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

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Bicycle helmets are designed to balance both safety and comfort. To understand the design trade-offs, testing methodologies need adequate fidelity to measure the relevant variables. Because the brain is not modeled, current bicycle helmet testing only measures the G forces transmitted to a simple metal head and thus offers no insight into the dynamics between the skull and brain during collisions. Furthermore, current testing does not examine helmet performance at varying impact angles even though several studies have indicated this could be an important consideration in helmet design. By utilizing an instrumented model of the skull and brain, this work investigated the angular dependence of the skull-to-brain impact dynamics for three different helmets at four different impact angles. The experimental head assembly, mounted to a homemade drop tower equipped with a velocity measurement system, consisted of an anatomically correct 3D-printed skull encasing a model brain cast from 0.5% agarose gel. The measured time response of the skull and brain accelerations showed there were additional acceleration peaks after initial impact, likely due to recoils within the skull-brain assembly. The measured G force variation with impact angle could be correlated to the shape of the helmet. 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 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.

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