# Development of a new CT scan based Foot-Ankle Multibody Model

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## Introduction

Multibody simulations of human motion have been widely applied in the orthopedic field, i.e. to predict the outcome of medical treatments [1]. These methodologies require representative models for the anatomical structures. The foot, being a highly complex structure has been extensively described by simplified kinematic [2] and to a lesser extent dynamic models [1], [3], [4]. However, a model that fully captures the complexity of the foot is still lacking. In the present work, a simple semi-automated tool used to construct a new 3D multibody foot-ankle model based on CT scans is described. The model consists of five rigid segments (Talus, Calcaneus, Midfoot, Forefoot and Toes), connected using eleven degrees-of-freedom (DOF's), defined for use with inverse kinematics and inverse dynamic procedures in Opensim [5].

## Methods

The semi-automated tool exists of a simple workflow that uses CT scans data to create the surfaces and volume meshes of both bones and soft tissue; From these, anatomical landmarks are selected, to allow the computation of the joint axes, segments origin as well as muscles and ligaments insertions [6]. The bone density is attributed according to the CT scans greyscale (in Hounsfield units) [7]. The soft tissue density is considered to be uniform (using *3-Matic*® and *Mimics*®). Based on this, the inertial properties, the total mass, the volume and the center of mass of each segment are computed [8] and assembled in an anthropometric datasheet (using *Matlab*). The model is then automatically generated using the *Matlab-OpenSim* interface. To test model performance, an integrated 3D gait analysis was used of one control subject, using the adapted marker set protocol of Duerinck by Burg [9]. This data was analyzed using inverse kinematic and inverse dynamic simulations in *OpenSim* [1].

## Results

Joint angles and joint moments for five DOF's more specific the ankle, subtalar and metatarsophalangeal joints are shown in Fig. 1. Furthermore, some less commonly reported variables such as joint angles and moments at the Chopart's and tarsometatarsal joints are presented.

## Conclusions

The proposed workflow allows the creation of a new generation of foot models that accurately represent the anatomical structure. The model-based inverse kinematic and inverse dynamic analysis of gait resulted in realistic kinematics and dynamics [4], [9]. Due to the more accurate representation of the degrees of freedom in the foot, this model has the potential to offer new insights in foot kinematics and dynamics. Future research will concentrate on updating the muscle and ligament parameters for use in forward simulations.

## References

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## Figures

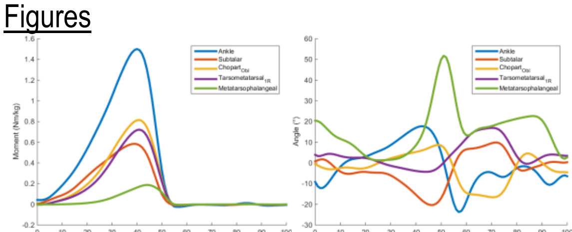


Fig. 1 – (Left) Kinematic Results – Joint Angles; (Right) Dynamic Results – Joint Torques.