Introduction
Concussions account for 1.6-3.8 million sports-related injuries in the U.S. each year. The most severe traumatic brain injury is caused by rotational acceleration of the head (whiplash), and current helmet designs do not mitigate this damage. The goal of this project was to improve on existing products by (1) increasing head range of motion during normal sports activity, and (2) reducing more head rotational acceleration upon impact.

Material Selection and Design

Fluid Selection
A shear-thickening fluid made of corn starch and water (Oobleck) was chosen for its rate-dependent properties, low cost, and ease of manufacturing. To identify the appropriate concentration of the Oobleck, drop tests were performed at an impact speed of 6.2 m/s with a 5.3 kg mass. The concentration that best minimized peak force, impulse, and rotational acceleration compared to an existing foam neck brace was selected (Fig. 3).

Foam-Oobleck Configuration Selection
A parametric study was performed in ABAQUS simulating a drop test on six foam-Oobleck configurations. The configuration resulting in the lowest angular acceleration was selected for the final design. (Fig. 4)

Mold and Casing Design
The inner fluid bladder is made of two layers of thin latex for flexibility and strength. The outer bladder is molded from 30A Silicone to protect against inner bladder rupture and to allow fluid movement. The outer bladder was molded on a 3D printed mold (Fig. 1).

Final Evaluation

Drop Testing
A drop test was performed on the final Comfy Crash brace design (Fig. 2). The peak force, impulse, and rotational acceleration were extracted from the drop test data and compared to the same metrics for the commercial foam brace (Fig. 5, 6).

Range of Motion (ROM) Testing
ROM in three planes (lateral, extension, and rotation) was measured using JTECH Inclinometers while wearing the existing foam brace and the Comfy Crash neck brace and compared to ROM without a brace.

Results

<table>
<thead>
<tr>
<th>Metric</th>
<th>Commercial Brace</th>
<th>Goal</th>
<th>Comfy Crash Brace</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotational Acceleration² (rad/s²)</td>
<td>12288</td>
<td>&lt;6383</td>
<td>8,237</td>
<td>33</td>
</tr>
<tr>
<td>Extension</td>
<td>31.4</td>
<td>18.4</td>
<td>7.8</td>
<td>75</td>
</tr>
<tr>
<td>ROM Reduction (*)</td>
<td>24.5</td>
<td>11.2</td>
<td>14.9</td>
<td>39</td>
</tr>
<tr>
<td>Lateral ROM Reduction (*)</td>
<td>9.11</td>
<td>6.2</td>
<td>4.7</td>
<td>48</td>
</tr>
</tbody>
</table>

Conclusions and Future Work
The Comfy Crash brace successfully decreased head rotational acceleration upon impact and increased head range of motion compared to off-the-shelf neck brace products. Future designs could be improved by testing a thicker Oobleck layer to meet the 50% concussive risk spec. The corn starch was found to come out of solution easily and future work may also include investigation of a chemical additive to improve long-term suspension. Finally, the brace currently has a short shelf life. An anti-fungal or preservative will need to be added to the fluid in future iterations.

References
1. 50% concussive risk value reported by Rowson et al., Ann Biomed Eng, 2012
2. Goal based on normal values from Youdas et al., Phys Ther, 1992, ROM baseline taken from average ROM values measured without wearing a brace.

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