Evaluating Anthropometrically Scaled Models of Lateral Pinch to Characterize the Pediatric Hand

Tamara Ordonez Diaz [1], Jennifer A. Nichols[1]
[1]J. Crayton Pruitt Family Department of Biomedical Engineering, Gainesville, FL, USA
Email: tordonezdiaz@ufl.edu jnichols@bme.ufl.edu

Summary

Musculoskeletal models provide a powerful approach for examining the human hand. We examined lateral pinch simulations using a generic model of the wrist and thumb anthropometrically scaled to represent heights reported across childhood, puberty, older adolescence, and adulthood. Results demonstrated the potential of anthropometrically-scaled generic models to study hand strength across the lifespan, while also highlighting that muscle control strategies may adapt as we age. We concluded that anthropometric scaling can accurately represent age characteristics of the population.

Introduction

Generic musculoskeletal models are often developed using average data from healthy adult males. Thus, subject-specific or scaled-generic models are needed to represent pediatric populations. To what extent scaled-generic models can accurately represent the spectrum of strength profiles across the pediatric population is unknown. The objective of this study was to evaluate the accuracy of these models by measuring maximum pinch strength, comparing muscle control strategies, and evaluating isometric force scaling.

Methods

Twenty models were scaled from a generic model of the adult wrist and thumb [1] to represent the full range of height (1st, 15th, 50th, 80th, and 97th percentile) for four ages: 7, 12, 16, and 30 years [2]. For each model, five lateral pinch simulations were performed in OpenSim v. 3.3. Given the contribution of the *flexor pollicis longus* (FPL) is more than 50% for lateral pinch [3], the first set of simulations maximally activated the FPL to simulate maximum pinch strength. Simulations employing different muscle control strategies (50th percentile male, age-matched, and literature-based) were then designed to generate the maximum force required for typical activities of daily living. The final set of simulations increased the maximum isometric force of all muscles by a factor of 2. The maximum pinch strength simulations were compared to published experimental data to identify if these models could represent the strength produced at distinct ages [4-9]. To examine how representative the generic muscle control strategy was, the effect of using various control strategies was evaluated. Doubling the maximum isometric force explored the force-length relationship between the muscle's isometric force and lateral pinch force achieved. Paired t-tests were performed to compare the maximum lateral pinch force across age groups for all simulations.

Results and Discussion

Anthropometric scaling successfully captured age-dependent differences in pinch strength during simulations that maximally activated the FPL (Fig. 1). However, the model's ability to represent the pediatric population is limited. The 7 y/o models failed to reach the target force of 40 N with all muscle control strategy simulations. Notably, the age-matched muscle control strategy simulations resulted in models activating the extrinsic thumb muscles similarly to published data, but the simulations also heavily relied on the wrist muscles to achieve the target force. Literature-based control strategy simulations failed to run to completion for models scaled below 0.75 corresponding to 132 cm (4 ft. 4 in.) height and showed no improvement for all other models. Linearly scaling the muscle force-generating capacity of all muscles resulted in a nonlinear relationship of maximum lateral pinch force achieved and maximum isometric force.

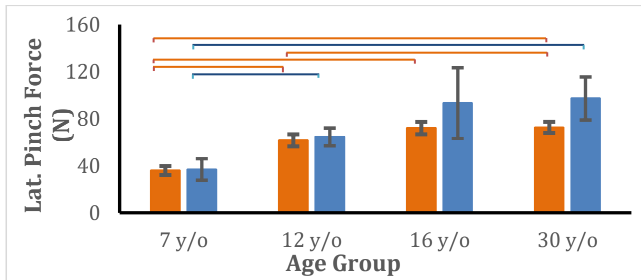

Figure 1. Lateral pinch force versus age for the maximum pinch simulations (orange) compared to experimental data (blue). Error bars represent standard deviation across height.

Given our simulations suggest that muscle recruitment may shift as we age, these models could be used to study how children adapt as their muscles develop and grow stronger. Our simulations were also able to highlight the complexity of the force-length relationship, and how it changes with age and task. The current simulation set-up prevented models younger than 7 y/o to reach completion. However, developing scaled-generic models to represent toddlers will further exemplify whether these results apply to the entire pediatric population.

Conclusion

Anthropometrically scaled hand models have the potential to represent the scope of strength profiles across the pediatric population. Modeling height difference with age is a critical step toward representing the full diversity of the population. This work motivates future research to elucidate how various musculoskeletal disorders and age-related changes in muscle strength and activation patterns influence hand strength.

References

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