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RESULTS OF EXPERIMENTAL RESEARCH OF WOUND BALLISTICS OF SEPARATE TYPES AND CALIBERS OF MODERN BULLETS

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Key words: *wound ballistics, ballistic plasticine, expansive properties of bullet, fragmentation, flower of death*
Ключові слова: *ранова балістика, балістичний пластилін, експансивні властивості кулі, фрагментація, квітка смерті*
Ключевые слова: *раневая баллистика, баллистический пластилин, экспансивные свойства пули, фрагментация, цветок смерти*

Abstract. Results of experimental research of wound ballistics of separate types and calibers of modern bullets. Tsymbalyuk V.I., Lurin I.A., Usenko O.Yu., Gumeniuk K.V., Krymchuk S.G., Gryshchenko O.V., Lopatuk K.A. *There was made the analysis of wound ballistics of modern expansive bullets in comparison with shell bullets on 25 blocks of ballistic plasticine (ROMA PLASTILINA No. 1, Ballistic Testing Backing Material), made in the USA, in which one shot from AK-74 assault rifle and carbine ZBROYAR Z-10 with an optical sight was fired. The bullet speed was the highest in 5.45x39 caliber cartridge with a V-max bullet – 1185 m/s, low – in the bullet of caliber cartridge .308 Win with a bullet SP – 664 m/s. The difference is significant at the level of significance α=0.05. In terms of the size of the entry hole, the largest is from the bullet of cartridge .308 Win with a bullet SP – 10.0 cm, the smallest – from the bullet "PS" with a steel core 5.45x39 mm, cartridge sample of the year 1974 (7H6) – 1.2 cm. The difference is significant at the level of significance α=0.05. In the expansive bullet of type "V-Max" of shortgun cartridge of caliber 5.45x39 mm, the size of the outlet hole was 9.1 cm, with asterial shape having radial gaps and turned edges of ballistic plasticine on the outside. All cartridges with expansive bullets did not have an outlet hole after the shot. The dimensions of the formed residual cavity were the largest after firing .308 Win caliber cartridge with a bullet SP – 25.0x5.0 cm., the smallest – bullet of a military caliber cartridge of 5.45x39 mm (7H6) – 6.0x4.0 cm. The difference is significant at significance level α=0.05. The shape and character of the residual cavity in ballistic plasticine was significant for all expansive bullets, in contrast to the bullet of cartridge 5.45x39 mm (7H6), where no such changes were detected. The considerable signs of expansion properties and deformation of the bullet in the form of a "flower of death" were identified in the bullet of caliber cartridge .308 Win with a bullet SP, other bullets with expansive properties showed significant fragmentation, with the location of fragments both in the residual cavity and outside its borders at various distances. Expansive bullets differ significantly at the level of significance α=0.05. The low flight speed of bullets (m/s) of .308 Win caliber cartridges with bullets BTHP and SP is due to their structure, weight, and caliber. Bullet of type V-max with cartridge 5.45x39 mm has the highest speed – 1185 m/s, and due to its design has significant expansive properties. Common to expansive bullets is a entry hole, the blind nature of the lesion with the presence of a large residual cavity, which is due to kinetic energy return 114.37 E, J/mm2 inside the object of lesion. Fragmentation of* *expansive bullets occurs inside an object with fragments located at different distances. A .308 Win caliber cartridge with SP bullet causes deformation of s bullet by the "flower of death" type causing significant damage.*

Реферат. Результаты экспериментального исследования раневой баллистики отдельных типов и калибров современных пуль. Цымбалюк В.И., Лурин И.А., Усенко А.Ю., Гуменюк К.В., Крымчук С.Г., Грищенко А.В., Лопатюк К.А. *Проведен анализ раневой баллистики современных экспансивных пуль по сравнению с оболочковыми пулями на 25 блоках баллистического пластилина (ROMA PLASTILINA № 1, Ballistic Testing Backing Material), производства США, в которые выполняли по одному выстрелу из огнестрельного автоматического стрелкового оружия АКС-74 и карабина ZBROYAR Z-10 с оптическим прицелом. Самая высокая скорость пули была у патрона калибра 5,45х39 с пулей V-max. – 1185 м/с, низкая у пули патрона калибра .308 Win с пулей SP – 664 м/с. Разница достоверна на уровне значимости α=0,05. По размерам входного отверстия: наибольшее от попадания пули патрона .308 Win с пулей SP – 10,0 см, наименьшее – от попадания пули «ПС» со стальным сердечником 5,45х39 мм патрона образца 1974 года (7Н6) – 1,2 см. Разница достоверна на уровне значимости α=0,05. В экспансивной пуле типа «V-Max» охотничьего патрона калибра 5,45х39 мм размер входного отверстия составлял 9,1 см, имел звездчатую форму с радиальными разрывами и вывернутыми краями баллистического пластилина снаружи. У всех патронов с экспансивными пулями после выстрела выходного отверстия не было. Наибольшие размеры образовавшейся остаточной полости были после выстрела патроном калибра .308 Win с пулей SP – 25,0х5,0 см, наименьшие в пуле военного патрона калибра 5,45х39 мм (7Н6) – 6,0х4,0 см. Разница достоверна на уровне значимости α=0,05. Форма и характер остаточной полости в баллистическом пластилине была значительной для всех экспансивных пуль, в отличие от пули военного патрона 5,45х39 мм (7Н6), где таких изменений обнаружено не было. Наибольшие признаки экспансивных свойств и деформация пули в виде "цветка смерти" были определены в пуле патрона калибра .308 Win с пулей SP, у других пуль с экспансивными свойствами отмечалась значительная их фрагментация, с расположением отломков как в самой остаточной полости, так и за ее границами на разных расстояниях. Экспансивные пули достоверно отличаются на уровне значимости α=0,05. Низкая скорость полета пуль (м/с) патронов калибра .308 Win с пулями типа BTHP и SP обусловлена их строением, весом и калибром. Пуля типа V-max патрона 5,45х39 мм имеет наибольшую скорость – 1185 м/с, благодаря своей конструкции обладает значительными экспансивными свойствами. Общим для экспансивных пуль является большое входное отверстие, слепой характер поражения с наличием большой остаточной полости, которая образуются благодаря отдаче всей кинетической энергии 114,37 Е, Дж/мм2 внутрь объекта поражения. Фрагментация экспансивных пуль происходит внутри объекта с расположением отломков на разных расстояниях. Патрон калибра .308 Win с пулей SP при попадании в объект вызывает деформацию пули по типу «цветка смерти», вызывая значительные разрушения.*

