An Assessment of a novel approach for determining the player kinematics in elite rugby union players

Tierney, G., Krosshaug, T., Simms, C.

Trinity College Dublin

Introduction

Rugby is intrinsically an impact sport which results in concussions being a frequent injury within the game. Repeated concussion is linked to early-onset dementia and depression, and the rules for limiting repeated concussion are an ongoing controversy [1]. Therefore a greater understanding of the dynamics of head impacts in rugby and the mechanism of concussion is required.

Accordingly, this project focuses on using Model Based Image Matching (MBIM) assessment and video evidence to determine the kinematic scenarios and thresholds of concussion injuries in elite rugby union players. This approach has already been used successfully for the biomechanical analysis of knee ligament injuries in basketball and skiing [2],[3].

Methodology

For many sports injuries, traditional lab methods cannot be used to obtain three-dimensional kinematics. However reconstructions of motion patterns from video sequences could improve the understanding of injury mechanisms. Model-Based Image-Matching (MBIM) can be used to measure three-dimensional temporal joint angle histories, velocities and accelerations from un-calibrated video data.

Since ethical approval is currently being processed, an initial assessment on the MBIM technique to measure head kinematics has been completed on a random video which was freely available online. No injury data is thus linked to this kinematic assessment. The video resolution was 1080p with one camera view recorded at 25 fps and the other at 125 fps. An example of the 125 fps video sequence can be seen in Figure 1.

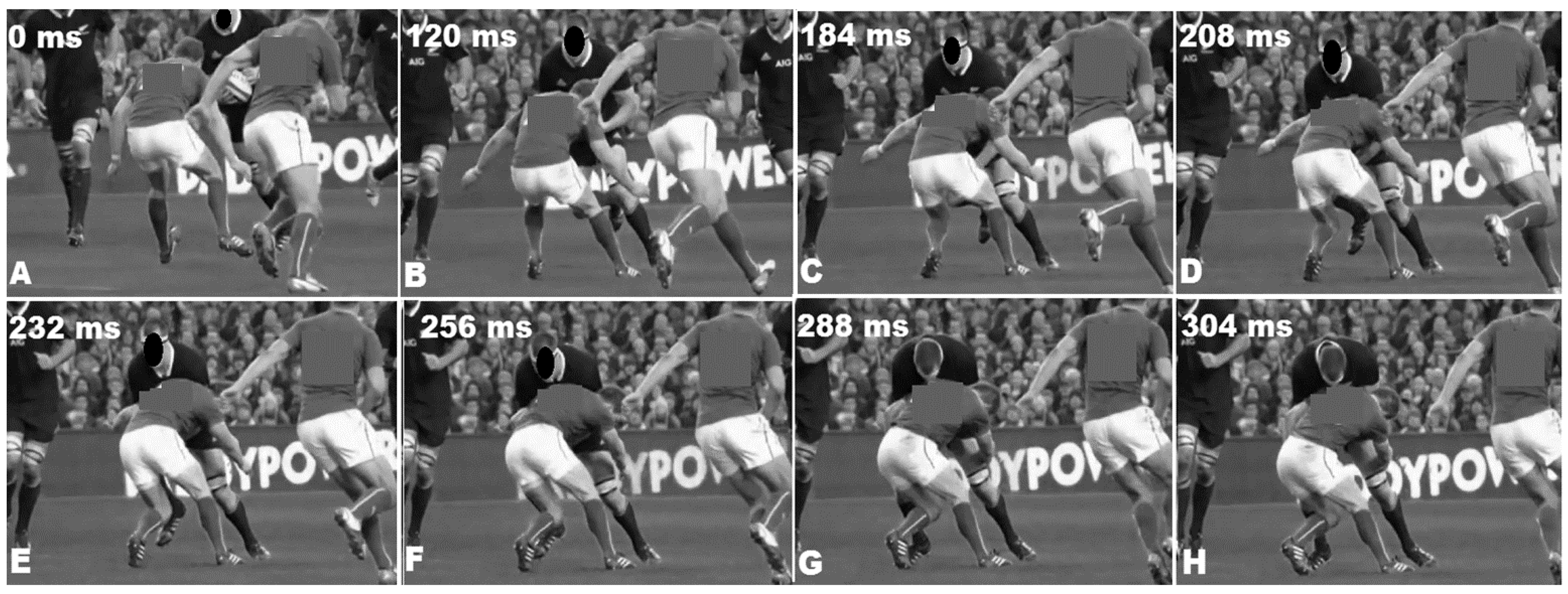

Figure 1: An image sequence at various times throughout the impact event. Velocity is reduced in image B due to planting of the foot from landing; initial impact occurs at D; the head collides with the opposing player's bicep due to a whiplash effect from the impact at D; the impact finishes at G.

