HIGH COEFFICIENT OF FRICTION AT THE HAND-OBJECT INTERFACE CONTRIBUTES TO INCREASED MAXIMUM GRIP FORCE BY THE PHALANXES DURING POWER GRIP

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INTRODUCTION

Power grip is commonly used in everyday activities such as holding a bottle or cup. During power grip, a person generates hand forces that are normal (perpendicular) and shear (parallel) relative to the surface of the gripped object [1]. A person may adopt different grip strategies depending on the coefficient of friction (COF) between the hand and handle for the following reasons. First, a high friction surface may reduce the need for precise coordination of hand muscles to direct digit force [2-3]. Secondly, both normal and shear forces produced by phalanxes can induce reaction force on the palm, which contributes to overall power grip force generation [4-5]. Thus, if the COF between the hand and handle is high, people may increase shear force at the phalanges to maximize overall grip force. It is important to investigate how persons compensate for different frictional surfaces during power grip in order to understand the biomechanical mechanisms that underlie a person's grip strategy and strength.

The goal of this study was to examine the effect of friction between hand and grip surface on a person's grip strategy. The hypothesis of this study was that during maximum power grip, normal force will be greater when the grip object provides a high COF with the skin compared to a low COF. Also hypothesized is that the increase in normal force will be accompanied by an increased shear to normal force ratio for the rubber surface compared to the paper surface.

METHODS

Thirteen young healthy individuals (ages 19-30 years) were seated with the forearm horizontal on an arm rest. Using the non-dominant hand, subjects were instructed to perform a 5 second maximum power grip on a custom-made grip dynamometer (Fig. 1). Each phalanx's normal force and shear force (in the proximal-distal direction of the finger) were recorded at 50 Hz. The grip dynamometer had two surface coverings: paper and rubber with COF with the finger skin of 0.3 [6] and 0.9 [7], respectively. The grip dynamometer's diameter was 26.6 mm for both coverings.

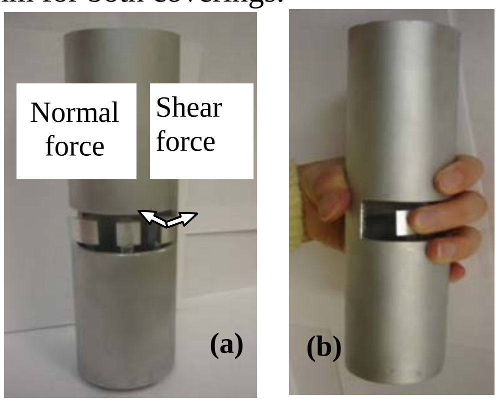

Figure 1: A custom-made grip dynamometer measuring shear and normal forces on three contact pads (a) that align with each phalanx of a single finger during power grip (b).

Maximum power grip was repeated three times for each finger and surface condition (for a total of 30 trials). Two minute breaks were allowed between consecutive grips to minimize muscle fatigue. For each grip trial, normal and shear forces were averaged over the two second period in which the mean normal force was the greatest. In addition, the mean ratio of shear force to normal force was computed for that period. ANOVA was performed to determine if the maximum normal force and the shear to normal force ratio observed for the phalanxes of the five fingers significantly varied with grip surface.

RESULTS AND DISCUSSION

Mean normal force for the phalanxes during maximum power grip was significantly higher for the rubber surface, 23.2 N, than for the paper surface, 22.5 N (Fig. 2; *p*=.012). The mean shear to normal force ratio produced with the rubber surface, 0.23, was significantly higher than that for the paper surface, 0.19 (Fig. 3, *p*<.01).

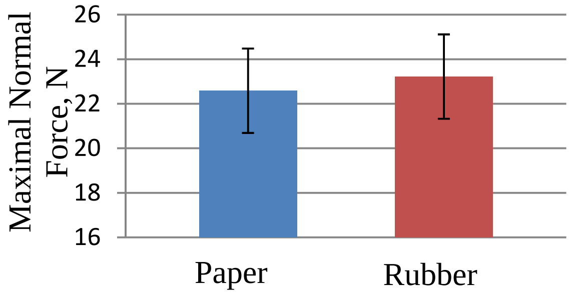

Figure 2: Mean ± SE normal force produced by the fingers during maximum power grip for the two grip surfaces (*p*=0.012), averaged across repetitions, phalanxes, fingers, and subjects.

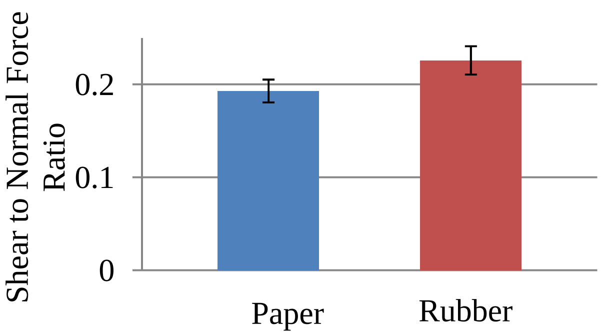

Figure 3: Mean ± SE shear to normal force ratios observed during maximum power grip for the two grip surfaces (*p*<.01), averaged across repetitions, phalanxes, fingers, and subjects.

The higher shear and normal forces for the rubber surface may be attributable to alleviated muscle coordination requirement. To achieve a stable grip, force vectors applied to the surface must fall within a specific angle range with respect to the object surface [3]. The angle range is dependent on COF. The higher the COF, the larger the angle range in which a person could apply a force and still maintain a stable grip [3]. Increase in the angle range may require less muscle coordination and precision [2], thereby allowing a person to exert greater normal and shear forces. In addition, the subjects may have generated greater shear force for the rubber surface to increase the reaction force against the palm and maximize overall grip force applied to the handle [4].

Wimer et al. [1] found little evidence of shear force contribution to grip force. The difference between the present study and the previous study could be due to study design. The latex gloves used in the previous study may have decreased sensory feedback for subjects and consequently decreased the effect of COF on the subjects' grip strategy.

CONCLUSIONS

The biomechanical investigation of the digit force generated during power grip is important in order to better understand people's grip strategy in completing everyday tasks. It was found that people generated shear force (approximately 19% to 23% of the normal force) in addition to grip force (normal to object surface) during maximum power grip. Furthermore, people produced greater grip force and greater shear force for a rubber surface compared to a paper surface. Increasing frictional coupling between hand and grip objects may assist people in generating greater grip force, thereby aiding in completing everyday tasks.

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