With the beginning of hostilities in the East of our country the medical service of the Armed Forces of Ukraine and all other law enforcement agencies involved in protecting the territorial integrity of Ukraine faced an important issue of organizing and providing assistance to the wounded by bullets from modern fire arms. The nature of gunshot wounds, the development of complications and the course of wound disease with high mortality confirm that in combat operations ammunition with different properties of bullets is used. In this regard, many authors [3, 7, 8, 10] point to the need to study wound ballistics, which is important for assessing the nature of the wound and the choice of surgical tactics and understanding the mechanisms of gunshot wounds [5, 6]. The use of modern combat automatic small arms with different bullets and their high speed and unstable position in flight has led to changes in wound ballistics and increasing the severity of injuries [1].

The aim of our work was to assess the results of the experimental study of wound ballistics of modern caliber cartridges 5.45x39 mm and .308 Win, compared with shell bullets with steel core caliber cartridges 5.45x39 mm (AK) and 7.62x51 mm NATO using ballistic material.

MATERIALS AND METHODS OF RESEARCH

The experimental study was conducted on the basis of a shooting range of the Kyiv Research Forensic Center of the Ministry of Internal Affairs of Ukraine with the involvement of specialists from the State Research Expert Forensic Center of the Ministry of Internal Affairs of Ukraine. Special certified ballistic plasticine (ROMA PLASTILINA N 1, Ballistic Testing Backing Material) made in the USA was used as a ballistic material, imitator of biological tissues. Ballistic plasticine gave us the opportunity to assess not only the nature and extent of damage after the shot, but also to determine a number of properties of the bullets (expansive properties, ability to change shape, number of fragments, their size). During the experiments in the shooting range 25 blocks of ballistic plasticine in the shape of a parallelepiped measuring 40.0x24.0x28.0 cm were used, in which one shot was fired from an AK-74 assault rifle (Fig. 1) and a carbine ZBROYAR Z-10 with an optical sight

(Fig. 2) from a distance of 25 m. The experiments were performed under normal environmental conditions (temperature 25°C, relative humidity 72%, atmospheric pressure 738 mm Hg). Blocks of ballistic plasticine before shot were heated to a temperature of 28-32°C.

Fig. 1. AK assault rifle “AK-74”

Fig. 2. Semiautomatic assault rifle “ZBROYAR Z-10”

The following ammunition was used for experimental firing: military 5.45 mm cartridges of the 1974 model with "PS" bullets with a steel core (7H6 or 7H6M), a PS bullet weighing 3.4 g (Fig. 3a and 4a); hunting (sports) caliber cartridges 5.45x39 mm, equipped with expansive bullets type "V-Max" weighing 3.9 g (Fig. 3b and 4b); military ammunition caliber 7.62x51 mm NATO with a bullet weighing 9.6 g (Fig. 3c and 4c); hunting (sports) cartridges of .308 Win caliber, equipped with BTHP bullets weighing 10.9 g (Fig. 3d and 4d); hunting (sports) cartridges of .308 Win caliber, equipped with SP bullets weighing 14.2 g (Fig. 3i and 4i).

