Simulations Capture Relationship between Upper Limb Posture and Thumb-Tip Force

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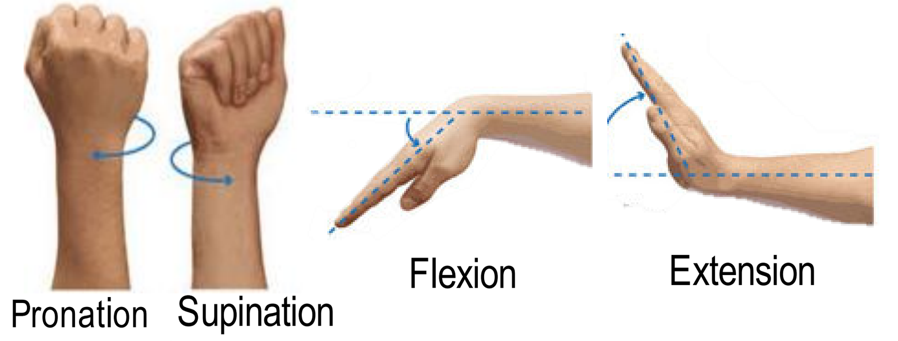
Introduction

Lateral pinch task while holding a key in neutral posture.

- The wrist and hand possess great versatility in grasping and manipulating objects, allowing humans to perform a variety of activities. However, forces generated by the hand during upper-limb tasks at various postures are not well understood [1].
- Simulations provide a unique tool to study how limb posture influences force generation, but simulations of force generation are typically run at a single, neutral posture.
- Understanding what postures result in excessive strength requirements can inform tool design and potentially prevent injury.

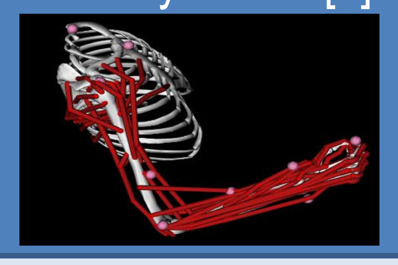
OBJECTIVE: To evaluate how **wrist and forearm posture** affect **thumb-tip force during lateral pinch** and compare simulated results with experimental literature in order to inform a model capable of predicting postures that require excessive strength inputs.



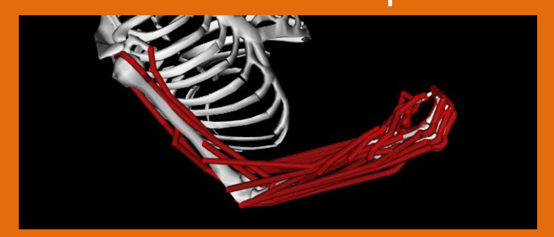
Wrist and forearm postures manipulated in this study.

Methods

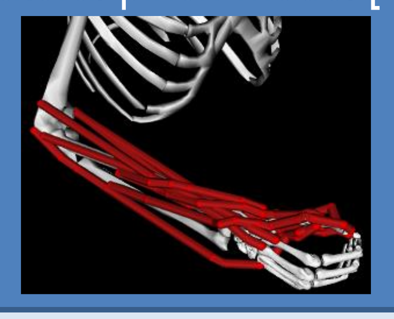
MoBL-ARMS upper extremity model [2]



Lateral pinch model with variable forearm and wrist posture



Lateral pinch model [1]



- A musculoskeletal model of the forearm, wrist, and thumb was created in OpenSim [v 3.3].
- This model importantly included 180˚ pronation/supination at the forearm and 140˚ flexion/extension at the wrist.

Model Creation

Target Posture & External Force Data → Computed Muscle Control (CMC) → Muscle Activations → Forward Dynamics (FD) → External pinch force vectors for 23 postures

- Simulations combined 5 forearm postures (-90˚ supination to 90˚ pronation in increments of 45˚) and 5 wrist postures (-60˚ extension to 60˚ flexion in increments of 30˚).

