EFFECT OF THE MECHANICAL CONSTRAINTS ON MULTI-FINGER PREHENSION

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KEY WORDS: grasping, enslaving, mechanical constraints

INTRODUCTION: When a finger produces a force, other non-task fingers of the hand also produce an involuntary force. This phenomenon has been known as finger enslaving (Zatsiorsky et al. 1998). In the present study, we examined the characteristics of the enslaving matrices obtained by the fixed object prehension and the free object prehension. Previous studies showed that two innate constraints (i.e. peripheral and central constraints) affect the performance of finger force production during fixed object prehension. However, it is unknown how the mechanical constraints, which are imposed externally, play a role in grasping tasks. The purpose of the current study was to investigate the finger enslaving for the fixed and free object prehension during maximum finger force production tasks in statics. The central nervous system (CNS) is required to satisfy linear and rotational equilibrium during the free object prehension, while the CNS does not need to satisfy any external constraints.

METHOD: Ten subjects participated in this study. Five six-component (i.e., three force and three moment components) transducers were used to measure each digit force and the moment, and one magnetic tracking device was used to provide an angular-positional feedback. There were five single-digit maximal voluntary force (MVF) production tasks (i.e., thumb, index, middle, ring and little finger) under the fixed object and free object condition. During the free object condition, the feedback of angular-position of the handle was given so that the subject were able to perform the static prehension.

RESULTS: [1] The enslaving of 1st non-task fingers adjacent to the task finger was larger than that of 2nd and 3rd adjacent finger during the fixed object prehension. During the free object prehension, however, the 3rd ranked finger showed the largest enslaving. [2] The directions of the moment of tangential force and normal force were opposite to each other during both fixed and free object prehension although the contributions to the resultant moment of force were different. During the free object prehension, the percentage contribution of the moment of the normal and tangential force to the resultant moment was almost 50% of each.

DISCUSSION: [1] The results of this study supported the “proximity hypothesis” (the close the non-task fingers to the task finger, the greater the enslaving) under the fixed object condition showing 1st adjacent non-task fingers have the largest force, significantly. During the free-object prehesion, CNS considered the moment equilibrium so that the “mechanical advantage” (the effector located further away from the axis of rotation generate larger forces) was utilized. [2] The tangential force during circular object graping was controlled actively (Shim and Park 2007). In this study, the contribution of the moment of tangential force to the total moment was significant, meaning the tangential force can be controlled actively if the tangential force is only concerned about the moment equilibrium.

Proximity hypothesis was valid for the fixed object prehension, while the mechanical advantage hypothesis was valid for the free object prehension.

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