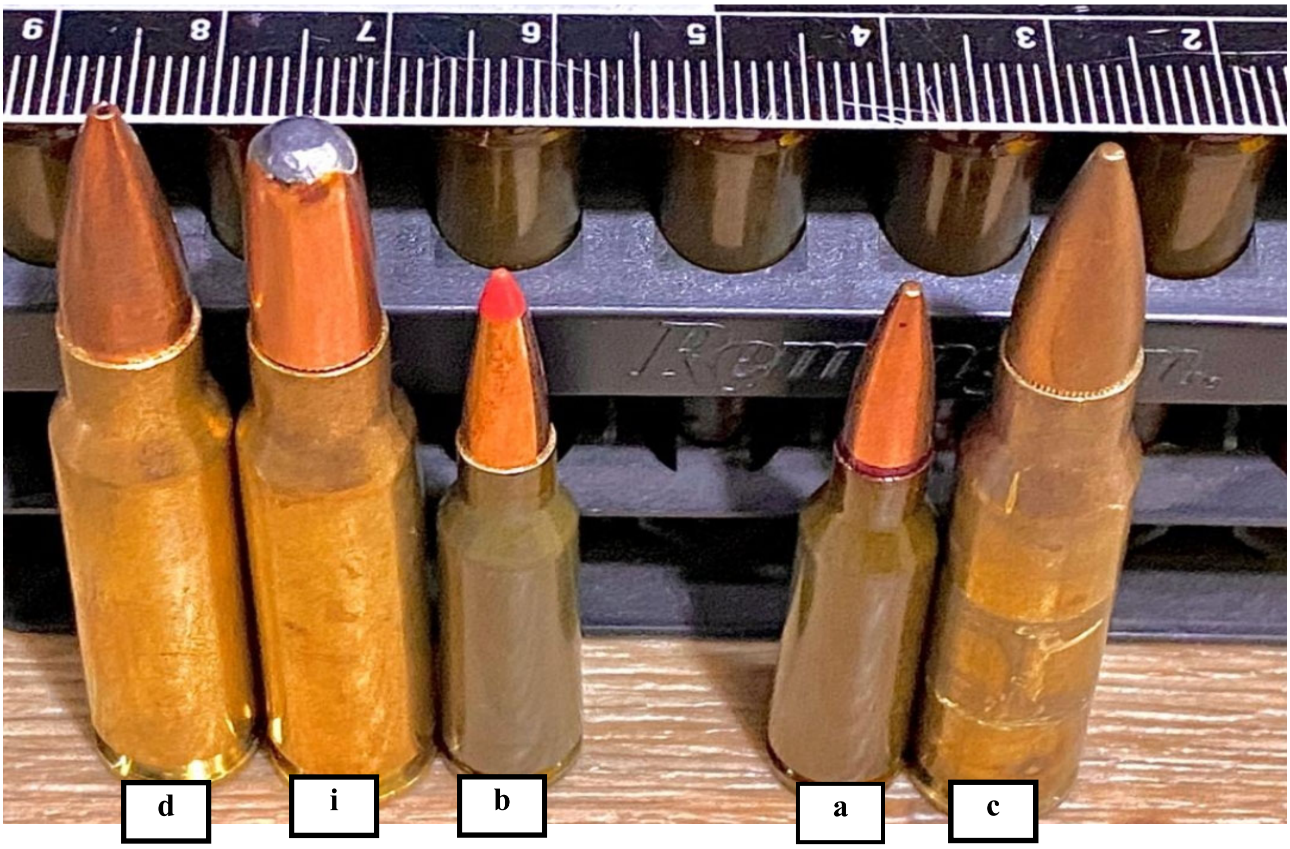

Fig. 3. General aspect of cartridges (3a – military 5.45-mm cartridge with bullets "PS" with steel core, 3b – 5.45x39 mm caliber cartridge with expansive bullet type "V-Max", 3c – military 7.62x51 мм NATO caliber cartridge, 3d – .308 Win, caliber cartridge with type BTHP bullet, 3e – .308 Win caliber cartridge with bullet type SP

