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Musculoskeletal modelling of elite handcycling motion: evaluation of muscular on- and offset

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Abstract

Handcycling, as a competitive sport, has been a Paralympic discipline since 2004 and is performed by handicapped athletes with impairments of the spine or brain. In this work a musculoskeletal model of a handcyclist is developed in the software AnyBody using kinematic data from a previous study of handcycling of one male elite handbiker (class: H3.2). The on- and offset timing of several muscles of the upper body (left and right of: m. pectoralis, m. deltoideus, m. biceps brachii and m. triceps brachii) were calculated with different thresholds and compared to results from surface electromyography (sEMG) measurements recorded during the previously mentioned subject study. It could be shown, that the mean overlap of muscle activation times was between a satisfying 64% and 75% depending on the threshold used. However, especially for m. deltoideus a very different on- offset behaviour was observed in the simulation than in the sEMG measurements resulting from the positioning of the electrodes in the subject study on one specific branch of the m. deltoideus and insufficient knowledge about the actual course of the crank torque for this specific athlete. Thus given sufficient accuracy of input parameters - musculoskeletal modelling could be used to predict changes in muscle activity timing for different handcycle setups.

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Keywords: handcycling, muscular timing, sEMG, musculoskeletal simulation

1. Introduction

Handcycling has been a Paralympic discipline since 2004 and is performed by athletes with impairments of the spine or brain. The propulsion of the front wheel results from a synchronous movement of two cranks turned by the athletes arms that is transmitted via a chain. Due to the similarity of the mechanical propulsion system, handcycling parameters are comparable to bicycle parameters. However, in contrast to bicycling there has been little research in handcycling in terms of parameters like sitting position, backrest height and crank height and length.

The main focus of previous research was on the effect of crank length and cadence on the power output [1], the differences between synchronous and asynchronous propulsion technique [2] and the influence of the backrest on

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the power output [3]. The influence of crank length, crank height and backrest height on muscular activities and kinematics were investigated for one elite athlete [4].

Musculoskeletal modelling has been used for the optimization of many parameters of human motion and sports equipment. De Jong et al.[5] used a musculoskeletal model to optimize seat height and distance as well as cadence for recumbent cycling. Holmberg and Lund[6] investigated the influence of different techniques in cross country skiing and Dubowsky et al.[7] used the approach in a medical application to minimize shoulder joint forces during wheelchair-propulsion.

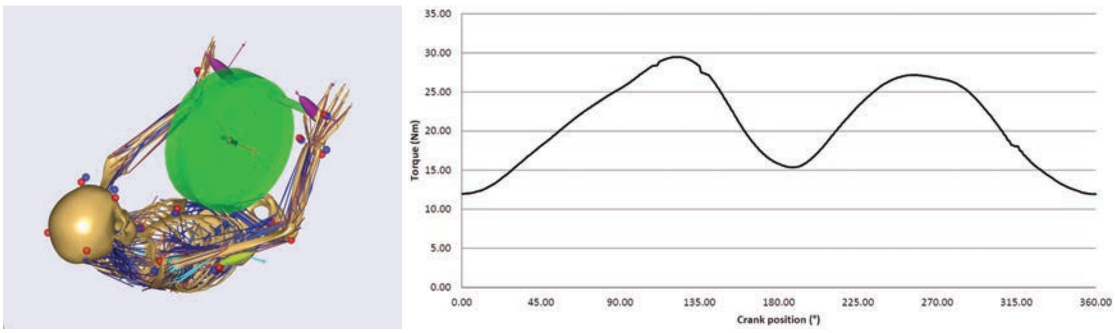
Whereas subject-studies always underlie a bias by the experience of subjects with standard parameters and lacking experience with new parameters. This can influence motion patterns, coordination and therefore measurement results. The solution to avoid those drawbacks can be musculoskeletal modelling. Musculoskeletal modelling has already been used to predict muscle forces under different settings, to perform motion optimization studies or to compare different algorithms [6,8–13].

The simulation of muscle activities has several advantages. Compared to experimental tests a validated musculoskeletal model is reproducible and independent from subjects. In case the simulation delivers promising results, the investigated parameters can be changed in real-life applications and tested experimentally.
The main reason why muscular activity is taken for the validation of the model is that it is easy to measure in comparison to other parameters. Compared to muscle-force or joint-moments, where special measuring equipment is needed for every motion, sEMG-electrodes can be easily placed on the muscles for almost all sportive motions.

In this study, an algorithm published in [14] is used for the computation of muscle activities of a motion capture driven handcycling model. The simulated muscle activities are compared to via EMG measured activities to validate the model. It was expected, that simulated muscular activity, in terms of muscular timing (i.e. on- and offset times of the muscles) is comparable to experimentally acquired data.

2. Methods and materials

The musculoskeletal modelling was done in the software AnyBody 6.0.5 (AnyBody Technology, Aalborg, DEN) by adapting the basic model *MoCapModel* from the AnyBody Managed Model Repository 1.6.3 (AMMR), for data analysis Matlab (V 7.11.0.548, The Mathworks Inc., Natick, USA) was used. The model is mainly driven by motion capture data, acquired in a previous study [4]. Some drivers had to be added in order to fix the model to the coordinate system and the modeled handbike.



(a) (b)

Fig. 1. (a) Musculoskeletal model of the handbiker including the environment, (b) Mean torque distribution over a crank-cycle (source:(b) [15]).

The AnyBody study consists of two sub-studies. The first study is a kinematic analysis that loads motion capture data from the c3d-file and optimizes marker positions and segment lengths according to the subjects segment lengths. From this study interpolation drivers are calculated which are used to drive the model in the inverse dynamic study, which is the second sub-study. The inverse dynamic study contains an environment including a handbike consisting of a frame, which is connected to the coordinate system, a crank and two handles, which are the connection between