Simulations

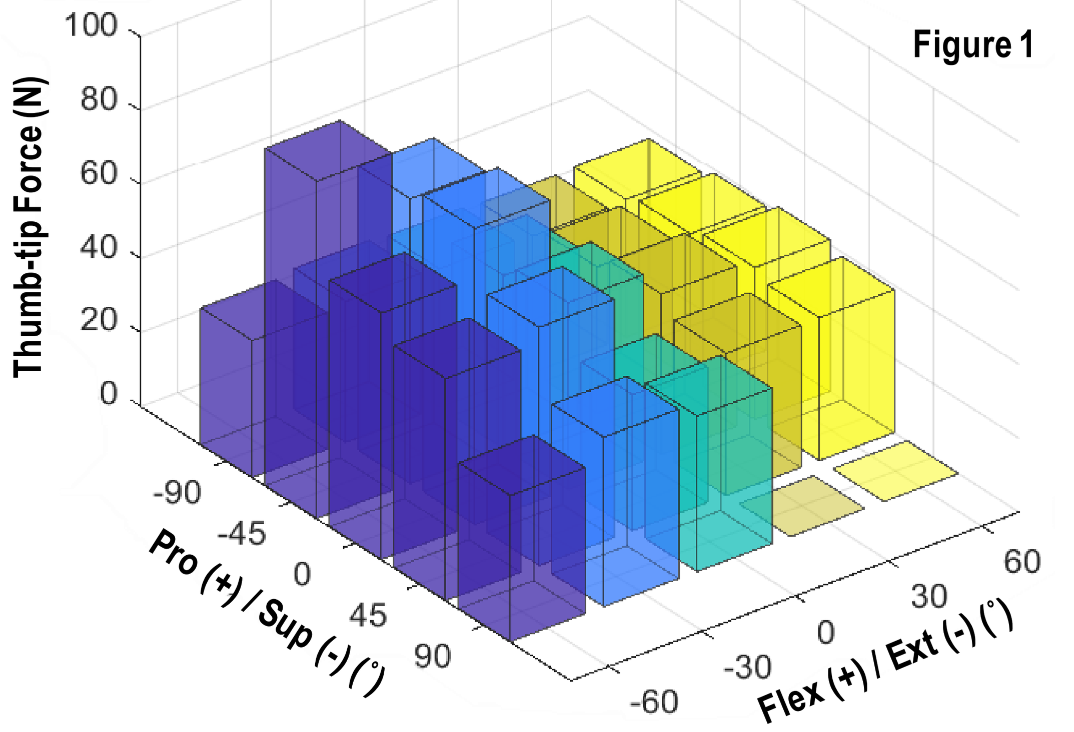
- For each posture, the maximum thumb-tip force magnitude was calculated and compared to reported experimental values [3, 4].

