MODELING OF THE DYNAMIC MUSCLE FORCE IN AN INDEX FINGER DURING TAPPING

John Z Wu [1 *], Kai-Nan An [2], Robert G. Cutlip [1], Kristine Krajnak [1], Ren G. Dong [1]
[1] National Institute for Occupational Safety and Health, Morgantown, WV, USA
[2] Mayo Clinic College of Medicine, Rochester, MN, USA
* E-mail: jwu@cdc.gov

INTRODUCTION

Since musculoskeletal disorders of the upper extremities are believed to be associated with repetitive excessive muscle force production in the hands, understanding the time-dependent muscle forces during key tapping will help to explore the mechanisms of disease initiation and development. Because the experimental evaluation of the dynamic loading in individual muscles of the hand during typing is technically difficult and expensive, researchers have studied the dynamic contact force between the fingertip and keypad, and joint angle motions, and assumed that these indices are related to the muscle/tendon excursions. The goal of the current study is to analyze the dynamic muscle forces in an index finger during typing using a universal finger model developed on a platform of the commercial software package AnyBody (AnyBody Technology Inc., Aalborg, Denmark).

METHODS

The index finger model consists of four phalanges: distal, middle, proximal, and metacarpal phalanges. These four phalanges are connected by three joints: distal interphalangeal joint (DIP), proximal interphalangeal joint (PIP), and metacarpophalangeal joint (MCP), as shown in Fig. 1. The dimensional scale of the normative finger model (An et al., 1979) is adopted into the current model. Seven muscles were included in the proposed model: flexor digitorum profundus (FP), flexor digitorum superficials (FS), extensor indicis (EI), extensor digitorum communis (EC), radial interosseous (RI), ulnar interosseous (UI), and lumbrical (LU). The responses of the index finger to tapping are simulated using an inverse dynamic technique. The time histories of impact force at the fingertip (Fig. 2a) reported by Jindrich et al. (2004) and the time-histories of DIP, PIP, and MCP joint angles during tapping reported by Kuo et al. (2006) (Fig. 2b) are applied to drive the model. The joint torques/power and muscle loading/power are predicted as a function of time.

RESULTS AND DISCUSSION

The predicted time-histories of power generated in each individual muscle as well as the total muscle power are depicted in Fig. 3(a). The predicted time-histories of the power in each joint and the total joint power are shown in Fig. 3(b). The sum of the power generated in the muscles agrees well with that in the joints, confirming that all muscle forces are transferred to the joints. Our analysis further indicates that the power generated by FP, EC, and EI muscles are predominant among all muscles, while the power transferred through MCP joint is predominant among all three joints. The predicted time-histories of muscle forces agree well with the EMG measurements made by Kuo et al. (2006) in time sequence (results not shown).

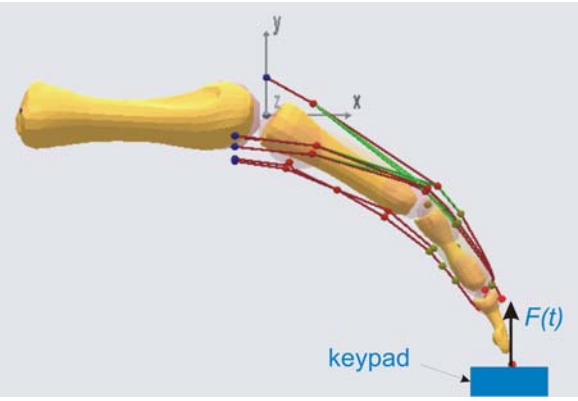

Figure 1: The finger is in contact with the keypad during tapping. The interface impact force *F(t)* is treated as external loading applied on the fingertip.

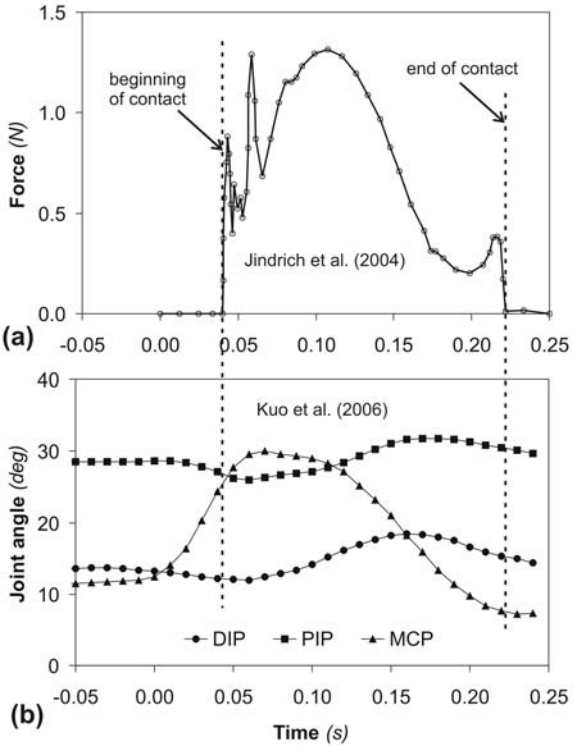

Figure 2: Time histories of representative force at fingertip (a) and joint angles (b) of an index finger during keypad strike reported by the previous researchers (Jindrich et al., 2004; Kuo et al., 2006).

SUMMARY/CONCLUSIONS

In the present study, we have theoretically analyzed the muscle forces and power generated by the muscles in an index finger during a tapping task. Our results suggested that that the powers generated by FP, EC, and EI muscles are predominant among all muscles, while the power generated in MCP joint is predominant among all three joints.

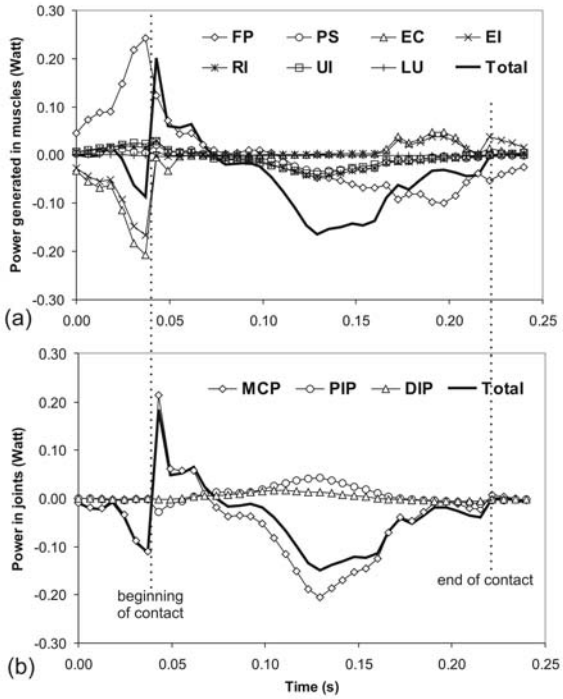

Figure 3: Predicted time-histories of power generated in each individual muscle (a) and joint (b).

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DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.