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

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Introduction: Generic musculoskeletal models have given us a deeper understanding of hand function, motor control, and joint loading [1,2]. Generic models typically represent an average adult male and can be scaled by anthropometric measures (height and weight) to represent individual subjects. Whether anthropometric scaling alone can generate accurate models of the hand that represent the full spectrum of strength profiles across the lifespan is unknown. Therefore, the objective of this study is to evaluate how well scaled generic models represent differences in age. We specifically examine to what extent scaled models that represent various heights across four age groups simulate lateral pinch strength, an important metric of hand strength.

Materials and Methods: Twenty lateral pinch simulations were performed using a generic model of the wrist and thumb [3] that was 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) across late childhood, adolescence, and adulthood [4]. For each model, two simulations were performed using forward dynamics in OpenSim v. 3.3. In the first simulation, the *flexor pollicis longus* (FPL) was maximally activated. Given that the relative contribution of FPL is more than 50% for lateral pinch [5], this simulation estimated maximum pinch strength. In the second simulation, the input was the muscle activation pattern necessary to produce a 40 N lateral pinch force in a 50th percentile adult male. This simulation examined to what extent an equivalent force could be produced with the same muscle activation pattern across all models. The maximum lateral pinch force from each simulation was analyzed, and results from the maximum pinch simulations were compared to published experimental data for each age [6-11].

Results and Discussion: The maximum lateral pinch force produced by the 12 and 16 y/o models was within one standard deviation of the experimental data, while that produced by the 7 and 30 y/o was not (Fig. 1A). Notably, for the FPL only simulations the largest difference (24 N) occurred between the 30 y/o model and the experimental data. 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; such uniform scaling may not be representative how muscle strength changes with age. The 40 N simulations demonstrated that given the same activation pattern not all modeled ages can produce 40 N (Fig. 1B). Interestingly, the 7 y/o models generated an average lateral pinch force of 29 N. Given that experimental data indicates that children can generate 40 N by age 7 and our maximum pinch simulations achieved a pinch force greater than 40 N for all ages, these results suggest that the assumed muscle activation pattern may be representative of adolescence and adulthood, but not childhood.

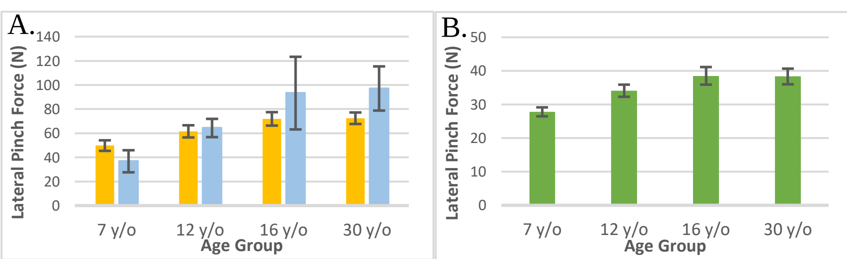

Figure 1. Lateral pinch force versus age for (A) the maximum pinch simulations (yellow) compared to experimental data (blue) and (B) the constant muscle activity simulations (green). Error bars represent standard deviation across height.

Conclusions: This work highlights the potential of using anthropometrically scaled generic models to study hand strength across the lifespan. This work also motivates future research to elucidate to what extent age-related changes in muscle strength and activation patterns influence hand strength throughout the developmental stages of life.

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References: [1] Mirakhorlo et al. 2018. *Comput Methods Biomech Biomed Eng*. 26:1-10. [2] Goislard et al. 2018. *Ann Biomed Eng*. 46:71-85. [3] Nichols et al. 2017. *J Biomech.* 58:97-104. [4] CDC. 2012. *Vital & Health Statistics*. 11. [5] Goetz et al. 2012. *J Hand Surg Am.* 37:2304-09. [6] Ager et al. 1984. *Am J Occup Ther*. 107-113. [7] Mathiowetz et al. 1986. *Am J Occup Ther*. 40:705-711. [8] Fain et al. 2016. *J Hand Ther*. 29:483-488. [9] Mathiowetz et al. 1985. *Arch Phys Med Rehabil*. 66:69-72. [10] Mohammadian et al. 2014. *Iran J Public Health*. 43:1113-22. [11] Smet et al. 2006. *J Pediatr Orthop*. 15:426-427.