

MAXIMAL VOLUNTARY FORCE, BUT NOT SUBMAXIMAL STEADINESS, IS LIMITED BY A LOW-FRICTION CONDITION DURING INDEX FINGER PRESSING TASKS

Keenan KG, Collins JD, Massey WV, & Walters T¹

¹University of Wisconsin-Milwaukee, Milwaukee, WI, USA

email: keenan@uwm.edu

INTRODUCTION

The index finger is a critical contributor to the successful performance of activities of daily living (e.g., buttoning a shirt, typing, etc) and many investigators have studied its biomechanics and neuromuscular control [1,2,3]. Pressing tasks with the index finger are common in the field of motor control, although previous experimental approaches have almost exclusively focused on the production of force magnitudes irrespective of accurately directed forces. This may be problematic; however, as manual dexterity tasks require not only the production of precise force magnitudes, but also well-directed forces. For example, Cole [1] reported that older adults have an inability to produce well-directed submaximal forces during force-matching tasks. While it is unclear what mechanisms might lead to an inability to accurately direct forces, or whether these impairments influence daily function, assessing its potential influence on manual dexterity is a logical next step.

The directional accuracy requirements of a pressing task can be altered by changing the coefficient of friction between the fingers and the object being manipulated. Specifically, a low-friction interface requires well-directed forces perpendicular to the surface being manipulated or the finger will slide along the surface. Conversely, a high-friction interface allows a wider range of force directions without slipping. Using a high- and low-friction interface between the thumb and a force-sensor, Valero-Cuevas and colleagues [2] found that maximal voluntary force production (MVC) was not altered for the two friction conditions. However, it was not reported if the actual force direction differed across conditions, which may be important as a similar force direction might lead to similar MVC forces. Also, muscle activity increased in two thumb muscles for the low-friction condition, which may have helped to preserve MVC force.

The purpose of the current study was to manipulate

the friction constraints of a novel index finger pressing task [3] to examine its influence on two commonly investigated motor outputs: i) MVC force magnitude, and ii) fluctuations in force during submaximal force-matching tasks.

METHODS

Subjects (n=21; 21.4±3.8 years old) pressed straight downward with the tip of their right index finger onto an aluminum surface (3cm x 3cm) that was attached to a 6-axis force/torque sensor (ATI Industrial Automation, Nano17). A thermoplastic cast was formed around the tip of the participant's index finger to allow maximal force production while reducing pain (Figure 1). Subjects received visual feedback of the force perpendicular to the aluminum surface (i.e., F_z) on a 24-inch LCD monitor and no information on force direction was supplied. Each subject performed MVCs with the contact point at the tip of the finger on two different surfaces: Teflon and sandpaper. Following the MVCs, subjects were instructed to hold a constant force at 2.5% and 10% of their MVC for 13 seconds. Subjects were instructed to keep the force trace as close as possible to the target line at 2.5%

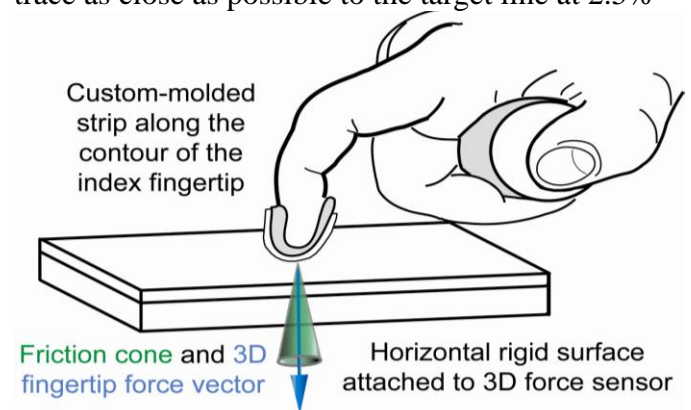


Figure 1: Subjects pressed with their finger into a rigid horizontal surface. The horizontal surface was attached to a force sensor and the surface was covered with either sandpaper or Teflon to establish a high- and low-friction condition, respectively. The size of the friction cone (i.e., allowable force directions without slipping off the surface) is decreased by a decrease in the coefficient of friction between the surfaces.

and 10% of MVC. Two trials were performed for each condition. The static steadiness trials were performed with and without visual feedback, though as no differences were found between visual conditions the results were combined. Muscle activity was estimated using surface electromyography (EMG) recorded from first dorsal interosseus, extensor digitorum communis, and flexor digitorum superficialis. EMGs were filtered, normalized, and processed as in [3]. Significant differences between friction conditions for MVC force magnitude and direction, submaximal force variability, and EMG amplitude were examined using t-tests ($p < 0.05$).

