Blast wave protection in combat helmet design: a historical comparison

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Background

Since World War I, helmets have been used to protect the head in warfare. They have been designed primarily for protection against artillery shell shrapnel. Starting in WWI, reports were made of 'shell shock', a brain injury caused by blasts. Recently, traumatic brain injury (TBI) has been called the 'signature wound' of conflicts in Iraq and Afghanistan. More modern helmet requirements have included ballistic and blunt trauma protection, but neurotrauma from primary blast has not been a key concern in helmet design.

Objective

This study compares the blast protective effect of historical (WWI) and current combat helmets, against each other and the 'no helmet' case, for realistic shock wave impingement on the helmet crown. The goal of this study is to analyze blast protection provided by these helmets, and aid in helmet design for protection against primary blast.

Methodology

Helmets (Figure 2) included WWI helmets from the UK/US (Brodie), France (Adrian), Germany (Stahlhelm), and a current US combat helmet (ACH). Helmets were mounted on a Hybrid III® (Humanetics) dummy head and neck, and faced towards the ground with a cylindrical blast tube (305 mm diameter) aligned along the crown of the head to simulate an overhead blast (Figure 1). Primary blast waves of different magnitudes (n = 46) were generated using compressed helium gas and a bursting polyethylene terephthalate (PET) diaphragm. Peak reflected overpressure at the open end of the blast tube was compared to peak reflected overpressure at the crown of the head. A general linear model was used to assess the effect of helmet type and tube pressure on the resultant crown pressure response (Figure 3). With tube pressure as a covariate, the Tukey HSD method was used to compare the outcomes of different helmet types. Statistical significance was defined as $p > \alpha = 0.05$.

Results and conclusions

The interaction term between helmet type and tube pressure was found to have a significant effect on the outcome. 'No helmet' and the Adrian helmet were each found to be statistically significantly different from all other helmets. The peak crown pressure was lowest in the Adrian helmet, which has a 'deflector crest' not found on the other helmets, and highest in the 'no helmet' case. The Stahlhelm, Brodie, and ACH were not found to be statistically different from each other. This shows that an increase in ballistic and blunt protection, as the ACH has over the historical helmets, does not necessarily equate to an increase in primary blast protection. The study demonstrates that both the historical and current helmets have some primary blast protective capabilities, and that simple design features may improve this capability for future helmet systems.

