

GRIP SURFACE FRICTION AFFECTS MAXIMUM TIP PINCH FORCE

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INTRODUCTION

Pinch grip is used in many daily activities such as picking up small objects and writing. Although pinch grip has been extensively studied, the friction condition between the fingers and grasped object has not been considered as a contributing factor to individuals' pinch strength. The maximum pinch grip force may vary with grip surface friction as described below.

The finger slips against a fixed object surface when the digit force is directed such that the ratio of shear to normal forces is greater than the coefficient of friction between the finger and the object [1]. To prevent slip, the digit has to generate force within an allowed range determined by the friction coefficient between the digit and grip surface [2] as illustrated in Fig. 1. A low-friction surface limits the digit force direction to a narrower range compared to a high-friction surface. In other words, a low-friction surface requires the digit force to be closer to the direction perpendicular to the grip surface than a high-friction surface does.

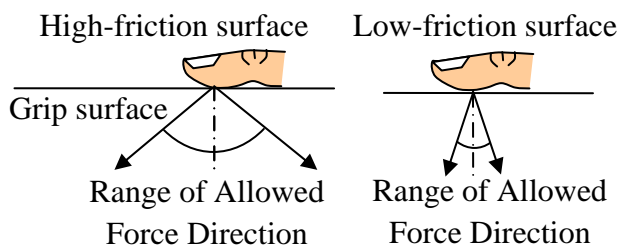


Figure 1: To prevent finger-object slip, the digit force has to be directed such that the ratio of shear to normal forces is less than the coefficient of friction between the finger and the object [1-2]. A high-friction surface allows a wider range of pinch force direction compared with a low-friction surface while not resulting in finger slip.

Generation of well-directed digit force requires precise coordination of all muscles of the finger [2-5]. When the requirement of precise control of digit force direction is lessened (such as in gripping a high-friction surface allowing a large shear to normal force ratio), the number of muscle coordination patterns to successfully complete the task [3,4] will also increase. This may result in increased pinch force. It was hypothesized that individuals will be able to produce greater pinch force when gripping objects with a high coefficient of friction between the fingers and the grip surface than when gripping objects with a low coefficient of friction.

METHODS

Twelve healthy subjects (5 males and 7 females, age = 21-30 years old, all right-handed) were seated with the forearm resting on a table. They performed maximum isometric tip pinch grip exertions (between the tips of the thumb and index finger) for 5 seconds on two fixed parallel flat surfaces (Fig. 2). Two grip surfaces – smooth rubber and paper – were tested to simulate high- and low-friction surfaces, respectively (coefficient of friction = 0.9 between rubber and skin [6] and 0.3 between paper and skin [7]). Each grip surface was connected to a load cell (Nano17, Mini40; ATI Industrial Automation, Inc.; Apex, NC) that measured pinch force (in the direction perpendicular to the grip surface) for the thumb and index finger separately.

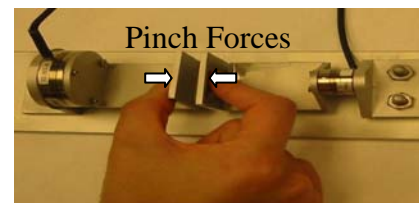


Figure 2: Subjects gripped two fixed parallel flat surfaces covered either with high-friction rubber or with low-friction paper. The grip surfaces were connected to load cells that measured pinch force.

Both hands were tested with each surface condition three times (for a total of six grip exertions per subject) to compute the means. The two flat surfaces were separated by a distance of 3.8 cm for both rubber and paper conditions. The maximum pinch force for each finger was defined as the maximum mean pinch force across a two-second period. Analysis of variance was performed to determine whether maximum pinch force was significantly affected by the grip surface (paper vs. rubber), the subject, hand (right, left) and finger (thumb, index finger) as blocking factors.

RESULTS AND DISCUSSION

The maximum tip pinch force for the rubber surface was 13% greater than that for the paper surface ($p=0.017$, Fig. 3). The data support the hypothesis that subjects can produce greater pinch force when gripping objects with a high coefficient of friction between the fingers and the grip surface than when gripping objects with a low coefficient of friction.

The increased pinch force for the rubber surface may be attributable to a greater range of pinch force direction allowed without slippage for high friction surfaces than for low friction surfaces (Fig. 1). Well-coordinated muscle activation patterns are needed to direct digit force within a narrow range of force direction [4-5]. This may have reduced the subjects' ability to generate maximum pinch force for the low-friction paper surface compared with the high-friction rubber surface.

Consistent with a previous study [8], the maximum pinch force was greater for the dominant right hand (58.3 N, standard error, SE, = 5.0 N) than for the non-dominant left hand (52.3 N, SE = 3.5 N). Greater force was recorded for the thumb (57.8 N, SE = 3.9 N) than for the index finger (52.8 N, SE = 5.5 N) most likely due to the thumb being stronger than the index finger [9].

CONCLUSIONS

Maximum tip pinch force increased 13% by changing the grip surface from paper (coefficient of friction of 0.3 with finger skin) to rubber (coefficient of friction of 0.9 with finger skin). This

effect of the grip surface on maximum pinch force has not been shown previously. Thus for daily living tasks that require high pinch force, use of a high friction surface may be beneficial. Future studies investigating pinch grip forces should control for the surface interface between the measuring device and the fingers.

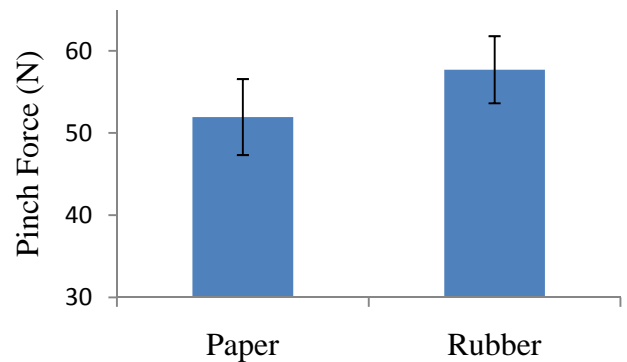


Figure 3: Mean \pm standard error maximum pinch force for the two grip surfaces (index finger and thumb, left and right hand, and subjects pooled)

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