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How Deminer Position Contributes to Injury

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The 50th percentile male and the fifth percentile female Hybrid III mannequins were selected to represent people of two different body compositions and because such differences impact on the standoff distance that deminers can realistically achieve during mine clearance. The mannequins were positioned in three body orientations with respect to the blast cone, defined by the angle between the vertical and a straight line joining the nose and the mine. The three angles (α), denoted A1, A2 and A3, were 35, 27.5 and 20 degrees, respectively. For each mannequin, three standoff distances were tested (50, 60, and 70 centimeters for the fifth percentile; 60, 70 and 80 centimeters for the 50th percentile). The mean values of the angles were also shorter for the fifth percentile to account for the shorter reach of smaller individuals. Each scenario was repeated at least three times to determine the extent of the standard deviation of the results.

Dry, coarse sand was placed without compaction in a sandbox (a cube measuring 600 millimeters [24 inches] on each side, large enough to mitigate the effect of shock reflections) built into the test platform. Given that soil moisture is an important variable in a blast event, the sand was dried to less than 1 percent moisture content prior to shipment and kept under cover until immediately before the test setup. Following each trial, fractured sand was removed and replaced with fresh sand.

The explosive simulant used (50 and 100 grams, 1:5 percent) were prepared by packing C4 plastic explosive into standard containers. Each charge was pre-armed with an RP87 detonator, boosted with 2 grams of Detax® and buried at “ground zero” (in the center of the sandbox), with 20 millimeters (0.8 inches) of soil overburden. Detonation was initiated from the bottom center of the charge.

Lightweight and thin body-conforming armor was developed to provide protection to the rubber neck and skin of the mannequin from ejected sand. This “protection” (668 grams and 992 grams for the fifth and 50th percentiles, respectively) did not significantly alter the mass distribution or the nominal profile exposure of the blast.

Each mannequin was instrumented with accelerometers triads mounted in the center of gravity of the head (Endevco 7270BA) and in the spine (Endevco 7264B), a load cell (Denton 1716A) for the upper neck forces and moments, as well as two “flat pack” pressure transducers (Kulite QL-125) near the ear lobes (Dionne et al., 1993b). One channel was 1 MHz, which was sufficiently high to capture the full frequency spectrum of the acceleration, force and pressure signals. The head acceleration signals, along with the neck force and moment signals, were digitally filtered (low-pass) using a four-pole Butterworth digital filter, with the cutoff frequency set to 500 Hz. The cutoff frequency was used for spindle acceleration, in accordance with known standards used in the automotive and aeronautical industries (Society of Automotive Engineers J2118). Similarly, the standoff distance was found to have a moderate effect against the larger injuries, with the results being greater when the standoff was shortest (see Figure 2 for an example).

Predicted neck injuries were slightly more severe when facing head on than against the charge. For the 50th percentile male, the cutoff was increased to the 50-g charge, although the difference was usually not very great (see Figure 3 for an example). It was also found that the risk was very comparable between the two mannequin sizes (fifth and 50th percentile Hybrid III), for an identical charge and standoff distance (see Figure 4).

Research shows injury risks to deminers can vary depending on their body positioning. Here, the authors present the preliminary results of a study testing the effects of body position on deminer injury using mannequins. They hope to refine their methodology and continue in learning what will benefit the demining community.
Dr. Aris Makris holds a Ph.D. in mechanical engineering from McGill University. After 20 years of experience in the fields of shock waves, detonation, combustion and protective technologies, Dr. Makris has managed numerous R&D programs focused on the development of highly advanced personal protective equipment and related tools.

Ismail El Maach is currently a senior research engineer at Med-Eng Canada. He has a Ph.D. in aerospace technical engineering from the University of Toronto. At DRDC-Suffield, he worked on projects that include spacecraft systems and weapons effects. Recently he chaired NATO Task Group 24 to define how personal protective equipment should be tested against AP landmines.

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Conclusions

A test series was conducted using Hybrid III mannequins to assess the effects of AP mine detonations on the upper body of a deminer who is positioned in various standoff distances from the mine and who is oriented in different positions relative to the blast cone produced by the detonation of the charge. Two Hybrid III anthropomorphic mannequins of different sizes were accurately positioned using a specially built test platform/positioning rig to face blasts from simulated mines made of C4 explosive. Based on transducers located in the mannequins, injury assessments were made using the latest injury criteria used in the fields of automotive accidents and blast scenarios.

It was found that changes in body orientation with respect to the blast cone had an effect in the harshest test conditions (short standoff and/or large charge) on neck and head injuries only. Injuries to the neck, ear and head were affected slightly by the standoff distance and charge mass used, but again, this effect was only evident in the harshest test conditions. When comparing between the two mannequin sizes, it was found that for the same blast, head injuries were more severe for the 50th-percentile mannequin, whereas ear injuries were more severe for the fifth percentile mannequin. Lastly, chest injuries resulting from spine accelerations were found to be unlikely in this study.

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