SUBJECT-SPECIFIC MUSCULO-TENDON PARAMETERS BASED ON MRI AND DYNAMOMETER TESTS

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INTRODUCTION

Subject-specific musculo-skeletal (MS) models are essential to reliably predict the effects of surgery on individual patients. Unfortunately, musculo-tendon (MT) parameters, which greatly affect model force predictions [1], are difficult to measure directly and are known to vary with age, gender and activity. The aim of this study was to estimate subject-specific MT parameters (tendon slack length, optimal muscle fiber length, and maximal isometric muscle force) of the lower extremity, by using functional scaling based on segmented MRI scan and dynamometer tests.

PATIENTS/MATERIALS and METHODS

We used the Twente Lower Extremity Model (TLEM) [2], implemented in the AnyBody Modeling System (version 5.1) (www.anybodytech.com). TLEM consists of 12 body segments, 11 joints and 21 DOFs, each leg containing 163 Hill-type MT elements. The model was scaled to one example subject. First, MT parameters were scaled according to the subject's height and weight. Second, muscle volumes were estimated based on a segmented MRI scan of the subject, using Mimics software (www.materialise.com/mimics). Third, MT parameters were optimized so that the model reproduced subject-specific strength profiles measured during a complete set of isometric and isokinetic maximal voluntary contractions (MVC), under the assumption that during MVC predicted muscle activity should be equal to 100% (Fig. 1).

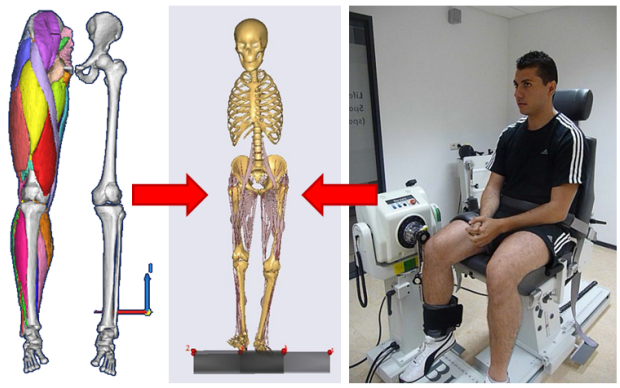

Figure 1: Subject-specific musculo-skeletal model (center) based on segmented MRI scan (left) and dynamometer tests (right).

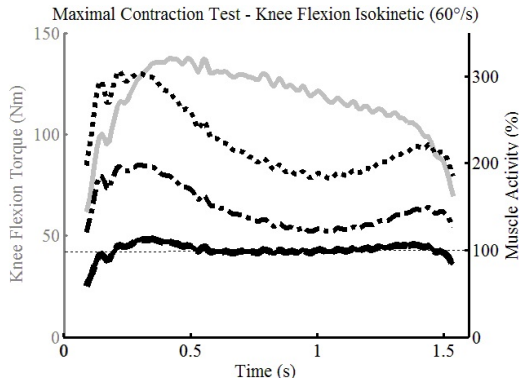

Figure 2: Knee flexion torque (grey) and knee flexor muscle activity (min-max criterion) after anthropometric (dotted), muscle volume (dash-dot) and functional (solid) scaling.

RESULTS

Model predictions became much more realistic after functional scaling. For instance, muscle activity necessary to reproduce measured knee flexion torque was too high after anthropometric (~300%) and muscle volume (~200%) scaling, but it improved drastically after functional scaling (~100%) (Fig. 2). Similar results were found for other joints.

DISCUSSION & CONCLUSIONS

The proposed functional scaling of MT parameters, based on MRI and dynamometer tests, was successful in achieving more reliable model outcomes, while simple anthropometric and muscle volume scaling were inadequate and caused unrealistic muscle activity prediction. Next, image-based muscle attachment sites will permit to further reduce errors in muscle force predictions [3] and hence improve the reliability of subject-specific model.

REFERENCES

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