are detailed in Table 1.

From all the available options to track scapular motion, the acromial method enables dynamic 3D measurement of scapula kinematics. A clinically feasible method requires unconstrained measurement to minimize load and pain for the patient and to allow for natural (including compensatory) movements, especially for (young) children. This method can be included in motion capture protocols, e.g. to evaluate the pre-operative and post-operative status of patients with upper extremity pathologies, especially when dynamic functional movements need to be studied. When upper extremity kinematic data are collected with an optoelectronic system by camera detection of active LED markers, no standard marker cluster is available. A special

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Table 1
Methods for measurement of scapular movement

Method	Proposed by	Remark
Scapulohumeral regression	[8,9]	Unsuitable for shoulder pathology
Scapula locator	[10–12]	Acceptable method for clinical measurements, although there is always a small error because exact replacement is impossible [5,10,12]. Requires static measurement positions
Skin-mounted acromion tracker	[6,13]	Valid up to 120° humerus elevation, enables dynamic measurements
Skin deformation, measured with markers	[14]	Requires minimal soft tissue coverage and muscle volume over the scapula. Preliminary results
Digital fluoroscopy	[15,16]	Subjects exposed to radiation. So far, scapular motions only measured in one plane

acromion tracker was therefore developed, based on a cluster with three markers. This acromion marker cluster (AMC) is different to the ones used in other studies [6,13] due to its specifically designed light-weight titanium frame (4 g) and small size of the base (15 mm diameter) that can be accurately placed on the flat part of the acromion.

Before applying the AMC, its accuracy would require evaluation, as part of the overall upper extremity 3D movement evaluation using optoelectronic measurements. Generalization from earlier evaluations would not be warranted since the AMC design in this study was very light weight, compared to electromagnetic trackers in previous studies [6,13]. Moreover, the use of this type of AMC should encourage users of these systems to include scapular kinematics in upper extremity evaluation, which is not yet a common procedure [17]. The existing literature is inconclusive concerning the under and over-estimation of scapular movement by an acromion sensor. Meskers et al. [13] found a general under-estimation of their acromial method compared to scapula locator (SL) recordings with a maximum rotation error of approximately 9°. Karduna et al. [6] found a maximal root mean square error of 11.4° for the acromial method and reported an over-estimation for external rotation. Therefore, we decided to study the accuracy of this AMC using the SL method to serve as reference [11]. It was hypothesized that no systematic error would be found between the results of the two methods, at least up to 120° humerus elevation. Since replacement of the acromion tracker was found to be a source of variability [13], an assessment of the test/retest reliability of the AMC was also included in our study.

2. Materials and methods

2.1. Subjects

Thirteen healthy subjects (six male and seven female), between 22 and 33 years of age, were recruited for this study. Two different measurement protocols were performed: a validation protocol and a reliability one. Four subjects performed both protocols, seven subjects performed a validation protocol only, and two subjects performed a reliability protocol only. Accordingly, there were eleven validation measurements and six reliability measurements. The right shoulder of all subjects was tested. Approval was obtained from the ethical committee of the Faculty of Human Movement Science of the VU University in Amsterdam, and all subjects provided informed consent.

2.2. Instrumentation

3D kinematic data were collected by means of an Optotrak (Northern Digital Inc., Canada) system with 3 camera-sensors. This system is accurate up to 0.1 mm, and the data were sampled at 50 Hz. Five clusters of markers were used to track the thorax, scapula, scapula locator, upper arm and forearm and all clusters consisted of three markers, except for the forearm cluster which consisted of six markers. The thorax cluster was attached to the sternum with double-sided adhesive tape. The upper arm cluster was attached to a cuff and strapped to the lateral arm just below the insertion of the deltoid. A forearm cuff with six equally distributed markers was strapped just proximally to the ulnar and radial styloids. Scapular movements were recorded using two methods: (1) the AMC attached to the flat part of the acromion with adhesive tape (Fig. 1), and (2) an SL. The SL is a fixture with an attached sensor, holding three pins which can be adjusted to fit the landmarks on the scapula prior to measurement. During the measurement, the investigator keeps the SL in close contact with the bony landmarks of the scapula, slipping over the skin. The SL pins were positioned on the acromial angle (AA), the root of the scapular spine (trigonum spinae (TS)) and the inferior angle (AI) of the scapula.

To link the position of the marker cluster to local anatomical coordinate systems, a standard pointer device was used to digitize 15 bony landmarks according to the ISB standardization proposal for the upper extremity [18]. The proximal landmark of the humerus, the glenohumeral rotation center, was estimated from scapular

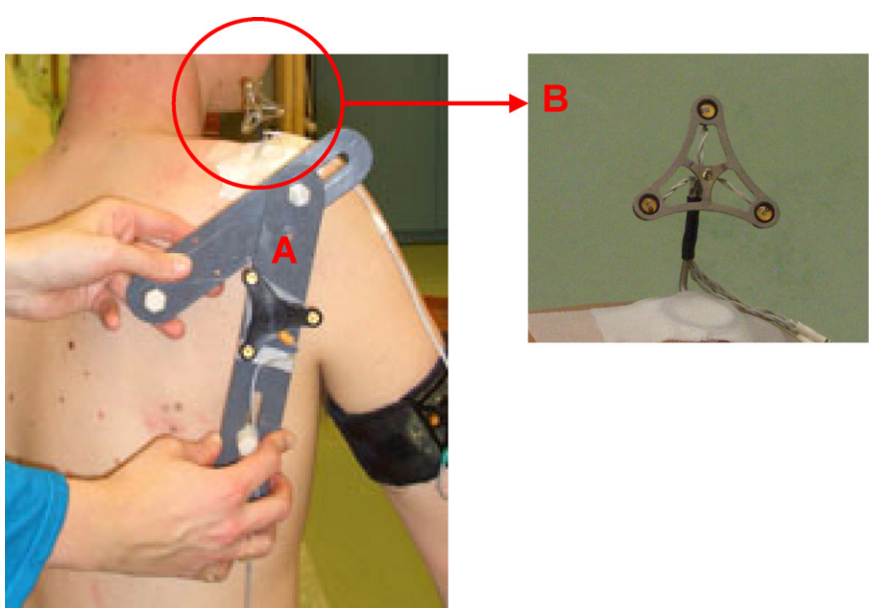

Fig. 1. Positions of the SL with a cluster of three markers (A) and the acromion marker cluster that was placed on the flat part of the acromion (B).