15th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
and
3rd Conference on Imaging and Visualization
CMBBE 2018
P. R. Fernandes and J. M. Tavares (Editors)

Abstract ID-180

UNCERTAINTY QUANTIFICATION IN JOINT REACTION FORCE ANALYSIS DURING A SIMULATED SQUAT ACTIVITY

Alexandra C. Vollenweider, Seyyed H. Hosseini-Nasab, William R. Taylor, Silvio R. Lorenzetti

Institute of Biomechanics, ETH Zurich, Switzerland
avollenw@ethz.ch, seyyed.hosseini@hest.ethz.ch, bt@ethz.ch, sl@ethz.ch

Keywords: maximum isometric force, muscle pathway, muscle properties, musculoskeletal modelling, pennation angle, tendon slack length, tibio-femoral force, uncertainty quantification

Summary: For a better understanding of total knee arthroplasty functionality, detailed knowledge of the loads applied to the implant and surrounding structures is crucial. Musculoskeletal (MS) models now open perspectives for the non-invasive assessment of in-vivo loading conditions, but such models remain limited in their predictive accuracy. Here, one factor affecting their joint reaction force (JRF) estimations is the uncertainty of the input parameters originating from inter-subject variability. These parameters can be assessed using probabilistic modelling, thus allowing studies to investigate the impact of muscle properties on JRF estimates. However, in addition to the lack of reliable data for model validation, such studies have generally been limited to level walking and cannot be generalised to activities involving deep knee bending. Within the recent CAMS-Knee project, detailed internal loading conditions (telemetry), whole body kinematics (Vicon) and ground reaction forces have become available for multiple subjects, and therefore now opens perspectives for understanding MS modelling inaccuracies.

The current study aimed to quantify the impact of uncertainties in muscle parameters on the JRF predictions of a scaled MS model while simulating weight-bearing knee flexion. Skin-marker trajectories and ground reaction forces were taken from the CAMS-Knee datasets for a subject performing squats. The input parameters (maximum isometric force (MIF), pennation angle, tendon slack length, muscle pathway) of twelve knee extensor/flexors were perturbed within the MS model (OpenSim) using Monte Carlo analyses in order to assess their impact on JRF distributions, which were compared against the measured in-vivo loads.

The results indicated JRF errors of up to 76% when compared to the known in-vivo forces. Probabilistic analysis revealed a relatively large variation in the maximum JRF output (SD= 13% of the max. JRF), when considering the combined effect of all sources of uncertainty. MIF of the semimembranosus and vastus lateralis were found to contribute up to four times more to the overall JRF variation than other studied parameters and were therefore identified as the most influential factors.

This study confirmed that uncertainty in muscle parameters can partially explain errors in the JRF estimates of a generic musculoskeletal model when simulating a quasi-static squat activity.