



**Bilenko A.,
Kyrychenko A.,
Kaidalov R.**

RESEARCH OF INFLUENCE BALLISTIC CHARACTERISTICS OF WEAPONS ON THE SHOOTING EFFICIENCY TAKING INTO ACCOUNT THE SAFETY OF THE SMALL ARM USE

Об'єктом дослідження є процес виконання вогневого завдання працівниками сил безпеки в умовах наявності сторонніх осіб у напрямку стрільби. У роботі досліджено вплив балістичних характеристик зброї на ефективність виконання вогневих завдань силами безпеки з урахуванням безпечності застосування зброї. Метою застосування зброї силами безпеки як правило є припинення дій правопорушника або його затримання. При цьому випадки загибелі або поранення заручника або сторонньої особи в результаті застосування зброї мають кваліфікуватися як невиконання поставленого вогневого завдання. Аналіз тактики дій та особливостей застосування зброї силами безпеки свідчить, що основною причиною, яка обумовлює небезпечність застосування стрілецької зброї для сторонніх осіб є надмірна відстань польоту кулі, на якій вона зберігає забійну дію. Водночас з цим відстань забійної дії кулі є одним з чинників, що піддається корекції. Вона залежить від сполучення балістичних характеристик зброї, а саме дульної швидкості та балістичного коефіцієнту кулі. Проведений аналіз відомих досліджень показав, що існуючий науково-методичний апарат визначення ефективності стрільби не дозволяє визначати ефективність виконання вогневого завдання з урахуванням безпечності застосування стрілецької зброї через недосконалість відповідних моделей. Вдосконалено модель процесу виконання вогневого завдання шляхом урахування впливу балістичних характеристик зброї на ймовірності ураження сторонніх осіб, що створює можливість для оцінювання безпечності застосування зброї. В результаті дослідження впливу балістичних характеристик зброї на ефективність стрільби з урахуванням безпечності застосування зброї встановлено, що існує необхідність максимального скорочення різниці між прицільною дальністю зброї та дальністю, на якій куля зберігає забійну дію. Надмірна енергія кулі підвищує ймовірність ураження сторонньої особи через збільшення площі зони небезпеки її ураження внаслідок наскрізного пробиття цілі. На ймовірність виконання вогневого завдання з обмеженням щодо безпечності застосування зброї позитивно впливає підвищення стабільності дульної швидкості кулі.

Ключові слова: ефективність стрільби, балістичні характеристики, стрілецька зброя, вогневе завдання, сили безпеки.

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1. Introduction

In the design and manufacture of small arms for the defense forces, considerable attention is paid to its ballistic characteristics. The most important of them are the muzzle speed of a bullet and the dynamics of a drop in speed on the trajectory, which is due to the ballistic coefficient of the ball. The value of ballistic characteristics is determined by such tactical characteristics of the weapon as the aiming range, the range of the direct shot and the range of the lethal action of the weapon, as well as the piercing, stopping and lethal action of the bullet. The higher the specified characteristics, the more chances to hit the target, that is, the shooting efficiency increases. Along with this, the likelihood of defeating any other persons and objects in the direction of fire increases, but this is not a problem, since there should not be civilians or friendly forces in enemy positions.

The purpose of the use of weapons by the security forces (SF) in the vast majority of cases is the cessation of the offender or its detention. Moreover, neglect of the life or health of a member of the society whom these forces protect from the offender is not acceptable. Cases of the death or injury of a hostage or an unauthorized person as a result of the use of weapons during the performance of military-service missions of the SF should qualify as failure to fulfill the assigned fire mission (FM). However, in the practical use of weapons by security officers, there is a possibility of a bullet falling into an unauthorized person and its defeat.

Thus, for SF, the need to simultaneously ensure a sufficient probability of hitting a target and minimizing the likelihood of hitting unauthorized persons. At the same time, increasing the efficiency of shooting due to the above tactical characteristics of weapons is not possible. So, the study of the influence of ballistic characteristics of weapons

on the effectiveness of shooting, taking into account the security of the use of small arms, is relevant.

