# Test Parameters for Lab-based Assessment of Behind Shield Blunt Trauma

Liam J. Burrows, Julia E. de Lange, Jean-Sebastien Binette, Cheryl E. Quenneville

## Background

Ballistic shields are a piece of equipment used by defence personnel during critical situations, designed to deform to dissipate energy for ballistic threats. The deformation along the back-face of the shield can interact with the user's arm, potentially resulting in injury or release of the shield. As limited research has been conducted in this area, an innovative testing method was required for developing novel injury limits in lab for this unique scenario. The purpose of this study was to characterize the impact conditions that would strike the arm to inform the design of a projectile for future PMHS tests.

## Methodology

Behind shield loading is more focal and faster than scenarios such as automotive. For accurate loading representation in lab, the impact velocity, energy, and shape of load application were captured. Six flat ballistic shields, with a level III protective rating, were tested per NIJ 0108.01 with seven shots per shield. High-speed footage was collected using two Fastcam SA-X type 324K-M2 cameras (30,000 fps) positioned with perpendicular fields of view. During testing, digital image correlation (DIC) was also conducted on two events to track the evolution of the back-face deformation. The shields were prepared to facilitate the imaging process by removing the back polyurea coating and applying a coat of white paint for a smooth surface. The surface was then speckled with black paint to provide landmarks for tracking. Once ballistic testing concluded, X-ray images of 13 shots were taken to assess the area affected by each strike. Fiji ImageJ (Fiji, version 1.53f51) with the MTrackJ plugin was used to determine the back-face velocity from the high-speed footage. The stiffness of the region of deformation was estimated using the affected area determined by the X-ray images and approximating the structure as a simple spring.

## Results

The peak back-face velocity was 205.64 ± 41.13 m/s based on 39 shots. This agreed with the 199.65 ± 9.37 m/s measured using the DIC (two shots). Furthermore, the back-face deformation captured by the DIC was averaged between the two shots and fit with a 10th order polynomial (R2=0.99) that represents the peak deformation profile. The average affected area from each shot (from X-ray analysis) averaged 1504.5 ± 258.3 mm2. Within these zones, shrapnel travelled primarily along the principal directions of the composite material. Based on the affected area, the stiffness of the ballistic shield was estimated to be 12.1 ± 2.1GN/m.

## Conclusions

The parameters of deformation such as energy, speed, stiffness, and resulting shape are essential for the development of realistic injury limits for the unique scenario of behind shield blunt trauma. The stiffness, area, and curvature values will be used to design a custom projectile for in-lab testing and combined with velocity data to represent the conditions applied to the upper limb during behind shield traumatic events. This will be used in the development of novel injury limits on post-mortem human specimens resulting from these impacts.