Evaluation of Skin Penetration From Less Lethal Impact Munitions and Their Associated Risk Predictors

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Introduction
The use of less lethal impact munitions (LLIMs) by law enforcement has increased in frequency, especially following nationwide protests regarding police brutality and racial injustice in the summer of 2020. Despite their advertisement as being less lethal, there are several reports of the projectiles causing severe injuries when they penetrate the skin including: pulmonary contusions, bone fractures, liver lacerations, and, in some cases, death. The skin’s penetration thresholds in different body regions are due to differences in the underlying structure (varying degree of muscle, adipose tissue, and presence or absence of bone).

Objective
The objective of this study was to further investigate what factors affected the likelihood of a LLIM to penetrate the skin in various body regions and to develop corresponding injury risk curves.

Methodology
A total of eight, fresh/never frozen, unembalmed postmortem human specimens (PMHS) were impacted by two types of projectiles: a 1” and 5/8” neoprene rubber (durometer 55A) ball. Impacted body regions included the thigh, abdomen, anterior torso between ribs, anterior torso on a rib, sternum, scapula, posterior torso on a rib, and lower back, for a total of 24 shots per PMHS. In an effort to achieve both a penetrating and non-penetrating shot for each set of impacts, the impact location was assessed post impact to determine if penetration occurred, and the velocity of the next shot was adjusted to target the other outcome on the contralateral side within the same body region. Post-test, each PMHS underwent x-rays to determine if any other additional injuries occurred.

Results
Binary logistic regression was performed to determine what factors (e.g., velocity and energy density) were statistically significant at predicting risk of penetration. Energy density was utilized as the primary predictor to evaluate the two projectiles’ data together and additional parameters (e.g., skin thickness and BMI) were also tested as co-factors. Statistical significance was obtained with energy density alone for the thigh (p=0.004), anterior torso between ribs (p=0.043), lower back (p=0.40), scapula (p=0.03), and posterior torso on a rib (p=0.005). The abdomen was not significant with energy density alone (p=.085) but when BMI was added as a cofactor to energy density significance was found to be (p=0.021). The sternum and anterior torso on a rib were not found to have statistical significance. The 50th percentile risk of penetration was found for each region that was statistically significant. The thigh had a 50th percentile risk at 12.62 J/cm², 22.3 J/cm² for the anterior torso between ribs, 28.6 J/cm² for the lower back, 33.3 J/cm² for the scapula, and 34.3 J/cm² for the posterior torso on ribs.

Conclusions
The results support that energy density is a good predictor for estimating the likelihood of the skin to penetrate and that the risk of penetration changes in different body regions.