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Guest Editorial

Special Issue: Current Trends in Impact and Injury Biomechanics

This special issue highlights current trends within the field of impact and injury biomechanics. This interdisciplinary domain combines the principles of mechanics and motion, with knowledge of anatomy, physiology, and human performance, to study how the body responds to impact loading and to understand the causes of injuries and, therefore, develop strategies to prevent them. Recent advances in computational capability, experimental methods, and data sciences have enhanced our efforts in the prevention and treatment of traumatic injury under a variety of loading scenarios. Injury prevention is a critical topic in transportation safety, sports performance, and defense and security given that traumatic injury is a leading cause of death and disability worldwide. Reflecting the wisdom of Franklin's aphorism, "an ounce of prevention is worth more than a pound of cure," our research community is dedicated to finding solutions to the substantial, yet often underrecognized, socioeconomic cost of injury.

Over the past 50 years, significant progress has been made in researching the biomechanics of injuries leading to significant developments in countermeasures and safety systems designed to prevent or mitigate the extent of the injuries. These advancements have had widespread applications, benefiting us in various aspects of our lives, including workplaces, public spaces, multiple modes of transportation, military operations, and sports fields. Despite these strides, there is still work to be done in addressing less-explored aspects of injury causation and prevention, such as achieving sex parity in prevention strategies. Additionally, the injury biomechanics community must adapt to emerging challenges, such as the safety of an ageing and active population and the dynamics of an ever-changing and autonomous world.

This continuing need underscores the importance of our community, comprised of researchers, regulators, manufacturers, and educators, to consistently meet to exchange ideas, ensuring that insight gained from fundamental studies can be effectively applied to shape policies, enhance safety rating programs, and drive innovations in the design of protective devices, including restraints and helmets. Organizations, such as the International Research Council on the Biomechanics of Injury, more commonly known as IRCOBI, help foster this process by holding every year since 1973 the world's premier conference on the biomechanics of injury, with active participation from academia, industry, and government from across the globe. This special issue provides an overview of achievements in the field of injury biomechanics from authors and organizations who are regular participants in IRCOBI over the 50 years that the annual conference has been held.

Virtual crash testing methods and safety analysis is an emerging topic in the automotive field, motivated by the need to study injury and optimize safety for a diverse population of occupants. Larsson et al. [1] explored the use of finite element human body models (HBM) to represent occupant variability in virtual crash testing for improved vehicle safety. Using rib fracture risk as an example injury outcome, they morphed the geometry of the models to represent variability in sex, height, and weight, and these models were employed to calculate population variability in rib fracture risk. Their study suggests simulations with 25 individuals of each sex is sufficient to model population rib fracture risk in a general crash scenario, with an optimization method identifying five to seven representative individuals for predictive models across different crash scenarios.

Similarly, Forman et al. [2] introduced a methodology using open magnetic resounance imaging to capture detailed information on body shape, soft tissue geometry, skeletal geometry, and seatbelt fit relative to the skeleton in automotive postures. Their findings reveal notable variability in body characteristics among volunteers, with distinctions in adipose tissue distribution, pelvis rotation, and seatbelt interaction during recline, emphasizing the importance of considering both interdemographic and intrademographic variability when assessing the robustness of automotive safety systems.

Also exploring the use of computational models to understand crash response was a study by Wang et al. [3], who investigated methods for how intelligent vehicles may predict the likelihood of occupant injury in near-collision scenarios. Using input such as vehicle crash pulses and a simulation model, their proposed knowledge distillation training method significantly improving head injury prediction accuracy without compromising computational efficiency. The study's approach offers a valuable reference for enhancing the safety of next-generation intelligent vehicles.

