DIFFERENCES IN SHOULDER COMPLEX 3D KINEMATICS IN EMPTY/FULL CAN ARM ABDUCTION

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SUMMARY
The controversy in the empty- and full can (EC, FC) exercises for rotator cuff tear remains in part because of the complexity of the shoulder. A three-dimensional shoulder complex model was applied to determine if there are kinematics differences between the two tests. A video-based system captured the motion of 33 markers fitted over the upper body of eight able-bodied subjects. They performed five 120° arm abductions in both conditions. There was more scapular anterior tipping and internal rotation as well as increase upward rotation of the scapula in the EC exercise. There was also greater motion in acromio-clavicular retraction and forward tilt in the FC exercise whereas the acromio-clavicular lateral rotation was more pronounced in the EC condition. In conclusion it appears that the FC exercise could further increase the size of the subacromial space and provide a better appreciation of the supraspinatus contribution.

INTRODUCTION
Rotator cuff tear is a common shoulder musculoskeletal injury. Several clinical tests are proposed [1] to estimate the presence of a torn supraspinatus tendon. One of them is the empty-can (EC) muscle test which solicits the supraspinatus by positioning of the upper arm in 90° of abduction and in full internal rotation. Reinold et al. [2] and others suggest that the full-can (FC) test where the upper arm is abducted and external rotation could better recruit the supraspinatus muscle for rehabilitation and testing. Both tests appear to be equivalent in terms of diagnostic accuracy though the FC test may be more beneficial in the clinical setting according to Itoi et al. [1]. The controversy remains in part because of the complexity of the shoulder in terms of joints, motions and muscle forces.

The purpose of this study was to determine whether the shoulder complex three-dimensional kinematics is the same in empty/full can arm abduction motions in able-bodied subjects in the unloaded condition.

METHODS
Eight asymptomatic male subjects having a mean age, height and mass of 26.3±4.5 years, 177.2±7.6 cm and 73.7±11.9 kg participated to this study. The subject’s dominant arm was used throughout the experimentation. Three-dimensional (3D) kinematics of the shoulder complex abduction was analyzed for EC and FC conditions. Thirty-three reflective markers were put over the pelvis (4), thorax (6), clavicle (4), scapula (6), upper-arm (5) and lower-arm (8) to be tracked by an eight-camera ViconTM system (OMG plc, Oxford, UK) at 60Hz. To determine the center of rotation (CoR) of the shoulder joints the method described by Ehrig et al. [3] was used. The elbow axis of rotation (AoR) was obtained by the method of O’Brien et al. [4]. Additional markers were placed over body landmarks during static trials to define anatomical systems of coordinates according to International Society of Biomechanics Shoulder Group recommendations [5] and to define the reference position. The Cardan sequence of flexion, abduction and axial rotation was used to calculate the joint angles, three for each of the gleno-humeral, acromio-clavicular and sterno-clavicular joint.

The participants performed five 120° arm abductions without weight and the subject standing in a standardized position. During the EC exercises subjects maintained the arm in internal rotation with their thumb pointed downwards towards the floor while the FC experiments were carried out with the arm in external rotation with the thumb pointed upwards towards the ceiling.

Separate repeated measures ANOVA were performed to compare the EC and FC exercises for each of the nine joint angles at 5° increments of arm abduction ranging from 5° to 115°. The 0° and 120° were excluded from the analysis because of marker interferences. Each analysis of statistical significance was set a priori at \( p \leq .05 \) for all analyses.

RESULTS AND DISCUSSION
The 3D kinematics at the sterno-clavicular, acromio-clavicular and gleno-humeral joints are given in Fig. 1. Statistical differences were observed between the EC and FC abductions in seven of the nine joint angles. In four angles EC motion was less pronounced than in the FC condition. As expected there was less gleno-humeral external rotation. The acromio-clavicular protraction and backward tilt and the sterno-clavicular backward rotation were also reduced in the EC elevations. The gleno-humeral plane of elevation and
acromio-clavicular lateral rotation (up) were greater in the EC experiments whereas the EC condition exhibited lower values between 5° and 25° and higher values between 90° and 115° during sterno-clavicular retraction.

To our knowledge there are only a few studies that describe the 3D kinematics of the gleno-humeral, acromio-clavicular and sterno-clavicular joints. Ludewig et al. [6] reported that shoulder motion consists of substantial angular rotations at each shoulder joint, but testing was only in the FC unloaded position. Thigpen et al. [7] investigated scapular kinematics in the FC and EC exercises to elicit the greatest amount of supraspinatus activity using an electromagnetic tracking system. Scapular angles were calculated at 30°, 60°, and 90° of the ascending and descending phases of humeral elevation with a handheld weight corresponding to 5% of the participant’s bodyweight. In contrast the humeral elevation in our study ranged between 5° and 115° with an interval of 5° for the three joints and the arm was unloaded. Thigpen et al. [7] reported more scapular posterior tipping (backward tilt) and internal rotation (protraction) during the FC exercise. Our results confirmed these observations in addition to increase lateral rotation (up) of the scapula in the EC condition.

CONCLUSIONS
All joint of the shoulder complex present kinematic differences due to the EC and FC testing conditions. It appears that in the abduction plane the FC exercise could further increase the size of the subacromial space and provide a better appreciation of the supraspinatus contribution.

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REFERENCES
5. Wu et al., J Biomech. 38(5):981-992, 2005

Figure 1: Kinematics of the three shoulder joints during arm abduction without weight at each 5° of elevation (* p ≤ 0.05)