Estimation of Low-Severity Rugby Union Ruck Collisions

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I. INTRODUCTION

Injury is an inevitable consequence of professional sports, particularly those involving a high degree of human contact, such as rugby union. In the English Premiership, knee injuries were identified as the only injury type to cause an absence of greater than 150 days per 1000 playing hours for all playing positions [1]. A surveillance study of professional English Rugby Union involving over 16,000 hours of match-play determined that human-on-human contact was the primary mechanism of knee injuries, which accounted for 72% of knee injuries sustained during matches [2]. Ogaki *et al.* [3] investigated knee injuries in Japanese college level rugby players and found that knee injuries sustained by forwards across four playing seasons primarily occurred during rucks and mauls (48.5% of cases), where the players are often contacted while in vulnerable positions such as the "jackal position", which refers to the defending player latching onto the ball or grounded player during the ruck, or when contacted by two players simultaneously. However, there has been no detailed biomechanical analysis of the forces/moments experienced in the knees joints resulting from player-on-player collisions at the ruck. Although wearable sensors provide validated data, their applicability to match-scenarios remains limited due to their intrusive nature. Our aim is therefore to develop and assess a semi-automatic framework that utilizes video footage from multiple viewpoints and incorporates deep learning-based human pose estimation and computational modelling to analyze the biomechanics of knee loading during a rugby union ruck.

II. METHODS

A multi-staged approach was adopted in the development of the proposed framework. The experimental procedure involved staged low-severity rugby collisions, with three spatially calibrated cameras arranged around the impact area. The collisions involved a player in the 'jackal' position, being contacted by another player at varying angles of attack (0˚, 30˚ and 60˚) at low collision intensity (as required by the TCD ethical approval). The 2D joint positions for both players were inferred using open-source software [4]. Validation of these predicted temporal joint locations was achieved by visually inspecting the key point locations overlaid on the input video footage on a frame-by-frame basis. Using synchronized video from three spatially calibrated cameras (MATLAB Camera Calibration tool) allowed for these 2D poses to be lifted to 3D space using algebraic triangulation. The three-dimensional predicted pose was passed through a custom temporal inverse kinematics post-processing tool to establish joint orientations for application in a computational model (MADYMO Computational Modelling), with some manual adjustments. By thus incorporating initial pre-impact joint degrees of freedom and their derivatives and by scaling to the known height and mass of the players, a 250ms forward dynamics MADYMO simulation was configured. From this, the predicted bending moments and loading forces in the knee joints experienced by the contacted player were assessed against known knee injury thresholds obtained from the literature [5,6].

III. INITIAL FINDINGS

Figure 1 shows a visual representation of the proposed semi-automatic, multi-staged framework for analysing the biomechanics on knee injuries that occur in rugby union. The optimized and formatted kinematic parameters were incorporated in conjunction with a temporal approximation of player approach velocity, which was determined from the distance between both players' pelvises over five frames prior to the initial contact, to initialize the collision sequence. As the kinematic post-processing tool is currently under development, a small number of postural adjustments were required to closely match the model to the collision footage (Figure 2). The valgus bending angles (Figure 3), torque (Figure 4) and shear displacement (Figure 5) in the knees of the contacted (Jackal) player were compared to literature thresholds for the case in Figure 2 (30˚ angle of attack).

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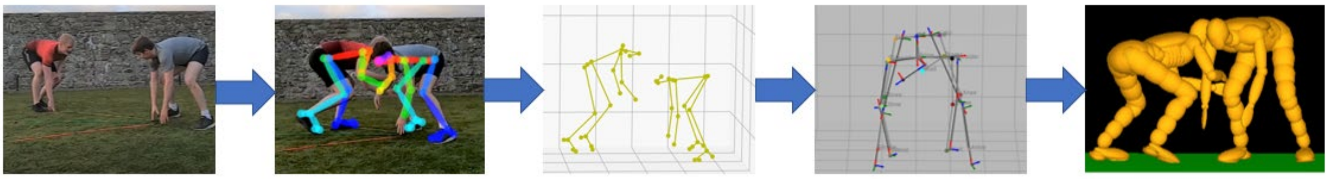

(a) (b) (c) (d) (e)

