IS THE THUMB A FIFTH FINGER?

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INTRODUCTION

Previous studies of finger interaction during maximal (MVC) and submaximal force production tasks (Li et al. 1998a,b; Zatsiorsky et al. 1998, 2000) revealed three characteristics of finger interaction: (1) Sharing (total force is shared among the fingers in a stable way); (2) Force deficit (FD, peak force produced by a finger in a multi-finger task is smaller than its peak force in a similar single-finger task, see also Ohtsuki, 1981; Kinoshita et al. 1995) and (3) Enslaving (voluntary force production by a finger leads to involuntary force production by other fingers of the hand, see also Kilbreath and Gandevia, 1994).

The thumb is special among human hand digits. Its muscular apparatus does not involve multi-digit, multi-tendon muscles. Its mobility is different: It can act in parallel or in opposition to the fingers. In this study we investigated whether indices of digit interaction between the thumb and the fingers differ from those that describe interaction of the fingers among themselves, and whether these indices depended on the thumb position with respect to the fingers.

METHODS

Apparatus: Six unidirectional piezoelectric force sensors (208C02, PCB Piezotronics, Depew, NY) were attached to a horizontal wooden board. Four sensors (for the index, middle, ring and little fingers) were positioned on the top of the board such that each finger could rest comfortably on a sensor. Two sensors were used to measure thumb force when it acted in parallel and in opposition to the fingers. During its action in parallel to the fingers, the thumb was abducted 45°. During its action in opposition, the thumb sensor was placed at the bottom of the board aligned with the middle finger.

Experimental Procedure: Subjects (n=12; 6 males and 6 females, all right-handed) sat on a chair, resting the right forearm on a foam pad attached to the armrest of the chair. The wrist was supported, and the proximal part of the palm rested on a wooden bar attached to the board. The upper arm was at 30° abduction and 10° of flexion, the elbow was at 120° flexion, the wrist was at 20° extension, the metacarpophalangeal joints were in a neutral position while the interphalangeal joints were at 20° of flexion. Subjects were instructed to produce maximal voluntary force (MVC) by pressing on the force sensors with subsets of digits. For each thumb position, 21 digit combinations were used. EMG was used to check for possible muscle co-contraction.

RESULTS AND DISCUSSION

The thumb produced much higher peak force when it acted in opposition to the fingers and showed a dramatic increase in its share of the total force in the five-digit test (Fig 1). The other digits also produced somewhat higher forces when the thumb acted in opposition. In the five-digit task, the fingers decreased their shares when the
thumb acted in opposition but showed unchanged sharing between the two thumb positions in the four-finger task.

Figure 1. MVC in a five-digit task.

Enslaving during multi-digit tasks increased significantly when the thumb acted in opposition, however, these effects were not seen in single-digit tasks. FD was high when the thumb acted in parallel and showed an increase with the number of task digits up to four but dropped in the five-digit task (Fig 2). FD was very small when the thumb acted in opposition. For both thumb positions, the indices of digit interaction showed no differences between groups of digits that did or did not include the thumb.

The fact that including or not including the thumb in a task, had no effect on the indices of digit interaction, indicates that for a given configuration of the hand the central nervous system treats the thumb as a fifth finger. These results provide strong support for the central (neural) origin of interactions among digits of the human hand. We modeled the data using a force mode approach (Danion et al. 2003). The model showed a small error (2.1 N) for the data when the thumb acted in parallel to the fingers, but a large error (over 6 N) when the thumb acted in opposition.

Fig.2. Force deficit in multi digit tasks.

REFERENCES

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