INTRODUCTION

Arm elevation consists of glenohumeral (GH) and scapulothoracic (ST) motion. Muscular stabilization of the scapula provides a critical platform for upper extremity dynamic activity. Thus, it is critical to quantify scapular motion during dynamic shoulder activity. Inman reported in 1944 that the ratio of GH to ST motion was 2:1 [1], but more recent studies indicate varying ratios [2]. It has been suggested that muscular stabilization of the scapula increases while lifting greater weights, thus less scapular motion will be seen in healthy shoulders[3][4]. Conversely, pathological conditions like rotator cuff tears cause an increase in scapular upward rotation as compensation for cuff deficiency. There may also be gender and age differences in healthy shoulder function, where muscle mass, training and coordination may significantly vary.

The goal of this study was to determine, in vivo, the influence of lifting 3kg hand-held weights, which are often used as part of shoulder rehabilitation programs, on scapular upward rotation. The study hypothesis was that arm abduction with a hand-held 3kg weight would result in decreased scapular upward rotation compared to arm abduction without a hand-held weight in males. In contrast, we also hypothesized that there would be an increase in scapular upward rotation with hand-held weights in females, where the 3kg hand-held weight represents a greater percentage of maximum shoulder load.

METHODS

Ten healthy shoulders in ten subjects (5 men, 27 to 38 years; mean age 32.2; 5 women, 24 to 34 years; mean age 29) were studied. All subjects provided informed consent to participate in this IRB approved study. CT scans of each shoulder were acquired at 0.5 mm intervals and 3D models of the scapula and humerus were created. The subject was positioned in front of a fluoroscope and motions were recorded during active abduction from 0°-120° in the plane of the scapula. The subjects performed two trials: one trial holding a 3kg weight (loaded) and one without the weight (unloaded). 3D motions of the scapula and humerus were determined using model-based 3D-to-2D registration (Fig. 1). The measured 3D kinematics of the humerus and scapula were analyzed to determine scapular upward rotation and arm abduction relative to the ground. Statistical analysis level of significance was set at $P < 0.05$. Two-way repeated-measure analysis of variance (ANOVA) with post-hoc pairwise Tukey test was used to compare the incremental data between loaded and unloaded.

RESULTS

Scapular upward rotation was significantly less during the loaded trial in males from 20°-100° of arm abduction (Fig 2). There were no statistically significant differences in scapular upward rotation between the loaded and unloaded trials in females from 20°-100° of arm abduction (Fig 3).

DISCUSSION

The scapulohumeral rhythm is considered important to understand shoulder and upper extremity function, and is indicative of correct neuromuscular stabilization of the scapula as the basis for dynamic upper extremity activity. This study showed that, in males, scapular upward rotation decreased over the range of glenohumeral abduction angles while holding a weight, suggesting that the scapula is relatively fixed to the torso in the elevation arc, providing a stable fulcrum for the rotator cuff. Conversely, women show some trends towards greater scapular upward rotation with a weight than without, suggesting scapular rotation may compensate for weakness of the cuff and deltoid muscles in elevating arm.

Much additional work is required to understand the mechanisms involved in glenohumeral and scapulothoracic function during shoulder motion. We believe this information will lead to better strategies to prevent shoulder injuries, enhance rehabilitation, and improve surgical treatments.

REFERENCES