JOINT LOAD OF THE THUMB IN JAR OPENING

[1,2]Jer-Hao Chang, [1]Kun-Yueh Ho, [1]Fong-Chin Su
[1]Institute of Biomedical Engineering, [2]School of Occupational Therapy, National Cheng Kung University
email: fcsu@mail.ncku.edu.tw

INTRODUCTION

The thumb plays an important role in daily activity because of its opposition characteristics. Jar opening is a common but challenging task for those who could not provide the sufficient twisting torque. Some researchers had developed the biomechanical model of the finger or thumb by means of the hypothetical loads [1,2,3]. This study aimed to develop a novel device to measure the actual three-dimensional loads of the thumb during jar opening and to establish a biomechanical model to reveal the joint loads of the thumb in such activity.

METHODS

The jar simulator was equipped with one torque sensor (Transducer Techniques, CA, ±22.6*N-m*) and a 6-axis force transducer (Nano25, ATI Industrial Automation, NC, Fx, Fy=±111*N*; Fz=±445*N*; Tx, Ty, Tz=±2.8*N-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. These data recorded by the jar simulator were used to calculate the normal forces (Fn), tangent forces (Ft), and the torque contribution (C) of the thumb applied to the jar lid. In addition, three-dimensional kinematical data were acquired 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 (Cx, Cy, Cz) and two constraint moments (Mx, My). 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 ($\Sigma F=0$, $\Sigma M=0$), the resultant forces and moments of three thumb joints were computed. 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 and put the right thumb on the 6-axis force transducer of the lid then did jar opening at maximal effort by both power grip and precision handling.

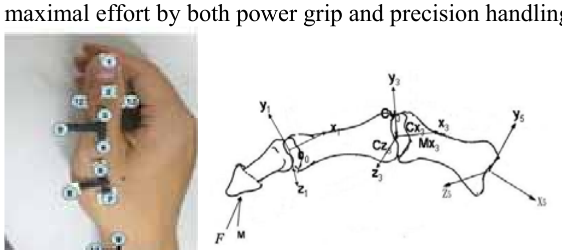

Figure 1: Markers setting and coordination system

RESULTS AND DISCUSSION

The normal force applied by the thumb to the lid was averaged about 45N and the tangent forces were averaged about 15N. The twisting torque contribution of the thumb was averaged about 32.5%. The joint constraint forces and moments of the thumb were calculated and also normalized with respect to applied thumb tip load. The joint contact forces were mainly applied at normal direction (Cx) of each articular surface. The CMC joint bore the largest dorsal and lateral shear forces among three joint. Figure 2 shows the joint resultant forces per unit external applied forces during jar opening. There were 221.5N at the CMC joint, 153N at the MCP joint, and 69N at the IP joint. They were respectively 4.8, 3.3 and 1.5 times the applied forces of the thumb. The external forces and the muscle forces were the major factors to influence the joint constraint forces and moments.

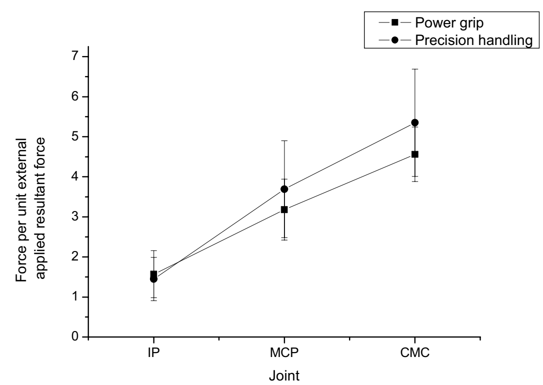

Figure 2: Joint resultant forces per unit external applied force

CONCLUSIONS

This study contributed to the measurement of the biomechanical express and calculation of the joint loads of the thumb in jar opening activity. The new apparatus provides a proper method for measuring the three dimensional load during the activities. The biomechanical analysis model would help to discover more information about the muscle and joint load in other twisting activities by further application.

REFERENCES

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