Influence of distance to depth shot of a CO₂-powered airsoft gun with lead shot ammunition and shape of the temporary and permanent cavity in ballistic gelatine.

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Abstract. The increasing aggression in the population, which is undoubtedly associated with the onset of narcissism, also entails an increase in the number of assaults in society. Of course, the number of clashes when a Weapon is used is also increasing. In most cases, these are weapons classified as weapons of category D (according to the Czech legislation), especially air guns, expansion weapons, and airsoft guns. This fact needs to be addressed, not by impulsive bans under duress, but by subjecting these weapons to the investigation, especially in the field of wounding ballistics, which answers the questions about the wounding potential of these weapons. This paper deals with one of these weapons, specifically airsoft gun with used ammunition lead shot. The depth of the shot and the size of the temporary and permanent cavity in relation to the distance were investigated, the contact distance was measured, and then the distance of 5 m.

1 INTRODUCTION

Aggression is growing in society; discussions about its causes can be lead. In the words of Dr. Andrej Drbohlav [1], this is directly related to the present time, which can be described as the time of narcissists. The fact is that the number of assaults is increasing and the number of cases, in which a weapon is used, increases. In most cases, these are weapons that are classified as weapons of category D (according to the Czech legislation), including weapons such as flobert weapons, air rifles, expansion weapons, airsoft guns, bows and crossbows and more. It is necessary to determine the wounding potential of these guns. Examples of their use in the Czech Republic are:

- February 20, 2019 - A man attacked his roommate with an airsoft gun – Brno-Židenice.
- June 4, 2018 - A man in a quarrel with his partner pulled out an airsoft pistol and threatened to shoot - Brno.
- April 11, 2018 - A man shot an airsoft gun at children - Karlovy Vary. [4]
- March 31, 2018 - A man assaulted shop with an airsoft gun.

There are not just attacks in the Czech Republic, but this trend is also in the world as is stated, for example in:

- October 23, 2018 - A pupil threatened a teacher with an airsoft gun - Paris-Creteil France. [6]
- May 7, 2017 - Policemen shot a 15-year-old boy who threatened them with an airsoft gun - San Diego - USA. [7]

- September 16, 2016 - Policemen shot a boy who had an airsoft pistol - Ohio - USA. [8]
- These are just a few illustrative examples, but the sad reality is that there is much more of these attacks.

The issue of the wounding potential of these weapons is more often reflected in the scientific sphere as the following publications demonstrate:

Injuries to the eye caused by airsoft guns are described by the authors of Khalaila S., Tsumi E., Lifshitz T., Kratz A., Levy J. in the article Airsoft gun – related ocular injuries: long – term follow - up. [9]

A very interesting approach was chosen by M. Gracla, Z. Malánik and M. Mikuličová in their article Detecting differences at a selected shooting weapon and its freely available copies. They examined the possibility of differentiation of weapons of Category B from weapons of Category D. [10]

The paper 10 - year Analysis of Head and Neck Injuries Involving Nonpowder Firearms by Dandu K.V., Carniol, E.T., Sanghvi S., Baredes S., Eloy J.A. also deals with weapons of category D.

In addition to the above-mentioned articles, the airsoft guns were investigated directly in Traumatic iridoid analysis from an Airsoft pellet in an aviator by PearceS.M. [12], or Strong B., Coady M.

Weapons, that generally have lower wounding potential, have been used in the papers: Toy gun eye injuries – eye protection needed - Helsinki ocular trauma study by Haavisto A.-K., Sahara and A., Puska P., Leivo T. [14], and in Prediction of the air gun performance by Horák V., Do Duc L., Vitek R., Beer S., Mai Q.H. [15],

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or in Expansion weapons and their wounding potential by M. Ficek, L. Juříček and M. Mikuličová.

2 Methods

The ballistic experiment was as follows: shooting a homogeneous substitution test block made from a replacement material, recording the passage and behavior of the missiles in this material using a high-speed camera.

The disposition of the experimental workplace was as follows:

- The airsoft pistol CZ 75 D COMPACT 2,7 JOULE (manufactured by ASG - ActionSportGames S / A under license of Česká Zbrojovka, driving drive siphon cylinder with CO2 12g brand UMAREX) was placed on the Caldwell Matrix shooting stand. 0.46 mm Umarex steel shots were used as ammunition.
- The shooting stand was placed 30 cm and 4.5 m from the Shooting Chrono Beta Master gates with a measuring range of 9 - 2100 m/s. The gates were placed 20 cm from ballistic gelatin.
- The ballistic gelatin block was scanned perpendicularly from the distance of 2 meters, using the high-speed Olympus I-SPEED FS camera with a resolution of 1280x1024, a maximum speed of 1,000,000 fps. A scan rate of 10,000 fps was selected for the experiment.
- 5 shots were fired from both distances.