The matching is performed using 3-D animation software Poser 4 and Poser Pro Pack (Curious Labs Inc, Santa Cruz, California). The surroundings are built in the virtual environment based on the real dimensions of the sport field. A skeleton model from Zygote Media Group Inc (Provo, Utah) is then used to fit the player's anthropometry (Figure 2) for each video frame thus yielding the player's kinematics. Using a customised script in Matlab (MathWorks Inc, Natick, Massachusetts), the joint angle time histories are processed and plotted.

Figure 2: The skeleton model matched to the player anthropometry for a given video frame

Results

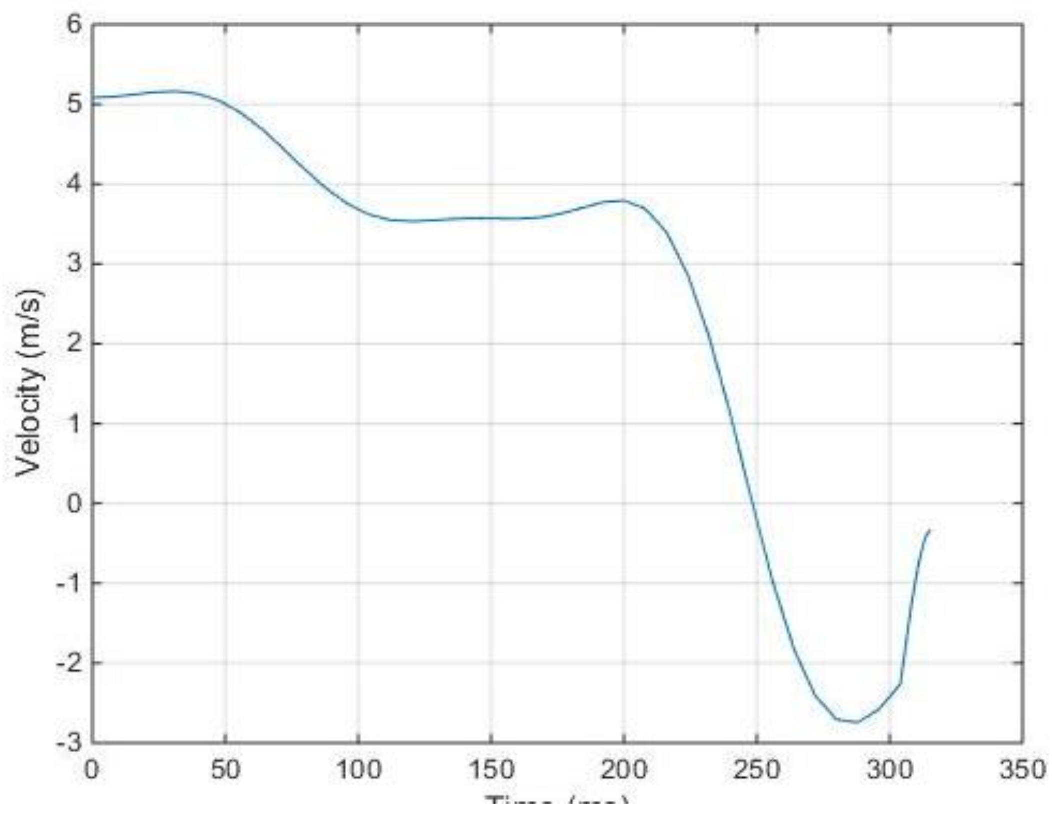

Figure 3: Resultant linear velocity of the head

Linear Kinematics	
Velocity before collision (m/s)	3.8
Velocity after collision (m/s)	-2.8
Change in velocity (m/s)	6.6
Peak acceleration (m/s^2)	138 (14.07g)
Average acceleration (m/s^2)	82.5 (8.41g)
Duration of Impact (ms)	80