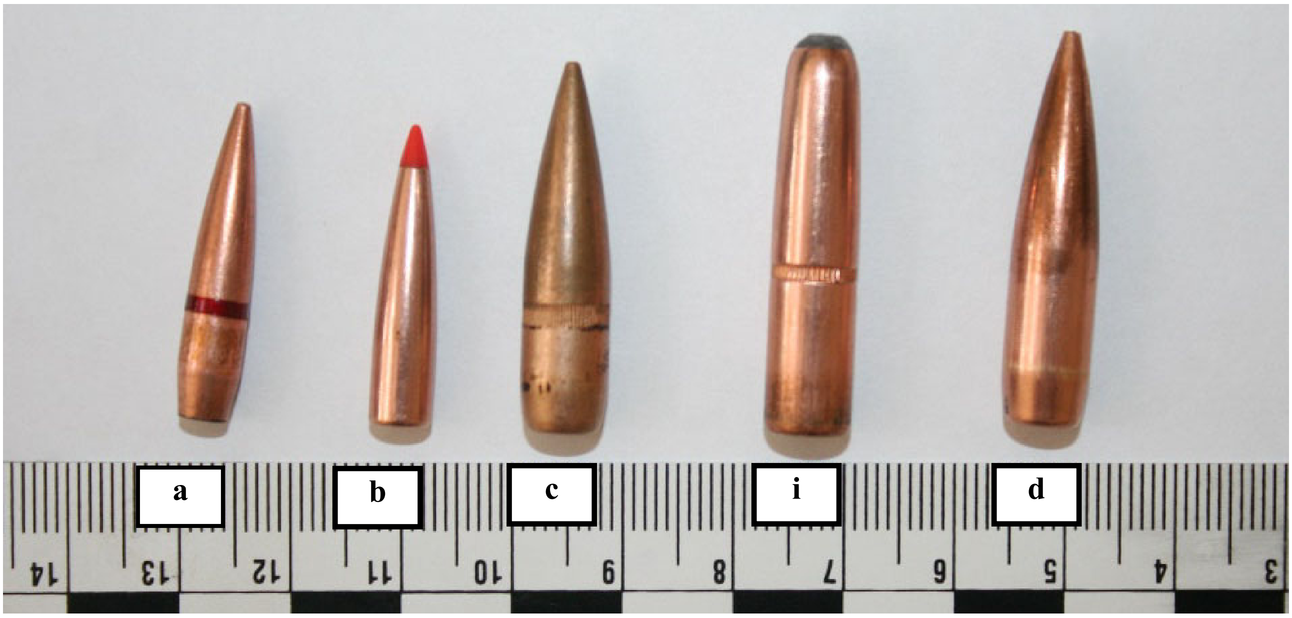

Fig. 4. General aspect of bullets (3a – bullet of military 5.45 mm cartridge with "PS" with steel core, 3b – expansive bullet 5.45x39 mm calibre "V-Max" type, 3c – 7.62x51 mm calibre NATO, 3d – bullet BTHP type .308 Win, 3e – bullet SP type calibre .308 Win)

After the shots, the following was studied: entry hole and outlet holes (cm), the course of the wound canal, the presence of signs of a temporarily pulsating cavity in the residual cavity with fragments of bullets, their number and shape. The velocity of the bullets (m/s) was determined by the measuring optoelectronic complex "IBH-73-3" No. HK056, which was located at a distance of 1 meter from the muzzle end. Calculations of kinetic energy and specific kinetic energy of bullets were determined by the formulas:

$Ek\ exp = m(V^2_1 - V^2_2)/2$;

$Ek = mV^2/2$

Statistical study of the obtained empirical results was performed in the Trial version of STATISTICA 13.3 EN (complete set of Statistica Base). Licensed for up to 2 cores, currently configured for 2 Direct 2D graphics supported V125UPD00, according to the calculation method [9].

RESULTS AND DISCUSSION

According to the results of our experimental study, we found that the highest bullet velocity was in a 5.45x39 caliber cartridge with a V-max bullet – 1185 m/s, low – in caliber .308 Win bullet with a bullet SP – 664 m/s. The Kolmogorov-Smirnov and Shapiro-Wilk criteria were used to test the normality of the distribution of the obtained results of sample observations, according to which there are no grounds to reject the hypothesis of a normal sample distribution. The tests performed for both samples have identical parameters (Table 1).

Table 1

Kolmogorov-Smirnov and Shapiro-Wilk tests for samples

Kolmogorov-Smirnov test results	Shapiro-Wilk test results
K-S d=0.23051, p>0.20; Lilliefors p>0.20	Shapiro-Wilk W=0.88104, p=0.31404

This indicates the possibility of using Student's t-test for independent variables to check the reliability of the difference between the results obtained (p>0.2 according to the Kolmogorov-Smirnov test and p>0.05 according to the Shapiro-Wilk test), (Table 1). Descriptive statistics for samples of 5.45x39 caliber bullet and .308 Win caliber bullet with SP bullet according to velocity is shown in Table 2.

Table 2

Descriptive statistics for both samples of bullets 5.45x39 calibre cartridge and .308 Win caliber cartridge with bullet SP

Mean Group 1	Mean Group 2	t-value	df	p	Valid N – Group 1	Valid N – Group 2	Std.Dev Group 1	Std.Dev Group 2	F-ratio Variances	p - Variances
1184.200	663.200	984.575	8	0.000	5	5	0.837	0.837	1.000	1.000

Table 2 shows that these samples have standard deviations that are not statistically different (p – Variances≥0.05), and significantly different mean values (p≤0.05) at the level of significance α=0.05. Similar studies were conducted on other characteristics of bullets. Thus, in terms of the size of the entry hole (cm), the largest was from the impact of a bullet 308 Win with a bullet SP – 10.0 cm, the smallest – from the impact of a bullet "PS" with a steel core of 5.45x39 mm cartridge sample 1974 7H6) – 1.2 cm (Fig. 5), which confirms the statistical significance of the difference between the results obtained on the basis of Student's t-test at the level of significance α=0.05 (p – Variances ≥0.05; p≤0.05) (Table 3).