2. The object of research and its technological audit

The object of research is the process of performing a fire mission by SF employees in the presence of unauthorized persons in the fire direction.

The components of the system in which this process takes place include:

- subject of the use of weapons is an employee of the security forces;
- object of the use of weapons – the enemy (target);
- sample of small arms;
- unauthorized persons who are in the direction of fire and are located at a distance of no less than the target and less than the distance of the lethal action of the bullet.

The aim of the process is to defeat the object of use of weapons. The process of performing a fire mission is characterized by:

- distance to the target;
- location of unauthorized persons in space;
- ballistic characteristics of weapons;
- accuracy of pointing the weapon at the target;
- technical accuracy of the shooter;
- probability of hitting the target;
- evidence of non-defeat by unauthorized persons;
- time to complete the fire mission.

Limitations on the process flow:

- minimum probability of hitting a target;
- minimum safety of the use of weapons;
- maximum time to hit the target.

In the process of performing a fire mission due to various adverse conditions, there is a likelihood of an outsider being struck, which is considered unacceptable. Adverse conditions include:

- low preparedness of the shooter;
- large distance to the target;
- significant target mobility;
- large number of unauthorized persons;
- the proximity of unauthorized persons to the target;
- significant time constraints on the performance of the fire mission;
- low technical accuracy of weapons;
- large distance of the lethal action of a bullet and the like.

An analysis of the tactics of action and the specifics of the use of weapons by security forces indicates that the main reason for the danger of using small arms of the SF is the excessive distance of the bullet's flight, at which it maintains the lethal effect of X_{LE} . When shooting at a target, there is always a chance of a miss. At the same time, when using a weapon, a security officer sees the space well to the target. But it does not concentrate on the situation behind the target and does not have the ability to control it in the direction of fire at a depth of the distance of the bullet's flight, at which it maintains a lethal effect. Therefore, there is the possibility of falling into a stranger and its defeat. At the same time, the slaughter distance of the ball is one of the factors that can be corrected. It depends on the ballistic characteristics of the weapon, in particular on the muzzle speed and ballistic

coefficient of the bullet. With certain combinations of ballistic characteristics of weapons, the X_{LE} is too large, which increases the likelihood of hitting unauthorized persons and reduces the likelihood of a fire mission as a whole.

Thus, the characteristic disadvantages of the object of research are the irrational ballistic characteristics of the weapon and the resulting unreasonably high probability of hitting an outsider.

To increase the security of the use of weapons by security forces, it is necessary to know how the distance of the lethal action of a bullet affects the likelihood of a fire mission with restrictions on the security of weapon use (SWU).

3. The aim and objectives of research

The aim of research is to study the influence of ballistic characteristics of weapons on firing efficiency, taking into account the safety of small arms.

To achieve this aim, it is necessary to complete the following objectives:

1. Improve existing models of firing efficiency in order to take into account the safety of the use of weapons.
2. Determine the effectiveness of the execution of the fire mission by law enforcement forces depending on the ballistic characteristics of weapons in peacetime.

4. Research of existing solutions of the problem

Enough work has been devoted to determining the effectiveness of shooting from small arms. So, in [1], applied aspects of probability theory are considered, in particular, general methods for determining the probabilities of hitting a target and hitting a target. The work [2] is devoted to the methodology of firing efficiency. In particular, it considers a generalized performance indicator, the conditional law of hitting a target, assessing factors affecting the accuracy of hitting a target, models for assessing the probability of hitting a target, taking into account counteraction to the like. These works can be used to develop models for performing a fire mission taking into account SWU, but these issues are not directly addressed in the work.

The authors of [3] highlight a wide range of questions from the basic information of probability theory to an experimental study of firing efficiency. The work also examined the laws of target destruction, criteria for firing efficiency and combat effectiveness, taking into account the enemy's fire counteraction, and the like. However, all the material is devoted to the combat use of weapons without taking into account SWU.

In [4], the authors focus on the theory of fire dueling, in particular, on the effectiveness of hiding and air dueling, as well as on methods for synthesizing fire control strategies. At the same time, aspects of the use of weapons by security forces in the work are not covered.

