ARE MUSCLE VOLUMES LINEARLY SCALABLE IN MUSCULOSKELETAL MODELS?

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INTRODUCTION

To represent various subjects, musculo-skeletal models are commonly scaled using simple linear laws, based on the subject's segment lengths. However, musculo-tendon parameters reported in literature vary widely and are often compiled from different cadaver specimens. Moreover, these properties are known to vary with age, gender and physical state of the subject.

The aim of this study was to compare four complete dataset of muscle volumes of the lower extremity, obtained from different sources, to estimate the potential effect of inter-individual variability on the error of anthropometric scaling. Our purpose was to compare the relative muscle volumes (as a % of the total volume), rather than absolute volumes that are known to differ a lot between subjects.

METHODS

The first dataset was the Twente Lower Extremity Model (TLEM) [Klein Horsman, 2007], based on an embalmed male cadaver (age: 77).

The second and third datasets were based on the dissection of two fresh male cadavers (age: 73 and unknown, respectively). Each muscle volume was measured using the water displacement method.

The fourth dataset was based on the MRI scan of a healthy male subject (age: 27). Each muscle volume was manually segmented using Mimic software (www.materialise.com) (Figure 1).

Each dataset was normalized by the total of the muscle volumes of the subject analyzed.

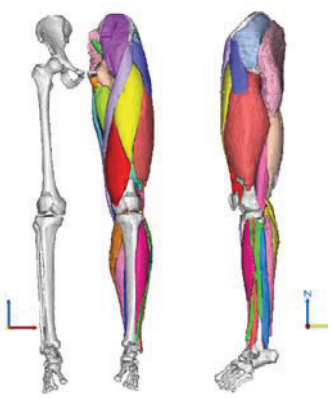

Figure 1: MRI-based muscle volume segmentation

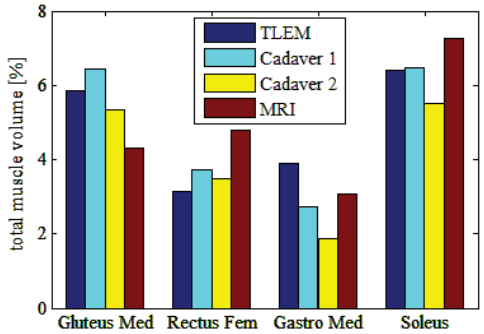

Figure 2: Normalized volumes of four prime mover muscles in the lower extremity.

RESULTS

The normalized muscle volumes showed a large relative variability between the four subjects (Figure 2). Since maximal isometric muscle forces are proportional to muscle volumes, model force predictions are likely to be affected by this variability, in particular when it concerns the prime mover muscles.

DISCUSSION

Anthropometric scaling of musculo-skeletal models, based on the subject's segment lengths, cannot account for all inter-individual variability in muscle volumes. Unfortunately, model force predictions typically use a force-sharing approach to divide joint moments over muscles, whose results depend largely on the relative muscle strengths, and thus on the relative muscle volumes. Therefore, scaling methods based on medical imaging techniques or measured strength profiles, by means of dynamometers, should be considered in order to develop reliable subject-specific musculo-skeletal models.

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REFERENCES

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