Robustness of musculoskeletal simulation in strength training

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Title:

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Abstract:

Introduction:

Musculoskeletal simulation software like OpenSim SimTK (Stanford University, Stanford, USA) offers many advantages such as the easy calculation of joint angles, joint and muscle forces of a strength exercise. However, to scale a model to subject's specific parameters such as the location of the joint centers (JC) as well as the way a musculoskeletal model should be run, is based on many input factors and mostly founded on users experiences. This input factors influence the kinematic and kinetic outcomes in a complex manner [1, 2]. Using different weightings of a data set to scale and run a simulation, the aim of this study was to quantify the robustness of a musculoskeletal simulation with respect of kinematic and kinetic measures during split squat.

Methods:

The data set consists of 3D kinematic and kinetic data of 11 subjects, 10 different types of execution of split squats with six repetitions [3]. Using OpenSim, inverse kinematics and dynamics were performed using 90 systematic different weighting concepts to scale and run the simulation. The concepts were created on altered skin marker weightings such as manual and automatic generated weightings based on skin marker artefacts, the in- or exclusion of functional defined centers of rotations (fCoR) and the in- or exclusion of pre-calculated joint angles by means of classical movement analyses [4]. Kinematically, the differences of the JCs as well as the differences in the range of motion (RoM) of ankle, knee and hip were compared to Schütz' data [3].As a kinetic parameter, the difference of the maximal external joint moment of knee and hip was chosen.

Results:

Kinematically, the results varied across the different concepts. The accuracy concerning the differences of the JCs was influenced with a factor of 5 across the different concepts. Values reached from 5.3 mm to 26.4 mm. Regarding the differences of the RoM of the movement, the values differed with a factor of 87 from 1.4% to 122%. Concerning the kinetic parameters, the values of the differences of the maximal moments differed from 0.07 Nm/kg to 0.23 Nm/kg.

Discussion/Conclusion:

This study quantifies the influence of weightings used in musculoskeletal simulation using 90 systematically different concepts with classical motion analysis. The outcomes differ with a factor up to 87 and show the importance of the right weighting systems to scale and run the simulation. For example, the inclusion of fCoRs in the scaling procedure of a model as well as in the running process of the simulation seems to be necessary to achieve accurate results. Therefore, the usage of fCoRs instead of just using anthropometric based data in a musculoskeletal simulation is highly recommended. Concerning the angles, the weightings of the skin markers and the in- / exclusion criteria of the precalculated angles seem to play a key role. Further on, the inclusion of all precalculated angles in the running process leads to similar RoMs compared to the classical analysis. Based on these outcomes, statistical analysis can be done to determine the right input parameter to achieve the most accurate result. Future research can then be performed to calculate muscle forces in strength exercises using an optimization process in a proper way.

References:

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