In studies [5], tasks and general principles for assessing combat effectiveness, combat effectiveness indicators, methods for determining the probability of defeating a small and a large target are considered. The paper also provides estimates of the economic effectiveness of weapons and statistical methods for assessing the combat effectiveness of weapons. But the above mathematical apparatus does not allow to assess the safety of using weapons for unauthorized persons.

The work [6, 7] is devoted to questions of theory and practice of choosing the optimal characteristics and parameters of barrel complexes according to the relevant performance criteria. However, the use of small arms is not addressed in these studies.

In [8], a method for calculating the penetration of sniper shells into specific targets is considered, but the issue of ensuring the safety of unauthorized persons is not considered.

A common feature of the above works is that they consider the use of weapons by the defense forces and do not take into account the presence of objects whose destruction is not desirable.

The work [9] shows a model for the response of specific targets to impacts at high speed, providing the dominant contribution of the friction shift. It reveals the protective capabilities of the shelter of military personnel during hostilities. It is not talk about ensuring the safety of civilians.

The study [10] shows the limited suitability of existing indicators and criteria for the effectiveness of firing for evaluating the effectiveness of specific fire tasks by security forces. A new indicator of the reliability of the performance of the fire mission by the security forces is developed, taking into account the probability of an unauthorized person's defeat. Along with this, the work does not address the dependence of firing efficiency indicators on the ballistic characteristics of weapons.

Thus, the results of the analysis allow to conclude that the existing scientific and methodological apparatus for determining the effectiveness of firing does not allow to determine the effectiveness of the execution of the fire mission, taking into account the SWU.

5. Methods of research

The likelihood of an unauthorized person being affected is influenced by several factors.

Target characteristics:

Y_C – target height, m;

Z_C – target width, m;

X_C – distance to the target, m.

Firing accuracy characteristics:

Y_{HM} – the position of the hits midpoint (HM) in height relative to the center of the target, m;

Y_{HM} – HM position in the lateral direction relative to the center of the target, m;

σ_y – standard deviation (RMS) of hits in the target plane in height, m;

σ_z – RMS of hits in the target plane in the lateral direction, m.

Characteristics of unauthorized persons:

Y_i – height of the i -th unauthorized person, m;

Z_i – width of the i -th unauthorized person, m;

X_i – distance to the i -th unauthorized person, m;

y_i – position of the center and the first third person in height relative to the center of the target, m;

z_i – position of the center and the i -th unauthorized person in the lateral direction of the center of the target, m.

Given that the likelihood of a slip indirectly increases the likelihood of hitting an unauthorized person, we can conclude that the probability of hitting an unauthorized person is positively affected by:

- the number of unauthorized persons;
- dimensions of the frontal projections of unauthorized persons;

- distance to the target;
- hits RMS in the target plane in height and lateral direction (up to a certain value);
- HM deviation from the center of the target (to a certain value).

In this case, negatively affect the likelihood of hitting an unauthorized person:

- dimensions of the frontal projection of the target;
- distance to unauthorized persons;
- deviation of the centers of unauthorized persons from the center of the target, starting from the values equal to the sums of half of the corresponding dimensions of the target and the unauthorized person.

To study the influence of the distance at which the bullet maintains a lethal effect on the SWU, a program is developed in the Mathcad environment.

6. Research results

The initial data for the calculations are the values corresponding to the factors that influence the probability of an unauthorized person hitting: $Y_C, Z_C, X_C, y_{HM}, z_{HM}, \sigma_y, \sigma_z, Y_i, Z_i, X_i, y_i$ and z_i .

Given that the RMS in the target plane depends on the distance to it, the scattering characteristics at a standard distance of 25 m for the gun are taken as the basis. For other distances that correspond to the position in space of the target and unauthorized persons, the RMS is calculated using the formulas:

$$\sigma_{yc} = \frac{\sigma_y X_c}{25}, \quad (1)$$

$$\sigma_{zc} = \frac{\sigma_z X_c}{25}, \quad (2)$$

$$\sigma_{yi} = \frac{\sigma_y X_i}{25}, \quad (3)$$

$$\sigma_{zi} = \frac{\sigma_z X_i}{25}. \quad (4)$$

Y_{HM} value has to be adjusted depending on the distance to the target. This is due to the movement of the ball along the coordinate in under the action of gravity. So, for example, a change in the ball's position in height at an aiming distance (200 m) for a 9-mm pistol is up to 1.5 m, and for a 5.45-mm automatic machine AKS-74U at a distance of 500 m – 0.95 m not to be ignored.