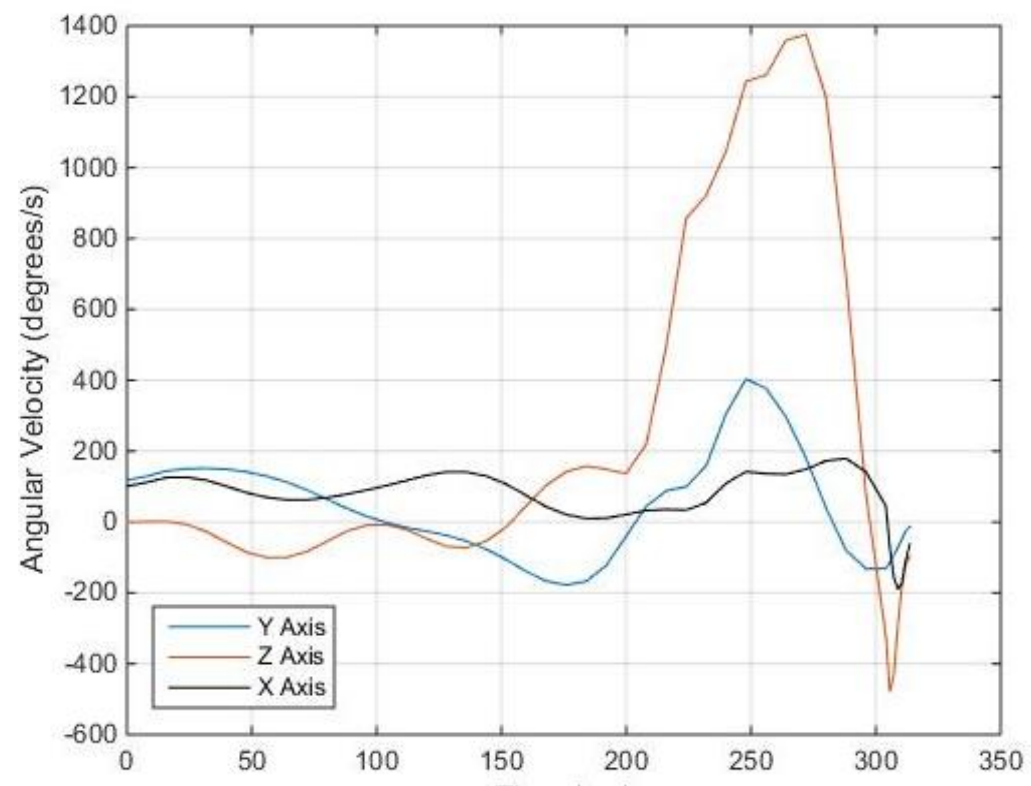

Figure 4: Angular velocity about the 3 axes of the head

Rotational Kinematics	
Change in angular velocity (degrees/s)	1905 (33.25 rad/s)
Peak acceleration ($degree/s^2$)	88354 (1542 rad/s^2)
Average acceleration ($degree/s^2$)	54428 (949 rad/s^2)

Discussion

The results from this initial study suggest that the MBIM method can be applied to head impact cases in rugby union. The peak linear and rotational acceleration value from this impact is significantly less than those reported in the literature for head impact cases in American Football (81-106g and 5022-7951 rad/s^2 respectively) [4]. This is mainly because American football players wear hard shell helmets in the game and that the kinematics of the impacts are different for both sports.

The change in linear and rotational velocity values determined in this impact, 6.6m/s and 33 rad/s, are in the same range as reported in previous rugby head impact studies [5],[6]. This provides significant reassurance on the validity of the MBIM method for analysing head impacts in rugby.

Conclusion

The results from this initial study are similar to that reported in literature for the sport of rugby particularly for the change in head angular velocity. It is argued that rotational kinematic parameters are more likely to predict concussion than linear kinematic parameters [7] so this will be a focus for analysis of future concussion cases.

The MBIM method should be applied to a number of head impact cases to establish thresholds for concussion injuries in rugby. The data gained from the MBIM method can allow for more reliable kinematic data to be inputted into finite element analysis and rigid body simulations of concussion impacts. This can allow multi-axis force measurements to be measured within the brain and neck. This can ultimately lead to an improvement in concussion injury prevention and management.

References

[1] SMITH D, JOHNSON V, STEWART W. 2013. Chronic neuropathologies of single and repetitive TBI: substrates of dementia? Nature Reviews Neurology, 9, 211-21.

[2] KROSSHAUG, T., NAKAMAE, A. BODEN, B. P., ENGEBRETSEN, L., SMITH, G., SLAUTERBECK, J. R., HEWETT, T. E. & BAHR, R. 2007. Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. Am J Sports Med, 35, 359-67.

[3] YAMAZAKI J, GILGIEN M, KLEIVEN S. 2015. Analysis of a severe head injury in world cup alpine skiing. Medicine and science in sports and exercise 2015;47(6):1113-8.

[4] MCINTOSH, A. S., PATTON, D. A., FRÉCHÈDE, B., PIERRÉ, P.-A., FERRY, E. & BARTHELS, T. 2014. The biomechanics of concussion in unhelmeted football players in Australia: a case–control study. BMJ Open, 4.

[5] MCINTOSH, A. S., MCCRORY, P. & COMERFORD, J. 2000. The dynamics of concussive head impacts in rugby and Australian rules football. Med Sci Sports Exerc, 32, 1980-4.

[6] PATTON, D. A., MCINTOSH, A. S., KLEIVEN, S. & FRÉCHÈDE, B. 2012. Injury data from unhelmeted football head impacts evaluated against critical strain tolerance curves. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 226, 177-184.

[7] GENNARELLI, T. A., THIBAULT, L. & OMMAYA, A. 1972. Pathophysiologic responses to rotational and translational accelerations of the head. SAE Technical Paper.