The anatomical, biomechanical and functional impacts of healthy muscle ageing

James P Charles[1], Karl T Bates[1]
[1]Department of Musculoskeletal & Ageing Science, Institute of Life Course and Medical Sciences, University of Liverpool, Liverpool, UK
Email: j.charles@liverpool.ac.uk

Summary

Even in “healthy” ageing, significant changes in muscle structure and function occur. However, the effects of these changes on the fibre architecture of lower limb muscles—and their link to functional performance during dynamic movements—remain unclear. Magnetic resonance and diffusion tensor imaging assessed lower limb muscle architecture in young and healthily aged individuals, where significant differences in muscle architecture and function between age groups were identified. Musculoskeletal simulations further indicated that aged individuals experienced higher metabolic costs and reduced efficiency during walking. These findings lay the foundations for further work in identifying key targets for interventions to counteract muscle ageing effects and improve mobility, strength, and overall function in older populations.

Introduction

Muscle ageing is linked to structural changes, including shorter muscle fibres, reduced muscle volume, and increased intramuscular fat, all contributing to lower force output. Severe cases are diagnosed as sarcopenia, but even healthy ageing can lead to strength loss and reduced quality of life by increasing fall risk and susceptibility to lower limb injuries. However, the effects of healthy muscle ageing on the architecture of different lower limb muscles and their functional capabilities during dynamic movements remain poorly understood. Diffusion tensor imaging (DTI) offers an opportunity to quantify individual muscle architecture *in vivo* and has demonstrated significant differences in muscle structure between young and aged individuals [1]. When combined with predictive musculoskeletal modelling, these data allow for the investigation of the impacts of healthy ageing on subject-specific predictions of both whole-body and individual muscle functional performance.

Methods

10 healthily aged individuals (72.1 ± 4.61 years, 73.6 ± 11.1 kg) were recruited for this study. 10 young individuals (27.2 ± 3.68 years, 71.4 ± 8.92 kg), who provided a comparison to the aged individuals, were recruited as part of a prior study [2]. The lower limbs of each individual were imaged using magnetic resonance and DT imaging, to quantify individual muscle volumes, fibre architecture and phenotype. These data were used as inputs into scaled musculoskeletal models in Opensim [3], which were used to predict differences in joint kinematics, individual muscle dynamics and metabolic cost of transport during walking in young and aged individuals using MOCO [4].

Results and Discussion

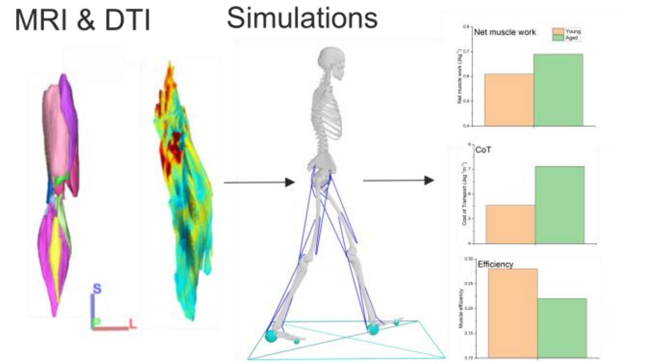

Figure 1. Young and aged anatomical inputs to predictive walking simulations reveal the functional consequences of healthy muscle ageing.

Significant differences in muscle architecture and fibre phenotype were found between the age groups. There was also a greater degree of heterogeneity in the aged population, particularly in metrics related to fibre phenotype. Walking dynamics in the aged populations were characterised by higher flexion at the hip joint (38° v 34°), higher net muscle work (0.68 Jkg^{-1} v 0.60 Jkg^{-1}), higher CoT (7.12 $Jkg^{-1}m^{-1}$ v 5.54 $Jkg^{-1}m^{-1}$) and lower muscle efficiency (0.22 v 0.28) (Figure 1).

Conclusions

These results highlight the degree to which muscle architecture, fibre phenotypes and gait dynamics are impacted by ageing, with healthy ageing negatively impacting functional performance even during low-demand tasks such as walking. Large-scale studies into the functional impacts of muscle ageing in various demographics using these methods have the potential to inform interventions which maintain mobility and quality of life in an increasingly ageing population.

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References

1. Charles et al. 2023. *Biology*
2. Charles et al 2020. *J Anat*
3. Seth et al 2018. *PLoS Comp Bio*
4. Dembia et al 2020. *PLoS Comp Bio*