Are dynamic measurements necessary for parameter estimation of the hill model in a subject-specific musculoskeletal model?

de Zee, Mark; Heinen, Frederik; Sørensen, Søren Nørgaard; King, Mark; Lewis, Martin; Lund, Morten; Rasmussen, John

Publication date: 2017

Document Version
Accepted author manuscript, peer reviewed version

Link to publication from Aalborg University

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

? Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
? You may not further distribute the material or use it for any profit-making activity or commercial gain
? You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.
ARE DYNAMIC MEASUREMENTS NECESSARY FOR PARAMETER ESTIMATION OF THE HILL MODEL IN A SUBJECT-SPECIFIC MUSCULOSKELETAL MODEL?

1Mark de Zee, 1Frederik Heinen, 1Søren N. Sørensen, 2Mark King, 3Martin Lewis, 1Morten E. Lund and 1John Rasmussen
1Aalborg University, Denmark
2Loughborough University, United Kingdom
3Nottingham Trent University, United Kingdom
Corresponding author email: mdz@hst.aau.dk

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.

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.

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.

REFERENCES