THE NUMERICAL ANALYSIS OF HUMAN BODY MOVEMENT DURING FALLS AND SPINE RESPONSE IN CONTACT SPORTS

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This paper presents modelling process and numerical analysis of human body behaviour during accidents in contact sports and its consequences for human cervical and lumbar spine. The researches contain creation of model which enables human body motion analysis in a situation corresponding to real falls with simultaneous analysis of internal physiological phenomena in human spine. The model of falling man was created using Working Model 2D program and used to numerical analysis of human motion in frontal plane under dynamical loading corresponding to falls in sport.

KEY WORDS: modelling, numerical analysis, spine response.

INTRODUCTION: Statistic data illustrate social problems connected with skeletal diseases and injuries in particular spine disorders. Many such spine failures connected with external loading corresponding to different types of accidents. Cervical spine is a part of human spine less protected and more exposed to injuries than the other ones (Hickey, 2003). The cervical spine is a multisegmented column with nonlinear structural properties. Its geometry is complex, and its constituent elements have nonlinear material properties. Cervical injury mechanisms are sensitive to the initial position of the neck, the direction of loading, the degree of constraint imposed by the contact surface, and possibly to the rate of loading (Panjabi et al., 1998).

Cervical spine injuries occur at an annual incidence of 210 per million, causing annually 25 to 35 spinal cord injuries per million. Despite being relatively rare - occurring in only 2.4% of blunt trauma admissions - the social and economic impact of cervical spine injuries is extensive, because the majority of cervical spine injuries complicated by spinal cord injury occur in young adults, with median age of only 31years, often with life-long consequences. Cervical spine injuries are about 50% of the total number of human spine injuries. The neck injuries most dangerous for human live are connected with simultaneous damage of spinal cord (Kiwerski, 1993).

The most common causes of spinal cord injuries include the following:

- Motor vehicle accidents (44.5%) are the major cause of spinal cord injuries in the United States.
- Falls (18.1%) are most common in persons aged 45 years or older.
- Violence (16.6%) is the most common cause of SCI in some urban settings in the United States, with a trend showing a slight decrease in violence as a cause of spinal cord injuries.
- Sports injuries (12.7%) cause many cases of spinal cord injuries.

These accidents can cause injuries that range from mild cases of pain, to injuries that can cause paralysis of the rest of the body below the level of injury or even death.

Biomechanical researches concerning human spine are mainly influenced by medical problems. It is connected with functions which are performed by the spine in the skeletal system such as protection of spinal cord, motion organ and organ supporting body. Scientists discuss about correlations between human spine loading conditions and their consequences directly for injuries and indirectly for human life. Athletic serious injuries to the cervical spine associated with quadriplegia occur especially as a result of axial loading (compression mechanism of injuries). Whether it is a football player striking an opponent with the top or crown of his helmet, a poorly executed dive into a shallow body of water where the subject strikes his head on the bottom, or a hockey player pushed into the boards head-first, the fragile cervical spine is compressed between the rapidly decelerated head and the continued momentum of the body (Christensen, 1998, Wismans & Janssen, 1994).

Modelling researches of human body movement in frontal plane corresponding to sportsmen falls 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 using Working Model 2D.

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).
Main anatomic parts involved in modelling process are: head, chest, abdomen, spine, upper and lower limbs connected by rotational joints and spring – damper elements as an open kinematical chain. We particularly takes into account cervical and lumbar segments of spine, which are divided into several vertebras. Spinal muscles, discs and ligaments are represented by spring – damper elements (figure 1).

