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THE INTERCROSSING FIBER BUNDLES OF THE FINGER EXTENSOR MECHANISM INFLUENCE THE MUSCLE FORCE TRANSMISSION

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Introduction

The extensor mechanism is a tendinous structure that plays an important role in finger function [1]. It transmits forces from several intrinsic and extrinsic muscles to multiple bony attachments along the finger via sheets of collagen fibers. How the forces from the muscles contribute to the forces at the attachment points and their changes with posture is, however, not fully understood [2]. In addition to the well-accepted medial and lateral bands [3], forming the extensor mechanism, there exist two layers of intercrossing fiber bundles (superficial interosseous medial fiber layer and deeper extensor lateral fiber layer), connecting them. In contrast to its common idealization as a minimal network of distinct strings, we built a numerical model consisting of fiber bundles to evaluate the role of multiple intercrossing fibers in the production of static finger forces and compared this more detailed model of the extensor mechanism to the idealized minimal network that only includes the medial and lateral bands.

Methods

We coded [4] a custom numerical environment that allows representing the extensor mechanism as contacting bundles of interconnecting fibers. Each string consists of a sequence of points, pairwise connected by elastic elements with a linear stress-strain model. This computational environment is written using MATLAB 2015 and C++. For a given vector of input muscle forces, it calculates the resulting net joint torques and fingertip wrench. Two models were compared: The first model was a full extensor mechanism model that includes multiple bundles of intercrossing fibers to approximate the known anatomical bands and sheets of collagenous tissue (full model); the second model was the baseline one, with no structures, connecting the lateral tendons with the medial one.

Results

We find the resulting fingertip force was lower for the full model than for trivial model for all postures for the same vector of input muscle forces. It was 31% lower in extension posture (metacarpal joint MCP = 10°; proximal interphalangeal joint PIP = 10°; distal interphalangeal joint DIP = 10°), 18% lower in mid-flexion (MCP = 45°; PIP = 45°; DIP = 10°), and 53% lower in flexion (MCP = 90°; PIP = 90°; DIP = 80°). The detailed analysis of the force distribution among the fiber bundles in full model showed force distribution among the fiber bundles vary with posture (Figure 1). We showed that force in interosseous medial fibers

(shown in red) attained the maximal value in mid-flexion posture; it was 34% higher than in extension, and 36% higher than in flexion. The forces in extensor lateral fibers arrived to maximal value in flexion posture: it was 25% higher in this posture than in extension and 40% higher than in mid-flexion.

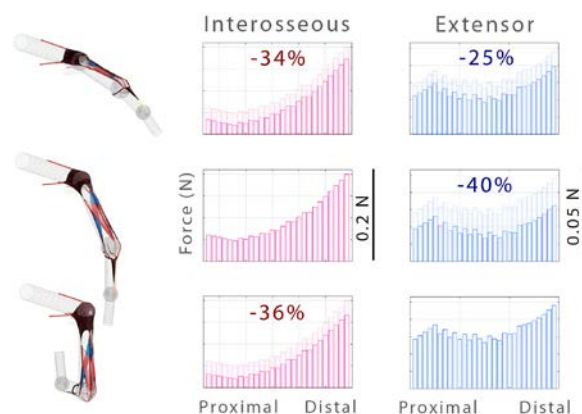


Figure 1: The full model of the extensor mechanism and the simulation results showing the force distribution in interosseous medial (red) and extensor lateral (blue) fibers according to the posture.

Discussion

Our detailed simulation showed that including bundles of intercrossing fibers strongly affects force transmission, which itself depends on finger posture. Output fingertip force produced by full model was lower than the force produced by the trivial model, in which there are no connections between the medial and lateral bands. We have shown that the bundles of intercrossing fiber can modify the force distribution according to posture. This may indicate that the nervous system has to modulate the sharing in involved muscle and intensity according to the finger posture in order to produce the wanted fingertip force.

References

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