Creating a standardization variable to assist law enforcement in classification of firearms as either lethal or non-lethal

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ABSTRACT

The purpose of this study is to create a standardization variable to assist law enforcement in classifying firearms as either lethal or non-lethal. Studies thus far have examined the minimum energy density of a projectile that is required to cause bodily harm to a target [1]. Though, velocity is a vector and the angle of impact has an effect on the damage done by the projectile. The goal of this study is to correlate "serious bodily injury" to pressures produced by projectiles during the moment of impact with the target. Plastic pellets were fired from different airgun models into a ballistic gel medium. Observables from the plastic pellet were collected using high-speed video and experimental data including the velocity of the pellet, impact time between the plastic pellet and ballistic gel, and penetration depth into the ballistic median. Using these observables, corresponding impact pressures were calculated and compared to referenced pressures that cause bodily injury. Preliminary results indicate that pressures change dependant on the firearm. Analyzing the pressures from these firearms and assigning them to a threshold pressure, a standardization variable for "serious-bodily injury" could be produced leading to aiding the distinction between lethal and non-lethal firearm.

INTRODUCTION

- The Canadian Criminal Code defines a firearm as a "barreled weapon from which any shot, bullet, or other projectile can be discharged and that is capable of causing serious bodily injury or death to a person" [1]. As there is no standard set for the type and quantity of damage that would qualify as "serious bodily injury", this makes the classifying the lethality of airguns as firearms difficult. Previous studies used velocity as a unit for determining the lethality of airguns. However, as velocity is a vector unit, the effects of direction and impact angle of the projectile on damage produced were not taken into account.
- The objective of this study is to analyze different pressures from various models of airguns to determine a "threshold pressure" as a measurement for the classification of airgun lethality. The threshold pressure is the pressure produced by the projectile at the moment of impact against the target. Using the derivation $I = F \cdot \Delta t = \Delta P = mv_2 - mv_1$, the change in momentum is calculated. The impact force (F) is then calculated as F= $\frac{\Delta P}{\Delta t}$. The threshold pressure (P) exerted onto the ballistic gel is then found by dividing the impact force (F) by the surface area of the pellet P= $\frac{F}{A}$. As pressure is a scalar unit, the amount of damage produced by the fired projectile will not be affected by direction or angle of impact and will have a direct correlation to the numeric value of the pressure.

Figure 1: Still Frame of BB Entering Gelatin Median

MATERIALS & METHODS

A 12-foot steel table was placed in a room with all firing being performed near the end of the table. A block of gelatin mold was placed near the end of the table. Colorless gelatin powder was used to prepare the gelatin blocks two days before each firing trial and placed in a refrigerator to set. Three markers are set on the table to assure that distance between the nozzle of the air gun and gelatin mold is held at a constant 12 cm for each trial. Perpendicular to the gelatin mold and projectile path, a high-speed mega camera set to 900 fps was placed to capture the path of the projectile, and an ultraviolet "JR" lamp was placed above the table to simulate daylight. Two types of air guns (Gun 1: "War Inc." Compact Softair 6 MM Caliber Air Pistol and Gun 2: "Crosman" CO_2 Airsoft BB Repeater) are used, while the projectile (6mm plastic premier ammo pellets) was kept constant between both air guns. After ensuring the gelatin, camera and air gun were in position, the projectile was fired to impact a segment of the gelatin mold. After each individual recording, velocity of the projectile and collision time were collected. The penetration depth of the projectile into the gelatin was measured using a ruler after each trial.