Ballistic gelatin has been produced as follows:

The gelatin was mixed into the room temperature water while stirring (without bubbling). It was then left in a fridge at 10 °C for 2 hours. Then the container with gelatin was settled in a 40 °C water bath where complete dissolution of the gelatin was achieved with stirring. Thereafter, the gelatin was poured into a preformed mold (cleared with transparent gelatin) and allowed to solidify in the fridge (10 °C). After solidification and control, the gelatin was removed from the mold and packaged in a polyethylene film and placed in a cooling apparatus of the temperature of 4 °C for 36 hours (according to M. L. Fackler) for its tempering. The gelatin thus prepared was used for experimental shooting.

Gelatin had the following characteristics:

Table 1. Properties of ballistic gelatine with a concentration of 20%.

Substance	t	ρ	K	η	ν	c
	[°C]	[Kg. m ⁻³]	[1.Ps ⁻¹]	[Ps.s]	[M ² . s ⁻¹]	[m.s ⁻¹]
Gelatine 20 %	20	1060	3,7.10 ⁻¹⁰	1,0.10 ⁻²	0,1	1535

t - temperature, ρ - density, K - compressibility, η - dynamic viscosity, ν - kinetic viscosity, c - sound velocity

The 20% concentration of the gelatin solution most corresponds to the muscle tissue characteristics.

3 Results

Based on the ballistic experiment, the following findings were obtained:

The apron depth for the contact distance (50 cm) was 13 mm in diameter. Table 2 shows the depths of the shots for individual shots and distances. The distances were measured using both caliper and image analysis. The deviation between the measurement methods was minimal and therefore negligible.

Table 2. Dependence of depth of the shot on distance.

distance	1. missile	2. missile	3. missile	4. missile	5. missile
	mm				
50 cm	14,45	9,94	12,58	16,33	11,70
500 cm	12,21	9,73	10,51	11,36	8,99

Table 2 shows that the average depth of the shot at a distance of 500 cm is 10.56 mm. As can be seen, at a distance of 450 cm the average depth of the shot is reduced by 2.44 mm. This confirms the assumption that the depth of the shot decreases with increasing distance. At the same time, it is already clear that the wounding potential of this weapon is relatively low.

Table 3. Bullet velocity on impact with gelatine.

distance	1. missile	2. missile	3. missile	4. missile	5. missile
	m / s				
50 cm	107	92	103	111	101
500 cm	83	70	76	90	60

The average impact velocity at a distance of 50 cm is 102.8 m/s. The average impact velocity at a distance of 500 cm is then 75.8 m/s. Therefore, the drop in the velocity of the bullets is quite significant – by an average of 27 m/s per 500 cm, which is an average of 5.4 m/s per meter.

The original intention was to subject the examined samples to the method of radial cracks however, it is a relatively inaccurate method and with such a non-efficient type of weapon and ammunition, the results would be inconclusive. For this reason, this intention was abandoned.

Fig. 1. Maximum size of the temporary cavity for the 1st bullet at a distance of 50 cm.

In Figure 1, the maximum height of the temporary cavity of the 1st bullet can be seen at a distance of 50 cm (red). This height is at the entry of the missile into ballistic gelatin and reaches a size of 10.57 mm.

Fig. 2. Maximum length of the uniform temporary cavity and the minimum height of the temporary cavity for the 1st bullet at a distance of 50 cm.

Figure 2 shows the maximum length of the uniform temporary cavity 21.6 mm (red) and the minimum height of the temporary cavity at the maximum expansion rate of 4.03 mm (blue color) for the 1st bullet at a distance of 50 cm. The bullet, of course, still penetrated; however, with the bullet going further into the gelatin block, there was already a shrinkage phase in the already penetrated part of the block. For this reason, the permanent cavity was partially divided into a uniform part of the temporary cavity (see Figure 1) and the remainder. The part, where a uniform temporary cavity can be detected, was further investigated in this paper.

Fig 3. Maximum and minimum permanent height for the 1st bullet cavity at a distance of 50 cm.

