INTRODUCTION

Efficient and coordinated scapular kinematics is essential for optimal performance and to minimize risk of shoulder injury in overhead athletes [1]. Altered scapular kinematics during slow-paced arm elevation has been observed in both healthy and symptomatic overhead throwers [2,3], but little is known about scapular kinematics during throwing. Most scapular kinematics studies have been conducted with electromagnetic tracking technology, which requires wired sensors that restrict subjects’ movement and may not be optimal for testing complex, multi-plane movements such as throwing due to noise in recorded signals [4]. Video-based motion analysis (VMA) offers greater freedom of movement and is capable of the higher sampling frequency necessary for measurement of high speed movements. VMA has been validated for scapular kinematics in a slow-paced arm elevation task [5]. Humeral angles are involved in throwing analysis for phase defining and inverse kinetic estimation. The validity of skin-based humeral kinematic measurements has been evaluated in slow-paced arm elevation but not in rapid movements like throwing [6]. The purpose of this study was to validate the use of VMA for three-dimensional scapular and humeral kinematics during simulated throwing. If validated, scapular kinematics can be integrated into throwing analysis for future biomechanical studies.

METHODS

This validation study involved the comparison of a VMA technique against a dynamic stereo x-ray (DSX), a previously established gold-standard for tracking scapular kinematics [7]. Five adult right-hand dominant 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 torso, right humerus, and right scapula, following the ISB recommendations [8]. 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 scapula markers. Markers attached to the scapula other than the AC joint were removed during testing. Subjects were seated and assumed a start position of about 90° shoulder abduction and elbow flexion, followed by a maximum effort overhead throwing movement. The VMA system (Vicon Motion Systems, Inc., Centennial, CO) and DSX system were synchronized to capture the movement at 150Hz during a one-second capture. A CT-scan of the subject’s humerus and scapula were used to create subject-specific 3D bone models. 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 were calculated following the ISB recommendations using the 3D trajectories from each system [8]. The initiation of movement was defined as the humeral resultant angular velocity exceeded 10°/s. For each angle, a Pearson’s product-moment correlation coefficient was calculated for every subject and averaged to examine the relationships between VMA and DSX data throughout the movement. Root mean-squared (RMS) error for each angle was also calculated. A paired t-test was performed to compare the range of motion of each angle between VMA and DSX data with alpha = 0.05 set a priori.
RESULTS AND DISCUSSION

Figure 1 is a representation of DSX model matching process and the comparison of scapular kinematic between VMA and DSX of one subject. Humeral angles with respect to the thorax measured with VMA were highly correlated to those measured with DSX, with all mean Pearson’s R over 0.976. Scapular angles with respect to the thorax measured with VMA had good to excellent correlation with DSX data, with mean Pearson’s r ranging between 0.693 to 0.969 (Table 1). RMS errors ranged between 0.97 to 4.13° with the initial angles set at zero (Table 1). VMA overestimated humeral internal rotation and scapular protraction (Table 2), likely due to soft tissue effect. The excellent correlations suggested high pattern similarity between the VMA and DSX data, but the overestimation should be acknowledged for data interpretation.

The current results suggest that VMA is valid for tracking scapular and humeral rotational movement patterns during a simulated throw. It is noteworthy that the Pearson’s r in the current simulated throwing task were comparable to those in the widely-applied, slow-paced arm elevation task [5]. Soft tissue effect, threatening the validity of any skin-based measurement technique, was not further increased due to the rapid nature of the current task. Although the velocity of the current simulated throwing task was not as fast as throwing in sports activities, we consider the proposed VMA technique appropriate for evaluating scapular kinematics during high velocity throwing for overhead athletes.

REFERENCES


ACKNOWLEDGEMENTS

This study was funded by the Central Research Development Fund, Office of Research, University of Pittsburgh.

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* Significant difference between two measurement techniques (p<0.05)