# MORPHOLOGICAL MUSCLE AND JOINT PARAMETERS FOR MUSCULOSKELETAL MODELLING OF THE LOWER EXTREMITY

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## INTRODUCTION

To assist in the treatment of gait disorders, an inverse and forward 3D musculoskeletal model of the lower extremity will be useful that allows to evaluate *if-then* scenarios. However, in the current anatomical datasets no sufficiently accurate and complete information is available to construct a sufficiently valid model (e.g. [1]).

The aim of this project was the collection of a complete and consistent anatomical data set. This can be achieved by collection of the three-dimensional location of the rotation centre of the hip and rotation axes of the knee and ankle for joint modelling. For muscle modelling parameters are collected such as optimum length, PCSA, tendon/belly length, and force application parameters such as attachment sites described as point, line, or plane and wrapping surfaces for estimation of curved lines of action.

## METHODS & MATERIALS

One lower extremity, taken from a male embalmed specimen (age 77, height 1.74m, weight 105 kg), was studied. Position and geometry were measured with a 3D digitizer. Optotrak was used for measurement of rotation axes of joints. Sarcomere length was measured by laser diffraction [2].

The following steps were taken:

- Collection of anthropometric data of body segments for estimation of mass and moments of inertia.
- Placement of reference screws in 6 body segments (pelvis, femur, tibia, calcaneus/talus, midfoot and phalanges) for the definition of technical coordinate frames.
- Measurement of bony landmarks with respect to screws for definition of anatomical reference frames.
- Dissection of the muscles and ligaments.
- Measurement of attachment sites and underlying geometries.
- Estimation of kinematic axes and centres of rotation for the hip, knee and ankle. Therefore instantaneous helical axes and their optimal pivot point were determined for each joint using the recorded motion data of the associated segments.[3]
- Measurement of macroscopic and microscopic muscle parameters. Pennation angle and the actual length of muscle fibre and tendons were measured with the digitiser.

Optimal fibre length determined by multiplying the actual fibre length with the ratio of optimal and actual sarcomere length.

PCSA at optimal muscle length is calculated as the muscle mass divided by the density (assumed to be 1.056 g/cm$^3$), resulting in muscle volume and subsequently multiplied by the cosine of the pennation angle divided by optimal fibre length.

## RESULTS

A total of 40 muscles were measured. Each muscle was divided in different muscle lines of action based on muscle morphology. For muscles with large attachment areas (such as the gluteus maximus) up to twelve muscle lines of actions were defined. In case of a curvature around an underlying contour, a geometric shape (sphere, cylinder, ellipsoid) was defined, representing the underlying structure. In the model, the shortest distance between origo and insertion over the surface will describe the curved force path of the muscle.

13 Ligaments of the hip, knee and ankle were included and will be modelled as a straight line between point origin and insertion.

Kinematic joint center and axes were constructed from motion data. A reconstruction of the hip joint rotation center by calculation of the optimal pivot point is shown in Figure 1. The mean distance of each helical axis to the pivot point is 9.12 mm.

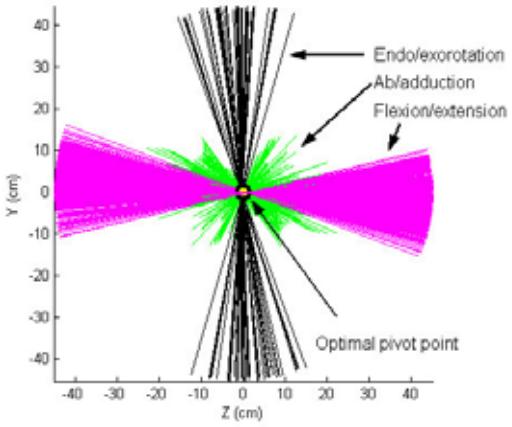


**Figure 1**: Frontal view of hip rotation centre, defined as the optimal pivot point, calculated with instantaneous helical axes of recorded hip rotations around three anatomical axes.

## DISCUSSION

We have now available a unique anatomical dataset comprising all necessary data for modelling. Implementation of these data into an (existing) model of the lower extremity is likely to significantly improve the estimation of muscle forces and will thus make the use of the model as a clinical tool more feasible.

## REFERENCES

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