A COMPARISON OF NON-INVASIVE METHODS OF MEASURING SCAPULAR ORIENTATION

Tej-Jaskirat Grewal & Clark R. Dickerson
Department of Kinesiology, University of Waterloo, Waterloo, Canada, cdickers@uwaterloo.ca

INTRODUCTION
Accurate measurements of scapular orientation are required for biomechanical models to predict structural loads and to detect abnormal kinematics that may contribute to shoulder pathology. It is difficult to measure scapular orientation non-invasively because the scapula is a broad, flat bone with no fixed center of rotation and substantial overlying soft tissue. Numerous non-invasive scapular orientation measurement approaches exist, such as palpation [1], where scapular landmarks (acromion angle, root of the scapular spine and the inferior angle) are digitized with a stylus; an acromion marker cluster (AMC) [2] which is a rigid plate with reflective markers adhered to the posterior flat surface of the acromion; and the scapular locator [2], a hinged structure that is attached over the scapula with its three ends aligned over the three bony landmarks. This study contrasts the performance of these methods by comparing the scapular orientation measurements obtained using the scapular locator and AMC methods with those obtained with the stylus.

METHODS
Twenty-eight (14M, 14F) right-handed individuals completed this study. Nine reflective markers were placed over specific anatomical landmarks on the trunk, clavicle and right upper arm. An AMC was adhered to the posterior flat portion of the acromion. With the elbow flexed at 90°, seated participants placed their arm in static postures spread over 5 arm elevation angles: 0°, 45°, 90°, 135° and 180°, 3 elevation planes: 0°, 45° and 90° and 3 axial rotations: maximum internal rotation, neutral and maximum external rotation. Participants held these arm positions while a scapular locator was placed over the scapula and the scapular landmarks were subsequently digitized with a stylus. The AMC remained attached to the acromion during all trials. The relative positions of reflective markers were recorded using a Vicon MX20® (Vicon Motion Systems, Oxford, UK) optoelectronic motion tracking system. A custom software in MATLAB 7.9.0 R2009B (Mathworks, Natick, USA) was used to calculate scapular medial/lateral rotation, anterior/posterior tilt and retraction/protraction for each trial via Euler rotation sequences based on International Society of Biomechanics recommendations [3]. Three 1-way ANOVAs, followed by a post-hoc Tukey’s HSD, determined how measurement method influenced each scapular rotation.

RESULTS
Differences between scapular angles measured using the different methods existed (maximums listed in Table 1). When measuring lateral rotation and posterior tilt, all three methods resulted in significantly different values across all postures. The locator and the AMC underestimated lateral rotation for all arm postures and underestimated scapular tilt at low elevation angles. The AMC and the locator overestimated posterior tilt during overhead postures and this difference decreased with plane of elevation and internal humeral rotation. When measuring retraction/protraction, the scapular locator measurements were significantly different from the other methods across all postures. The scapular locator overestimated protraction by ~7° in all postures. Conversely, the AMC underestimated protraction at low elevation angles but overestimated it during overhead postures, especially in planes closer to the sagittal plane and during internal rotation. The maximum difference occurred at maximum elevation angle in the sagittal plane with internal humeral rotation. At low elevation angles the protraction measured using AMC approximated the stylus measurements better than the locator.

Table 1: Average maximum difference between the methods. Positive values indicate overestimation. All values indicate a significant difference between stylus and alternative methods.

<table>
<thead>
<tr>
<th>Scapular Angle</th>
<th>Stylus vs. Locator</th>
<th>Stylus vs. AMC</th>
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<tbody>
<tr>
<td>Lateral Rotation</td>
<td>-10.16°</td>
<td>-1.41°</td>
</tr>
<tr>
<td>Posterior Tilt</td>
<td>8.93°</td>
<td>9.55°</td>
</tr>
<tr>
<td>Protraction</td>
<td>7.43°</td>
<td>14.67°</td>
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</tbody>
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DISCUSSION AND CONCLUSIONS
This study is the first to directly compare multiple methods of measuring scapular orientation and to use the stylus method as a comparison standard. Meskers et al. [4] also found that the scapular locator underestimated lateral rotation of the scapula at low elevation angles in the sagittal plane. Contrary to the current study, van Andel et al. [2] found that the AMC underestimated scapular tilt, however, the locator was used as the ‘gold-standard’, which may be flawed. The large variation between protraction values supports earlier commentary [5] that protraction may be most sensitive to soft-tissue artifacts. Since scapular kinematics differ depending on measurement technique, caution is imperative when comparing results across studies. For future studies, the choice of scapular tracking method should be predicated on which specific scapular rotation is most germane to the research question.

REFERENCES