Adjustment of Muscle Parameters in Elderly Musculoskeletal Models and its Impact on Muscle Activations and Metabolic Consumption

Josée Mallah and Luigi G. Occhipinti
Electrical Engineering Division, Department of Engineering, University of Cambridge, Cambridge CB3 0FA, United Kingdom
Email: jm2508@cam.ac.uk, lgo23@cam.ac.uk

Summary

Muscle parameters of a musculoskeletal model are modified to reflect muscle weakening due to ageing. This results in the increase of muscle activations, the total metabolic consumption and the energy expenditure of the hip adductors, hip flexors, and glutes, along with a reduced expenditure at the dorsiflexors and calves, which highlights the occurrence of an ankle-to-hip strategy in elderly.

Introduction

The number and proportion of older adults aged 60 years or more is expected to reach 2.1 billion by 2050 [1]. Ageing comes with a weakening of the body, changes in muscle mechanisms and loss of strength [2], and a higher metabolic cost of walking [3].

In this work, we modify the muscle parameters of a generic OpenSim model to better represent muscle contraction parameters of healthy old adults and observe the effects of these modifications in muscle activations and metabolic consumption.

Methods

Motion capture, force plate, and EMG data for 10 older adults are taken from [4] (3 males and 7 females, age: 78.1 ± 5.3 years, weight: 69.2 ± 10.0 kg, height: 160.0 ± 8.8 cm).

Muscle parameters in the Gait2392 OpenSim model were modified according to [2]: isometric strength was reduced by 30%, the maximum contraction velocity was reduced to 8 optimal fibre lengths per second, passive muscle strain due to maximum isometric force decreased to 0.5 for older adults, and deactivation time constant increased to 60 ms.

Scaling, inverse kinematics, inverse dynamics, residual reduction, and computed muscle control with metabolic probes were then executed on the Gait2392 model. Control constraints were used to better match the computed muscle activation to the actual EMG. Only the portion of the gait cycle between 15%-100% is considered, during which significant ground reaction force is present.

Results and Discussion

Table 1 shows the results for all subjects, the total metabolic consumption for the whole body increased on average by 4.7% in all subjects.

The energy expenditure of the hip adductors, hip flexors, and glutes always increases, with the highest increase happening at hip adductors (+136.2%). Conversely, the energy expenditure of the calves always decreases; dorsiflexors decrease the most on average (-90.3%).

Muscle activations always increase across all the considered muscle groups, with the highest increase being at the hip adductors (+174.3%), while the lowest increase is at the calves (+127.0%). Previously published work [5] reported a 67.3% increase in muscle activations in elderly.

These findings are compliant with literature data, whereby it is often suggested that the cost of walking increases with age, along with the 'distal-to-proximal shift' that occurs in elderly who tend to rely more on the hip rather than ankle muscles for propulsion and gait support. These adaptations, in turn, are responsible of the increased energetic cost, as plantarflexors are relatively low on energy due to the storage and release of elastic energy in the Achilles tendon [3].

Table 1: Total metabolic consumption (Watts) per subject.

Subject	Unmodified Model	Age-Adjusted Model	Relative Increase (%)
SUBJ01	484.01	490.32	1.31
SUBJ02	492.79	527.47	7.04
SUBJ05	367.22	372.75	1.51
SUBJ08	449.26	491.33	9.36
SUBJ16	622.38	657.01	5.56
SUBJ19	494.46	509.97	3.14
SUBJ22	462.36	485.02	4.90
SUBJ25	404.61	434.62	7.42
SUBJ26	509.06	517.22	1.60
SUBJ28	385.33	405.48	5.23
Mean	**467.15**	**489.12**	**4.70**

Conclusions

Age-adjustment of muscle parameters in musculoskeletal models is a valid model of ageing, and is better used for older subjects. It highlights the ankle-to-hip strategy used by elder population in gait control.

References

[1] World Health Organization (WHO), Ageing and health, 1 Oct. 2024, in https://www.who.int/news-room/fact-sheets/detail/ageing-and-health (accessed 25 Nov. 2024).
[2] Thelen DG. (2003) *J Biomech Eng*, **125**: 70-77.
[3] Boyer KA *et al.* (2023). *Exp Gerontol*, **173**: 112.
[4] Van Criekinge T *et al.* (2023), *Scientific Data*, **10**: 85.
[5] Hortobágyi T *et al.* (2011), *The Journals of Gerontology: Series A,* **66A**: 541-