Making It Less Deadly Down Under: Lessons Learned at Leading Injury Biomechanics Research Laboratories

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I. INTRODUCTION

In Australia, preventable injuries are the leading cause of death for people younger than 45 and account for ~8% of national health expenditure annually [1]. A large proportion of these cases are caused by road trauma (over 40,000 injuries and 1,100 deaths annually [2]) and sporting accidents (6,000 life-threatening hospitalizations per year [3]), both of which are associated with Australian-specific injury scenarios. Australia's vehicle fleet comprises a uniquely large proportion of 4×4s and SUVs fitted with after-market "bull bars" to protect the vehicle during collisions with animals. These vehicles were designed for rural driving, but are common in urban environments [4]. Injury database studies of pedestrian impacts have identified that SUVs cause more severe injuries than smaller cars [5], and bull bars increase the risk of pedestrian injury and mortality [6], yet there are very few published investigations into the biomechanics of injuries caused by bull bars, nor their influence on crash mechanics [6]. The current Australian New Car Assessment Program (NCAP) testing protocols are derived from the Euro NCAP, which were designed for assessing smaller European-style cars [7], and there are no regulations regarding after-market modifications to the front end of Australian vehicles. Empirical information that demonstrates the unique dangers posed by SUVs and bull bars may provide a foundation for challenging current practices, regulations and design standards in Australia.

Of the ~60,000 Australians hospitalised for sports injuries annually, over 7% are related to Australia Rules Football (AFL) [3]. This is comparable to the number of soccer-related hospitalisations, even though AFL participation rate is less than half that of soccer [3]. These findings highlight the unique injury risks posed by this high-impact sport, which differ from other tackling sports [8]. Furthermore, there has recently been considerable media attention regarding a potential concussion-related class action from former AFL players, in response to the posthumous diagnosis of chronic traumatic encephalopathy (CTE) for three prominent former footballers, all of whom suffered from neurological disease and/or mental illness later in life [9]. These developments have sparked a growing awareness of the long-term health consequences associated with AFL and have prompted discussions on player safety, concussion protocols, and the overall well-being of athletes; however, there has been little research into AFL-specific brain injury mechanisms, and significant gaps persist in understanding concussion diagnosis and establishing return-to-play guidelines for Australian sports [10].

Dedicated research into the mechanisms underlying Australian-specific injuries is required to develop mitigation and prevention strategies. Human injury mechanisms and tolerances are typically investigated by measuring the response of post-mortem human surrogates (PMHS), anthropometric test devices, or animals, to simulated trauma environments [11]. However, Australian research is hindered by a lack of large-scale impact simulation devices in research laboratory environments. As such, The University of Adelaide's Centre for Orthopaedic and Trauma Research, and Centre for Automotive Safety Research, have identified the need for an advanced injury biomechanics facility in South Australia. The objective of the Fellowship described herein was to acquire a deep understanding of the design and operation of the impact apparatus, and technical details of the experimental and computational protocols, used at leading injury biomechanics laboratories internationally, to inform the scope and specifications of the facility proposed for South Australia.

II. METHODS

To make informed decisions about the infrastructure, equipment, and personnel required to establish and operate a research-dedicated injury biomechanics center, it was deemed important to tour the facilities and meet with the researchers at the numerous well-established laboratories around the world, particularly in Europe and North America. The Winston Churchill Trust Fellowship Program offers a unique opportunity for Australians to travel internationally to gain experience and information in their chosen area of expertise, and to translate that into benefit for all Australians. Dr Quarrington was awarded the 2022 Dr Dorothea Sandars Churchill Fellowship and visited leading injury biomechanics laboratories in the UK, Europe, Canada and USA.

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III. FINDINGS

Dr Quarrington toured the facilities and impact laboratories of 19 institutions and met with over 70 academics, managers, students, and technicians. Several key considerations were identified:

- ***Human body computer modelling (HBM) is becoming a necessary aspect of injury biomechanics research***, especially in the area of passive vehicle safety, but there is a lack of well characterized human cadaver experimental data (from the tissue level through to the body segment level) required to develop and validate these models. The NHTSA have proposed to incorporate HBM outcomes into vehicle occupant safety evaluations as early as 2026, so it is critical that the fidelity of these models, and their validity in a range of loading scenarios, continues to be improved. Appropriate use of HBMs can also offer a method for reducing the test matrix of injury biomechanics experiments, reducing the substantial time and resources required to execute these experiments. Assisting with the development and validation of HBMs, and using them to inform our experimental test matrices, will be critical to achieving timely and relevant research outputs related to our investigations of Australian-specific injuries.
- ***Research groups that hope to improve the safety of vehicle occupants will likely require access to a sled*** or similar high acceleration, high-capacity testing device. This area of research is particularly relevant with the increasingly widespread adoption of autonomous systems in vehicles, where manufacturers are offering consumers flexibility in how they position themselves in the vehicle, adding to the uncertainty around the efficacy of occupant safety features. Servomechanical reverse acceleration sled systems (e.g. Seattle Safety ServoSled) offer the most accurate and repeatable pulse profiles for large payloads and high accelerations, when compared to decelerator systems, but they are more expensive and require routine maintenance. A research-dedicated sled system that is compatible with cadaveric and pre-clinical experiments would allow us to investigate the influence of bull bars on crash mechanics and injury risk to occupants and pedestrians.
- ***Large-scale experimental research requires a lot of space!*** Not only are the test equipment large (sleds, drop towers, etc.), these typically require experiment-specific apparatus. It is also likely that the custom apparatus will need to be manufactured and modified in-house, so space for a basic machining workshop is advantageous. Storage facilities for instrumentation, test dummies, peripheral measurement devices, and specimens (alarmed freezers plus backups) may also be required. For PMHS testing, a dedicated cadaver preparation room is a necessity.
- ***In addition to performing the research experiments, at least three skilled duties need to be filled by members of the laboratory: research program director; laboratory technician; and, specimen administrator.*** The research program role involves managing the financial and administrative aspects of all projects undertaken by the laboratory and writing funding applications. The laboratory technician is responsible for maintenance of testing instruments, general upkeep of laboratory equipment, and design, manufacture, and modification of custom test apparatus. The specimen administrator role involves managing all aspects of the procurement, storage, and appropriate disposal of cadaveric tissue.

IV. CONCLUSIONS

The findings of this travel Fellowship will inform the scope and specifications of a new research-dedicated facility proposed for South Australia. We anticipate that this facility, and the lessons learned from leading injury biomechanics laboratories, will accelerate research of Australian-specific trauma and ultimately reduce the burden of injury. We hope that the dissemination of these findings will assist other researchers establishing their own laboratory, and will contribute towards the global effort to reduce preventable injuries.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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