Figure 3 shows a maximum height of 2.3 mm (blue color) and a minimum height of 1.28 mm (red color) of a permanent cavity for the 1st bullet at a distance of 50 cm.

As can be seen in the figures, the maximum heights are variable not only in terms of dimensions (10.57 and 2.3 mm) but also in terms of position: for the temporary cavity the maximum height is at the entrance, for the permanent cavity, the maximum is near the missile itself. The maximum height of the temporary cavity has more than 4.5 times the size. Similarly, for the minimum heights (4.03 and 1.28 mm), the placement is also variable: for the temporary cavity, the minimum height is approximately in the middle of the temporary cavity, and for the permanent cavity, the minimum is near the bullet entry. The minimum height of the temporary cavity is more than 3 times the size.

Fig. 4. Maximum height of the uniform temporary cavity and the minimum height of the temporary cavity for the 1st bullet at a distance of 500 cm.

In Figure 4, the maximum height of 5.04 mm (red color) of the temporary cavity for the 1st bullet at a distance of 500 cm can be seen. It is located in close proximity to the bullet, reaching the size of 5.04 mm. It is also possible to see the minimum height of the temporary cavity at the maximum expansion rate of 3.72 mm (blue color) for the 1st bullet at a distance of 500 cm. The bullet, of course, was still penetrating, but with the bullet going further into the block of gelatin, there was a shrinkage phase in the already penetrated part of the block. For this reason, the permanent cavity was partially divided into a uniform part of the temporary cavity (see Figure 4) and the remainder. The part, where a uniform temporary cavity can be detected, was further investigated, as in the 1st shot at 50 cm.

Fig. 5: Maximum and minimum height of the permanent cavity for the 1st bullet at a distance of 500 cm.

Figure 5 shows a maximum height of 3.07 mm (red color) and a minimum height of 2.41 mm (blue color) of the permanent cavity for the 1st bullet at a distance of 500 cm.

As can be seen in the figures, the maximum heights are variable not only in terms of dimensions (5.04 and 3.07 mm) but also in terms of position: in the case of the temporary cavity, the maximum height is near the

missile itself, and in the case of the permanent cavity, the maximum height is in the middle of the cavity. The maximum height of the temporary cavity has more than 1.5 times the size. Similarly, for the minimum heights (3.72 and 2.41 mm), the placement is also variable: for the temporary cavity, the minimum height was approximately in the middle of the cavity, and for the permanent cavity, the minimum is near the bullet entry. The minimum height of the temporary cavity is more than 3 times the size.

Similar information was obtained with other tested missiles.

3 Conclusion

This article explored the wounding potential of a CO₂-powered airsoft gun with lead shot ammunition. The wounding potential was measured by the depth of the shot in the replacement ballistic material. Moreover, the permanent cavity and the temporary cavity were measured using a high-speed camera. It was found that the effect of distance on the depth of the shot is noticeable. The speed of the bullet dropped by an average of 27 m/s, and the depth of the shot decreased by an average of 2.44 mm. Findings based on high-speed camera recordings are essential. Specifically, information about the temporary and permanent cavity is invaluable. Permanent cavity height is about 1 mm greater at a distance of 500 cm. At a distance of 50 cm, the height of the temporary cavity is strikingly greater. It should be noted that the maximum measured depth of shot is 16.33 mm. It can be assumed that a 20 mm depth of shot could be theoretically achieved; however, it is a relatively small wounding potential of a CO₂-powered airsoft gun with lead shot ammunition.

Intentionally, distances of 50 cm and 500 cm have been selected because these distances can be considered as the boundary distances for defending shooting with this type of weapon. The measured maximum shot depth of 16.33 mm and the theoretical maximum depth of 20 mm in the muscles would be greatly reduced in the real situation due to the previous penetration of the skin. Based on these findings, the real wounding potential of a CO₂-powered airsoft gun with lead shot ammunition can be assessed as relatively low.

Obtained results are valuable to specialists, judges, lawyers, forensic experts, ballistics, or doctors. A limitation is that there was no skin replacement in the experiment. Only the ballistic gelatin block with a concentration of 20% corresponding to the muscle was shot in the experiment. However, despite this deficit, it has been shown that a CO₂-powered airsoft gun with lead shot ammunition does not have a wounding potential that would lead to serious injury unless shooting at biologically poorly protected areas such as eyes is taking place.

One of the challenges for future research is to perform an experiment with skin replacement. Moreover, a CO₂-powered airsoft gun should be compared with other similar weapons (weapons of Category D according to the Czech legislation).

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