Abstract

In contact sports, such as American Football, the players head trauma remains a significant challenge. This topic is highlighted each year by the players association and media. The literature analysis proved that using Finite Element (FE) models to explore head kinematics and injury mechanisms is an ongoing trend. My career as an American Football player led me to understand that human safety awareness is not enough highlighted. The findings will focus on American Football; however, an accident can occur while riding a bicycle or walking.

The first study describes an attempt to record the behaviour of the athletes during the simulated tackling situation. Due to the limited game recordings and poor video quality at the domestic game level, it was decided to attempt to record the athlete in two separate movements and combine them in prepared simulations. The recordings took place cooperating with the Wrocław University of Science and Technology and Wrocław University of Health and Sport Sciences. To verify, the attempts were recorded for further analysis with TEMA software (IMAGESYSTEMS). Finally, coupling two numerical codes – MADYMO and LS-DYNA enabled the author to progress further and prepare a set of two simulations with different tackling mechanics (so-called open-field and side tackle). The multibody dummies available in MADYMO served as athletes' models, and the American Football helmet was modelled in LS-DYNA.

The second experiment aimed to develop an additional energy-absorbing layer for the developed American Football helmets. There was an established cooperation between the Cracow University of Technology, the University of Aveiro (Portugal) and the Wrocław University of Science and Technology to develop state-of-the-art cork porous composites from sustainable materials. Twelve different samples were tested under dynamic loading to assess the ability to absorb energy, and finally, the tests were recreated numerically to obtain a validated material model. With the analysed and chosen material the thesis leads to physical experiments carried out during my stay at the University of Virginia in the Center for Applied Biomechanics (United States of America). The aim of the dissertation was to develop an additional absorbing layer that would minimize the probability of injury. The tests with two different design approaches proved that cork could serve as an additional energy-absorbing layer.

The final study focused on the verification of linear accelerations as a predictor for head injury. Analysing the trend visible in car or urban accidents, I adopted a similar strategy in sports accidents. Analysing the available simplified numerical head model αHEAD I proved that hydrostatic pressure values do not correlate with HIC under selected impact conditions. After considering that the available numerical head models on the market offer a broad but simplified geometry choice. According to the state of the art presented, the geometry of the human brain might greatly influence the results.

The first examined objective of the study was partially fulfilled due to the multi-body models limitations. The lack of literature studies about the active human body models is not sufficient to use the models with success. The dynamic testing of biocomposites were successful, however the tests proved that agglomerated cork would perform better under dynamic impact conditions. The scientific target was partially proven as the additional energy-absorbing layer, designed as an add-on, has successfully mitigated head acceleration for lower energy impacts. Lastly, no linear correlation was found between the head's centre of gravity accelerations and intracranial pressure. This information showed that the standards should be refreshed and updated to provide sufficient safety to users.