PROCEEDINGS

The 33rd International Conference

on Biomechanics in Sports

Poitiers, France

29 June – 3 July 2015

INTERNATIONAL SOCIETY OF BIOMECHANICS IN SPORTS

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FROM MEASUREMENT TO MODELLING IN SPORT COLLISIONS.

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KEY WORDS: experimental data, computer simulation, soft tissues, integrated analysis, injury prevention.

INTRODUCTION:
Understanding the factors and the mechanism causing injury is one of the fundamental stages of the "sequence of prevention" of injury in sport (van Mechelen et al., 1992). Sports activities typically impose high and repetitive biomechanical demands on the neuro-musculo-skeletal system (e.g. Dufek & Bates, 1991; Trewartha et al., 2015), which research can try to capture and characterise. However, despite the progress of technologies and experimental methods, it is often impossible to directly measure the effects of specific sport events on the anatomical structures of the human body. In particular, the analysis of injury mechanisms in sports involving impacts (e.g. scrummaging and tackling in rugby, landing after a jump, or kicking in martial arts) needs to face a number of interdependent challenges, for which conventional approaches are not always adequate.

Experimental settings during *in-vivo* tests must be ecologically valid and representative of the phenomenon under analysis. However, some sport-specific situations cannot be easily recreated in the lab because they may be a one-off event (e.g. competition intensity), they may involve very complex open-skill scenarios (e.g. multiple player interactions), or they may involve risk of acute/chronic injuries for participants (e.g. collisions) and therefore impose obvious ethical considerations. Another major issue in the characterisation of injury factors in events involving impacts is the understanding of how and to what extent external loads on the athlete's body are translated into internal stresses on specific anatomical elements. Sport events may often generate forces and accelerations that exceed the magnitudes indicated as potentially harmful by *in-vitro* studies on cadaveric specimens (Preatoni et al., 2015; Trewartha et al., 2015). However, it is evident that injuries are not as frequent and that there are a number of factors, such as muscle activity and physical condition, which interact with loading patterns and affect the transfer and absorption of mechanical stresses.

An integrated approach that combines experimental observations with modelling and computer simulation may offer a framework for overcoming the limits of single-level analysis of sport collisions. *In vivo* measures based on multiple acquisition systems and realistic scenarios can give a first description of the phenomenon and inform computer-based models. Computer simulation can allow the estimation of quantities not directly observable from experimental measures (e.g. internal stresses) and the implementation of "what-if" scenarios through which potentially hazardous conditions are recreated and analysed. By definition, modelling provides a simplified representation of reality and therefore is based on initial assumptions (e.g. rigid bodies and joint constraints) that should be carefully evaluated before models are systematically applied.

SHORT SUMMARY:
This applied session presents an integrated approach for the analysis of sport collisions and comprises three main parts. In Section 1, practical examples from rugby activities (scrummaging, tackling) will be used to describe the issues related to *in vivo* measurement (e.g. preparation of the set-up, ecological validity, synchronisation, calibration) when impact events are observed and multiple players interact in a complex environment. The data needed to inform computer simulation modelling will also be discussed. In Section 2, attendees will be introduced to modelling with OpenSim (Delp et al, 2007) and a hands-on approach will be used to explore the potential of musculoskeletal modelling in the analysis of rugby-related events. In Section 3, the issue of giving an appropriate characterisation to the biomechanical model will be addressed. In particular, the activity will focus on the hypothesis of the human body as a system of rigid bodies vs. the inclusion in the model of soft tissues and wobbling masses, and the effect of such assumptions on the system dynamics in the presence of impacts will be explored.

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Acknowledgement

The authors would like to thank Delsys Inc. for supporting the organisation of the applied session.

The authors would also like to acknowledge World Rugby and the RFU Injured Players Foundation for funding some of the research presented in the session.