Figures

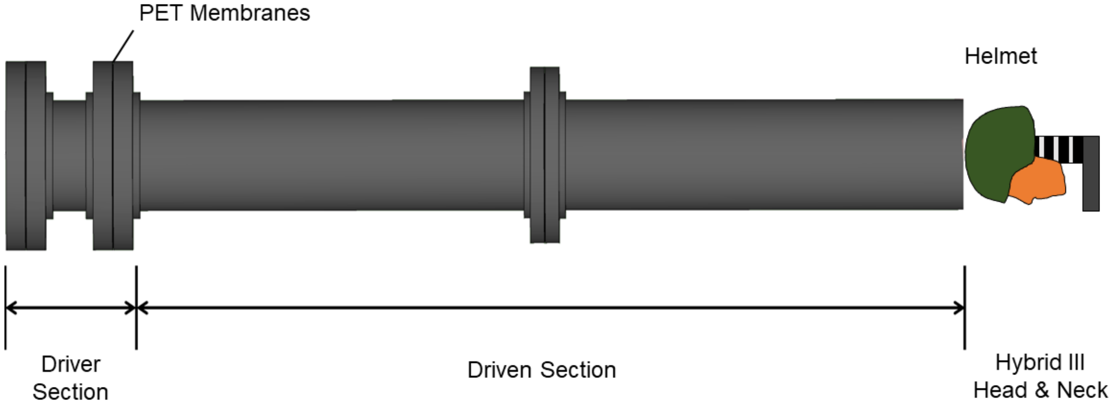


Figure 1: Blast Tube Setup

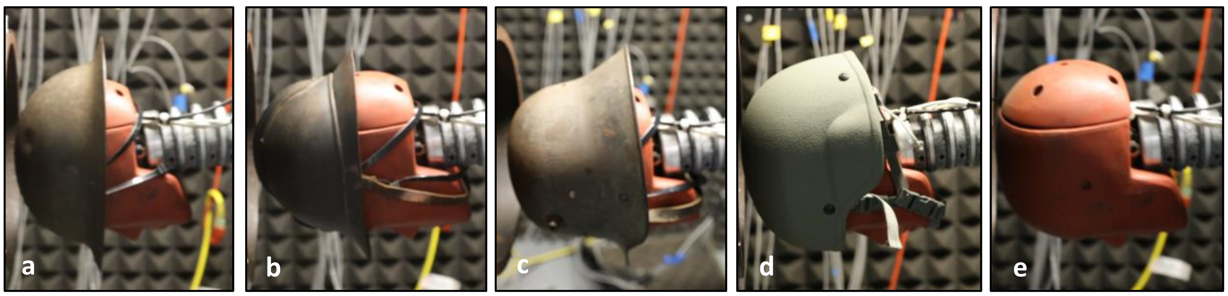
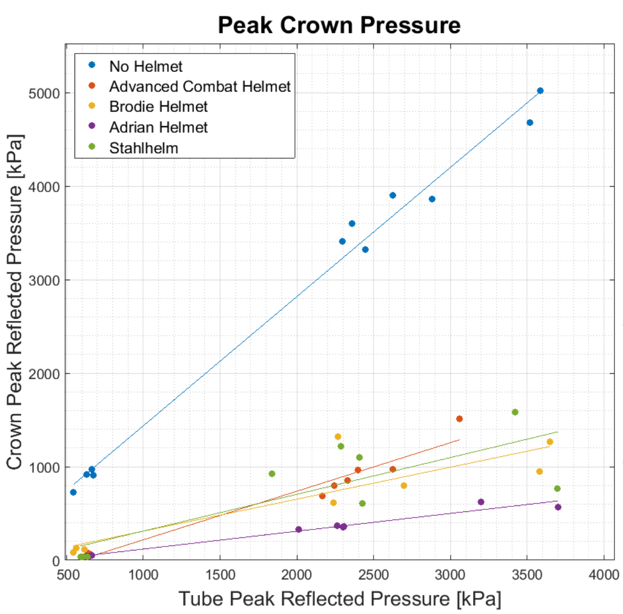


Figure 2: Brodie Helmet (a), Adrian Helmet (b), Stahlhelm (c), Advanced Combat Helmet (d), No Helmet (e)



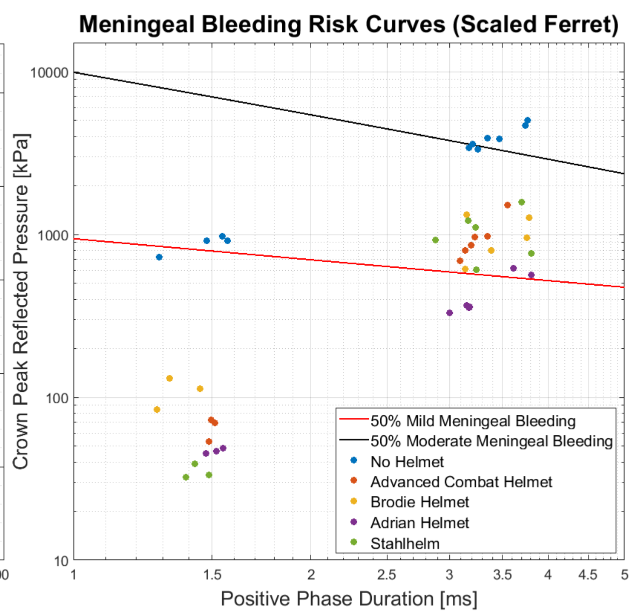


Figure 3: Linear Model Fit for Crown Pressure

Figure 4: Risk Curves Scaled from Ferret Blast Data[1]

[1]Rafaels K. et al., Brain injury from primary blast, *J Trauma Acute Care Surg,* vol 73, no 4, 2012