Full-face motorcycle helmet protection from facial impacts

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Context

- Facial impacts are common
  - 63.6% damage around facial opening (34.6% chin bar)
  - >60% cases in NSW in-depth Crash Study (2012-2014)

- Facial impacts are particularly injurious (Otte 1991)
  - Uninjured in 37% vs 70%
  - 3 x soft tissue injuries
  - 2 x fractures
  - 2 x brain injuries

Otte 1991
Context

- No required impact attenuation in AS/NZS or US standards.
- Some researchers suggest stiff chin bars while others recommend soft chin bars with an energy-absorbing liner.
Aims

- Investigate the effect of a full-face motorcycle helmet on the risk of head injury in a facial impact.

- Investigate the effect of energy-absorbing foam placed in the chin bar of the full-face helmet.
Methods

- THOR dummy
- Nine accelerometer package in headform
- 23.4 kg flat-faced pendulum impactor
- One accelerometer
Methods

- Specialty THOR headform with face skin (GESAC 2005)
- Based on US Navy recruit data
- Facial impacts were performed at 3, 4 and 5 m/s and headform response was compared
Methods

- Comparable peaks and area under acceleration pulse
Methods

- Impacts performed unprotected, helmeted and with added EPS foam in the chin bar.
- Three impact speeds of 3, 4.3 and 5 m/s.
- Added 20 mm thickness Rmax Isolite EPS with nominal density of 24 kg/m$^3$. 
Methods

- Simulated Injury Monitor (SIMon) finite element head model
- Maximum principal strain (MPS)
- Cumulative strain damage measure (CSDM)
- Correlated with brain injury risk

Takhounts et al. 2008
Methods

- Multiple linear regression used to investigate the effect of the helmet and of the padding on head injury risk:
  - Pendulum force
  - Headform peak accelerations and rotational velocity
  - SIMon outputs

- Dummy variables used:

<table>
<thead>
<tr>
<th>Helmet Condition</th>
<th>Dummy Coded Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NHvH</td>
</tr>
<tr>
<td>No helmet</td>
<td>-2</td>
</tr>
<tr>
<td>Full-face helmet</td>
<td>1</td>
</tr>
<tr>
<td>Full-face with EPS padding</td>
<td>1</td>
</tr>
</tbody>
</table>
Results
Results

- Headform responses

![Graphs showing peak COG linear and rotational acceleration with different impact speeds and helmet types.](image)
Results

- SIMon outputs

**Cumulative strain damage measure 0.1 threshold**

<table>
<thead>
<tr>
<th>Impact speed</th>
<th>No helmet</th>
<th>Full-face helmet</th>
<th>Padded chin bar</th>
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</thead>
<tbody>
<tr>
<td>3 m/s</td>
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<td></td>
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<tr>
<td>4.3 m/s</td>
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<td>5 m/s</td>
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**Maximum principal strain**

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<tbody>
<tr>
<td>3 m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3 m/s</td>
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<tr>
<td>5 m/s</td>
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</tbody>
</table>
Results

- Specific brain regions

![Graphs showing CSDM10 and MPS in brain regions for 5 m/s impacts]
Results

- Impact speed and NHvH added significantly (p<0.05) to the prediction of all headform responses and SIMon outputs.

- NPvEPS was not significant (p>0.05), except for CSDM05 in the brainstem.
Discussion

- Low risk of head injury when compared to injury risk thresholds.
- Related to the face structure of THOR.
- Minimal crushing of the low density EPS foam.
Discussion

- European Regulation chin bar test simulation
Discussion

- Limited area of foam being fully crushed.
Discussion

- Importance of other components.
- Chin bar impacts different to cranial impacts.

No chin strap
300 g

Tight chin strap
155 g

Stiffer shell
108 g
Discussion

- Full picture of head and neck injury
Summary

- Despite no required impact attenuation, full-face motorcycle helmets provide head injury protection from facial impacts.

- Chin bar impacts are different to cranial impacts with components such as the shell and chin strap playing a greater role in energy absorption/dissipation.

- Optimal chin bar characteristics (foam and shell stiffness) are unknown and require further investigation considering multiple injury types.
Acknowledgements

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Thank You