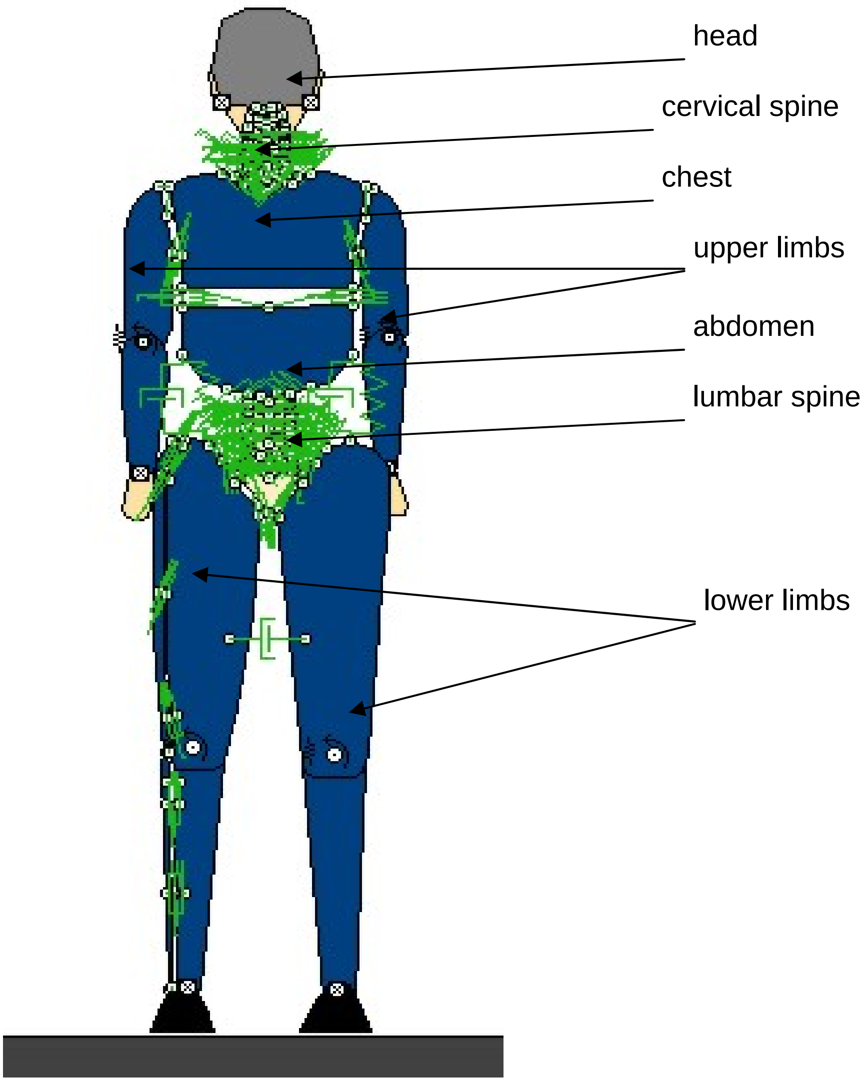

Figure 1: Two - dimensional model of man

The 2-dimensional model of man was created on the basis of the following simplified assumptions:

- the model of man corresponds with parameters of typical adult (75 kg), main parts involved in modelling process i.e.: head, cervical vertebras, chest, abdomen, lumbar vertebras, upper and lower limbs are treated as rigid bodies,
- elements of man anatomical structure are joined by articulated joint as an open kinematical chain and additionally joined by spring–damper elements,
- the model takes under consideration 7 cervical vertebrae, neck muscle, ligaments, intervertebral joints and discs,
- the model consists of 5 lumbar vertebrae, back muscle, abdomen muscle, ligaments, intervertebral joints and discs,
- the movement of falling man in frontal plane was analysed (figure 2).

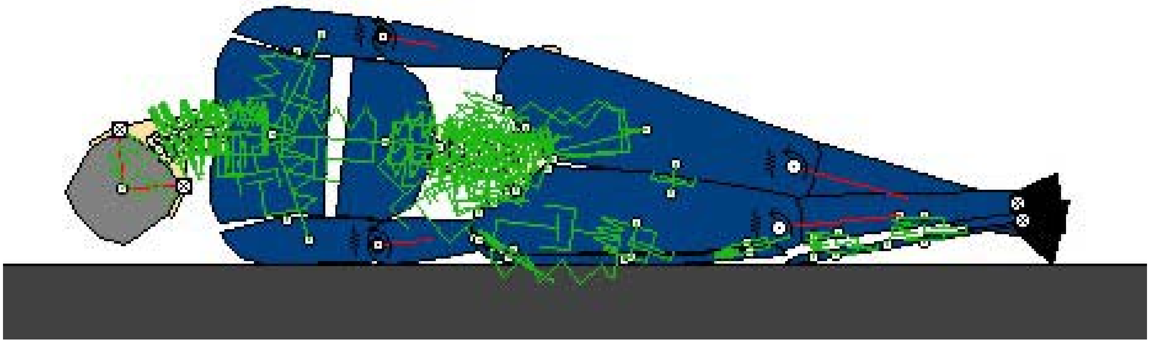

Figure 2: Analysed situation corresponding to fall of man - movement in frontal plane

RESULTS: The model of falling man was used for numerical analyse of main factors directly influencing internal forces inside human cervical and lumbar spine. Large difficulties in modelling process were caused by verification of the model. It has connection with modelling rules in biomechanics and absence of publications concerning experience, which might be used for these purposes. Modelling in biomechanics, despite large progress of computer technique in recent years, still has many defects. First of all, these defects are connected with absence of data of human tissues parameters, particularly soft ones, as well as data essential to verification. Therefore obtained results should be treated as qualitative.
Several different variants taking under consideration different conditions during man fall were analysed. It reveals correlations between human body kinetics and place where appear greater forces inside human spine.
Numerical analysis proves that cervical spine is part of human spine mostly exposed to injuries during falls because there appeared greater dynamical forces.

DISCUSSION: Analysis proves the most important role in aspect of spine injuries playing human body mass, external force come from contact with other sportsman, speed at collision moment and physical conditions of contact with ground at the hit moment.

CONCLUSION: Two – dimensional model of 75 kg falling down man was created using Working Model 2D. The program based on multibody dynamics and gives opportunity to carry out fast calculation. It is especially important for biomechanical models of man.
Created model was used to analysing of the human body behaviour in frontal plane, as well as dynamical simulations of forces, which appear in human cervical and lumbar spine in situations under consideration. The outcomes of numerical analysis proved important influence of body mass, external forces acting on sportsman, and conditions of contact with ground during hit moment on human spine injuries during falls.

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