Table 3

Descriptive statistics of bullet samples by sizes of entry hole

Mean Group 1	Mean Group 2	t-value	df	p	Valid N – Group 1	Valid N – Group 2	Std.Dev Group1	Std.Dev Group2	F-ratio Variances	p - Variances
9.9	1.16	145.67	8	0.00	5	5	0.12	0.05	5	0.15

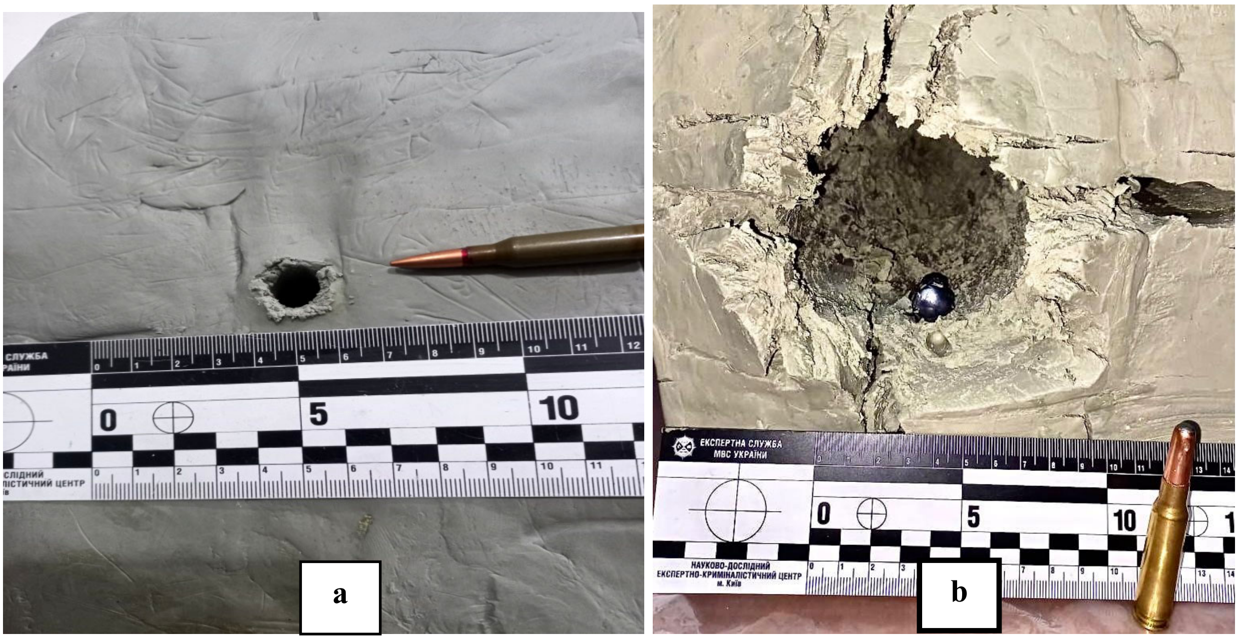

Fig. 5. Assessment of entry hole on firing in ballistic plasticine of 5.45x39 calibre cartridge with bullet PS (7H6), (a) and expansive bullet SP of .308 Win (b) caliber cartridge

In the expansive bullet type "V-Max" hunting caliber cartridge 5.45x39 mm, the size of the entry hole was 9.1 cm, with a star shape with radial gaps and twisted edges of ballistic plasticine to the outside (Fig. 6).

It should be noted that all cartridges with expansive bullets did not have an outlet hole after the shot. After the sagittal section of the ballistic plasticine, the dimensions of the residual cavity (cm) were examined: the largest was a .308 Win caliber cartridge with a SP bullet – 25.0x5.0 cm, and the smallest was a 5.45x39 mm caliber bullet (7H6) – 6.0x4.0 cm, (Fig. 7a, b).

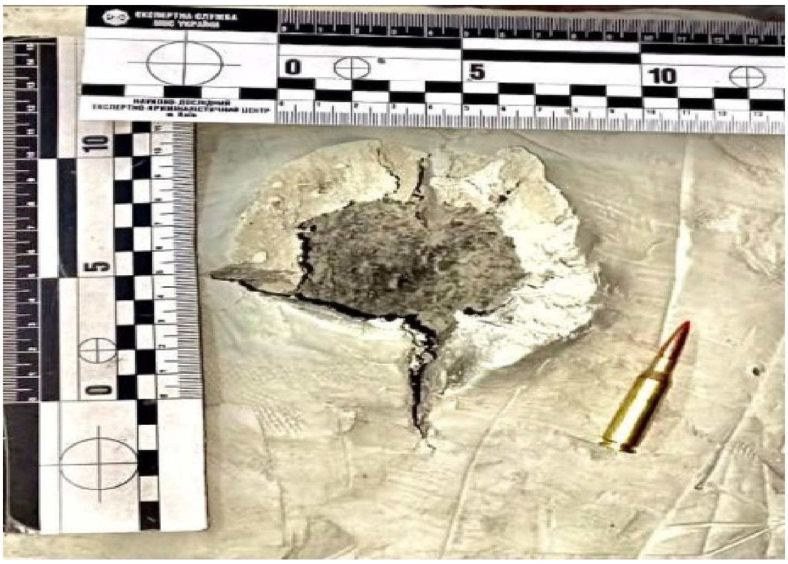

Fig. 6. Assessment of entry hole caused by expansive bullet type «V-Max» 5.45x39 mm caliber cartridge

The shape and size of the residual cavity in ballistic plasticine was significant for all expansive bullets (Fig. 8a), in contrast to the bullet with a steel core of a 7.62x51 mm NATO cartridge (Fig. 8b), where no such changes were detected. The statistical significance of the difference in the obtained values was determined by the cavity area and confirmed by Student's t-test at the significance level $\alpha=0.05$ (p – Variances ≥ 0.05; $p \leq 0.05$) (Table 4).

