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Influences of EMG-informed musculoskeletal simulation approaches on estimations of lower limb muscle and joint contact forces

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Background

Loadings acting on the locomotor system can be estimated through musculoskeletal (MSK) simulation. The generic models used in those applications can be personalized in various ways. Personalizing muscle parameters based on electromyography (EMG) signals and tracking EMG data to account for the subject-specific motor control has gained popularity in recent years [1], [2]. Various EMG-tracking toolboxes have been published for the MSK modeling environment of OpenSim [3]. Our aim was to investigate how estimations of muscle and joint contact forces in the lower limb are influenced by different simulation approaches, i.e. different personalization of muscle parameters and different EMG-tracking settings.

Methods

Walking and dance steps were performed by a professional female dancer and captured with a three-dimensional motion capture system (12-camera Vicon Motion Systems, Oxford, UK), five force plates (Kistler Instrumente AG, Winterthur, Switzerland) and a 16-channel EMG system (Cometa SRL, Bareggio, Italy).The model of Rajagopal et al. [4] was scaled to the anthropometry of the participant [5]. Inverse kinematics and dynamics were used to estimate joint angles and moments. Dynamic optimization [1] was used to run 136 simulations varying in three aspects - weighting properties of the objective function, muscle parameter estimation settings and muscles chosen for EMG-tracking - for each movement trial (one gait cycle and two different dance steps). Simulation results were compared within and between each movement.

Results

All three aspects, i.e. weighting, muscle parameters and chosen EMGs for tracking, had an influence on the results. Only small deviations between simulation approaches were observed for the walking trial. The two dance movements were however higher dependent on the EMG-tracking of vastus medialis and rectus femoris muscles as well as on the estimation of muscle parameter than the walking trial. Large differences of more than two times of body weight were found in peak hip and knee joint contact forces, which altered the interpretation when comparing the different movements.

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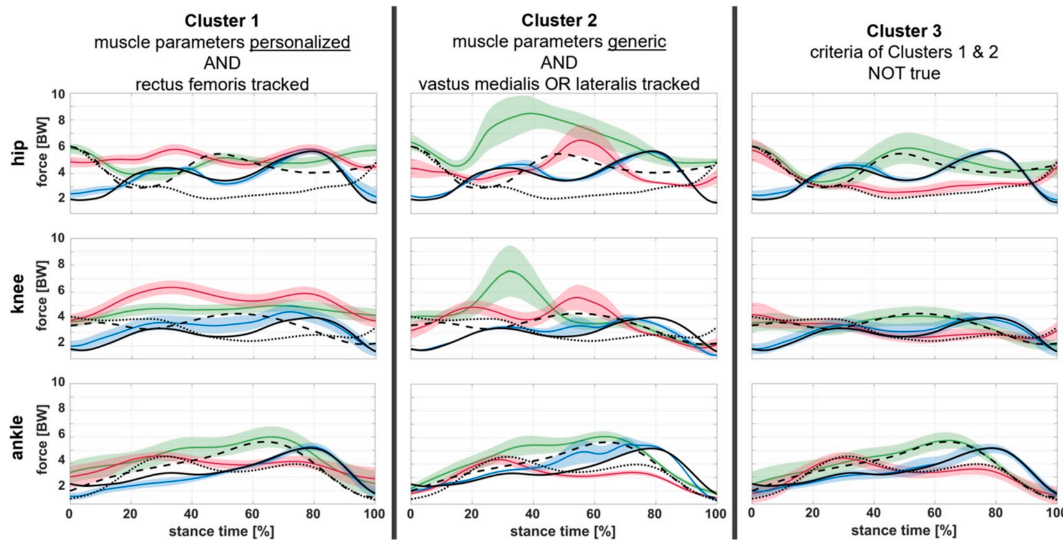

Resultant joint contact forces obtained from a single walking step (blue), dancing side step (red) and dancing cross step (green) based on different modelling settings and clustered into three simulation approaches (mean and SD, n = 42, 45 and 35). EMG-uninformed dynamic optimization (black: walk – solid, side step – dotted, cross step – dashed)

Conclusions

Settings in EMG-informed MSK simulations and muscles chosen for tracking can have significant influences on simulation outcomes. The impact of the simulation approaches on dancing steps was higher than on walking. Hence, we recommend the use of EMG-informed MSK simulations, especially when analyzing out of sagittal plane movements.

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