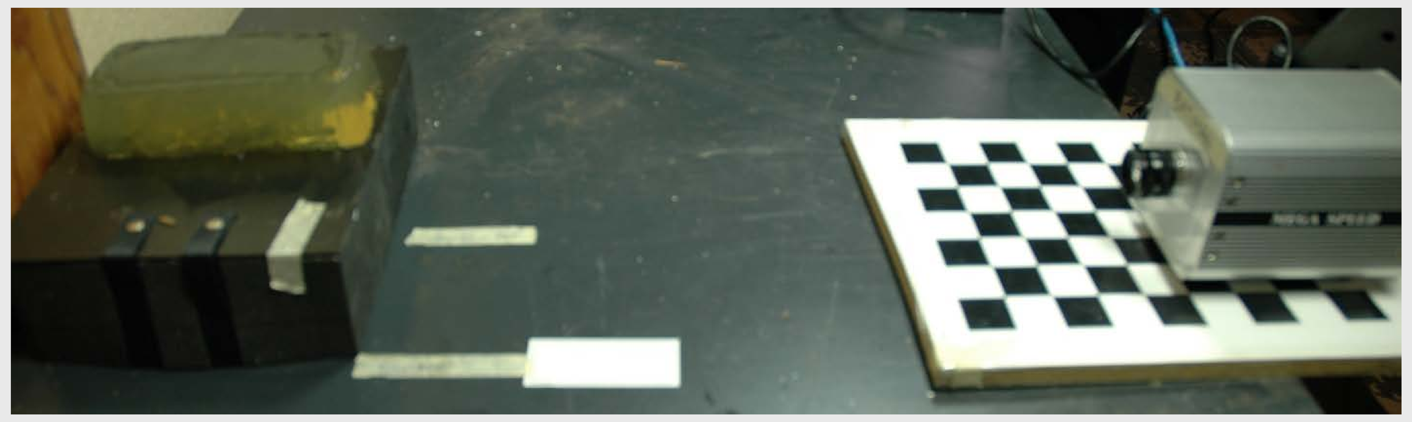

Figure 2: Positioning of Gelatin Median and Camera

RESULTS

- The depth of penetration as a function of velocity for Gun 1 and Gun 2 are displayed in Figure 3. The pressure as a function of velocity for Gun 1 and Gun 2 are displayed in Figure 4. The pressures and penetration depths were compared between Gun 1 and Gun 2. All data points have an identification based on when the ballistic gel was made, and which gel block was used for each trial.