Table 4

Descriptive statistics of samples by sizes of residual cavity

Mean Group 1	Mean Group 2	t-value	df	p	Valid N – Group 1	Valid N – Group 2	Std.Dev Group 1	Std.Dev Group 2	F-ratio Variances	p - Variances
121.116	22.684	41.205	8	0.000	5	5	5.027	1.807	7.738	0.073

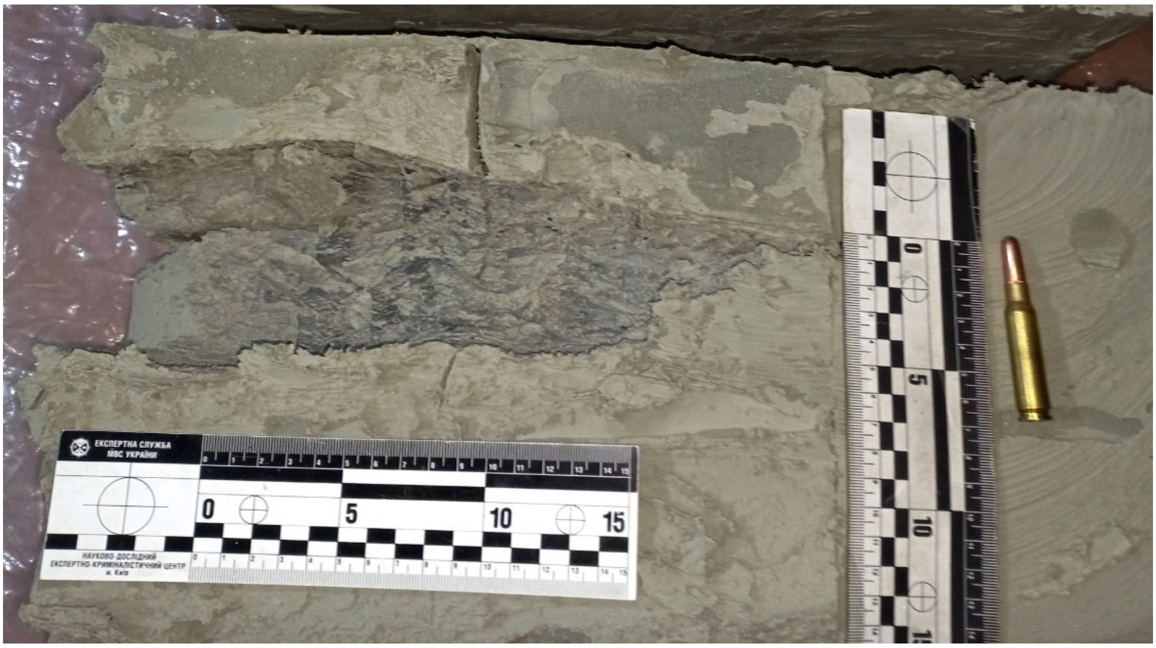

Fig. 7a. Residual cavity on firing a .308 Win caliber cartridge with SP bullet

Fig. 7b. Residual cavity on firing a PS bullet of a military caliber cartridge 5.45x39 mm (7H6)

Fig. 8a. Residual cavity on firing expansive bullet V-max 5.45x39 mm caliber cartridge

Fig. 8b. Residual cavity on firing a bullet with a steel core of caliber cartridge 7.62x51 mm NATO

The specific kinetic energy (E, J/mm2) transmitted by the bullets and other results of the obtained indicators of ballistics of wounding projectiles in comparison are presented in Table 5.

All of them were tested by Student's t-test and received confirmation of the statistical significance of their mean values at the level of significance α=0.05 (p – Variances ≥0.05; p≤0.05).

Table 5

Indicators of ballistics of wounding projectiles

Indicators					
Calibre cartridge and bullet type	Velocity of bullet, m/s,	Specific kinetic energy (E, J/mm2)	Entry hole, cm	Outlet hole, cm	Formation of residual cavity, cm
5.45x39 PS	918±1.4	61.41±1.8	1.2±0.8	2.7±1.3	6.0x4.0
5.45x39 V-max	1185±2.7	114.37±2.7	9.1±1.5	no	8.0x5.0
7.62x51 NATO	792±2.1	66.67±2.1	7.8±1.0	no	12.4x5.8
.308 Win BTHP	759±2.0	68.85±1.4	8.4±1.3	no	9.0x6.2
.308 Win SP	664±1.8	68.64±2.9	10.0±1.7	no	25.0x5.0

Notes: determined by forensics and forensic medicine, the minimum value of the specific kinetic energy of the bullet required to cause fatal injuries to humans is 0.5 J/mm2.

The main characteristics of cartridges and their bullets with the study of expansive properties, deformation, fragmentation of bullets in ballistic plasticine are presented in Figure 9. It should be noted that the greatest signs of expansive properties and deformation of the bullet in the form of a "flower of death" were identified in a bullet of caliber cartridge .308 Win with a bullet SP, in other bullets with expansive properties there was a significant fragmentation, with the location of fragments both in the residual cavity and outside it at different distances.