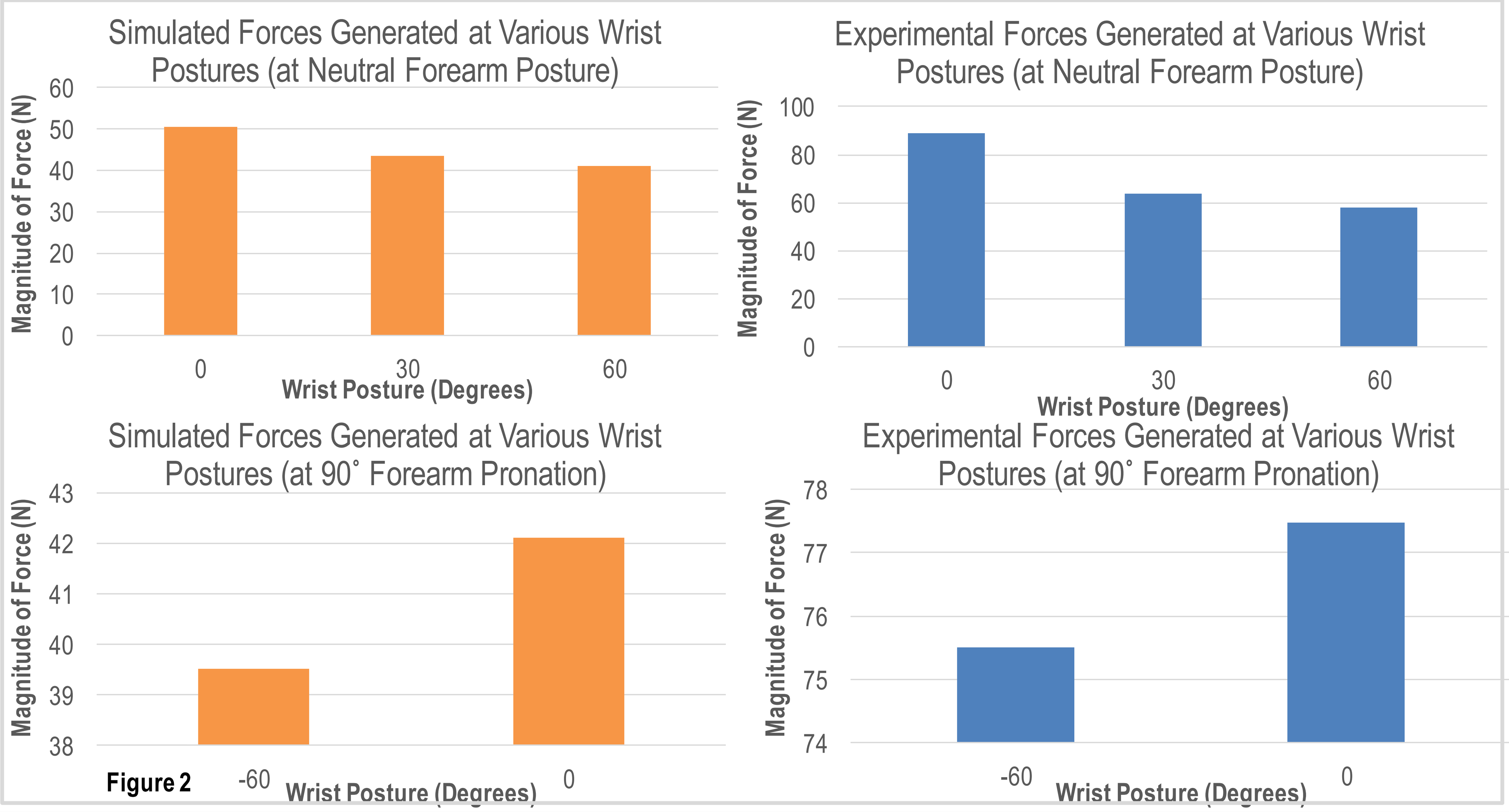
Maximum lateral pinch magnitude calculated for all postures; Force data from literature → Comparison

Analysis

Results & Discussion

- Maximum thumb-tip force magnitudes were plotted to examine the relationship between force and posture (Fig. 1).
- Simulations demonstrated **lower pinch force magnitude during wrist flexion** in forearm postures in the range of -45˚ to 45˚.
  - This result is exemplified by the **80% difference in pinch force between peak wrist extension and flexion at forearm 45˚ pronation**.
  - Validity of this result is supported by literature, which demonstrates up to a **40% decrease in pinch force between a neutral and flexed wrist posture** [3,4].
- Simulations demonstrated **neutral and supinated wrist postures resulted in up to 20% larger pinch strengths on average compared to pronated postures.**
  - This result is supported by experimental literature reporting the greatest pinch force in a neutral forearm posture [4].





- Comparing trends across postures between simulated and experimental results was another important part of the analysis (Fig. 2).
- Simulations demonstrated **a decrease in pinch force from neutral wrist posture to complete wrist flexion** at a neutral forearm posture.
  - The validity of this result is supported by literature, which demonstrates **a similar decrease in force generation** and asserts that flexion results in decreased pinch force [3,4].
- Simulations demonstrated **that an extended wrist resulted in lowered pinch force** compared to force generated in the neutral wrist posture at a forearm posture of 90˚.
  - This result is supported by experimental data reporting that **the greatest pinch force occurs at a neutral wrist posture [4].**
  - Data showing force generated during lateral pinch with a flexed wrist at a forearm posture of 90˚ was not collected due to inability to run simulations at these postures.

Conclusions

- Through our simulations, we demonstrate our model's ability to generate physiologically reasonable force data. This is an important step toward creating a model capable of predicting which postures result in suboptimal force generation.
- Our model indicates that changing wrist posture results in lower force generation. This greater force generating requirement relative to a neutral wrist posture is consistent with the literature [3,4].
- Future work will involve varying muscle activations across postures to further improve the model's predictive power.

References

[1] Nichols, et al. (2017) *J Biomech.* 58:97–104.

[2] Saul, et al. (2015) *Comput Methods Biomech Biomed Eng.* 18:1445-58.

[3] Imrhan S.N. (1991) *Appl Ergon.* 22(6):379-384.

[4] Halpern, et al. (1996) *J Hum Ergol.* 25(2):115-130.