BIOMECHANICAL MODEL OF BICYCLIST AND NUMERICAL ANALYSIS OF BIKE ACCIDENT IN ASPECT OF CONSEQUENCES FOR HUMAN CERVICAL SPINE

Marek Gzik, Eugeniusz Świtoński and Dagmara Tejszerska

Division of General Mechanics and Biomechanics, Department of Applied Mechanics, Silesian University of Technology, Gliwice, Poland

Modelling researches concerning falling down man on the head during bicycle accident and its consequences for human cervical spine are presented in this paper. Studies mainly focus on compression, flexion and extension injuries mechanisms which appear during human body movement in saggital plane. The interaction with environment, the human body behaviour, inertial and external forces have a significant influence on type and scale of spine injuries. In order to analyse correlation between head movement and physical phenomena in the neck, two dimensional dynamical model was created using Working Model 2D professional system. The model allows to analyse internal forces which appear insight human spine and body kinematics in saggital plane. Moreover created model could be used to analysing movement of diving man into shallow water. Research results of numerical simulations allowed to qualitatively estimating the most dangerous conditions for people falling down on the head during bike accident and during jumping into shallow water.

KEY WORDS: bicycle accident, neck injuries, modelling, numerical simulation.

INTRODUCTION: The spine is functionally one of the most important parts of the human musculoskeletal structure which plays the leading role in the organism as a motion organ, spinal cord protection and body support. Backbone is divided into five parts: cervical (7 vertebrae), thoracic (12 vertebrae), lumbar (5 vertebrae), sacrum and coccyx. Cervical spine is a part of human spine less protected and more exposed to injuries than the other ones (Hickey, 2003). Neck injury can occur in many types of accidents. Road and sport accidents are one of the most frequent reasons of human cervical spine injuries, especially dangerous are motorcycle, bike accidents and jumps into shallow water. Compression mechanism of injury in cervical spine, being the consequence of acting force along body axis is typical for falling down and jumps into shallow water on the head (fig.1).

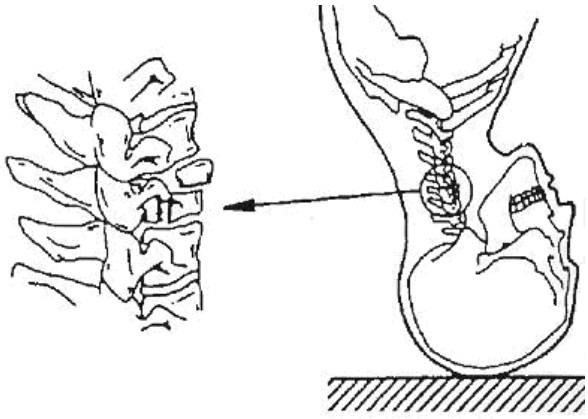

Figure 1: Compression injury mechanism of human cervical spine (Wismans et al, 1994)

The damage of vertebral body connected with penetration into spinal cord is the most dangerous one for human life (Panjabi, Myers, 1995). Accidents of that kind happen in most cases to young people. About 60% of these injuries cause the paralysis of four limbs (quadriplegia).

Neck injury mechanism is especially connected with a head motion (Adams et al., 1994). Improvement of knowledge about correlation between dynamics, human body behaviour and internal cervical phenomena could contribute to the defence against dangerous traumas. The

best information about above mentioned correlation could be obtained during test on volunteers but experimenting on people is usually impossible because of its dangerous character. Researches on volunteers could be conducted only in safe condition or on animals, dummies and cadavers (Panjabi et al., 1998). Another way to study the behaviour of the human body and internal interactions during accidents is the mathematical modelling, with the use of latest numerical methods. This is proposal a non-invasive method, which great advantage is unlimited repetition of numerical simulations for different assumptions (Gzik, Tejszerska, 2004). Many models have been used to understand the injury mechanism responsible for neck trauma, which appear during different accident. Animals and cadavers, despite of a number of important drawbacks, have been exposed to different types of motion to study tissue failures or property changes. Volunteer studies have been carried out to understand the kinematics and the data, although below injurious level, have been used to suggest injury mechanisms. Numerical models have been used to study injury mechanism, but these models have until now been either too crude or poorly validated.
Modelling researches of human body movement during bicycle accident and jumping into shallow water and analysis of internal dynamical forces are presented in this paper. In order to carry out the numerical analysis of interactions between vertebrae two – dimensional model of 75 kg falling down man was created.

