EFFECTS OF THE GRASPING FORCE MAGNITUDE ON THE INDIVIDUAL DIGIT FORCES DURING PREHENSION WITH FIVE DIGITS

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INTRODUCTION

To control dextrous manipulation of mechanical 5-digit hands, the engineers should know the interrelations existing between the individual digit forces and moments during the performance [1]. The information obtained on humans can be useful in this case. When manipulating hand-held objects, people can grasp them with different forces. In this study, we address the following question: does the pattern of individual digit forces depend on the grip force magnitude? Subjects were asked to keep an instrumented handle with minimal effort and then double the grip force. The following questions are addressed: (a) Does doubling the total grip force double the individual digit forces? (b) Does the sharing percentage of normal forces among the fingers depend on the total force magnitude? (c) Does the percentage contribution of the normal and tangential forces into the total moment exerted on object depend on the grasping force magnitude?

METHODS

Seven right-hand-dominant subjects were required to stabilize in the air an instrumented handle (575 g) using prismatic grip (the tips of the fingers and thumb oppose each other). Four clockwise (negative) and four counterclockwise (positive) torques and one zero torque were applied to the handle. Five six-axis force-torque transducers (Nano-17, ATI Industrial Automation, Garner, N.C.) were mounted on the handle to measure the digit forces. The experiment had two phases. First, the subjects were instructed to hold the handle vertically with minimal normal (grip) force for 3 s. The computer recorded the force and then set a target force level at the double value. Visual feedback on the grip force and on the target force was provided on the computer screen. The subjects were instructed to squeeze the handle until the grip force matched the target. The second phase lasted 17 s.

RESULTS AND DISCUSSION

The doubling of the grip force induced complex changes of the both normal and tangential digit forces (Figure 1). After grip force doubled, the percentages of the individual finger's contribution to the grip force at all torque values changed (Figure 2) although the changes were minimal at the zero torque. The contribution of antagonist fingers (fingers producing moments in the direction of the external torque) increased (e.g. during supination efforts of 460.6 Nmm, the contribution of the little finger changed from 6% to 13%, see Figure 2). The doubling of the grip force also affected the percentage contribution of the normal and tangential forces into the total moment production: the contribution of the moment of the tangential forces increased (e.g. during supination efforts of 460.6 Nmm, the contribution of the little finger changed from 38% to 55%).

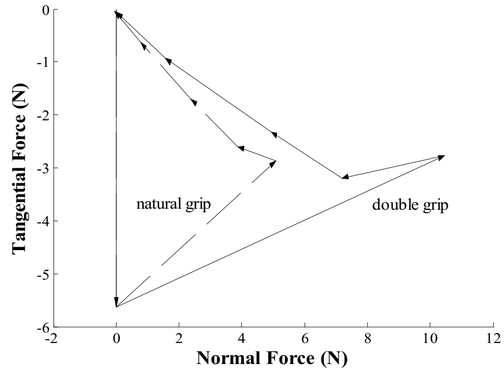

Figure 1: Force polygons. The polygons are obtained by adding tail-to-head the individual forces. Starting from the upper left corner the following forces are shown: gravity, the thumb, index, middle, ring and little finger force. Ideally, in static conditions the polygon should close. Representative example: external torque is zero.

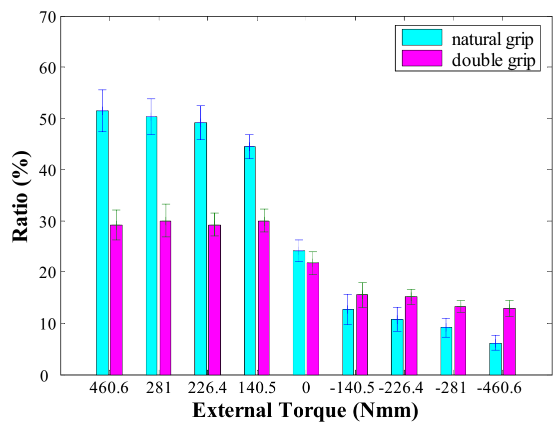

Figure 2: Exemplary little finger's contribution to grip force at different external torques before and after doubling the grip force. Error bars show standard errors.

CONCLUSIONS

The increase of the grip force magnitude during prehension results in increased percentage contribution of (a) the normal forces of antagonist fingers into the total grip force and (b) the moment of the tangential forces into the total moment exerted on the object.

REFERENCES

1. Zatsiorsky VM, Gregory RW, Latash ML (2002) Force and torque production in static multifinger prehension: biomechanics and control. I. Biomechanics. Biol Cybern 87: 50-57.

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