# THE EFFECT OF FRICTION AND ARM POSTURE ON MAX PULL / PUSH FORCE

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## INTRODUCTION

An individual's limited pull/push capability can pose safety risks in situations such as climbing a ladder or propelling a wheel chair. An understanding of pull/push force in relation to hand-handle friction and arm posture is important to design grip objects that prevent slippage or overexertion.

Previous studies used handles that produced mechanical interference to prevent the hands from slipping (e.g., pushing against a wall, Davis and Stubbs, 1977; Mital et al., 1995). In many cases, however, it is necessary to rely on friction for coupling between the hand and handle.

This study tests the hypotheses that 1) maximum pull/push force is limited by hand-handle friction and 2) maximum pull force varies with different arm postures.

## METHODS

Eight healthy right-handed subjects (4 male, 4 female, average age = 26.4 yrs, SD = 5.3 yrs) grasped a cylindrical handle with the right hand and performed maximum pull/push exertions. They were seated on a chair that supported the back and feet to minimize the effect of balance and slip on pull/push force. The handle height was adjusted to each subject's elbow height.

Independent variables were handle material (aluminum, rubber), gloves (bare hand, cotton glove – GoldKnit™ Mediumweight 70-227, PVC dot glove – Performers Extra™ Knit Series D2-09), handle orientation (long axis of the handle parallel to the pull/push direction and the floor, vs. perpendicular to the pull/push direction and the floor), and elbow angle (flexed at 90˚ vs. extended). The dependent variable was maximum pull/push force, measured using a load cell. The cylindrical handle diameter was 40 mm. Each condition was repeated twice and randomized.

## RESULTS AND DISCUSSION

Pull/push forces for different friction conditions and elbow postures are shown in Fig 1 and 2. When the handle was oriented parallel to the exertion direction, pull/push forces decreased 10% ($p<0.01$), compared to the handle perpendicular to the exertion direction. Pull/push force further decreased 17% for the low friction aluminum handle, compared to the high friction rubber handle. These results support the first hypothesis that axial pull/push force is limited by hand-handle friction.

Use of the PVC dot glove and cotton glove resulted in 18% and 42% reduced pull force compared to the bare hand, respectively ($p<0.01$, Fig 1). It is probably due to decreased friction with gloves, especially for the cotton glove.

Similar with Davis and Stubbs (1977), pull force was 29% greater for the extended elbow than for the flexed elbow ($p<0.01$). The shoulder strength to move the upper arm backwards may have limited pull force when the elbow was 90º flexed. For the

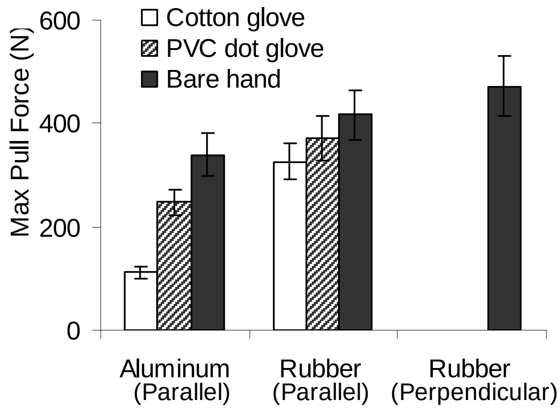


Figure 1. Mean ± SE pull force for different gloves (cotton glove, PVC dot glove, bare hand), handle materials and orientations. Low friction aluminum and high friction rubber handles were tested for a handle parallel to the pull/push direction. A handle perpendicular to the pull/push direction was also tested. (n=8, extended elbow only)

extended elbow, torso extension strength may have limited pull force. Pull force was greater than push force ($p<0.01$, Fig 1), probably because push force was primarily exerted by the upper arm whereas subjects could engage the torso for pull exertion in the apparatus provided in this study.

## SUMMARY/CONCLUSIONS

Pull/push capabilities can increase 22% by orienting the long axis of a handle perpendicular (as opposed to parallel) to the pull/push direction so that pull/push force is not limited by hand-handle friction. When the handle should be oriented parallel to the pull/push direction, a high friction handle is preferred over a low friction handle, to improve hand-handle friction and thus the pull/push capability, as exampled by wheelchair rim design (Richter et al., 2006).

Gloves are often used in industry. Low friction gloves such as cotton gloves can reduce friction and the pull/push capability 42% (compared to the bare hand), and may

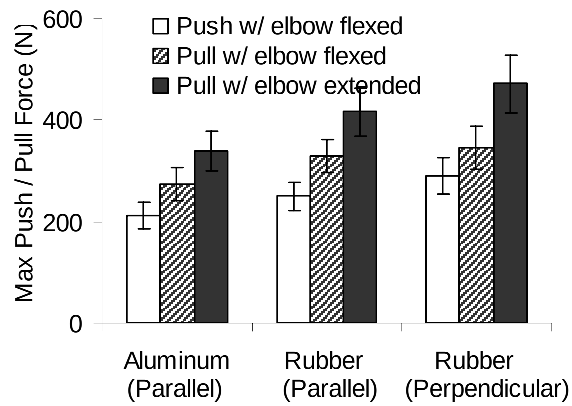


Figure 2. Mean ± SE push/pull force for different elbow postures, handle materials and orientations. (n=8, bare hand only)

result in hand slippage. In addition, use of gloves can decrease tactile sensitivity (Kinoshita, 1999). Reduced sensitivity or low hand-handle friction can result in high grip force exertions which, if repeated, can cause local fatigue and musculoskeletal disorders (Armstrong et al., 1993).

Pull force can be limited by shoulder extension strength. This limitation can be relieved by elbow extension.

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