Comparison of CORA to Head Injury Biomechanical Metrics Using an American Football Helmet Model

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I. INTRODUCTION

Head injury is a growing concern within contact sports, including American football. Helmets worn by players of this sport help reduce injury risk. Computational tools such as finite element (FE) models provide an avenue for researchers to study, and potentially optimise, helmet performance. However, like any FE model, those of football helmets must first be validated at relevant impact velocities and loading conditions.

CORelation and Analysis (CORA) [1] is a widely used tool to validate computational models vs experimental data. CORA determines how closely two time history curves match by comparing their phase, slope and magnitude. A score of 0 indicates no correlation, and a score of 1 represents a perfect match between the simulation and experiment. The process of analysing the match between experiment and test data using these three independent rating metrics is intended to provide a comprehensive comparison of the two signals.

However, while CORA is used to compare time history outputs from computational models to experiments, it is unknown how well CORA scores correlate to agreement in head injury metrics. In this study, we present the development of a FE model of an American football helmet, and compare the quantitative validation metric (CORA) with the agreement between simulated and measured metrics used to evaluate head injury risk, specifically Head Injury Criterion (HIC) [2], and the Brain Injury Criterion (BrIC) [3]. This is accomplished using 36 matched simulations of linear and pendulum impacts.

II. METHODS

The FE model of a Schutt Air XP Pro football helmet was developed through three major steps: geometry development, material characterisation, and model validation. Computed Tomography (CT) scans were used to quantify the geometry of the helmet components, which were then segmented and meshed. Material characterisation was performed using coupon testing across various strain rates, and material models were fit to the material-level experimental data. The model and mesh can be seen in Fig. 1(A).

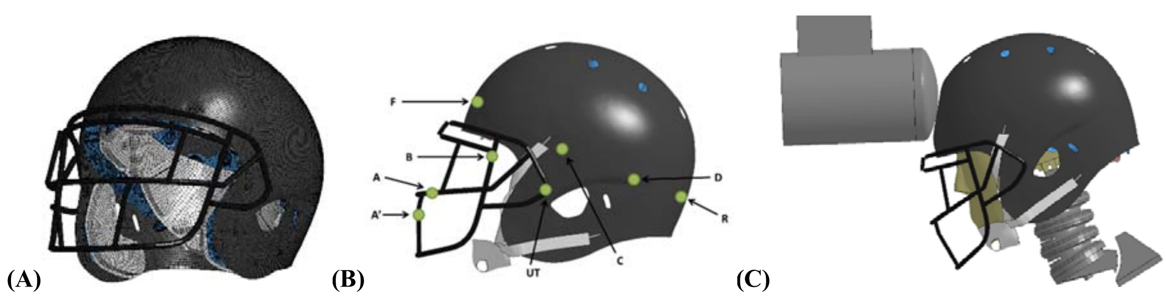

Fig. 1. (A) Meshed model of the Schutt Air XP Pro football helmet, (B) locations of impact for the linear impactor tests, (C) an example of front pendulum simulation.

The helmet model was fit onto an FE model of a Hybrid III headform and evaluated in 36 matched-pair simulation-experimental tests: 24 linear impactor tests, and 12 pendulum tests. The linear impactor tests were conducted at eight different locations of impact (Fig. 1(B)) and three different impact velocities (5.5 m/s, 7.4 m/s and 9.3 m/s). The pendulum tests (Fig. 1(C)) were conducted at four different impact locations (front, front-boss, side and back), and three different impact velocities (3.0 m/s, 4.6 m/s and 6.1 m/s). The CORA scores presented were calculated using only head linear acceleration and head angular velocity, respectively, for HIC

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and BrIC. Values for HIC and BrIC were calculated for the experimental and simulation data, which were then used to determine the corresponding probability of an Abbreviated Injury Scale (AIS) of 2 or greater [4]. The difference between risk predicted by the model and by the experiment were then calculated and plotted against the CORA score.

III. INITIAL FINDINGS

The delta between risk values from the simulation and the experiment are plotted against the CORA value for each test in Fig. 2. The data points are colour coded for impact speed of the corresponding test.

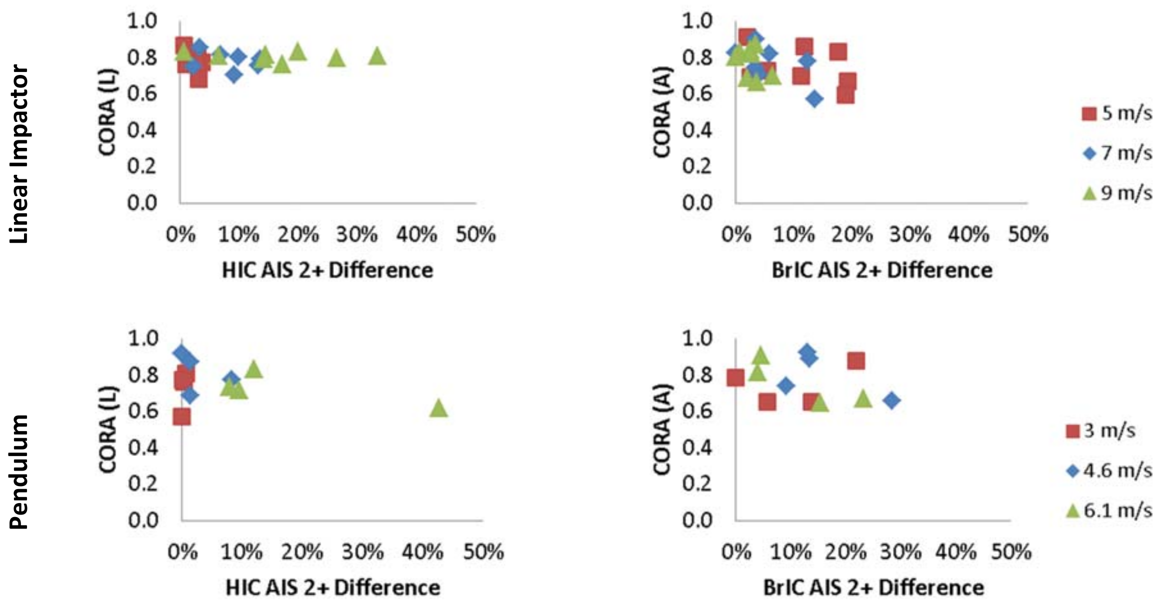

Fig. 2. The relationship between CORA scores and the differential of AIS2+ probabilities between the experiment and simulation data. CORA (L) is from linear acceleration, while CORA (A) is from angular head velocity.

IV. DISCUSSION

Overall, CORA scores were relatively high across the range of tests used to validate the model, which indicates reasonable agreement between the model and the experiment. In addition, discrepancies of HIC and BrIC were kept reasonably low, with the vast majority of data points indicating risk differences of less than 20%, and a majority less than 10%. The linear impactor data shows conflicting correlations of injury prediction related to impact severity; BrIC calculated injury prediction shows better agreement in more severe impacts, whereas HIC shows better agreement in less severe impacts. It should be noted that the nonlinear risk curves associated with HIC and BrIC may exacerbate differences due to where the metrics fall on their curves.

The preliminary findings indicate that the helmet model in this study demonstrates high CORA scores. While many cases indicated a low differential in risk prediction, some cases with high CORA scores demonstrated fairly divergent risk prediction. The results indicate that, when possible, comparisons of head injury metric values (and associated risk) between simulated and experimental trials should accompany more traditional, objective evaluation techniques like CORA.

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VI. REFERENCES

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