# Calculation of muscle forces and joint reaction loads in shoulder area via an OpenSim based computer calculation

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**Abstract** – In modern chirurgic science a bunch of alternative approaches exist for nearly any muscular injury. Therefore, it is desirable to find a way to calculate biomechanical values such as muscle forces, activations and moment arms or joint reaction forces. Due to the fact that there are more unknown muscle and joint forces than equilibrium equations the muscle forces are calculated by mathematical optimization with the objective function muscle power to be minimized under the constraints of moment equilibrium. This is followed by an inverse dynamics step and is enclosed in a loop of a muscle control algorithm [1]. To realize this calculation a musculoskeletal model of the upper limb was build and implemented in the OpenSim environment. OpenSim is a freely available tool for musculoskeletal modelling and movement simulations. It is published by the NCSSR (national centre for simulation and research, Stanford, USA) and is used by hundreds of research teams worldwide [2].
The used model of the upper extremity contains as well values of mass, inertia of all 9 bodies as their position and joints. It further more features a description of 10 muscles containing their path and possibly wrapping, as well as their maximal isometric force, optimal fibre length, tendon slack length, and possible activation to define their behaviour within the *Thelen* muscle model [3].
These values enable OpenSim to solve an inverse optimisation problem and calculation the respective muscle activations and forces that are necessary to perform a certain movement. With these forces OpenSim can further more calculate joint reaction forces in every included joint.

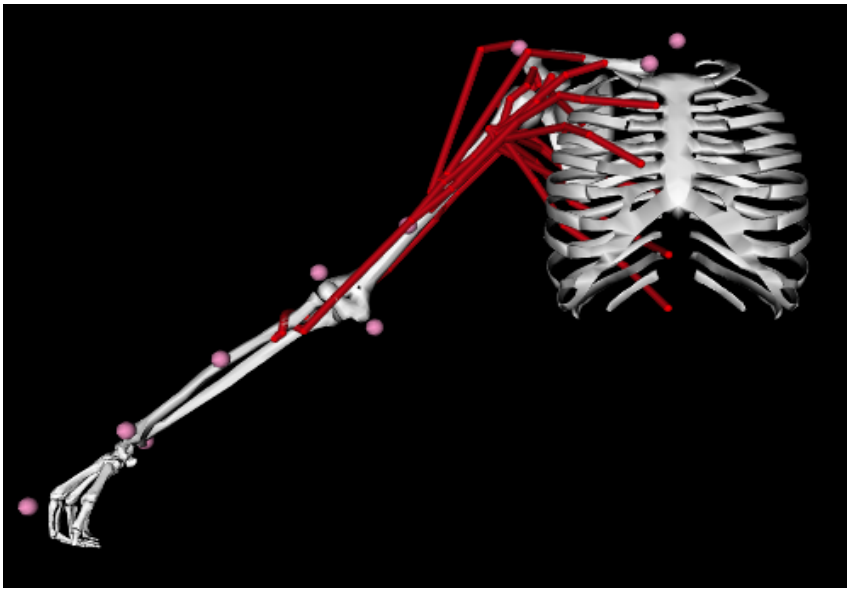

*Fig.1: The build musculoskeletal model in OpenSim*

With this model, the influence of changes regarding the insertion points of muscles was examined. To handle tears of the rotator cuff there are the approaches of reattaching the tendon more laterally or medially. By calculating the necessary muscle forces to perform an abduction up to 90° for situations in which the insertion points where shifted from 1mm to 5mm laterally or medially it was possible to find the optimal position for every of the rotator cuff muscles. This might help to unburden the respective muscles after an injury.

In addition, a calculation of the joint reaction forces provides information about how the changes influence the joint reaction forces. This gave us the possibility to draw a conclusion about the joint`s stability regarding to the biomechanical changes caused by the relocation of muscle insertion points.

By using a modified computational shoulder model the present research confirms that a medialised non-anatomical reinsertion of the supraspinatus muscle within a range up to 10 mm is biomechanical acceptable in regard to the supraspinatus moment arm. Nevertheless, it revealed that a medial shift of the insertion point of the muscle leads to a decrease of its moment arm and therefore a decreasing maximal moment which the muscle can contribute to arm abduction. It furthermore leads to a decrease of the compressive glenohumeral joint reaction force. This influences the glenohumeral stability in a negative way reducing the stability ratio (compressive force/ shear force).

Such a change in biomechanical stability of the joint leads to not only an increase of the force of the supraspinatus but also to such an influence on all muscles forces the of rotator cuff which are mainly responsible for joint stability during abduction.

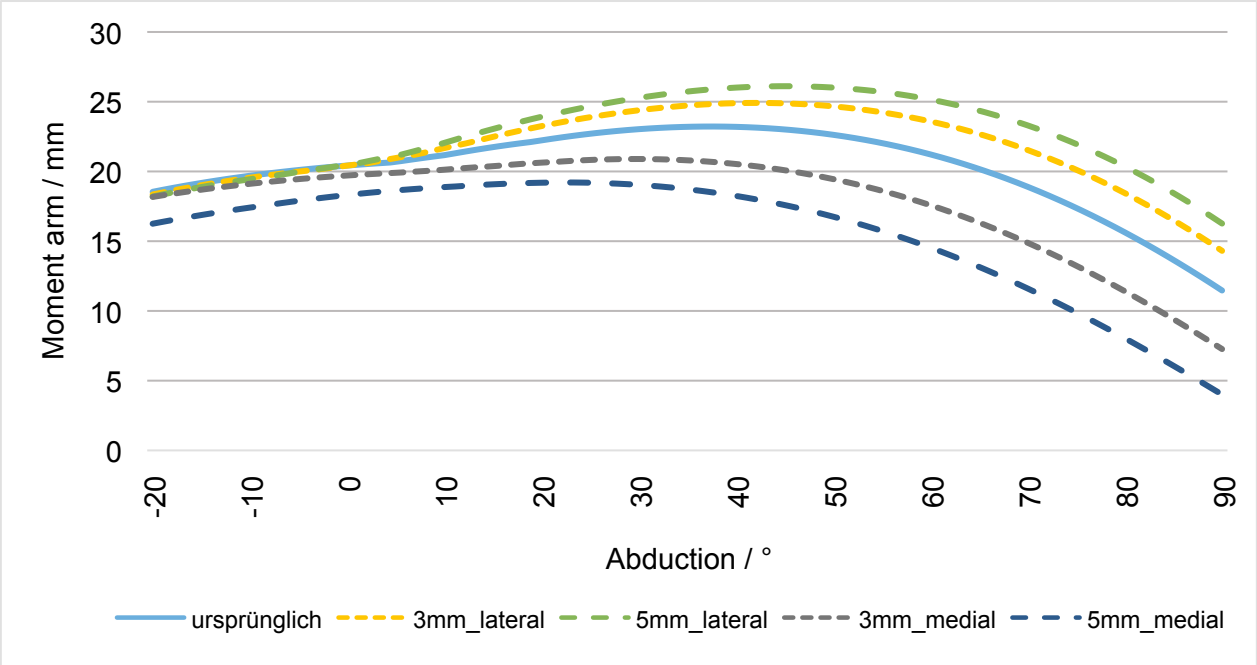


*Fig.2: Supraspinatus moment arm vs. abduction*

## References

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