INTRODUCTION
An understanding of joint stability is beneficial for assessing injury risk and is critical for human movement. To evaluate joint stability it is necessary to evaluate the system’s ability to respond to a disturbance. One approach is to quantify mechanical impedance, or the resistance of a joint to rotation [1, 2]. Impedance is largely influenced by muscle contributions and in the upper extremity, knowledge of the system’s initial state (including muscle loading and posture) prior to a disturbance is needed to understand muscular contributions to joint stability. Impedance can increase with changes in muscle co-contraction, muscular synergy and limb position [1]. The purpose of this study was to examine the effects of body orientation and hand load on individual muscle contributions to joint rotational impedance (JRI) at two time periods immediately prior to a sudden external perturbation that caused elbow extension.

METHODS
Fifteen male participants (179.5 ± 6.0 cm; 81.2 ± 8.5 kg; 26.0 ± 3.0 yr) held a combination of 3 body orientations and 3 hand loading tasks while a sudden perturbation caused elbow extension. The body orientations required a supinated forearm with elbow flexed to 90° while: i) lying supine on a table, ii) sitting (shoulder flexed to 90°, upper arm resting on table), and iii) standing. Hand loading conditions included: i) no load, ii) holding a tube horizontally, and iii) balancing a water-filled tube horizontally. For each condition, a perturbation device instrumented with a load cell extended outward in a single plane to deliver a push force to each participant’s arm, causing sudden elbow extension (Figure 1). Perturbation timing was both known and unknown to the participant. Surface EMG (Bortec Biomedical Ltd., Calgary, Canada) was collected from eight muscles of the right upper extremity including: anterior deltoid (AD), triceps brachii (TB), biceps brachii (BB), brachioradialis (BR), flexor carpi radialis (FCR), flexor digitorum superficialis (FDS), extensor carpi radialis longus (ECRL) and extensor digitorum communis (ED). An electrogoniometer measured elbow angle (Biometrics Ltd., Gwent, UK). Two time periods were examined, baseline (-150 to -100 ms pre-perturbation) and anticipatory (-15 to 0 ms pre-perturbation). Elbow kinematics and muscle activations were input into a biomechanical model [3] to determine anatomical muscle coordinates and muscle forces. Individual muscle contributions to JRI were calculated [2] and expressed as a percentage of the total contribution from all muscles (% JRIi).

RESULTS
JRI about the flexion/extension axis was greatest for brachialis (30.4 ± 1.9%), followed by BR (21.7 ± 2.2%), BB short head (19.7 ± 0.8%) and BB long head (15.5 ± 1.2%). The combined JRI for the forearm muscles and triceps was 5.5 ± 0.6% and 9.2 ± 1.9%, respectively. All elbow flexors demonstrated a posture x time period interaction (p<0.023). JRI was greater during the anticipatory period than baseline and the largest contributions were during the standing orientation (BB short head increased by 7.4% and BR increased by 2.4%). A hand load x time period interaction (p<0.002) was found for ECRL and FDS, with a greater contribution during the anticipatory period and when holding the fluid hand load.

DISCUSSION AND CONCLUSIONS
Sudden arm perturbations are common in occupational settings and if the muscular response is poorly coordinated, joint or tissue injury can occur. In this study, body orientation and hand load provided challenges to the system and a muscle’s individual contribution to resist motion was quantified. The primary elbow flexors provided the largest contributions, and for the conditions tested the elbow extensors provided limited support. The elbow flexors and forearm contributions increased immediately prior to the perturbation (baseline to anticipatory), indicating an augmented neuromuscular response [4] beneficial for resisting rotation. This was the first study to document individual forearm contributions to JRI at the elbow and increased forearm loading was necessary to control the challenging fluid filled load [5]. Forearm muscles are not often considered when evaluating elbow stability, yet this work demonstrates that they contribute to elbow joint impedance and can provide insight into potential injury risk.

REFERENCES

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