CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

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Project Number

S0325

Project Title

Assessing the Angular Dependence of Skull-to-Brain Impact Dynamics to Inform Future Bicycle Helmet Design

Abstract

Objectives

Since bicycle helmets are designed to balance both safety and comfort, testing methodologies should have adequate fidelity to measure the relevant variables. Because the brain is not modeled, current bicycle helmet testing offers no insight into the dynamics between the skull and brain during collisions, nor does it examine helmet performance at varying impact angles. By utilizing an instrumented skull-brain model, this work investigated the angular dependence of the skull-to-brain impact dynamics for 3 different helmet designs at 4 different impact angles.

Methods

A modified weight lifting machine served as a drop tower and photo sensors were used to measure the impact velocity achieved. The instrumented head assembly consisted of an anatomically correct 3D-printed skull encasing a model brain cast from 0.5% agarose gel which mimics the physical properties of the brain. 3D-printed angle brackets controlled the impact angle of the head assembly. Peak accelerations were computed from accelerometers embedded in the skull and brain for test drops from 0.5 meters. Time history data was recorded at 500Hz.

Results

The measured peak G force on the skull increased more significantly for flatter helmets than a round helmet as the impact angle was increased. The round helmet showed significant bounce or recoil effects at the highest impact angle whereas the flatter helmets showed about a 20% reduction in the transfer of the peak acceleration from the skull to the brain.

Conclusions

The measured G force variation on the skull with impact angle can be correlated to the shape of the helmet. Most importantly, the peak G force increased with large impact angles for the helmets with a flatter design. This is likely due to the initial surface area contacting the ground decreased as the impact angle increased. This result suggests that certification protocols should include testing at higher impact angles. Secondly the time evolution of the tests showed additional acceleration peaks after initial impact, likely due to recoils within the skull-brain assembly. Depending on helmet shape and impact angle, the fraction of the peak G force on the skull transferred to the brain changed. This could indicate energy was being dissipated over a longer time by rotational or tangential forces as opposed to axial recoil which would be a significant factor to consider in the design of future helmets.

Summary Statement

This project focused on using drop tests to understand the relationship between bicycle helmet design and helmet performance as measured by the peak G force transferred to a skull/brain model as the angle of impact was increased.

Help Received

I would like to thank my parents for their financial support, for their safety oversight, and for their assistance in running the video camera while I was in the scene conducting tests. I would also like to thank my adult supervisor, Mr. Jonathan Brix, for his encouragement.