PREDICTING THUMB FORCE CHANGES WITH ULNAR NERVE IMPAIRMENT

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INTRODUCTION

There is no "gold standard" to objectively and sensitively quantify the impairment in 3D force-production caused by palsies. For example, in nerve entrapment syndromes leading to low ulnar or low median nerve palsies, clinicians must prescribe treatment based on sensory tests, the patient's reported clumsiness in grasp, and measures of maximal force in one or two directions. As each muscle uniquely contributes to the force-production capabilities of a digit (Valero-Cuevas, 2002), measuring the magnitude of thumbtip force in a variety of 3D directions may be informative of the impairment level.

A thumb's *Feasible Force Set* (FFS) represents the relative force production in every 3D direction (Figure 1). The size and shape of this polyhedron will naturally change with impairment (Valero-Cuevas, 2002). The FFS is directly calculated by combining all possible combinations of muscle forces. The goal of this study is to use the actions of thumb muscle measured in cadaver hands to calculate the 3D FFS and its changes with complete low ulnar and low median nerve palsies. This approach avoids assumptions needed in biomechanical models, and the confounding effects of adaptive strategies and muscle control variability in live people.

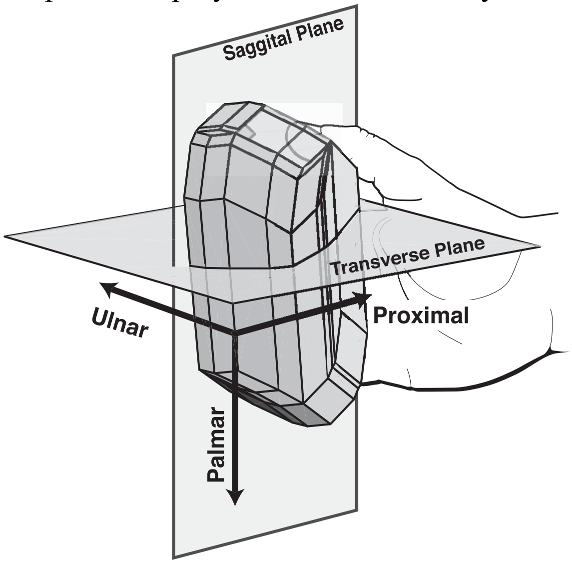

Figure 1: A FFS and Two Planes of Interest.

METHODS

Nine fresh-frozen cadaver hands were dissected, and nylon strings fixed to the following muscles: *abductors pollicis brevis* and *longus* (AbPB, AbPL), *adductors oblique* and *transverse* (ADDo, ADDt); *first dorsal interosseus* (DIO); *extensors pollicis brevis* and *longus* (EPB, EPL); *flexors pollicis brevis* and *longus* (FPB, FPL); *opponens pollicis* (OPP). The hand was mounted to a custom-fixture and the thumbtip rigidly fixed to a six-degree-of-freedom load cell (ATI Nano17, Apex, NC). The nylon strings joined each muscle's tendon to its own stepper motor via a spring. The computer-controlled motors pulled each tendon to one-third of its maximal force while the others were slack in both key and opposition pinch. Nine hands yielded data sets for key pinch, and 6 yielded data sets for opposition pinch (Pearlman et al., In review) Assuming linear scaling, the convex hull of the data is a one-third scale FFS of the thumb.

Changes in the FFS were calculated for each palsy by omitting the contributions of the affected muscles (low ulnar nerve palsy: ADDo, ADDt, DIO removed, FPB reduced to 50% of the intact case; low median nerve palsy: AbPB and OPP removed, FPB reduced to 50% of the intact case). The transverse and saggital cross-sections were selected for further study. Each FFS was appropriately "sliced" and its area and aspect ratio (characterized by the ratio of its principal moments of inertia) calculated in MATLAB (The MathWorks, Natick, MA). We compared these cross-sections across conditions using an Analysis of Variance followed by Tukey's post-hoc procedure in SPSS (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

For the transverse plane, the area of the cross-section did not change with any impairment in key pinch, (p=0.646), but did in opposition pinch (p=0.024), though the palsies were not distinguishable form each other (p=0.996). For the saggital plane in key pinch, the area of the low ulnar palsy cross-section was statistically different from the other two cases (p=0.00031). In opposition pinch, this plane can distinguish the low ulnar palsy from the intact case (p=0.033), but cannot tell either from the low median nerve palsy (p=0.390).

The aspect ratio of the transverse cross-section of the FFS is insensitive to posture for all cases (p>0.422). The aspect ratio of the saggital cross-section is sensitive to posture for the low ulnar nerve palsy only (p=.048). In addition, the aspect ratio of the transverse cross-section can distinguish the median nerve palsy case (p=0.013) regardless of posture. The saggital cross-section aspect ratios statistically distinguish between the low ulnar and low median nerve palsy cases (p=0.018), but neither from the intact case (p=0.662). Slight variations in hand posture could have clouded these differences in the FFS.

This study is limited in that it assumes that thumb muscle actions scale and superimpose linearly. Our goal was to simulate the worst-case FFS changes with complete palsies to guide the development of clinical measures of force impairment. We expect that the sensitivities to impairment found are robust against the system nonlinearities.

The transverse cross-section's sensitivity suggests that measuring it in patients may be an objective and sensitive measure of partial and evolving decrements in force production, as in nerve entrapment syndromes. The results of this study motivated and guided the development of a clinical method to quantify changes in force production in palsies affecting the thumb.

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