VERIFICATION OF MUSCLE-TENDON PATHS FOR INTERACTIVE, 3-DIMENSIONAL COMPUTER SIMULATION OF THE EXTREMITIES

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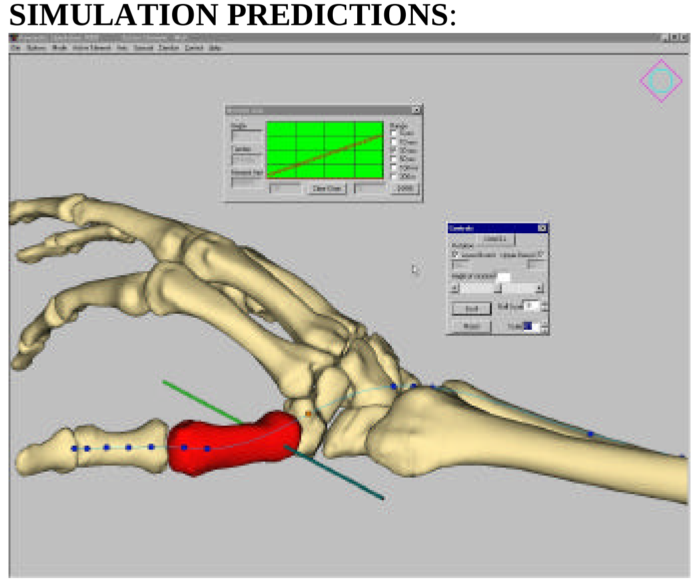
INTRODUCTION:

Simulation of musculoskeletal kinematics as a tool for the study of functional anatomy, a predictive research tool, and for computer assisted prosthesis design or surgery is a rapidly growing area in biomechanics research and development. Realism has been increasing at a rapid rate as imaging resolution, 3_D structural development and kinematic modeling capabilities improve. However, the accuracy of such modeling efforts should not be taken for granted and researchers in the field must continuously concentrate upon experimental verification of the component models in their simulations. This report concentrates upon verification of muscle-tendon path models developed for a 3-D simulation of the extremities through the comparison of muscle moment arms generated by the simulation with those measured in fresh cadaver experimentation.

METHODS:

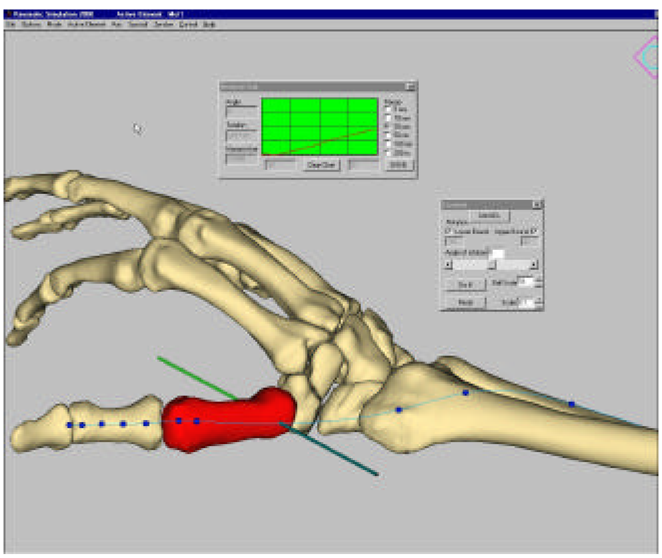
Using the simulation described in [1], hypotheses are tested for several proposed muscle-tendon-joint models by interactively rotating a given joint through its range-of-motion, and observing/recording the calculated moment arms of the muscles crossing that joint. This study undertook experimental verification of the normal moment arm for the extensor pollicis longus (EPL) to the thumb (at the CMC joint), and the moment arms following release of the EPL from its distal radius pulley (Lister's tubercle). Moment arms are derived from tendon excursion – angular motion data as the derivative of excursion with respect to angle.

SIMULATION PREDICTIONS:



The figure above is a captured image from the upper extremity simulation depicting the path of the normal EPL muscle/tendon unit when modeled as a B-spline curve through a few anatomical control points (highlighted as blue spheres). The tendon exits the forearm at Lister's Tubercle on the dorsal surface of the distal radius and courses directly to a soft tissue pulley structure at the distal end of the first metacarpal (this bowstringing action forms the dorsal part of the “snuffbox.” – the extensor pollicic brevis forms the more volar part).

The following figure is the same for the path of the EPL released from the pulley structure of Lister’s tubercle. The simulation predicts a significantly reduced moment arm for the released EPL throughout the abduction-adduction range-of-motion. In both, the moment arm is minimum at full abduction and increases as the tendon bowstrings during adduction. The moment arm is calculated and displayed (see the upper center graph) in real-time as the joint is rotated using the mouse controlled slider (in the box to the right above the radius and ulna).

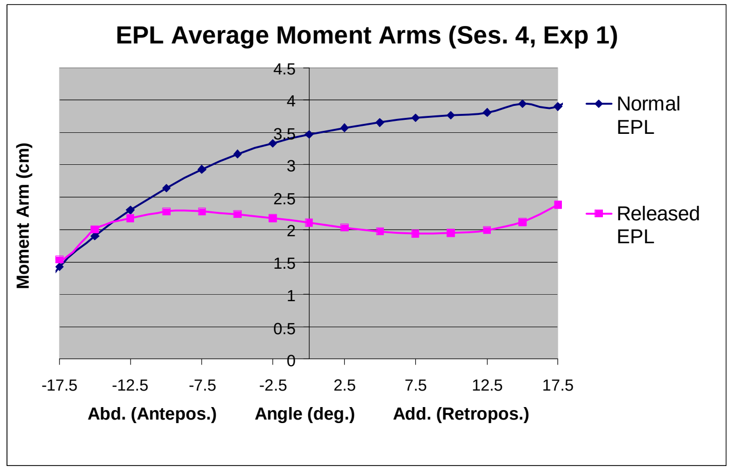


EXPERIMENTAL RESULTS:

The moment arms determined in a single fresh cadaver experiment for the normal and released EPL are depicted in the folowing figure (EPL Average Moment Arms). Note that the moment arm decreased nearly 50% following release from the pulley point(at Lister’s tubercle).

CONCLUSIONS:

The simulation predicted a reduction in moment arm for the released EPL to 25%,



50%, and 75% of the normal EPL at full adduction, mid-range and full abduction respectively. Experimental results confirm the bowstringing (increasing moment arm with adduction) seen in the simulation prediction. However the experimentally released EPL does not exhibit bowstringing. The experimental moment arms exhibited less bowstringing in adduction motion than that of the simulation. The extension moment arms agreed in magnitude and had similar bowstringing, suggesting that another soft tissue constraint should be considered in the B-spline model for abduction-adduction at the CMC joint. Future work includes continued experimental validation and investigation of varied blending functions for improved muscle/tendon B-spline paths.

REFERENCE: [1] Buford, W. L., Jr., Andersen, C. R., Elder, K. W, Pickard, J.M., and Patterson, R.M., **Proceedings**, VIIth International Symposium on Computer Simulation in Biomechanics, Aug 5-7, 1999.
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