Combined finite element and musculoskeletal models for analyzing the pelvis dynamics throughout the gait cycle

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ABSTRACT

Biomechanical analysis of human loco-motor system has been performed widely by applying rigid-body musculoskeletal models. This method enables to investigate the influence of muscle activation on body movements. Also, the finite element (FE) method enables the prediction of the internal forces and deformations. So, the musculoskeletal model and FE method are supplementary. At this point, integrative biomechanics can identify important unsolved problems in basic biomechanics, and provide the route whereby their solution can be translated into advances in clinical medicine [1]. The utility of FE models in clinical biomechanics are often criticized due to their inadequate model verification and validation [2]. However Viceconti et.al., proposed that Biomechanics community should start to consider these instruments in clinical practice, accepting that no numerical model can be totally validated when are applied in simulating biological tissue. By this, the interpretation as well as assessing the sensitivity of models becomes vital [3]. The aim of the present study is therefore to develop a FE computational model of pelvis. The model included the muscle forces estimated from a musculoskeletal model of the lower limb as boundary load conditions. A sensitivity study of our model under physiological load conditions and joint movement throughout the gait cycle was also analyzed. We used a musculoskeletal model with 23 degrees of freedom and 92 musculotendon actuators [4]. High resolution CT image of pelvis was used for provided baseline geometry of bones. Pelvic bone was assigned to behave as a homogeneous, isotropic, linear-elastic material. Femur bone was modelled as a rigid body structure; and cartilages were modelled as a homogeneous, isotropic, nearly incompressible, neo-Hookean hyperelastic material [5]. The 3D model was imported to FE solver FEBio 1.7 for nonlinear, large deformation stress-strain analysis. So, changes in material properties assumed were performed to investigate how such properties affects the stress predictions throughout the gait cycle to find a more realistic stress field.

REFERENCES

[1] G. Ateshian and M. H. Friedman, *Integrative biomechanics: a paradigm for clinical applications of fundamental mechanics*. Journal of biomechanics, vol. 42, no. 10, pp.1444-51 (2009).

[2] A. Anderson, et al., *Verification, validation and sensitivity studies in computational biomechanics*, Computer Methods in Biomechanics and Biomedical Engineering, vol. 10, pp. 171-184(2007).

[3] M. Viceconti, et al., *Extracting clinically relevant data from finite element simulations.* Clinical Biomechanics (Bristol, Avon), vol. 20, no. 5, pp. 451-4 (2005).

[4] S. L. Delp, et al., *OpenSim: open-source software to create and analyze dynamic simulations of movement.* IEEE Transactions on Bio-medical Engineering, vol. 54, no. 11, pp. 1940-50 (2007).

[5] T. M. Phillips, et al., *Finite element modelling of the pelvis: inclusion of muscular and ligamentous boundary conditions.* Medical Engineering & Physics, vol. 29, no. 7, pp. 739-48, (2007).