INTRODUCTION
Reverse shoulder arthroplasty has been successful in treating massive rotator cuff tears combined with arthritis [1], a condition that is not adequately managed using conventional shoulder arthroplasty. Despite this, complication rates remain high with instability being one of the most common complications [2]. The effects of only a few factors have been studied in a model that includes bony geometry and muscle forces and any interactions between factors remain unclear. Therefore, the goal of this investigation was to investigate the effect of loading direction, arm posture, humeral socket constraint, and glenosphere diameter and eccentricity and the interactions between these factors on the stability of reverse shoulder arthroplasty.

METHODS
The force required to dislocate the shoulder, determined using a biomechanical shoulder simulator, was used as a measure of stability. The simulator consisted of artificial bones (1028 and 1050, Sawbones) with the prosthesis (Delta XTEND, DePuy) installed. The three heads of the deltoid (anterior, middle, and posterior) were modelled using pneumatically actuated cables. The rotator cuff was not included as patients who receive this surgery generally have massive rotator cuff tears and a worst case scenario was assumed. A displacing force was applied to the humeral head using a material testing machine (5500R, Instron) and could be applied in four directions (anterior, posterior, superior, and inferior) relative to the scapula. A 3.6 kg weight was fixed to the humerus to simulate the weight of the arm. Kinematics were recorded using optical tracking (Optotrak Certus, Northern Digital Inc.) and the ISB recommended coordinate systems [3] were used to calculate joint angles.

A half-fraction factorial experiment design was employed to examine six factors and the interactions between factors. The factors included: loading direction, abduction angle, abduction plane angle, humeral socket depth, and glenosphere eccentricity and diameter. A normal probability plot of effect estimates and a six-way ANOVA were used to determine significant factors and interactions.

RESULTS
A 30% increase in force to dislocate the shoulder was observed when the abduction angle was increased from 45 to 60° (p<0.0001). Using an inferior-offset as opposed to a standard centred glenosphere resulted in a 17% increase in force to dislocate (p<0.001). Additionally, a significant interaction was found between humeral socket depth and loading direction (p<0.001). Use of the retentive humeral socket, which is 4mm deeper than the high mobility option, improved stability, but only if the shoulder was dislocated anteriorily, posteriorily, or superiorily (Figure 1). Glenosphere diameter and abduction plane had no effect on stability (p>0.05).

DISCUSSION & CONCLUSIONS
The increase in stability observed for larger abduction angles was likely due in part to the greater muscle forces required to attain these postures. Therefore, stability may be improved by increasing deltoid tension intraoperatively. The results of this study also indicate that the risk of dislocation may be reduced by using an inferior-offset glenosphere, which is also beneficial in decreasing the likelihood of impingement and scapular notching. More constrained humeral sockets can also add stability to the shoulder, although there is no benefit for inferior dislocations. This interaction also highlights the complicated nature of instability in reverse shoulder arthroplasty and the importance of understanding dependencies between factors.

REFERENCES