EVALUATION OF MUSCLE RECRUITMENT AND MUSCLE MODELS IN MUSCULOSKELETAL SIMULATION OF DYNAMIC MOTION

Simon Auer (1,2), Lukas Reinker (1,2), Sebastian Dendorfer (1,2)

1. Laboratory for Biomechanics, Ostbayerische Technische Hochschule (OTH) Regensburg, Germany; 2. Regensburg Center of Biomedical Engineering, OTH and University Regensburg, Germany

Introduction

Musculoskeletal simulation plays an increasingly important role in sports biomechanics. In the last years, the field of application widened from orthopaedics and ergonomics to sports [1]. A muscle recruitment algorithm with a quadratic objective function is usually used to calculate muscle activity in dynamic movements. The agreement of calculated and measured thigh muscle activity has already been investigated [2]. They found a strong agreement for sprinting and running, while the correlation decreased for side-cutting manoeuvres. Nevertheless, the influence of different muscle recruitment criteria on muscle activity in dynamic musculoskeletal simulations is currently unknown. Hence, this study aimed to analyse the effect of different muscle recruitment criteria and muscle models on the correlation of numerical and measured muscle activity in highly dynamic movements.

Materials & Methods

For this study, 50 datasets per muscle from five amateur football players were captured. They performed five knee flexion (prone, 0°-90°) and extension (sitting, 90°-0°) movements for the left and right leg at an audio signal as fast as possible. The muscle activity of vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), semitendinosus (ST) was analysed. Muscle activity was measured via surface Electromyography (EMG) sensors (Delsys Trigno EMG, Delsys Inc., UK). Inertial motion capture (MVN Link, Xsens Technologies, NL) was used to record kinematic data. The numerical muscle activity was calculated with the AnyBody Modeling System (AMS, v. 7.3, AnyBody Technology, DK) with four different scenarios: simple muscle model with a quadratic target function for the muscle recruitment (S2), simple muscle model with composite target function (SC), Hill-type muscle model with quadratic muscle target function (H2) and Hill-type muscle model with composite target function (HC). The composite target function consists of a polynomial with infinite exponent and an additional quadratic term [3].

The measured and calculated muscle activity results were processed with Python (v. 3.7.6). Each muscle's activity was normalised to the maximum activity of the five left/right flexion/extension movements. The Pearson correlation coefficient r for numerical and measured activity was determined for each muscle. It was categorised as small ($r \leq 0.3$), medium ($r \leq 0.5$) or strong ($0.5 < r \leq 1$) [4].

Results

The overall correlation of measured and numerical muscle activity is strong for all muscles, although there are differences for flexor and extensor muscles. There is only a small influence of target function on the agreement of numerical and measured muscle activity. On the other hand, the Hill-type muscle model increases r up to 0.72 for the extensor muscles. Table 1 shows the mean r values of the four scenarios for the five muscles.

Table 1: Mean r of the muscles for the scenarios.

	S2	SC	H2	HC
VL	0.59	0.59	0.72	0.72
VM	0.58	0.58	0.72	0.71
RF	0.52	0.52	0.63	0.63
BF	0.67	0.63	0.60	0.57
ST	0.67	0.64	0.66	0.66

Discussion

This study aimed to analyse the effect of different muscle recruitment/model scenarios on the agreement of numerical and measured muscle activity in highly dynamic motion. The overall correlation of numerical and measured activity is strong, with r ranging from 0.52 to 0.72 regardless of the recruitment scenario. This corresponds with the findings of [2]. The target function barely influences the correlation regardless of the muscle model. The changes for the target functions are within the standard deviation. Hence, only the Hill-type muscle model improves the agreement of numerical and measured activity. This effect is limited to the extensor muscles, where the correlation rises from r=0.59 to r=0.72. In the flexor muscles, the Hill-type model does not increase the correlation or even lowers it slightly.

Nonetheless, the investigated movements are relatively simple flexion/extension movements, which might explain the low influence of the target function. However, the flexion/extension motions represent fast and reflex-like movements, which often occur in various sportive activities.

Overall, the Hill-type muscle model should be considered in highly dynamic movements. Furthermore, the data confirms the use of quadratic target function of the muscle recruitment algorithm.

References

1. Auer et al., Sci Med Football, 2020
2. Dupré et al., J Biomech, 84:73-80, 2019
3. https://anyscript.org/tutorials/MuscleRecruitment/
4. Cohen, Statistical Power Analysis for the Behavioral Sciences. 1988