MODELING OF THE MUSCLE/TENDON EXCURSIONS IN AN INDEX FINGER USING THE COMERCIAL SOFTWARE ANYBODY

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INTRODUCTION

Biomechanical models of the hand and fingers are essential tools to explore the mechanical loading in the musculoskeletal system, which cannot be easily measured in vivo. There are multiple biomechanical models of the hand and fingers simulating different problems (e.g., Sancho-Bru et al., 2003; Brook et al., 1995). However, all these previous models are formulated analytically/numerically and are not suitable for bioengineers and scientists to deal with practical problems. The goal of our study was to develop a universal biomechanical model of the hand, which includes the factors in physiological conditions. Specifically, we develop a kinematical finger model on the platform of the commercial software Anybody (version 2.0, Anybody Technology, Aalborg, Denmark) that includes the real micro-CT-scans of the bony sections and realistic tendon/muscle attachments on the bones. The model predictions on muscle excursions in an index finger are compared with published experimental data.

METHODS

The index finger is modeled as a linkage system, based on the normative model proposed by An et al. (1979) (Fig. 1). The index finger consists of distal, middle, proximal, and metacarpal phalanges. The DIP (distal interphalangeal) and PIP (proximal interphalangeal) joints are modeled as hinges with one DOF about the z-axis; while the MCP (metacarpophalangeal) joint is modeled as a universal joint with two DOFs about the y- and z-axes. The dimensional scale of the normative finger model (An et al., 1979) is adopted into the current modeling. The attachment locations of the tendons are also defined according to the normative model. Seven muscles were included in the proposed model: Flexor profundus (FP), flexor sublimis (FS), extensor indicis (EI), extensor digitorum communis (EC), radial interosseous (RI), ulnar interosseous (UI), and lumbrical (LU). In order to better visualize the muscle/tendon attachment locations and to guide the muscle/tendon during the movements, the real bony section meshes were implemented into the proposed index finger model. These bony section meshes were obtained via micro-CT scanning of a cadaver right hand and included into the model. The predicted muscle/tendon excursions and moment arms were compared with the published experimental data (Fowler et al., 2001; An et al., 1983). Only the excursions of each individual muscle/tendon have been calculated directly in the study. The moment arm of the muscles/tendons corresponding to a particular joint is derived by differentiating the excursions with respect to that joint rotation (An et al., 1979).

RESULTS AND DISCUSSION

The variations of the muscle/tendon excursion and moment arm in response to

the flexion/extension of the DIP and PIP joints as well as the flexion/extension and adduction/abduction of the MCP joint individually are calculated and compared with the experimental data. Typical results, the moment arms of the muscles/tendons corresponding to the PIP flexion, are shown in Fig. 2. In this test, there are six relevant muscles: EI, EC, UI, LU, FS, and FP. Since the moment arms of EI and EC muscles are identical, only the result for the EI muscle is shown. The model predictions agree well with the experimental measurements that the moment arms for the FS/FP muscles are negative, while those for the other three muscles (EI/UI/LU) are positive.

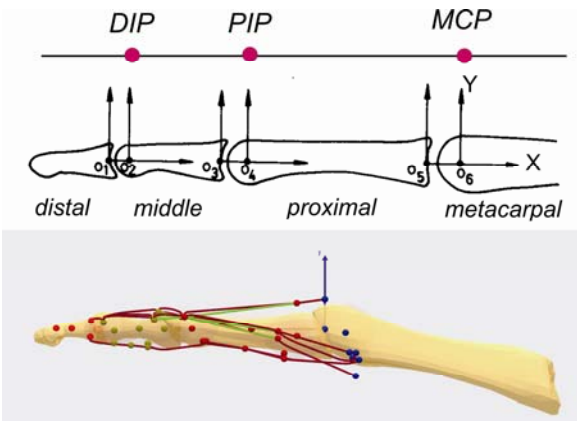

Figure 1: Schematic of the proposed finger model, which is based on the normative model (An et al., 1979). The DIP, PIP, and MCP joints are assumed to be located at O2, O4, and O6, respectively.

SUMMARY/CONCLUSIONS

In the present study, we proposed a universal model to simulate the muscle/tendon excursions and moment arms of the fingers on the platform of the commercial software AnyBody. One of the important features of the proposed model over the previous models is that the proposed approach can include the realistic bony geometries, which are associated with the muscle excursion and moment arms.

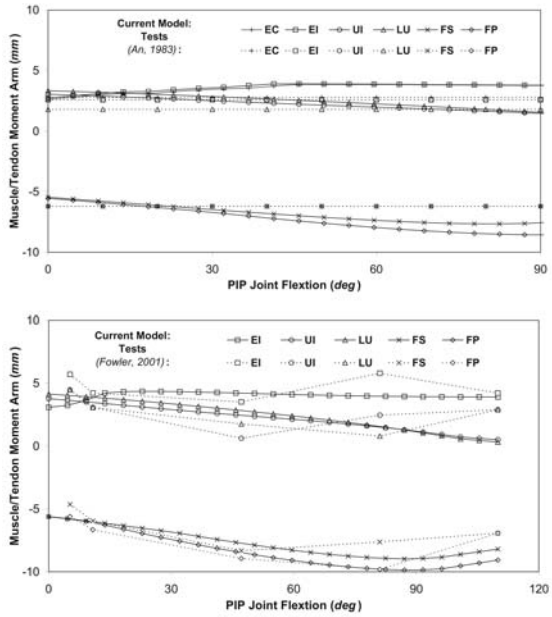

Figure 2: The predicted muscle/tendon moment arms as a function of the PIP joint flexion in comparison with the corresponding experimental data by An et al. (1983) and Fowler et al. (2001).

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DISCLAIMER

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