Influence of Blast Directionality, Intensity, and Combat Helmet Use on Head Surface Pressure Responses

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Introduction: Use of explosive weapons in military conflicts has grown over the last century, leading to an increase in traumatic brain injuries (TBIs). Blast events were found to be the most common cause of TBI among U.S. military servicemembers during the Iraq and Afghanistan war era, and the prevalence of blast TBIs in these conflicts brought the conversation of combat helmet blast protection effectiveness to the forefront. Current infantry combat helmets offer fragmentation, ballistic, and impact protection, but none are designed for protection against primary blast.

Numerical simulations have computed under-helmet pressures during blast events that suggest the blast wave infiltrates the gap between the head and helmet and generates regions of increased pressure on the surface of the head. While this phenomenon, coined the underwash effect, has been reproduced with various computational models, the effect has been evaluated experimentally in only a limited number of studies, and the underlying mechanism responsible for the increased pressure regions under the helmet remains unclear.

Objective: The objective of this work was to experimentally evaluate the effects of combat helmet use, blast orientation, and blast intensity on head surface loading in order to assess the protective performance of an existing combat helmet in various blast scenarios.

Methodology: A fabricated headform was instrumented with four pressure sensors mounted flush with the head surface. Three sensors were placed along the midline in the forehead, top front, and top back of the head, while the fourth sensor was positioned on the side of the head superior to the temporal bone. A large Advanced Blast Simulator (ABS) located at Virginia Tech was used to expose the headform to two blast overpressure levels (approximately 16 and 24 psi), in two blast orientations (0-degree or 45-degree rotation about the transverse axis), with and without a combat helmet. Three tests were conducted for each combination of experimental conditions. Peak pressure and total impulse were evaluated at each sensor location.

Results: In the 0-degree orientation, the peak pressure was attenuated at the forehead and front of the head but was notably increased at the back of the head with the helmet compared to without the helmet. Rotation of the headform 45 degrees about the transverse axis resulted in increased peak pressure and total impulse at all sensor locations with the addition of the combat helmet. When comparing between the 16 and 24 psi tests in any orientation, the 24 psi test consistently resulted in higher peak pressures and total impulses at all sensor locations.

Conclusions: The collected data suggest the underwash effect was observed experimentally. The combat helmet appeared to offer some reduction in peak pressure towards the front of the head in the 0-degree orientation, but peak pressure and total impulse were predominantly increased with the helmet. While these results seem unfavorable for blast protection, future directions should investigate how this increased loading

under the helmet might translate into injury. Moreover, future work should investigate different pad geometries and helmet liners to help mitigate the increased pressure under the helmet.

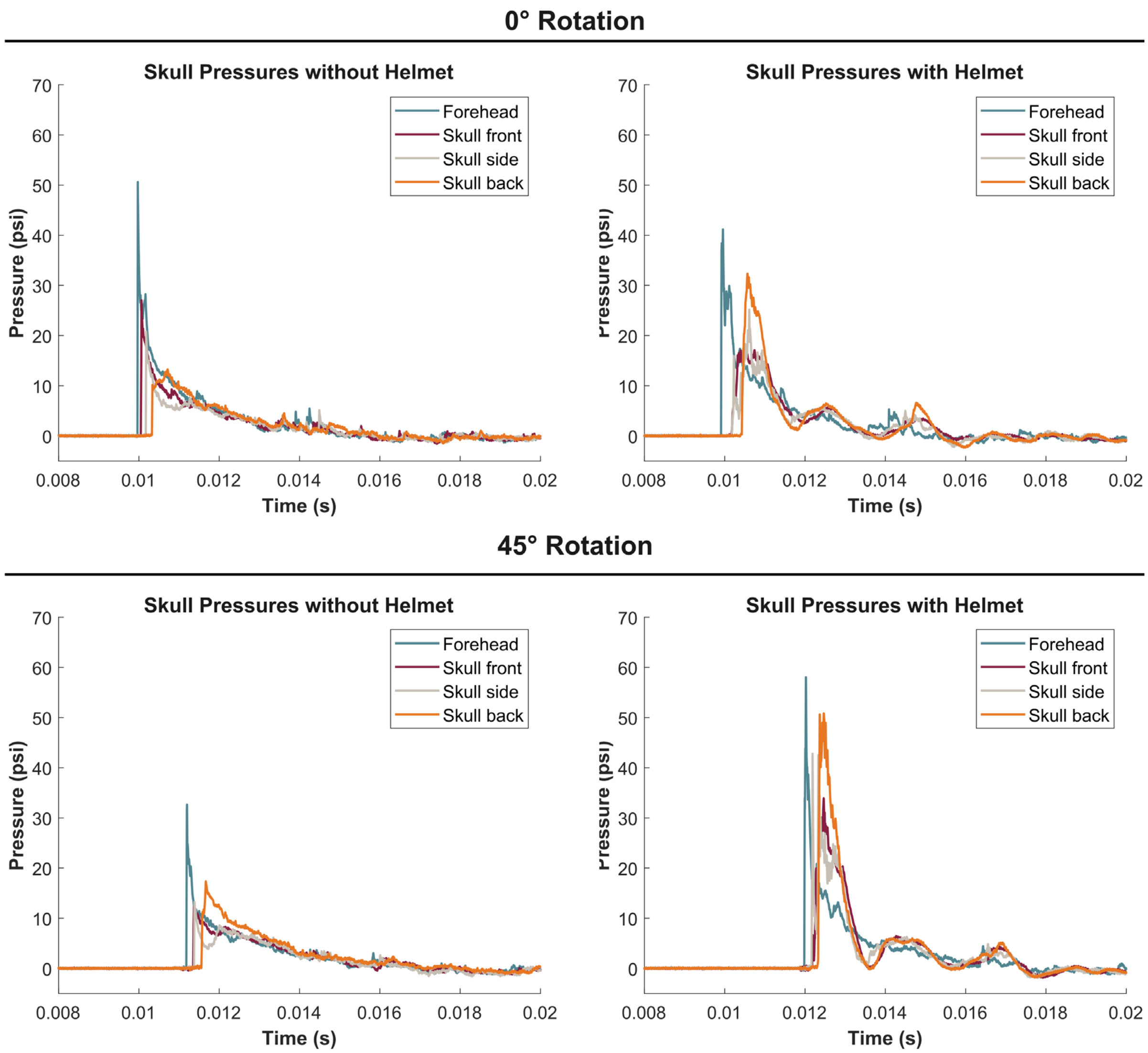

Figure 1. Representative pressure-time traces measured on the head surface without the helmet (left) and with the helmet (right) and in the 0° rotation orientation (top) and the 45° rotation orientation (bottom) for the 16 psi target incident pressure.