Parametric computational head-and-neck model and anthropometric effects on whiplash loading

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Abstract

Currently, human body computational models, e.g. detailed finite element models, are used to investigate potential injury mechanisms for whiplash associated disorders. These models are mostly designed to represent the average male subject only. NCAP rates the whiplash risk of new car seats based on kinematic and dynamic performance criteria using the 50th percentile male BioRID II dummy; this ATD does not take anthropometric subject differences into account either. The current research addresses such a shortfall. A simplified parametric computational model of the head and neck is designed to investigate how anthropometric subject differences affect the kinematics and dynamics of head-and-neck behaviour.

A lumped parameter approach, consisting of the head and cervical spine in the sagittal plane with segmental mass and inertia, is used to develop the model for the head and neck responses to typical whiplash acceleration pulses. There are two stages for this model: first, the geometry and the inertia properties are predicted based on regression equations rather, therefore not simply scaled from an average model. These prediction equations use mainstream anthropometric data such as height, BMI and gender. Also, the lumped nonlinear stiffness and damping functions are defined for each joint to represent the segmental and overall viscoelastic neck behaviour. In the second stage, the model is subjected to a dynamic pulse applied at the first thoracic vertebra, obtained from published physical rear-end sled experiments.

Six models were generated to represent the 5th, 50th and 95th percentile male and female subjects respectively. The models prediction for mass and moment of inertia have been verified against anthropometric data in the literature for each respective model/subject. The model predictions are within the tolerances derived from literature data. Then, the 50th percentile male subject model was dynamically tested and verified against published volunteer rear-end experiments. Finally, further models with different anthropometric parameters close to the 50th percentile model were generated and their changed dynamic head-and-neck response was investigated.

The change of an anthropometric parameter has a coupled effect on the model properties, e.g. the height and also the BMI have a primary effect on the inertia properties, but also a minor effect on the cervical curvature. However, the effect of each anthropometric parameter has been investigated with respect to the head-and-neck response of the model, while the same whiplash acceleration pulse was applied at the first thoracic vertebra. Dynamic behaviour differences are visible for global (gross) head motion and intervertebral (segmental) motion. The parameter with highest effect on global motion is the head mass, and on intervertebral motion is the initial cervical curvature. It is concluded that anthropometric subject differences would have likely an effect on the whiplash injury risk for individuals, as subjects respond differently to the crash condition. This work may also have possible applications in other research areas, e.g. other impact directions or impact sports-engineering.