RESULTS AND DISCUSSION

MVC force declined ($p < 0.01$) by 14.6% when pressing on Teflon (38.4 ± 17.5 N) compared to sandpaper (44.9 ± 21.1 N, Figure 1). This force magnitude decline cannot be explained by a change in MVC force direction. Fingertip forces in the proximal/distal direction were calculated when F_z was maximal. Forces were directed distally for both sandpaper (2.0 ± 6.6 N) and Teflon (0.4 ± 2.4 N), although the difference was not significant ($p = 0.11$). Interestingly, EMG amplitude dropped by 16.3% in FDI ($p < 0.05$), but there were no significant differences in EDC ($p = 0.47$) and FDS ($p = 0.12$). Although it is unclear why EMG amplitude decreased in first dorsal interosseus, it is possible that after practice trials subjects adapted a control strategy to limit pressing as hard as possible to avoid slipping on the low-friction surface.

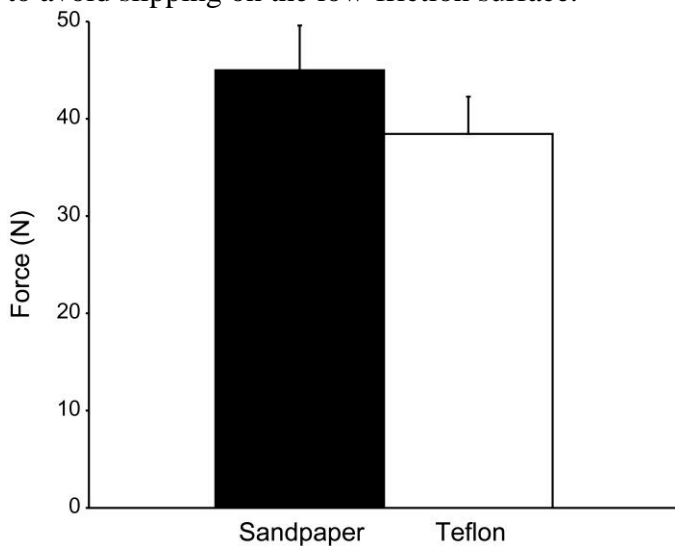


Figure 2: Maximal voluntary force production was reduced when pressing into a force sensor covered with a low-friction Teflon surface compared to a high-friction sandpaper surface. Bars are grouped means \pm SE.

In contrast to MVC force, fluctuations in force during submaximal force-matching tasks were not different across friction conditions (Figure 3). Specifically, the coefficient of variation in force was similar at 2.5% (sandpaper = $34 \pm 5\%$; Teflon = $36 \pm 4\%$; $p = 0.25$) and 10% (sandpaper = $21 \pm 2\%$; Teflon = $22 \pm 2\%$; $p = 0.38$) MVC force.

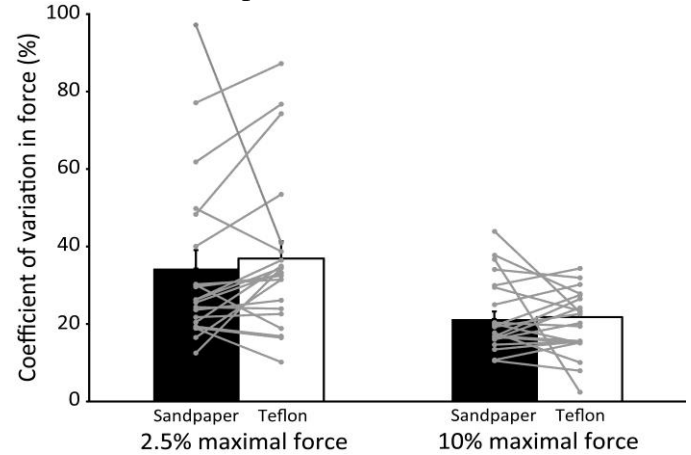


Figure 3: Performance on submaximal force-matching tasks was not influenced by the friction condition. The coefficient of variation in force (in the direction perpendicular to the surface being pressed against) was similar regardless of pressing into a sandpaper- or Teflon-covered surface. Bars are grouped means \pm SE and individual data are also represented by gray dots connected by lines.

CONCLUSIONS

Maximal voluntary fingertip force was influenced by the friction condition. Thus, for those tasks performed at high levels of force the coefficient of friction may be an important determinant of manual dexterity performance. However, for submaximal forces, there was no impairment in motor performance during force-matching tasks. It should be noted that these findings are generalizable to young healthy adults, it is unclear if the same results will be found in clinical or older populations.

REFERENCES

1. Cole KJ. *Exp Brain Res*, 285-291, 2006.
2. Johanson ME et al. *J Hand Surg*, 698-705, 2001.
3. Keenan et al. *J Neurosci*, 8784-8789, 2009.

ACKNOWLEDGEMENTS

We acknowledge the University of Wisconsin Research Growth Initiative and the Judd Leighton Foundation for their support of this project and to Hillary Gruska, John Hubbard and Ryan Kern for their assistance in data collections.