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ARE DYNAMIC MEASUREMENTS NECESSARY FOR PARAMETER ESTIMATION OF THE HILL MODEL IN A SUBJECT-SPECIFIC MUSCULOSKELETAL MODEL?

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INTRODUCTION

Musculoskeletal models have now reached a state where we see a transition from more fundamental research towards applications within the clinical field and the industry. In particular models applied within the clinical field, a high level of subject-specific detail is required. Using imaging technology, it is nowadays possible to get a precise model of a specific person's bone geometry. However, it is much more difficult to obtain person-specific parameters of the Hill muscle-tendon model typically used in musculoskeletal models.

Imaging is not sufficient to measure an important parameter like tendon slack length; and even if it were possible, there is no direct relationship between the real anatomy and the parameters in the phenomenological Hill model. Heinen et al. [1] gave an overview of different methods to scale the parameters of the Hill model to an individual person. Using isometric and isovelocity measurements obtained from a dynamometer is one of the few options to get subject-specific parameters of multiple muscles crossing multiple joints, e.g. the muscles of the lower extremity. The disadvantage is that dynamometer experiments require much effort from the subject. This is especially the case for the isovelocity measurements. The aim is therefore to investigate if it is necessary to obtain a full isometric and isovelocity dataset of the joints of the lower extremity.

METHODS

One male long distance runner (height: 1,85 m, weight: 66,5 kg) was included in this study, which was carried out in accordance with the Loughborough University Ethical Advisory Committee guidelines. The isometric and isovelocity experiments were conducted for the ankle, knee and hip (flexors/extensors) of the dominant leg using a Contrex multi-joint isovelocity dynamometer (CMV AG, Switzerland) using a similar protocol as by Lewis [2]. A total of 21 isometric measurements were performed at different joint angles at the three joints. And a total of 22 isovelocity measurements were performed with different velocities at the three joints.

A lower extremity model was used based upon the TLEMsafe 2.0 model [3] using the AnyBody Modeling System (AnyBody Technology A/S, Denmark). The model was scaled based on anthropometric measurements. Each experimental condition was mimicked in the model to evaluate the joint strength of the model after which two optimization procedures were conducted using the SNOPT optimizer.

The first procedure (Isom-opt) minimized the difference between the experimental and simulated isometric joint strengths. The second procedure (Dyn-opt) minimized the difference between the experimental and simulated isovelocity joint strengths based on the results from the first optimization.

RESULTS AND DISCUSSION

Firstly, adjusting the Hill parameters using only the Isom-opt on the isometric experimental data resulted in a much better subject-specific model compared to a general scaling algorithm (Ref-model). The average RMS value between the isometric experimental data and the model decreased from 112.4% (Ref-model) to 15.5% (Isom-opt). Moreover, only using isometric data also leads to an improvement of the dynamic muscle characteristics of the subject-specific model. The average RMS percentage difference value between the isovelocity experimental data and the model decreased from 256.2% (Ref-model) to 192.3% (Isom-opt). Using the isovelocity experimental data together with the Dyn-opt procedure, the latter RMS value could be further improved to 157.6%. Figure 1 gives an impression of the effect of the different procedures on the hip extensors in the concentric phase.

The additional improvement using Dyn-opt is relatively small especially if one considers the extra experimental time, the extra computation time and the considerable load on the subject.

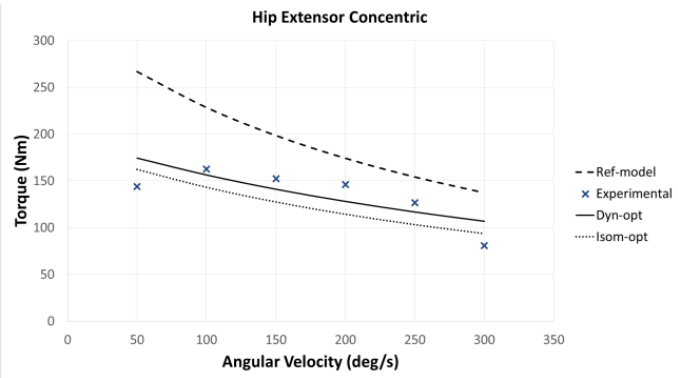

Figure 1: Concentric isovelocity joint-torque for the hip extensors experimental, Isom-opt predictions, Dyn-opt predictions and the reference model.

CONCLUSIONS

For general use, isometric measurements to obtain subject-specific parameters of the Hill model can suffice. This is particularly advantageous when dealing with patients. Highly dynamic applications with subjects who can tolerate the isovelocity experiments would would benefit from the use of the Dyn-opt procedure.

REFERENCES

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