# Evaluating Lateral Pinch Force Across the Lifespan through Scaled Musculoskeletal Models of the Hand

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## INTRODUCTION

- Musculoskeletal models of the hand have given us a deeper understanding of hand function, motor control, and joint loading.[1,2]
- Pinch strength is an objective index of upper limb function and is used clinically as an indicator for treatment and rehabilitation.[3]
- For a model to accurately represent the diversity of the population, parameters such as **age, biological sex, anthropometric measurements, and neuromuscular disorders** need to be incorporated.

### Types of Musculoskeletal Models

**Subject-Specific Models** [4,5]
- Improved accuracy
- Time and cost inefficient

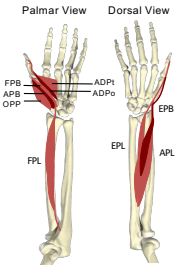
***Scaled generic models***

**Generic Models** [4,5]
- Represent average adult males
- Low accuracy due to individual variation in musculoskeletal geometry and tissue

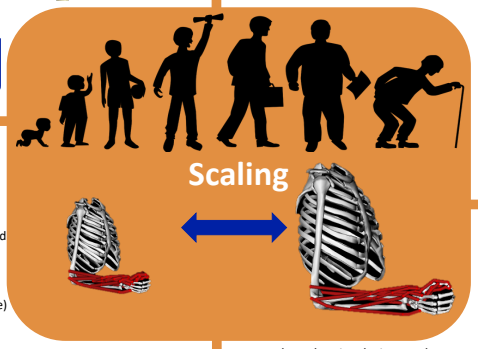
### Types of Scaling

**Linear Scaling** [6,7]
- Anthropometric measurements:
  - Height, weight, BMI
- **Assumption:** Force-size relationship is the same across individuals

**Nonlinear Scaling** [7,8]
- Digitization of medical images:
  - Computed tomography (CT)
  - Magnetic resonance imaging (MRI)
- Bone geometries and muscle volume meshes from cadaveric specimens




**Objective:** Evaluate how well scaled, generic, hand models performing pinch simulations represent differences in age.




## METHODS

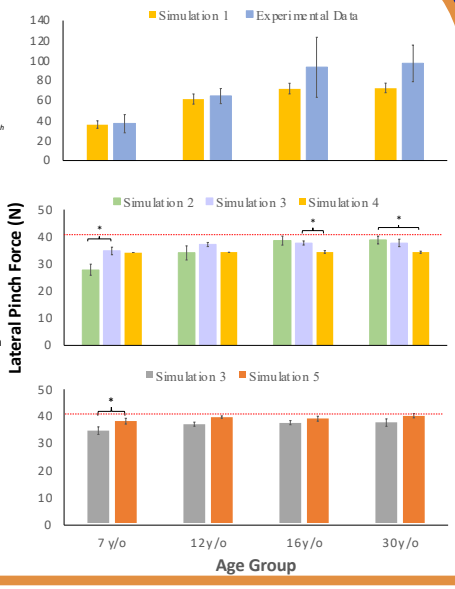
- *Musculoskeletal Models* [9]:
  - 9 extrinsic and 5 intrinsic muscles of the wrist and thumb
  - 6 degrees-of-freedom (2 at wrist and 4 across thumb)
  - Initial thumb position: 15° CMC extension, 20° CMC abduction, 20° MCP flexion, and 40° IP flexion
- *Scaling of Models:*
  - Scaled to represent the full range of heights (1st, 15th*, 50th, 80th, and 97th percentile) reported for four ages (7, 12, 16 and 30 years) [4].
- *Simulations:*
  - Lateral pinch force was measured for five sets of lateral pinch simulations using OpenSim (v. 3.3)
  - One-way ANOVA and Bonferroni procedure were used to compare simulation means for each color group (see below)

| *Comparison Groups* | *Maximum Pinch Strength* | | *Muscle Control Strategy* | | | *Linearly Scaling* |
|---|---|---|---|---|---|---|
| *Group Name* | Simulation 1 | Experimental Data | Simulation 2 | Simulation 3[a] | Simulation 4 | Simulation 5 |
| *Input Config.* | 50th percentile male control strategy & maximally activating the FPL | Articles that have measured muscle control strategy during lateral pinch task | 50th percentile male control strategy | Unique muscle control strategy for each model | muscle activations controlled to match data collected through EMG | Muscle control strategy after doubling the max. iso. force |
| *Target Force* | Unconstrained | Unconstrained | 40 N | | | 40 N |
| *Descriptive Name* | FPL Exclusive | Experimental Data | Customary Control Strategy | Age-matched Control Strategy | Literature-based Control Strategy | Double Isometric Force |
| *Desired Output* | Max force | N/A | Effect of muscle control strategies on force achieved | | | Relationship between scaling and force output |

[a] Simulation 3 was compared with the muscle control strategy and linearly scaled group

## RESULTS

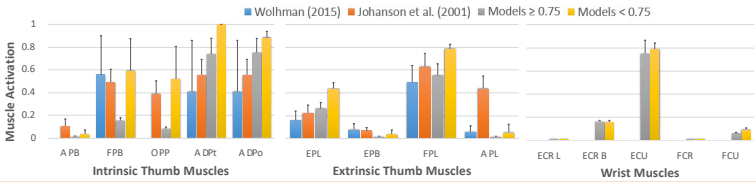
- Anthropometric scaling captured age-dependent differences in pinch strength
  - Simulations that *maximally activated the FPL* (Simulation 1) are not significantly different from the experimental data.
- Muscle activation strategies required to complete a task may shift as we age
  - 7 y/o model increased in pinch force from *50th percentile male control strategy simulations* (Simulation 2) to the *age-matched control strategy simulations* (Simulation 3).
- Simulations can follow a similar muscle activation strategy as literature-based data
  - The *literature-based control strategy simulations* (Simulation 4) were able to reach completion.
- Simulations did not employ the optimal muscle fiber length to complete a pinch task
  - Doubling the max. isometric force (Simulation 5) did not double the lateral pinch force




## DISCUSSION

Anthropometrically scaled generic hand models have the potential to elucidate changes in strength across the lifespan.

- Together, the simulations enhance our knowledge of when anthropometric scaling can accurately represents differences in age.
  - The majority of scaled models were able to replicate experimental data and ran to completion.
  - However, the smaller scaled models (< 0.75, corresponding to below 132 cm height) implemented an unrealistic muscle control strategy to complete the task (see ECU activation in figure below) or failed to run to completion.
- Differences between simulations and experimental data could be attributed to the fact that model scaling assumes a linear correlation between model parameters and anthropometric data.
- Future research could explore how to incorporate age-related changes in muscle strength and/or activation patterns in order to model older adults.




**ACKNOWLEDGEMENTS:** Funding from the National Science Foundation through the Florida-Georgia Louis Stokes Alliance for Minority Participation (FG-LSAMP) and BME Individual Travel Award are acknowledged

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