3DOrthoTwin: highly automatic generation of subject-specific foot finite element models.

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1. Introduction

A digital twin consists of a virtual replica of a physical entity enriched with data. The ultimate goal of this technology is to detect issues earlier, predict outcomes more precisely, and help to make better decisions. This approach successfully used already in industry now is starting to be exploited in healthcare.

Twin models of patients are in the early stages of development. There are still many challenges to overcome starting from cost and reliability. The aim of this work is twofold: first, present an approach to generate subject-specific foot models that require little manual interaction and second, assess the reliability of the model predictions.

2. Methods

The subject-specific finite element model generation process consists of three highly automated phases: anatomy creation (geometrical model), muscle activation (multibody model), and gait simulation (finite element model). Each phase, in turn, is divided into two steps.

For the geometrical model, the anatomical data is segmented from a CT-scan of the subject. Then, the skeleton and the skin geometry is imported in a CAD software where the rest of the internal tissues are generated. For the multibody model, the gait kinematics and the ground reaction forces of the subject are measured in a gait lab using a motion analysis system. Then, the geometrical model and the gait kinematics are imported into a multibody simulation software to compute the muscular activation scheme of the subject. For the finite element model, the geometry, the kinematics and the muscular activation scheme of the subject are assembled together via a custom python code. Two loading cases are simulated: standing and gait. The model predictions are evaluated against subject measurements and *in-vivo* experimental values from the literature.

3. Results and Discussion

The standing simulation reproduces correctly the plantar pressure distribution, peak location and magnitude, contact area and, heel pad deformation, see Figure 1. The gait simulation matches the foot movement measured in the gait lab (Figure 2) and the measurements from the literature: the interosseous movement [1], the fascia elongation [2], the pad deformation [3].

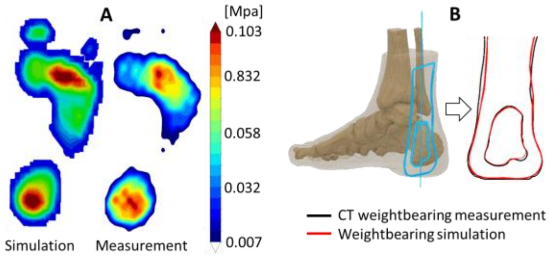

Figure 1: Simulation vs measurement of the subject. (A) Plantar pressure (B) heel pad deformation.

4. Conclusions

Here we present a highly automatic workflow that generates a finite element model of a foot based on subject-specific geometry and boundary conditions. The model demonstrates to predict accurately the foot *in-vivo* response of the subject.

Fast generation of reliable finite element models like the one described here, pave the way for personalized medicine and *in-silico* clinical trial applications at mass scale.

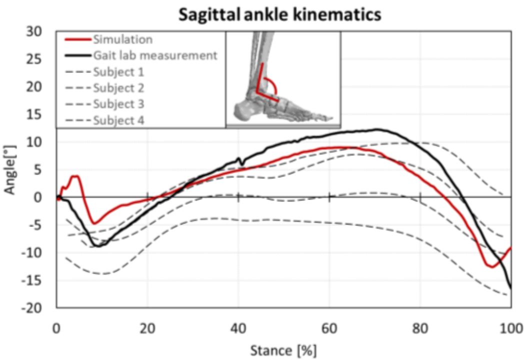

Figure 2: Sagital ankle kinematics during gait. Simulations vs mesurément vs Lundgren et al 2008.

References

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