# A PRACTICAL MODEL OF THE MUSCLE/TENDON MOMENT ARMS IN A THUMB

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## INTRODUCTION

Many occupation-related hand injuries are associated with excessive loadings in the tendons and muscles in the fingers. A biomechanical model of a thumb can be used to explore the mechanical loadings in the musculoskeletal system in the finger, which cannot be measured in vivo. One of the technical difficulties for the development of such a model is the correct description of the kinematics of the thumb joint motions (Valero-Cuevas et al., 2003). The previous thumb models (e.g., Valero-Cuevas et al., 2003) are formulated analytically/numerically and are not convenient for the researchers to solve practical problems. The purpose of the current study is to develop a practical kinematical thumb model using the commercial software Anybody (Anybody Technology, Aalborg, Denmark), which includes the real micro-CT-scans of the bony sections and realistic tendon/muscle attachments on the bones.

## METHODS AND PROCEDURES

The thumb is modeled as a linkage system, consisting of a fixed trapezium, a metacarpal bone, a proximal and distal phalanx (Fig. 1). The IP joint is considered as a hinge (1 DOF) while MP and CMC are considered as universal joints (2 DOFs). The dimensional scale of the thumb model is consistent with An et al. (1979). Nine muscles were included in the proposed model: FPL, EPL, EPB, APL, FPB, APB, ADPt, ADPo, and OPP. In order to better visualize the muscle/tendon attachment locations and to guide the muscle/tendon during the movements, the real 3D bony section meshes were implemented into the thumb model. The predicted muscle/tendon excursions and moment arms were compared with the experimental data by Smutz et al. (1998). Initially, the attachment locations of the tendons from the normative model (An et al., 1979) were applied. The attachment locations were then adjusted for the model predictions to match the muscle moment arms measured experimentally by Smutz et al. (1998). The excursions of each individual muscle/tendon were first calculated from the model. The moment arms of the muscles/tendons corresponding to a particular joint were then derived by differentiating the excursions with respect to that joint rotation.

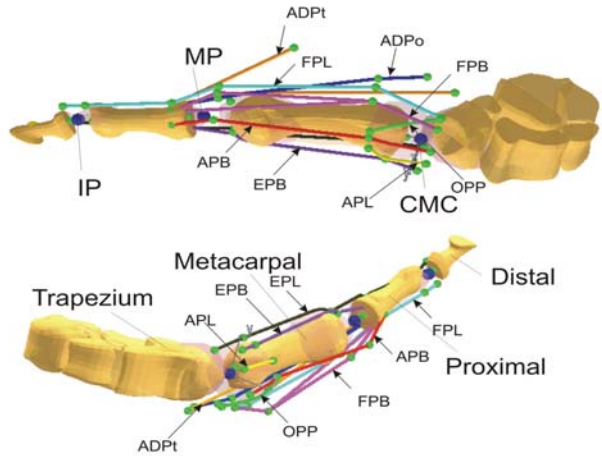


**Figure 1:** Schematics of the proposed thumb model developed using AnyBody.

## RESULTS

The variations of the muscle/tendon moment arm as a function of the angular motions of the IP, MP, and CMC joints were calculated and compared with the experimental data (results

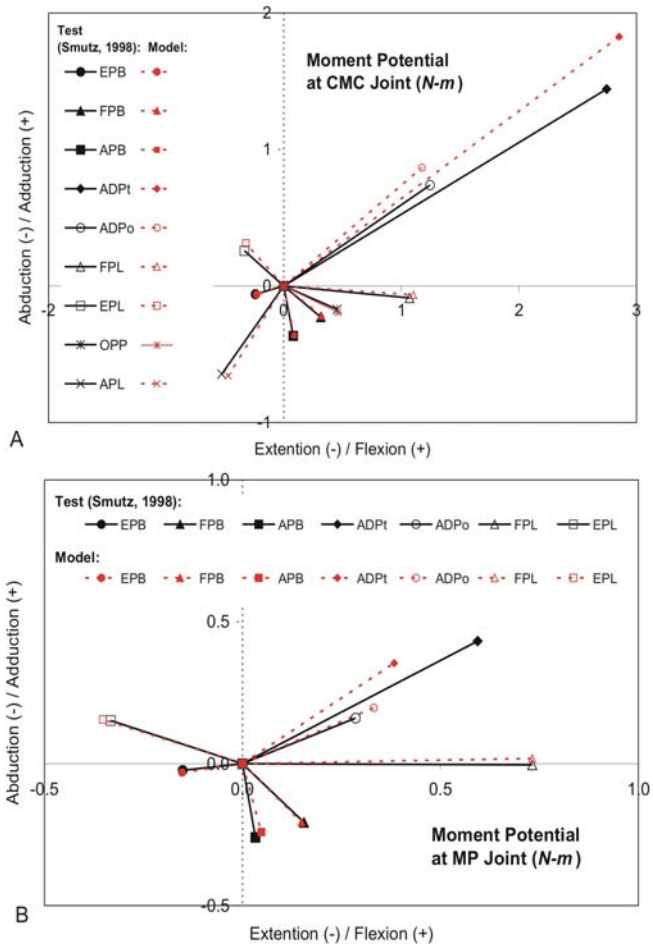


**Figure 2:** The predicted muscle/tendon moment potentials in CMC (A) and MP (B) joints compared with the experimental data by Smutz et al. (1998).

not shown). The calculated moment potentials of the MP and CMC joints using the current model were compared with the experimental data in Fig. 2. The muscle moment potentials were constructed using the averaged moment arms multiplied by their corresponding maximal isometric forces, which were evaluated by multiplying the physiological cross-sectional area (PCSA) by a specific muscle strength (35 N/cm$^2$). The diagrams illustrate the magnitude and direction of the maximal muscle moment that can be generated in each muscle.

## DISCUSSION

Except the ADPo muscle for both MP and CMC joint motions, all other calculated muscle moment arm potentials agree well with the experimental data. The abductor pollicis muscle has a large PCSA and is attached to the metacarpal bone and proximal phalanx in a region; however, it is modeled as a string and attached to the bony sections at points in the biomechanical model. The difference between the finger anatomies and model representations may contribute to the difference between experimental data and the theoretical predictions.

## SUMMARY

In the present study, we proposed a universal model to simulate the muscle/tendon excursions and moment arms in a thumb using the commercial software AnyBody. One of the important features of the proposed model over the previous studies is that the proposed approach can include the realistic bony geometries, such that the mechanical consequence of the variations in the attachment locations of the muscles/tendons can be investigated.

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