METHOD:

Assumptions in modelling process: Modelling process was preceded by literature studies on anatomy of human cervical spine, properties of particular elements and kinds of living organisms modelling (Guilak et al., 1999; Wismans et al., 1994).
In order to carry out of numerical analysis of interactions between vertebrae two – dimensional model of 75 kg weight fall down man was created. Modelling process was carried out using WorkingModel 2D. The model (fig.2) was created on the basis of the following assumptions: head, vertebrae, trunk and lower limbs are treated as rigid bodies, joined by articulated joint and non-linear spring – dumper elements representing natural connections, the model takes into consideration natural cervical curve - lordosis, interaction of soft tissues is represented by linear spring – dumper elements.

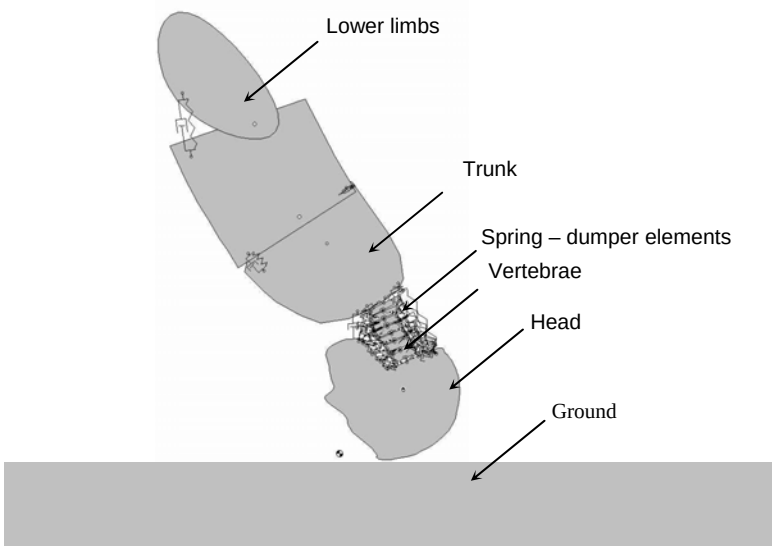

Figure 2: Two - dimensional model of falling down cyclist or man jumping into shallow water

The described model was verified by comparing displacements of the head centre of gravity obtained from numerical simulation and tests conducted on cadavers by Panjabi et al.

RESULTS: The model of falling down man was used for numerical analyse of main factors directly influencing internal forces inside human cervical spine, and indirectly neck injuries. The determination of correlation between internal forces and tissues damage need the

performing of additional strength experimental tests. Therefore obtained results should be treated as qualitative, as well as only possibility of injuries appearance. Three variants of human body movement in saggital plane presented in figure 3 were analyzed.

