

## THUMB MUSCLE FORCES IN JAR OPENING

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### INTRODUCTION

Twisting activities such as jar turning and door opening are common functional activities in our daily living. It is a big challenge for the patients with arthritis or after hand injuries. The literature in understanding the muscle contribution of the thumb during jar turning still lacks [1,2]. It is interesting to understand how the muscles of the thumb play their roles in mobility and joint stability. The purpose of this study was to establish a biomechanical model to predict the muscle forces in the thumb and to understand their roles during jar opening.

### METHODS

The jar simulator was equipped with one torque sensor (Transducer Techniques, CA,  $\pm 22.6N\cdot m$ ) and a six-axis force transducer (Nano25, ATI Industrial Automation, NC,  $F_x, F_y = \pm 111N; F_z = \pm 445N; T_x, T_y, T_z = \pm 2.8N\cdot m$ ). The single-axis torque sensor set inside the jar center was for recording the total torque of the hand and the six-axis force transducer mounted under the tap was for the applied forces and moments of the thumb while jar opening. In addition, three-dimensional kinematical data were captured by a motion analysis system (Motion Analysis Corp., CA). Thirteen 4 mm diameter retro-reflective markers were attached on the dorsal surface of the thumb to define the local coordination system of the thumb and three other markers were on the jar simulator to define its coordination system (Figure 1). The IP joint was represented by a hinge joint with one degree of freedom and three constraint forces ( $C_x, C_y, C_z$ ) and two constraint moments ( $M_x, M_y$ ). The MCP joint was regarded as a universal joint with two degrees of freedom and three constraint forces and one constraint moment. The CMC joint was also regarded as a universal joint. According to the mechanical equilibrium at each joint, the optimization technique was used to solve the redundant system. The objective function minimizing overall muscle stress was selected.

$$\text{Min } \sum (F_i^M / PCSA)^2$$

$$0 \leq F_i^M \leq PCSA * \sigma_{\max} \quad i = 1, m$$

where  $PCSA_i$  and  $F_i^M$  were cross section area and forces generated in the  $i$ th muscle or tendon.  $\sigma_{\max} = 35.3 N/cm^2$  was the maximum which a thumb muscle could bear. Eight female and two male volunteers without hand impairment took part in this study. They were all right handed and asked to grip the base of this jar simulator by left hand in a comfortable position. The right hand held the lid of the jar simulator and put the thumb pad on the six-axis force transducer. The subject then turned the jar lid counter-clockwise three times at maximal effort by both power grip and precision handling.

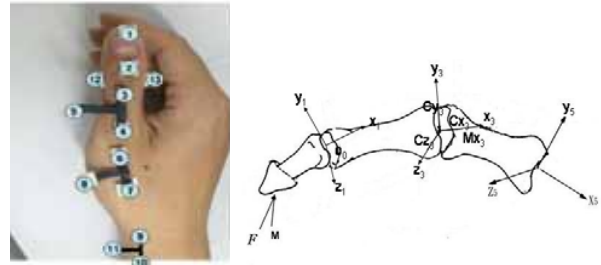


Figure 1: Markers setting and coordination system

### RESULTS AND DISCUSSION

Figure 2 shows the muscle forces of the thumb in jar opening. The major active muscles were FPL, FPB, APB, ADP and OPP. The forces of extensor muscles (EPL, EPB, APL) not larger than flexor muscles were average 15N and were about 6 % of total muscle forces. Total muscle forces in precision handling were 5.6 times the applied forces of thumb but that in power grip were 4.7 times. It indicated that power grip was more effective than precision handling. To compare with previous researches, this study adopted measured data instead of assumed value as Cooney et al. and Giurintano et al. did. They measured the moment arms of cadaver muscles by X-ray and CT images. The muscle loads thus varied. This new apparatus here presented a proper method to measure the actual load in jar opening activity and the biomechanical model developed contributed to the prediction of the muscle forces of the thumb during such activity.

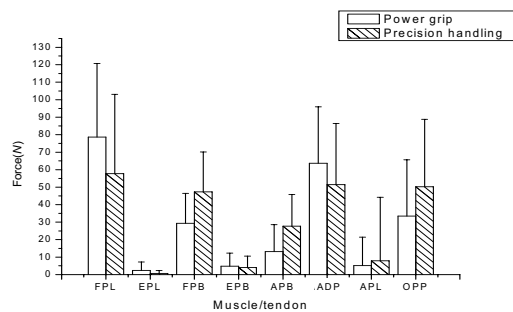


Figure 2: Muscle forces of the thumb in jar opening.

### REFERENCES

1. Cooney WP, et al. *J Bone Joint Surg-Am* **59**, 27-36, 1977.
2. Giurintano DJ, et al. *Med Eng Phys* **17**, 297-303, 1995.

### ACKNOWLEDGEMENTS

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