IDENTIFICATION OF FINGER FORCES OVER RANGES OF MOTIONS: A COMPARISON BETWEEN HEALTHY AND REDUCED HAND FUNCTIONALITY PARTICIPANTS

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Introduction

Diagnosing the amount of hand function lost due to injury, arthritis, or nerve damage is currently task-based and subjective to the clinician [1, 2]. Recently, work has modeled the differences in kinematic finger space between hands with and without reduced functionality due to arthritis [3]. This model includes the full range of motions for each finger; however, the forces that each finger can produce at each posture are not included.

Both motion and forces associated with each finger posture are necessary to generate a comprehensive hand model for clinical use. Such a model will result in a tool for clinicians to easily compare changes in hand function and finger strength pre- and post-rehabilitation, treatment or surgical intervention.

Thus, to achieve this comprehensive model, the forces that can be applied over various finger postures must first be quantified and compared. The goal of this work was to map forces associated with the index finger at different positions and orientations within the kinematic fingertip workspace of participants with and without reduced hand functionality.

Methods

Twelve participants (average age 26.5 years, SD 5.99 years) without any reported injury or arthritis, termed “Healthy”, and fifteen participants (average age 73.5, SD 4.81 years) with doctor diagnosed arthritis, termed “Arthritic”, were included in this study.

The maximum forces of the index finger were measured in two tests. In-plane forces (no adduction on the U-shaped device) were collected with the task of pushing or pulling with the index finger from the center to different positions on the device. For in-plane motions, the U-shaped device was moved in toward the participant resulting in 7 different positions (line 1-7).

Figure 1: Healthy and Arthritic data. Experimental setup and force data for in-plane push (A, D), in plane pull (B, E) and out-of-plane (C, F) motions with standard error of the mean. For in-plane motions, the U-shaped device was moved in toward the participant resulting in 7 different positions (line 1-7).
or abduction of the finger) measured differences by using a “U-shaped” metal bracket placed in seven positions along a line, each a half inch apart. This set-up was developed to measure the maximum forces related to changes of finger flexion. Each participant was asked to press down on the bracket with their maximum load (Figure 1A) then pull the bracket with maximum load for each position (Figure 1B). During data collection participants were asked to continually grip a cylindrical handle to isolate the finger forces and to maintain a consistent orientation of the wrist.

Out-of-plane maximum finger forces were measured at each of six positions to determine force differences related to abduction/adduction. Three of the positions were at maximum extension and the other three positions were at moderate flexion of the interphalangeal joints (Figure 1C).

Results/Discussion

Using a two-way ANOVA, several differences were identified in the finger forces. Overall, the forces of Arthritic participants were less than those of Healthy participants (p<0.001). Neither the Healthy or Arthritic groups showed differences in the forces perpendicular to the palm (push) with varying amounts of finger flexion or extension, p=0.967 (Figure 1D). While there was no statistical significance, there was a visible trend showing maximum applicable force for the pull motions at position 4 (Figure 1D). Both push and pull forces varied with respect to abduction/adduction. In both Healthy and Arthritic groups, maximum forces were lower with abduction (left) and increased with adduction (right). While not statistically significant (p=0.077), this is should be investigated with a larger sample size (Figure 1F).

Models overlaying these force data with the kinematic space were also successfully developed. Figure 2 shows the kinematic fingertip workspace for a single participant with the measured force directions and magnitudes represented by the vectors projected onto the sagittal plane of finger flexion. The color scale represents the sum of possible ways to reach that position with the finger tip, with red indicating the most possibilities. The forces pointing towards the top left represent the push motions and the forces pointing towards the bottom left represent the pull motions.

Subject specific modeling that includes both force generation and kinematics will allow for clinical comparisons pre-/post interventions. With the combination of motions and forces, these models will be robust tools for clinical assessment of the hand and fingers.

![Figure 2: Sagittal plane view of kinematic finger space for the index finger of a healthy participant with overlaid force vectors. The displacements of the workspace and force vector origins were measured from the center of the wrist with the vertical axis normal to the palm.](image)

Acknowledgments

The authors would like to thank the Pearl J. Aldrich Endowment in Aging Related Research for their funding as well as Wu Pan, Jessica Buschman, Jeffrey Hall, Eric Waldron and Anand Saripalli for assistance in capturing and analyzing data.

References