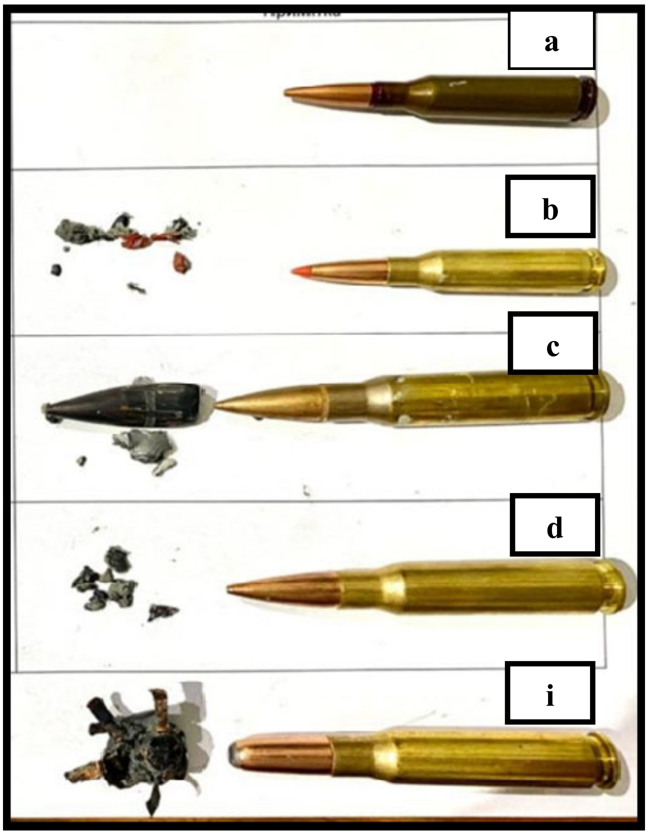

Fig. 9. General view of live ammunition and bullets with signs of fragmentation and deformation after the shot 9a - military 5.45-mm cartridge with bullets "PS" with steel core, 9b - caliber cartridge 5.45x39 mm, equipped with an expansive bullet type "V-Max", 9c - military caliber cartridge 7.62x51 mm NATO, 9d - caliber cartridge .308 Win, equipped with a bullet type BTHP, 9i - caliber cartridge .308 Win, equipped with type SP bullet

Thus, the obtained results of the study of ballistic properties show that in terms of the velocity of bullets (m/s) only one of the expansive bullets of a 5.45x39 mm cartridge with a V-max bullet has the highest speed – 1185±2.7 m/s, in our opinion, due to its structure, weight, caliber and the presence of a plastic component at the top. The lowest velocity is in a .308 Win caliber bullet with an SP bullet – 664±1.8 m/sec, due to its caliber, weight and blunt structure of the bullet top, which affects its aerodynamic properties in flight slowdowning. These data were also confirmed in a study [2]. However, the SP bullet has the largest entry hole – 10.0±1.7 cm, a significant residual cavity – 25.0x5.0 cm, with significant deformation of the bullet by the "flower of death" type [4], which leads to significant damage not only along flight trajectory, but along lateral sections of it, due to lateral shock waves. We found that common to all expansive bullets is the absence of the outlet hole in the ballistic plasticine, so all the kinetic energy (E, J/mm2) was distributed inside with the highest specific kinetic energy in the bullet 5.45x39 V-max – 114.37±2.7 E, J/mm2. This is of great clinical importance, when such a bullet hits the anatomical parts of the human body, all the kinetic shock energy is transmitted inward with significant destruction of surrounding organs and tissues at different distances. This, of course, will significantly affect the speed and content of diagnostic and therapeutic measures, the volume of surgical interventions. Other bullets with expansive properties were characterized by fragmentation, to multiple fragments, which were wounding projectiles for other areas of ballistic plasticine. Such fragmentation is due to the structure of the bullet and significant kinetic energy, which leads to its destruction. The results obtained by us testify to the various destructive effects of modern types and calibers of bullets. This scientific work is part of a multi-stage scientific work, which continues and is carried out jointly with specialists of the National Academy of Medical Sciences of Ukraine, the Medical Service of the Armed Forces of Ukraine and the State Research Forensic Center of the Ministry of Internal Affairs of Ukraine.

CONCLUSIONS

Based on the performed experimental study of wound ballistics of certain types of modern expansive bullets of 5.45x39 mm and .308 Win cartridges, compared to shell bullets with steel core cartridges of 5.45x39 mm (AK) and 7.62x51 mm NATO cartridges, on ballistic materials it was found that expansive bullets significantly have differences at the level of significance $\alpha=0.05$. The low velocity of bullets (m/s) of .308 Win caliber cartridges with BTHP and SP bullets is due to their structure, weight and caliber. Bullet type V-max cartridge 5.45x39 mm has the highest speed – 1185±2.7 m/s and due to its design has significant expansive properties. A large entry hole, the blind nature of the lesion with the presence of a large residual cavity, which is formed due to the return of all its kinetic energy 114.37±2.7 E, J/mm^2 inside the object affected is common to expansive bullets. The fragmentation of expansive bullets takes place inside the object with the location of the fragments at different distances. A .308 Win caliber cartridge with an SP bullet causes deformation of a bullet by the "flower of death" type when it hits an object causing significant damage.

