BIOMECHANICAL RISK ESTIMATES FOR CONCUSSION IN COLLEGIATE FOOTBALL PLAYERS

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INTRODUCTION

Past efforts to determine head injury tolerance have been hampered by the need to study injury in cadavers or primates. American football presents a unique opportunity to study concussion, or mild traumatic brain injury (MTBI), in living humans.

Based on video footage of NFL games, Pellman et al. (2003) reconstructed 31 head impacts, 25 of which resulted in a player sustaining a concussion, using helmeted Hybrid III dummies. King et al. (2003) presented risk curves for MTBI based on logistic regressions of the NFL data. However, the NFL data was intentionally biased towards injurious impacts, and was not intended to document the head impact exposure experienced by players in the NFL. The purpose of the present study was to analyze the risk of MTBI in the collegiate football setting in light of more complete head impact exposure data.

METHODS

Head impact data obtained from instrumented helmets worn by Virginia Tech (VT) football players during the 2003 and 2004 seasons were analyzed. The helmets were instrumented with the Head Impact Telemetry (HIT) System (Simbex, Lebanon, NH), which consisted of six spring-mounted accelerometers designed to stay in contact with the player’s head. The methodology and validation of the HIT system are described by Duma et al. (2005).

The risk of MTBI was analyzed in terms of peak resultant linear head acceleration, the head injury criterion (HIC), and peak resultant rotational head acceleration. A biomechanical data set was generated that included all injurious head impacts as well as the most severe non-injurious head impact sustained by each instrumented player. Risk curves for MTBI were calculated using the consistent threshold (CT) estimate for doubly censored data (Nusholtz and Mosier, 1999). The CT estimate is a non-parametric maximum likelihood estimate.

RESULTS AND DISCUSSION

The total data set included 11,605 head impacts sustained by 52 players. Although most impacts were of low severity, there were 993 impacts over 4500 rad/s\textsuperscript{2}, 225 impacts over 80 g, and 114 impacts with a HIC greater than 250. Only three concussions were recorded (Table 1). All three concussions resulted from impacts to the front of the head. For two of the injured players, the concussive impacts were the second-most severe impact recorded. For the other (MTBI #1), there were 6 – 13 more severe impacts recorded, depending on the severity measurement used. However, all three concussive impacts were the most severe frontal impact recorded for that player.
In spite of the small sample size, the results of the present study are in general agreement with the results of Pellman et al. (2003), at least with regard to injury data. The average peak linear acceleration and HIC associated with MTBI are similar in both studies. The average peak rotational acceleration associated with MTBI was somewhat higher in the VT data than the NFL data.

Table 1: Summary of VT injury data.

<table>
<thead>
<tr>
<th>MTBI #</th>
<th>$a_{res}$ (g)</th>
<th>HIC</th>
<th>$\alpha_{res}$ (rad/s$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56</td>
<td>121</td>
<td>5165</td>
</tr>
<tr>
<td>2</td>
<td>118</td>
<td>366</td>
<td>10776</td>
</tr>
<tr>
<td>3</td>
<td>137</td>
<td>518</td>
<td>11727</td>
</tr>
<tr>
<td>Mean</td>
<td>103</td>
<td>332</td>
<td>9223</td>
</tr>
<tr>
<td>S.D.</td>
<td>42</td>
<td>200</td>
<td>3546</td>
</tr>
</tbody>
</table>

With regard to non-injury data, the VT data is markedly different from the NFL data. The VT data is a random collection of head impacts, and is therefore an unbiased sample of the head impact exposure experienced by VT football players. As a result, the VT data includes a large number of non-injurious impacts, most of which are of low severity. However, a surprising number of high severity non-injurious impacts were recorded in the VT data that were not found in the NFL data. As a result, the CT estimate of MTBI risk using the VT data was considerably lower than the MTBI risk estimated from the logistic regression (LR) of the NFL data (Figures 1, 2, and 3).

**SUMMARY AND CONCLUSIONS**

MTBI risk curves were estimated from data obtained from VT football players wearing instrumented helmets. These unbiased head impact exposure data complement the injury data from Pellman et al. (2003), and allow for a more accurate determination of concussion risk. These data may be useful in designing equipment to protect football players and the general public.

**REFERENCES**


King, A.I. et al. (2003). *IRCOBI*.
