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AN OPEN SOURCE FEMALE FE HUMAN BODY MODEL FOR COMPUTATIONAL IMPACT BIOMECHANICS

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1 INTRODUCTION

Finite Element (FE) Human Body Models (HBMs) provide a means for simulation of the impact response of the human body, for instance in vehicle crashes. At the present, automotive manufacturers have started to use FE HBMs in their virtual product development process, enhancing development work traditionally done with crash test dummies, both virtual and physical. Today, there is no available HBM that represents the average female occupant, which is a limitation for the study of injuries for which females are at a higher risk. One particular such type of injury are the so called Whiplash Associated Disorders (WAD), which originate from the soft tissues of the neck and commonly cause long term disability. The risk for females to sustain WAD symptoms is at least the double of males[1].

Therefore, we are developing an average female FE HBM, with focus on rear impact assessment, since it is the most common cause for WAD.

2 METHODS

A a whole body model was developed with focus on a biofidelic kinematic response when seated in an automotive seat. In addition, a cervical spine model which has a higher anatomical detail level was developed and validated for quasistatic loads[2]. The model was developed for the explicit FE code LS-DYNA (LSTC, Livermore, CA), using the parallelized version of the code (MPP-DYNA, R8.1).

2.1 Cervical Spine Model

The cervical spine model was created from skeletal surfaces digitized from computed tomography data for the first thoracic vertebra to the base of the skull of a 26 year old female (stature: 167 cm; weight: 59 kg)[3]. The vertebrae are modelled as combination of triangular shell elements and tetrahedral elements, representing cortical and trabecular bone respectively, Figure 1. The cervical ligaments are modelled with orthotropic non-linear elastic quadrilateral membrane elements, calibrated with respect data for relatively young human subjects[4]. The mesh of the vertebrae is continuous with that of the cervical ligaments. The intervertebral discs were composites of hexahedral bulk elements and orthotropic membrane elements, attached with a tied contact to each of the vertebrae. Facet joints are modeled using sliding contacts between the articular cartilages, tied by contacts to the vertebrae.

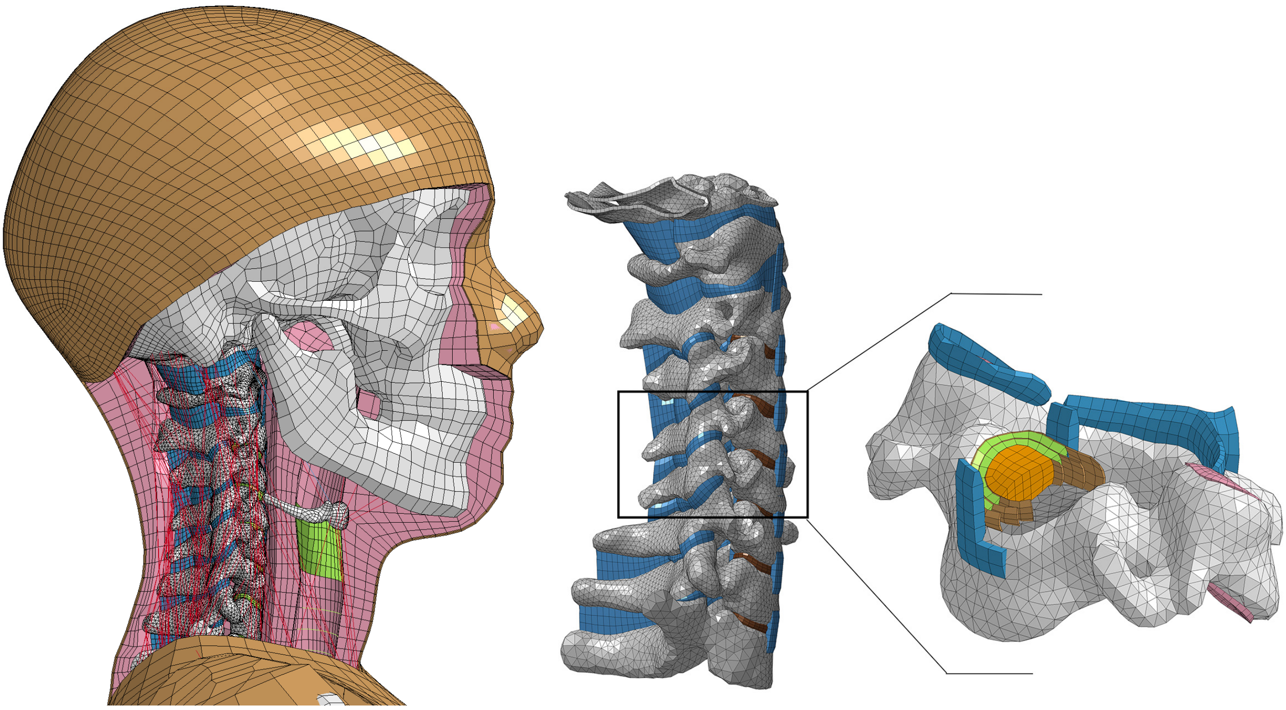

Figure 1: Overview of the cervical spine model.

2.1 Whole Body Model

The geometry of the whole body model was based on surface data generated from a total of 138 scan series with approximately 20,000 images of a 50th percentile female, captured in an automotive seated posture5. Stereolithography (STL) surfaces were created from the image data and based on this surface data the mesh was created, Figure 2. Soft tissues were modeled with deformable elements, and the skeleton was modeled with rigid bodies, connected by compliant kinematical joints, to provide a biofidelic kinematic response during impact, Figure 2. Intervertebral joint properties for the thoracolumbar spine and the costovertebral joints were based compliance data from human subjects published in the biomechanical literature, while the extremity joints are based on range-of-motion measurements on volunteers.

Figure 2: Left : The mesh of the human body model. Right: Whole body model with detailed cervical spine model in rear end impact (ΔV = 6.7 m/s, a_{mean}=45 m/s^2).

4 DISCUSSION

Validation simulations have showed that the model's ligamentous cervical spine represents the properties of female human subjects recorded in vitro when subjected to quasi-static loading[2]. Validation in dynamic rear impacts for the isolated head-neck complex is ongoing. In addition, the kinematics of the whole body model is being assessed and preliminary results are promising. The developed model is released under an Open Source license, in the hope that it will enable the development of better automotive protective systems, enable virtual assessment of safety systems, and be used for impact biomechanical research for which a female specific model is needed. The model is available for download from https://www.chalmers.se/en/projects/Pages/OpenHBM.aspx.

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