Conflict of interest. The authors declare no conflict of interest.

REFERENCES

1. Zarutskyi YaL, Khomenko IP, Verba AV, Burluka VV. [Combat surgical trauma. Military field surgery]. editors YaL Zarutskyi, Via Bilyi. Kyiv: Feniks; 2018. p. 45-59. Ukrainian
2. Kravchenko YuN, Sapelkyn VV, Serbynenko YIu, Kolomyitsev AV. [Application of a biological tissue simulator to diagnose through gunshot wounds caused by 5.45 mm bullets]. Theory and practice of forensic expertise and criminalistics. 2015;15:408-10. Russian.
doi: https://doi.org/10.32353/khrife.2015.51
3. Mishalov VD, Mykhailenko OV, Khokholieva TV, Petroshak OIu. [Forensic examination of objects in case of gunshot wound]. monograph. Kyiv; 2019. p. 303. Ukrainian.
4. Fetysov VA, Emelyn VV. [International experience in the development and adoption of the criterion "unnecessary suffering and excessive damage" for the assessment of weapons and ammunition]. Bulletin of Forensic Medicine, Tomsk. 2019;2:55-60. Russian.
5. Fylypchuk OV, Hurov AM. [Features of the use of ballistic gelatin as an imitator of human biological tissues]. Forensic examination. 2015;15:367-8. Ukrainian. doi: https://doi.org/10.32353/khrife.2015.46
6. Shcherbak VV, Tolmachev OO, Kundyus OV, Abdurasulov AA. [Methodology for conducting a ballistic experiment on biological simulators of the human body]. Criminal Bulletin. 2015;2(24):131-2. Ukrainian.
7. French RW, Callender GR. Ballistic characteristics of wounding agents, editor JC Beyer. Wound bal-

listics, Office of the Surgeon General, Department of the Army, Washington, D.C.; 1962. p. 91-141.

8. Hill PF, Edwards DP, Bowyer GW. Small fragment wounds: Biophysics, pathophysiology and principles of management. Army Med. Corps. 2001;147:41-51. doi: https://doi.org/10.1136/jramc-147-01-04

9. Kim TK. T-test as a parametric statistic. Korean J Anesthesiol. 2015;68(6):540-6.
doi: https://doi.org/10.4097/kjae.2015.68.6.540

10. Beat P, Robin M, Markus Rothschild A, Thali M. Wound Ballistics: Basics and Applications. Springer-Verlag Berlin Heidelberg; 2011. p. 2-10.

СПИСОК ЛІТЕРАТУРИ

1. Заруцький Я. Л., Хоменко І. П., Верба А. В., Бурлука В. В. Бойова хірургічна травма. Воєнно-польова хірургія / ред. Я. Л. Заруцький, В. Я. Білий. Київ: Фенікс, 2018. С. 45-59.

2. Кравченко Ю. Н., Сапелкин В. В., Сербиненко И. Ю., Коломийцев А. В. Применение имитатора биологических тканей для диагностики сквозных огнестрельных ранений, причиненных пулями калибра 5,45 мм. *Теорія та практика судової експертизи і криміналістики.* 2015. № 15. С. 408-410.
DOI: https://doi.org/10.32353/khrife.2015.51

3. Мішалов В. Д., Михайленко О. В., Хохолєва Т. В., Петрошак О. Ю. Судово-медична експертиза об’єктів при вогнепальній травмі: монографія (видання доповнене). Київ, 2019. 303 с.

4. Фетисов В. А., Емелин В. В. Международный опыт по разработке и принятию критерия “излишние страдания и чрезмерные повреждения” для оценки оружия и боеприпасов. *Вестник судебной медицины, Томск.* 2019. № 2. С. 55-60.

5. Филипчук О. В., Гуров А. М. Особенности применения баллистического желатина как имитатора биологических тканей человека. *Судово-медична експертиза.* 2015. № 15. С. 367-368.
DOI: https://doi.org/10.32353/khrife.2015.46

6. Щербак В. В., Толмачев О. О., Кундиус О. В., Абдурасулов А. А. Методология проведения баллистического эксперимента на биологических имитаторах тела человека. *Кримінальний вісник*. 2015. Т. 24, № 2. С. 131-132.

7. French R. W., Callender G. R. Ballistic characteristics of wounding agents / ed. J. C. Beyer. Wound ballistics, Office of the Surgeon General, Department of the Army, Washington, D.C. 1962. P. 91-141.

8. Hill P. F., Edwards D. P., Bowyer G. W. Small fragment wounds: Biophysics, pathophysiology and principles of management. *Army Med. Corps*. 2001. Vol. 147. P. 41-51.
DOI: https://doi.org/10.1136/jramc-147-01-04

9. Kim T. K. T test as a parametric statistic. Korean *J Anesthesiol.* 2015. Vol. 68, No, 6. P. 540-546.
DOI: https://doi.org/10.4097/kjae.2015.68.6.540

10. Wound Ballistics: Basics and Applications / P. Beat et. al. *Springer-Verlag Berlin Heidelberg*. 2011. P. 2-10.

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