Virtual efforts, while becoming more advanced every year, need to be supported by new experimental data to validate the accuracy of the model's predictions. A study authored by Somasundaram et al. [4] aimed to compare the kinematics and injuries of small female occupants in frontal impacts with upright and reclined postures using six postmortem human surrogates. While the kinematics between the two seated postures was similar in magnitude and shape, the reclined occupants moved downward more in the thoracic spine as well as in the horizontal direction in the head. At higher velocities, both groups exhibited multiple rib failures, with upright specimens having a greater number of severe fractures, suggesting a potential risk for pneumothorax despite similar maximum abbreviated injury scale values.

Graci et al. [5] investigated the impact of belt-positioning booster seats on the kinematics of small female occupants in low-acceleration lateral-oblique impacts, aiming to mitigate submarining effects that can undermine the effectiveness of safety systems. Their results indicated that severe reclined seatback angles, coupled with a booster seat, lead to reduced lateral head and trunk displacements in small female adult occupants, highlighting the potential benefits of booster-like solutions in minimizing injury risks during such impacts.

Computational HBMs are also widely used outside of the automotive field to predict injury and assess safety. Hostetler and Gayzik [6] described the validation of a computational lower extremity model in the underbody blast environment and developed methods to identify optimal metrics for developing injury risk curves to the calcaneus and tibia. Their findings emphasize the significance of boots in reducing injury risk and suggest the potential applications of the developed injury risk curves in model prediction, personal protective equipment evaluation, and experimental protocols.

Similarly, Bustamante and Cronin [7] discussed the assessment of behind armor blunt trauma resulting from dynamic deformation of protective ballistic armor into the thorax. Using a validated HBM, their study demonstrated that behind armor blunt trauma outcomes vary depending on the impact location, with high compliance areas leading to increased thoracic compression and pulmonary lung contusion, while low compliance areas cause hard tissue fractures. Their findings underscore the importance of considering impact location in armor design and assessment, emphasizing the need for location-based injury risk curves for more accurate predictions.

To further support development of HBMs, Chen et al. [8] focused their study on the superficial medial collateral ligament of the porcine knee joint to investigate the functionality of the distinct anterior and posterior fiber bundles. Quasi-static tensile tests on matured porcine stifle joints provided material properties for the two bundles and whole ligament. Based on the results, they recommend assigning different material properties to the two fiber bundles for accurate ligament simulations in human body models. Furthermore, they introduced a microstructural model-based approach to predict the mechanical properties of the bundle properties.

Safety concerning brain injury and head protection remains a crucial focus in various fields, including sports, military, and automotive sectors. Constantly evolving technologies and innovations in experimental, computational, and preventative approaches continue to emerge in addressing this concern. Singh et al. [9] experimentally investigated head kinematics and two-dimensional brain simulant deformations in head surrogates subjected to blunt impacts, both with and without helmets. Different head surrogate configurations were considered, and the response was analyzed for sagittal and coronal plane rotations at varying impactor velocities. Their results demonstrated that the choice of head surrogate significantly influenced the spatiotemporal evolution of strain, and the use of helmets, particularly those with antirotational pads, substantially reduced peak head kinematics and brain simulant strains in various loading scenarios.

Similarly, King et al. [10] investigated a novel elastomeric honeycomb helmet design proposed as an alternative to traditional expanded polystyrene foam helmets for bicycle accidents. The honeycomb design, tested in multiple modes of impact, improved brain injury protection by allowing greater shear deformation than conventional foam. Using full-scale drop tests, they demonstrated that the honeycomb helmet design could potentially reduce the risk of brain injury in bicycle accidents, making it a promising alternative with benefits for both safety and consumer convenience.

Research to understand the biomechanics of injury and the development of new technologies are essential to provide solutions for injury mitigation and safety. The contributions to this Special Issue represent just a fraction of the broader efforts within the injury biomechanics community who are working toward advancements in injury prevention. These collective efforts will lead to significant improvements in safety, reduction of injury, and improvements in injury outcomes, particularly when addressing current and future challenges, such as accommodating the diversity of today's population, encompassing demographic, anthropometric, and sex differences.

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