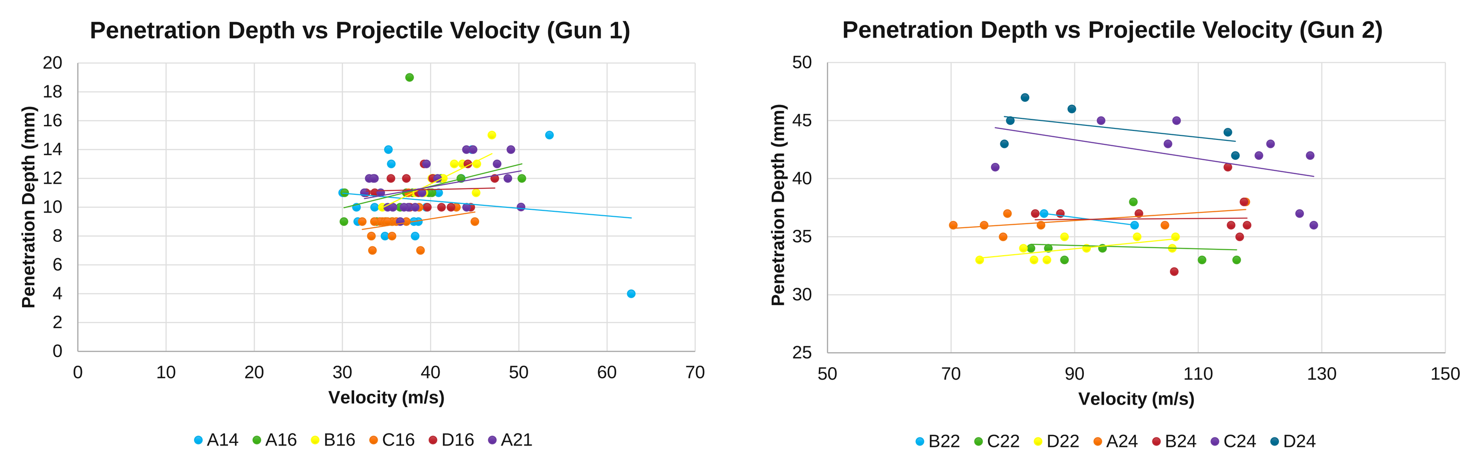

Figure 3: Penetration Depth vs Projectile Velocity of Air Guns

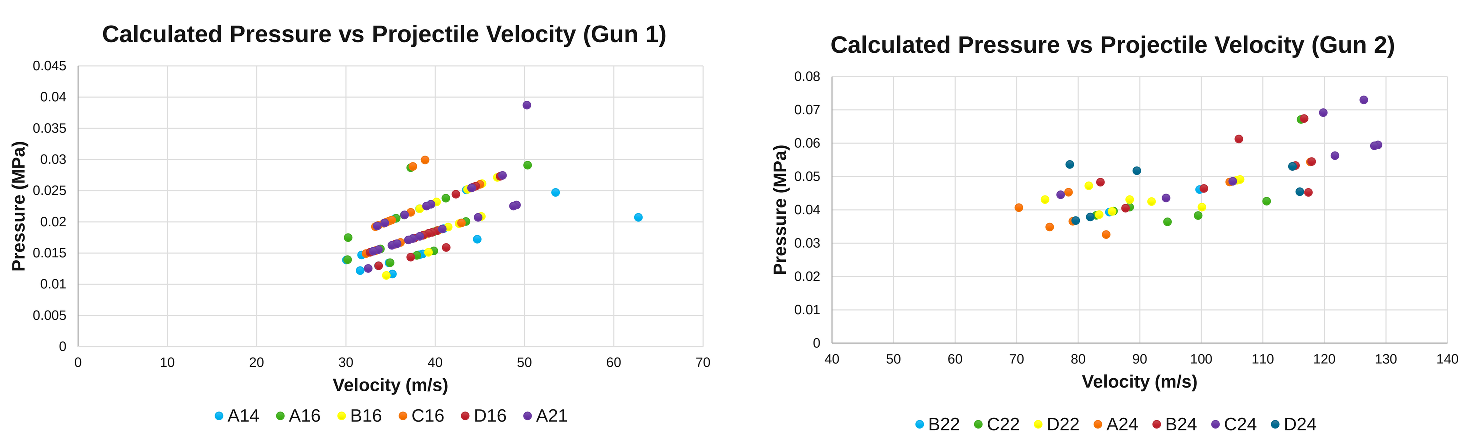

Figure 4: Calculated Pressure vs Projectile Velocity of Air Guns

DISCUSSION

- The bullet velocity for two guns (same bullet type), as well as the impact time and depth of penetration for the ballistic gel were successfully recorded. Figure 3 (left) displays a large scatter in the velocity vs. depth of penetration plot. Results indicate that the variation in depth of penetration for Gun 1 were not significantly different when the velocity changed. Figure 3 (right) displays more scattering along the linear regression for a similar plot for Gun 2, though the vertical trend can still be found. It can be assumed from this study that the variance in the depth of penetration for Gun 1 and Gun 2 is due to the inconsistent density between ballistic gel blocks, and is clearly shown in Figure 2 with data sets "D24" and "C24".
- To test this hypothesis, the Pressure was plotted vs. the velocity for both guns. Figure 4 display linear relations for both guns, which is expected since $P = \frac{F}{A}$ and $F = \frac{m*v}{A\Delta t}$ where A is the cross sectional area of the bullet, and t is the impact time (i.e. the time it takes the bullet to slow down to a complete stop. However, there appears to be more than one linear relation between the data, although the data can be easily grouped in 4 data subsets, having similar linear relations but different slope. The slope is given by: $\frac{m}{A\Delta t}$, and since the mass and cross sectional area of the pellet remain constant, the difference between each linear equation is the impact time. This is due to the impulse of the pellet.
- We assumed that the force was time independent in this experiment, however, given the nature of the experiment, it is more likely that the force be written as $F = F(t)$, which would include the differences in the density of the gel in the equation. We expect that future calculation with the force being a function of time should produce a better distribution of the data, and a single linear relation between P and v.

FUTURE WORK

- The study will be continued with future testing of different models of air guns and ammunition types. In order to determine a stronger correlation between depth of penetration and pressure, future testing will account for time and median density dependence in the calculation of force F (t, ρ). The air gun models will be re-tested using pig's eyes in place of the ballistic gel blocks. The goal of the altered experimental setup is to determine the "P_{50}", the pressure at which the eye will be ruptured 50% of the time, for each model of air gun tested as an alternative threshold unit to the "V_{50}" established in previous studies [2].

REFERENCES

1. Marshall W. John, Dahlstrom B. Dean, Powley D. Kramer, *Minimum Velocity Necessary for Nonconventional Projectiles to Penetrate the Eye.* The American journal of forensic medicine and pathology: official publication of the National Association of Medical Examiners. 32(2): 100-103.
2. Powley D.Kramer, Dahlstrom B. Dean, Atkins J. Valerie, Fackler L. Martin, *Velocity Necessary for a BB to Penetrate the Eye: An Experimental study using Pig Eyes.* The American journal of forensic medicine and pathology: official publication of the National Association of Medical Examiners. 25(4):273-275.