Name(s)
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Project Number
S0329

Project Title
What Does the Brain Feel? Assessing Skull to Brain Impact Dynamics to Inform Improved Bicycle Helmet Design

Abstract

Objectives/Goals
Over 15% of deaths in bicycle accidents occur while the riders are wearing helmets. Current bicycle helmet impact testing focuses on measuring the reduction in G forces by using calibrated drop towers to inflict shocks into simple metal head assemblies outfitted with accelerometers. This method of testing does not measure the stresses transferred to the brain because the brain is not physically modeled. The purpose of this work was to investigate the skull to brain impact dynamics using similar test conditions but replacing the simple metal head with an instrumented model brain inside a 3D-printed skull.

Methods/Materials
A modified weight lifting machine served as a drop tower and photo sensors were used to measure the impact velocity achieved. The head assembly consisted of an anatomically correct 3D-printed skull encasing a model brain cast from 0.5% agarose gel, mimicking the physical properties of the brain. Both the skull and brain were equipped with accelerometers designed to measure the x,y,z accelerations up to 200 G. Two different helmet designs were tested on three impact surfaces.

Results
Results showed that the G loads transmitted to the brain were 10-30% lower than those transmitted to the skull, but the direction of the acceleration between the skull and brain changed significantly on impact. These results indicate that the brain may suffer shear forces in addition to compression forces, indicating more damage to the brain tissue. Both helmet designs tested showed similar results.

Conclusions/Discussion
An experimental drop tower for testing bicycle helmets using an instrumented skull/brain model was successfully demonstrated giving insights not available in current helmet certification testing where only a simple metal model of the head is used. The drop tests confirmed the hypothesis that the acceleration in the brain is lower than that experienced by the skull and that softer impact surfaces like dirt generate less G acceleration than firmer surfaces like cement. Most significantly, test results show the acceleration direction of the brain relative to the skull can change abruptly on impact, indicating a torque on the brain that induces shear forces in addition to compression forces. Higher fidelity helmet testing that incorporates a realistic instrumented skull/brain assembly should be performed to inform new helmet designs to minimize induced torques.

Summary Statement
Using a realistic helmet/skull/brain assembly instrumented to measure the accelerations transferred to the brain, I showed the brain can suffer both shear and compression forces during a simulated bicycle accident.

Help Received
I designed, built, and performed the experiments myself. I presented an overview of my project to my science teacher, Mr. Brix, before starting the project.