Figure 1: Framework: (a) Experimental footage, (b) 2D pose estimation, (c) 3D pose estimation, (d) Inverse kinematics for MADYMO model initialization and (e) Forward dynamics MADYMO modelling

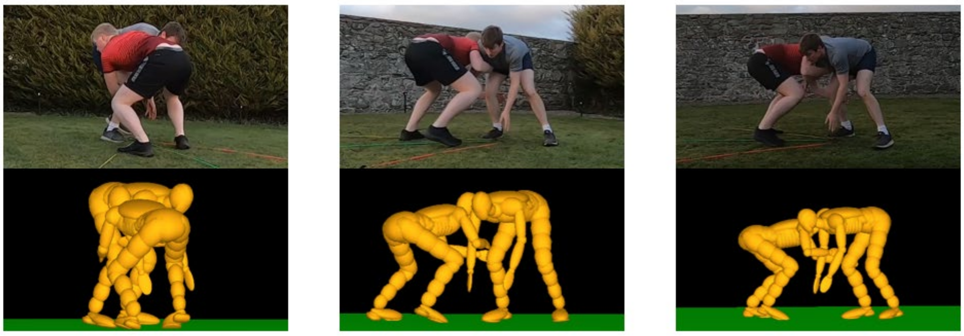

Figure 2: Comparison between MADYMO model and experimental footage at the time of collision

(a) (b)

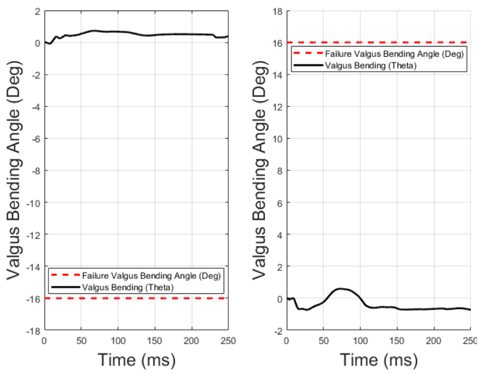

Figure 3: Valgus bending angles
(a) Left knee, (b) Right knee

(a) (b)

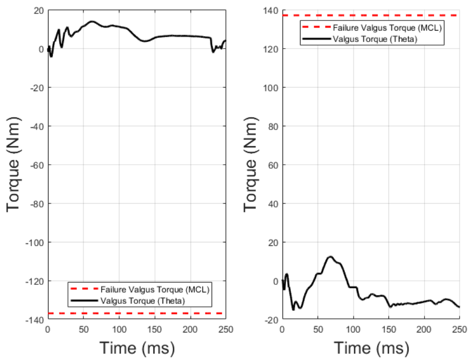

Figure 4: Resultant torque
(a) Left knee, (b) Right knee

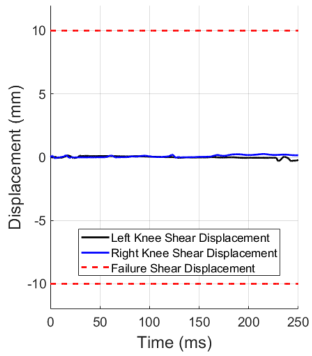

Figure 5: Knee Shear Displacement (Valgus-Varus)

IV. DISCUSSION

In this case, the contacted player experienced minimal valgus bending, torque and shear displacement in the knee joints during the collision sequence, as expected for a low-severity impact. However, the proposed framework shows great potential as a foundation for which a fully automatic biomechanical assessment tool could be based upon, using calibrated footage from training and game events. Achieving validated injury biomechanics data could be possible when used in sporting venues that utilize a calibrated camera configuration. Nevertheless, there are currently several limitations to the proposed framework including the inability to account for natural human response, such as bracing prior the contact. Although the models are scaled for height and mass, the joint restraints and stiffness characteristics are generic. Additionally, the simulation produces results solely based on the initial joint velocity condition set during the initialization process, which doesn't consider the variation in muscle activation over the duration of the collision sequence. Future work will apply this framework to the biomechanics of sporting injuries arising from higher contact speeds, and an analysis of the details of the predicted knee loading, which will focus on MCL loading in the ruck. Additionally, implementing an approximation of muscle activation over the duration of sports collisions would further improve biomechanical analysis.

V. REFERENCES

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