AN INVESTIGATION OF EXTERNAL LOADING PATTERNS APPLIED DURING MAXIMAL GRIP

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INTRODUCTION

The external loads applied to the fingers have been previously measured using different gripping tools in several wrist orientations [1],[2],[3]. Uniaxial or planar forces applied to a grip tool are typically measured in order to examine the force distribution across the digits. These kinetic studies have not been concurrent with kinematic measurement and there is therefore little information on the external moments generated at the finger joints during whole hand grip.

The aim of the current study was to investigate the three dimensional externally applied forces and moments on each individual finger during whole hand grip. The variation of the external loading patterns and the finger force distribution was also studied in relation to the orientation of the wrist joint.

METHODS

A cohort of fifty healthy right-hand dominant adults (25 males, 25 females) were required to provide their maximal gripping force in five different wrist orientations: maximal flexion, extension, radial (RD) and ulnar deviation (UD) and a position of 'functional neutral' (N). A custom-built gripping tool with five independent six-degree-of-freedom force transducers was used to measure the three dimensional forces and moments applied to individual digits during each grip task. The kinetic data was synchronized with an eight-camera VICON (Oxford Metrics) motion analysis system in order to obtain concurrent kinematic data of each finger/thumb segment, the wrist and forearm. These kinematic data were used to express the transducer loads in terms of individual metacarpal axis systems.

RESULTS AND DISCUSSION

The mean (SD) percentage distribution across the fingers of the applied normal transducer force for the neutral wrist position was found to be: 35% (7.6%) in the index, 30% (6.9%) in the middle, 21% (5.5%) in the ring and 14% (5.9%) in the little finger. These results are comparable with several previous studies [2]. Others suggest however that the middle finger exerts the highest normal force during maximal grip with a neutral wrist [3]. Figure 1 shows the force distribution across the digits in the coronal plane for three wrist positions. It is evident from this figure (and table 1) that during maximal grip trials there is a significant contribution from shear forces which cannot be neglected.

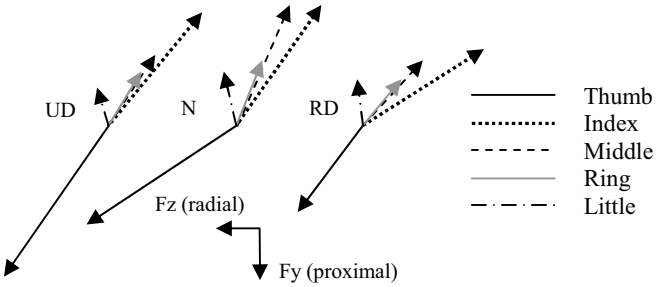

Figure 1: Force vector diagrams showing the force distribution between the digits for three wrist positions in the coronal plane with respect to the metacarpal axis systems.

Table 1 shows how the external loading patterns applied to the index finger (with respect to the metacarpal axis systems) vary with wrist joint orientation in maximal grip. The maximum resultant grip loads are generated in a neutral wrist position. The largest ulnarly directed forces occur during ulnar deviation and this coincides with the largest applied adduction moments. This evidence agrees with current knowledge of hand biomechanics and is clinically important because it explains the contribution of external loading patterns on the development of several deformities in the pathological hand.

CONCLUSIONS

The three dimensional loading patterns generated during whole hand grip are complex and vary with wrist orientation. Significant shear force components are produced during simple grip activities and these can generate large adduction/pronation moments at the finger joints. These results have important implications for both biomechanical modelling and joint implant design.

REFERENCES

1. Amis AA. *J Biomed Eng* **9**, 313-320, 1987.
2. Kinoshita H, et al. *Ergonomics* **38**, 1212-1230, 1995.
3. Ohtsuki T. *Ergonomics* **24**, 21-36, 1981.

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Table 1: Averaged maximum external loads (SD) applied to the index finger with respect to the metacarpal axis system.

Wrist Position	Fx (N) +ve volar	Fy (N) +ve proximal	Fz (N) +ve radial	Mx (Nm) +ve adduction	My (Nm) +ve pronation	Mz (Nm) +ve flexion
Neutral	-3 (4.6)	-19(7.3)	-13 (4.5)	1.0 (0.35)	0.6 (0.23)	-0.1 (0.49)
Flexion	-5 (3.5)	-14 (5.0)	-7 (2.9)	0.7 (0.25)	0.2 (0.17)	-0.8 (0.44)
Extension	-6 (4.5)	-14 (5.4)	-12 (6.4)	0.8 (0.32)	0.4 (0.31)	-0.9 (0.43)
Radial Dev.	1 (4.2)	-18 (6.6)	-15 (7.5)	1.0 (0.42)	0.6 (0.33)	-0.7 (0.45)
Ulnar Dev.	1 (5.2)	-12 (4.4)	-19 (9.3)	1.1 (0.34)	0.7 (0.42)	-0.4 (0.28)