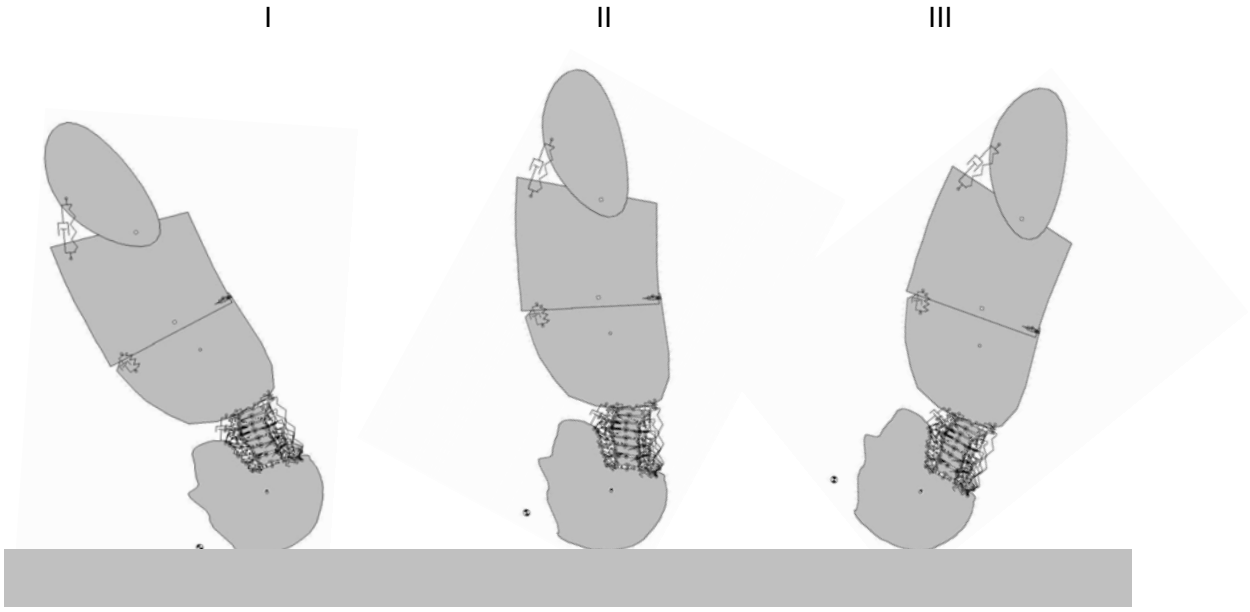

Figure 3: Analyzed variants: *I – variant:* 30^{o} angle between body axis and perpendicular, *II – variant*: body axis is perpendicular, *III – variant:* -30^{o} angle between body axis and perpendicular

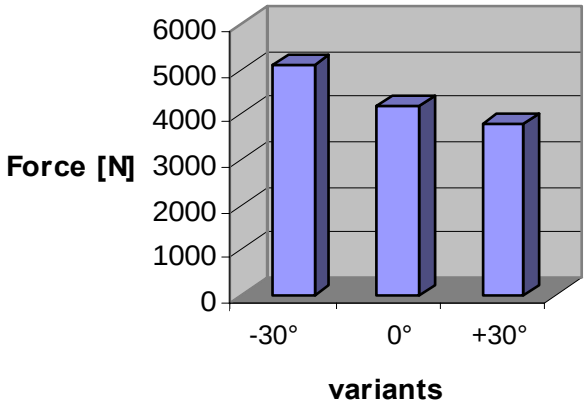

Figure 4: Results of numerical simulations: maximal forces between C1-C2 for three variants

DISCUSSION: Analysis proves the most important role in aspect of neck injuries playing human body mass, speed and physical conditions of contact with ground at the impact moment, especially friction coefficient and angle between body axis and ground. In our research we were simulated falling down assuming low speed and in spite of it the maximal internal forces reached 5.1 KN at the hit moment (first variant). In many cases such loading conditions cause serious consequences for human life.

CONCLUSION: Modelling researches allowed analysing of the human body behaviour, as well as dynamical simulations of the forces, which appear in human cervical spine in situations under consideration. The results of numerical analysis proved a great influence of body mass and movement, type of ground and a way of contact during accident on internal forces. Another important aspect concerns the emotional condition of a given person during accident, which influenced neck muscles tension. This tension can cause greater scale of neck injuries. Obtained results prove worse for neck is drop down on the head when body axis is at an angle than body is perpendicular. It is connected with anatomical shape of

cervical spine. Another important conclusion is using helmet by cyclists are not defence neck against injuries.

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