INTRODUCTION
Overhead work is associated with shoulder injury. Where overhead work is unavoidable, horizontal and vertical reach distance should be reduced [1]. Shoulder musculature, especially the rotator cuff, is highly susceptible to fatigue in these overhead postures [2]. This risk is exacerbated by strength deficits, with minimum outputs reported between 90°-120° of arm elevation [3]. Previous research has focused only on the dominant limb in drilling tasks, although the gross movement and stabilization efforts between limbs [4] makes inferences regarding bilateral tasks difficult. In addition, most strength data for the shoulder has focused on isolated joint exertions, and has not considered effects of the contralateral limb on these outputs [5]. The purpose of this study was to identify differences and quantify activity levels in unilateral and bilateral overhead drilling scenarios while manipulating overhead work locations and force application directions.

METHODS
8 right-handed male participants completed 24 overhead drilling exertions in two force directions (forward, upward) with two gross body postures (seated, standing) at three overhead work locations (15, 30, 45cm forward) in two configurations: 1) Bilateral: stabilization of a 1kg weight in the left hand at the work location while exerting force with the right hand, and 2) Unilateral: exerting force with only the right hand. Work heights were chosen to elicit 120° of humeral flexion in a 50th percentile male, ensuring at least 90° of flexion across the population. Right hand forces are 30N and held for 5 seconds. 6 muscles were monitored bilaterally (anterior (ADEL) and middle deltoid (MDEL), upper trapezius (UTRP), supraspinatus (SUPR), infraspinatus (INFR), thoracic erector spinae (THES) for 12 total sites) with surface electromyography (EMG) and normalized to muscle-specific maximal values.

Figure 1. Normalized average muscular activity across all muscles showing interactions between force direction and drill location (A), posture (B) and configuration (C). Levels of significance are denoted by letters (p<0.05).
3-D right hand forces were recorded with a 6-DOF force transducer. A 4-way ANOVA (drilling location, configuration, force direction, and body posture) assessed influences on normalized individual and overall muscle activity (defined as an average over all muscles from both arms).

RESULTS AND DISCUSSION
Force direction, work location, posture and task configuration all had effects on muscular activity during these overhead drilling scenarios. Normalized EMG data from 8 participants shows upward exertions have increased overall muscular activity compared to forward exertions across postures (Figure 1B, p<0.01). Secondly, standing resulted in higher average activity than sitting (p<0.01). Finally, the most forward location generated more muscular activity than the other two locations in upward exertions, and changes in configuration (unilateral or bilateral) resulted in significant changes in muscle activity for most muscles (p<0.05). Force direction interacted with each other independent measure, but these other measures did not interact with each other (p<0.01).

Direction of force application was the most significant factor identified. Exertions in a forward direction produced significantly lower average EMG outputs than upward exertions across work locations, body postures, and hand configurations (Figure 2). Forward exertions reportedly generate the lowest muscular demands in overhead postures [5], which is supported by the current results for both unilateral and bilateral drilling tasks (Figure 1C).

Work configuration profoundly influenced muscle activity. Bilateral configurations resulted in increased activity of middle deltoid and decreases in upper trapezii on the right side (Figure 2). These changes suggest redistribution of muscular effort in more symmetric positions. Bilateral exertions also caused higher average muscle activity in both force directions (Figure 1C), largely due to an increase in demand for the non-dominant (left) arm. Drill location and whole-body posture only affected upward force exertions, resulting in increased activity levels as locations moved further forward (Figure 1A), or in moving from a seated to a standing position (Figure 1B). Increased horizontal distances in overhead work are a reported risk factor for upper extremity disorders and injury [6]. The increased activity level in shoulder muscles found in this study for upward exertions supports this body of research, and overhead work should be positioned to minimize these reach distances.

CONCLUSIONS
Performing tasks that require the non-dominant arm modifies activity patterns on both sides of the body compared to a unilateral task. Generally, overall muscle demands increase. Much of the existing strength data for industrial tasks was collected on isolated joint exertions. These results are of potential utility to practicing ergonomists and work task designers in order to minimize injury fatigue risk when working in overhead positions, especially when interpreting potential exposures associated with performing bilateral tasks.

REFERENCES