

# Validation of Scapular Kinematics utilizing Video-Based Motion Analysis

## Introduction

Efficient and coordinated scapular kinematics are essential for safe and injury free overhead movements of the upper extremity and dynamic joint stability of the shoulder complex. Altered scapular kinematics have been observed in groups with shoulder injury, such as rotator cuff impingement, and is significantly affected following fatigue.<sup>1-3</sup> Quantification of scapular kinematics is necessary to prospectively predict risk of injury and determine the efficacy of injury prevention interventions. Currently, the most prevalent methodology to test scapular kinematics is with the use of electromagnetic tracking technology (EMT). Unfortunately, EMT has some inherent disadvantages as most devices require the subject to be tethered to the data collection computer which prevents testing of high speed, dynamic sport movements. Video-based motion analysis offers greater freedom of movement and newer cameras are capable of the higher sampling frequency that is necessary for measurement of high speed movements. Additionally, newer cameras utilized in video-based motion analysis have been significantly improved providing greater resolution and greater capability to visualize and distinguish multiple small markers in a concentrated area. Therefore the purpose of this study was to validate the use of video-based motion analysis to capture three-dimensional (3D) scapular kinematics. If validated, this would provide researchers with greater flexibility to quantify scapular kinematics.

## Methods

This validation study involved the comparison of a video-based motion analysis (VMA) technique against a dynamic stereo x-ray (DSX) technique, which is a previously validated gold-standard.<sup>4</sup> Five adult male subjects (Age=27.8±6.9 yrs; Ht=1.81±4.9 cm; Wt=77.9±9.5 kg) participated in this study. Reflective markers were attached to anatomical landmarks on each subject's trunk (jugular notch, xiphoid process, and spinal process of C7 and T10), right humerus (medial and lateral epicondyle), and right scapula (AC joint, acromial angle, root of scapular spine, and inferior angle). A custom-made triad with three reflective markers was attached to the flat, broad portion of the acromion process. A static capture of the marker set was taken for each subject, establishing the spatial relationship between the triad and the anatomical landmarks of the scapula. Markers attached to the scapula other than the AC joint were removed during testing. Subjects performed scapular-plane humeral elevation following the guidance of a metronome at the pace of one repetition per two seconds. The VMA system (Vicon Motion Systems, Inc., Centennial, CO) and DSX system were synchronized to capture the movement at 50Hz during a two second capture. A CT-scan of the subject's humerus and scapula were used to create subject-specific 3D bone models using Mimics (Materialise Group, Leuven, Belgium). The anatomical landmarks of the humerus and scapula were marked on the bone models. The 3D trajectories of these anatomical landmarks were reconstructed by matching the bone models to the DSX images. The 3D trajectories of the reflective markers were exported from the VMA system, and the virtual trajectories of the anatomical landmarks of the scapula were reconstructed.

Humeral and scapular angles following the ISB recommendations were calculated with the 3D trajectories from each system.<sup>5</sup> Three-dimensional humeral kinematics were calculated (only elevation is currently reported). Scapular position was decomposed into three components of protraction/retraction, medial/lateral rotation, and anterior/posterior tilt. Data from each device were extracted at 30°, 60°, 90°, 120°, and 140° of humeral elevation for comparison. A Pearson product moment correlation coefficient was calculated to examine relationships between VMA and DSX for each individual and for the averaged group data. Measurement bias (the average difference across a trial) and dynamic precision (the standard deviation of the differences across a trial) were also calculated for each subject.

## Results

Figure 1 is a representation of model matching process in DSX and the average angles for each movement across all subjects. The correlation coefficients comparing the VMA and DSX are presented in Table 1. Within each subject, correlations were moderate to high for all

movements. All of the group average correlations were high. The bias and precision are reported in Table 2. Medial/Lateral rotation had the lowest precision.

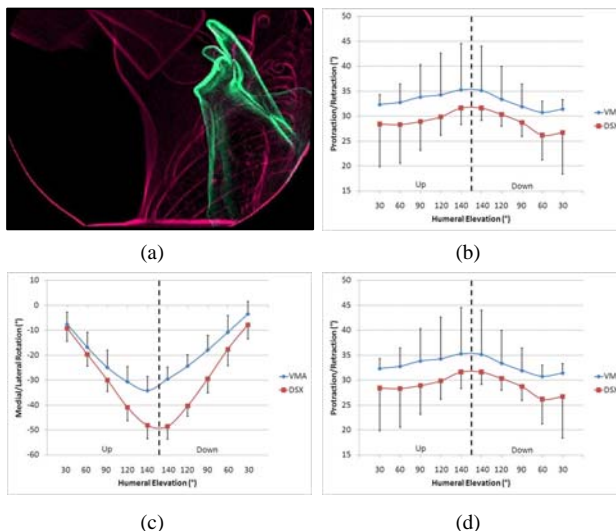


Figure 1: (a) Scapular model matching in DSX (b) Protraction / Retraction, (c) Medial / Lateral Rotation, (d) Anterior / posterior tilt

Table 1. Correlation Coefficients between the VMA and DSX

|                         | Individual  | Group Average |
|-------------------------|-------------|---------------|
| Protraction/Retraction  | 0.735±0.147 | 0.939         |
| Medial/Lateral Rotation | 0.953±0.034 | 0.961         |
| Anterior/Posterior Tilt | 0.701±0.437 | 0.960         |

Table 2. Measurement Bias and Dynamic Precision (mean±SD)

|                         | Measurement Bias (°) | Dynamic Precision (°) |
|-------------------------|----------------------|-----------------------|
| Protraction/Retraction  | -3.95±8.41           | 2.60±1.14             |
| Medial/Lateral Rotation | -9.88±3.43           | 6.38±1.72             |
| Anterior/Posterior Tilt | 3.93±6.28            | 3.16±1.69             |

## Discussion

The objective of this study was to determine if video-based motion analysis can quantify 3D scapular kinematics. Validity was assessed based on a comparison with a previously established gold-standard. The statistical analyses revealed high correlations within subject and for the group averages. Based on the total range of motion for each movement, the measurement bias and precision appears acceptable. The lower precision for Medial/Lateral Rotation is likely due to the increased differences observed as humeral elevation increases. Although further analysis is necessary to examine the other humeral movements, this preliminary analysis demonstrates that video-based motion analysis is a valid technique to quantify 3D scapular kinematics.