THE EFFECT OF TORQUE DIRECTION ON HAND-OBJECT COUPLING

Na Jin Seo and Thomas J. Armstrong

University of Michigan, Ann Arbor, MI, USA
E-mail: najins@umich.edu

INTRODUCTION

Torque is applied with the hands in many activities at work, daily living and recreation. Some examples are joining and removing threaded and non-threaded parts such as containers and vacuum hoses, using hand tools, and using controls.

Torque that can be produced on a handle is related to the radius of the handle and the friction force acting tangentially to the surface. Previous studies have shown that friction is related to the normal force and coefficient of friction between the hand and the handle (Pheasant and O'Neill 1975). The coefficient of friction itself is related to contact force, handle material (Buchholz et al. 1988) and texture and the presence of lubrications (Bobjer et al. 1993). The normal force is related to the grip strength of the individual. It is hypothesized that skin friction produced by twisting an object in the direction of the fingertips causes palmar flexion of the phalanges and increases grip force and torque (see Figure 1).

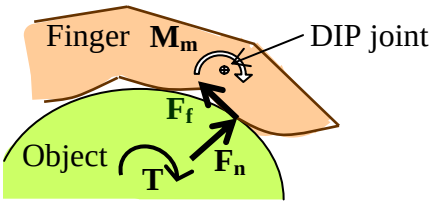

Figure 1: Friction force (F_f) causes increase in normal force (F_n), thus increased torque (T), for a given muscle strength (M_m).

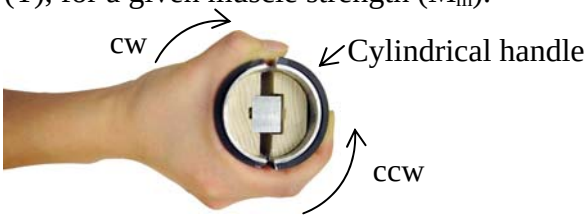

Figure 2: Direction of the counter-clockwise (ccw) and clockwise (cw) rotation

METHODS

To test the proposed hypothesis, an experiment was conducted in which 12 subjects (6 females and 6 males, age = 21 to 35, mean age = 26.7) performed isometric maximum torque exertions on a cylindrical handle in the counter-clockwise and clockwise direction when viewed from the lateral side of the hand (see Figure 2).

Two halves of the cylindrical handle were separated via a force transducer. The handle was covered with a pressure sensitive pad (Tekscan Pressure Measurement System) that recorded normal pressure at each 5.08 by 5.08mm sensor. The pressure pad was covered with a 3.5 mm-thick sheet of rubber. Handle diameters of 38.1, 50.8 and 76.2mm were tested. This presentation will discuss the results for the 50.8mm handle.

Subjects' grip strength measured with a Jamar dynamometer (2nd position) and wrist strength measured using a BTE Work Simulator (wrist neutral) is summarized in Table 1. All exertions were performed with a right hand in a random order.

Table 1: Grip strength, wrist flexion and extension strength by gender (mean ± SD)

	Male	Female
Grip (N)	442 ± 107	215 ± 101
Flexion (Nm)	15.6 ± 5.1	6.2 ± 3.2
Extension (Nm)	11.6 ± 3.6	5.0 ± 2.0

RESULTS

The maximum torque, grip force, contact area, total normal force (arithmetic sum of normal forces around the handle) and fingertip force (normal forces on the index to little fingers' distal phalanges) for the clockwise and counter-clockwise rotations are shown by gender in Table 2. The maximum torque was 33% greater for the counter-clockwise rotation than clockwise rotation (gender pooled, $p<0.05$). Total normal force and fingertip force were 25% and 42% greater, respectively, for the counter-clockwise rotation than for clockwise rotation (gender pooled, $p<0.05$).

Figure 3 shows a representative recording of the pressure distribution for a clockwise and counter-clockwise rotation. Forces were concentrated on the index to little fingers' fingertips more so for the counter-clockwise rotation than for the clockwise rotation. More contact and force were observed on the thenar area for the clockwise rotation than for the counter-clockwise rotation.

DISCUSSION AND CONCLUSIONS

By comparing wrist strengths (Table 1) and maximum torques, it can be seen that the coupling between the hand and the work object is the limiting torque factor – not the wrist. The increase in torque, total normal force and fingertip force for the counter-clockwise exertion supports the proposed hypothesis: the maximum torque is greater for the counter-clockwise than the clockwise rotation.

Forces were concentrated on the distal phalanges, thumb and thenar area. For the counter-clockwise rotation, greater forces were concentrated on the index to little fingers' fingertips.

REFERENCES

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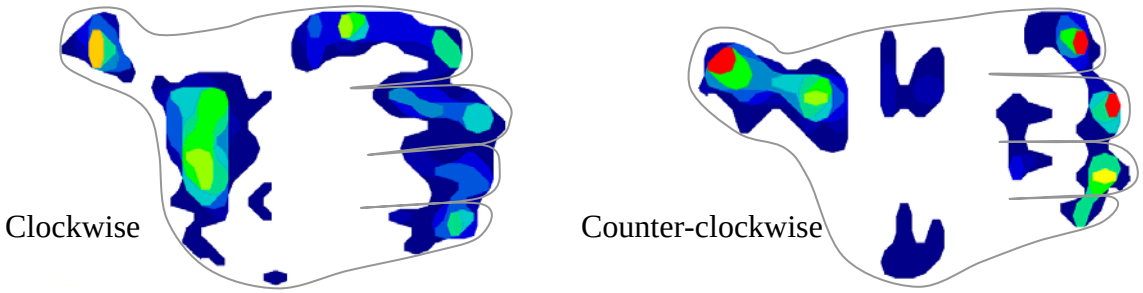

Figure 3: A typical force distribution during the clockwise and counter-clockwise rotation

Table 2: The maximum torque, grip force, contact area, total normal force (arithmetic sum of normal forces around the handle) and fingertip force (normal forces on the index to little fingers' distal phalanges) for clockwise (cw) and counter-clockwise (ccw) rotations (mean ± SD)

Gender	Direction	Torque (Nm)	Grip force (N)	Contact area (cm^2)	Total normal force (N)	Fingertip force (N)
Male	cw	5.3 ± 1.3	173 ± 41	63 ± 19	261 ± 99	116 ± 52
	ccw	7.2 ± 1.7	198 ± 91	65 ± 14	342 ± 123	172 ± 65
Female	cw	2.2 ± 1.5	106 ± 87	62 ± 19	145 ± 27	67 ± 21
	ccw	2.9 ± 2.5	107 ± 94	60 ± 18	168 ± 48	88 ± 24