To correct the value of y_{HM} , equation [11] is used, which allows one to calculate the air drag force of PE motion:

$$R_{x_a} = C_{x_a} \frac{\rho v^2}{2} S_m, \quad (5)$$

where R_{x_a} – air drag force; C_{x_a} – aerodynamic drag coefficient; ρ – density of the atmosphere; v – speed of PE movement; S_m – the area of the PE midsection, as well as the acceleration of the drag force I_R :

$$I_R = \frac{C_{x_a}}{m}, \quad (6)$$

where m – PE mass.

Based on the well-known dependence connecting the path of the body with its initial speed, acceleration and time of movement [12] let's obtain:

$$S_y = -\frac{gt^2}{2}, \tag{7}$$

$$S_x = V_0t + \frac{I_R t^2}{2}. \tag{8}$$

From (8) let's find the time of PE movement in the selected section of the path S :

$$t = \frac{V_0 - \sqrt{V_0^2 - 2I_R S}}{I_R}, \tag{9}$$

and after substituting (8) in (7) let's obtain the expression for calculating the magnitude of the PE displacement along the coordinate y :

$$S_y = -\frac{g}{2} \left(\frac{V_0 - \sqrt{V_0^2 - 2I_R S}}{I_R} \right)^2. \tag{10}$$

In this case, the trajectory should be divided by distance into sufficiently small sections so that the PE speed at the beginning of the section does not differ significantly from the average value in this section. Calculations show that for the studied cases, the length of the plot of 0.05 m provides a quite acceptable relative error in determining the speed, and therefore the time – 0.014–0.023 %. This is confirmed by the high convergence of the calculation results with the operational documentation data for weapons samples for which such data are given [13–15].

The calculation of the probability of hitting the target P_C and by unauthorized persons P_{UP} is carried out according to the formulas [3]:

$$P_C = \left[\frac{1}{\sqrt{2\pi\sigma_{yc}^2}} \int_{-0.5Y_c}^{0.5Y_c} e^{-\frac{(y-y_{HM})^2}{2\sigma_{yc}^2}} dy \right] \times \left[\frac{1}{\sqrt{2\pi\sigma_{zc}^2}} \int_{-0.5Z_c}^{0.5Z_c} e^{-\frac{(z-z_{HM})^2}{2\sigma_{zc}^2}} dz \right], \tag{11}$$

$$P_{UP} = \left[\frac{1}{\sqrt{2\pi\sigma_{yi}^2}} \int_{-0.5Y_i}^{0.5Y_i} e^{-\frac{(y-y_{HP}+y_i)^2}{2\sigma_{yi}^2}} dy \right] \times \left[\frac{1}{\sqrt{2\pi\sigma_{zi}^2}} \int_{-0.5Z_i}^{0.5Z_i} e^{-\frac{(z-z_{HP}+z_i)^2}{2\sigma_{zi}^2}} dz \right]. \tag{12}$$

The probability of hitting the target W_C and the unauthorized person W_{UP_i} can be calculated by the expressions [10]:

$$W_C = 1 - (1 - P_C)^n, \tag{13}$$

$$W_{UP_i} = 1 - (1 - P_{UP_i})^n. \tag{14}$$

The probability of performing a fire mission by an SF employee, taking into account SWU, is calculated according to the formula [10]:

$$W_{SWU} = \left[1 - (1 - P_C)^n \right] \cdot (1 - P_{UP})^n. \tag{15}$$

The indicated formula follows from (13) under the condition that for hitting an outsider one bullet hit is enough and the energy characteristics of the ball are sufficient for hitting. That is, the case of the location of the target and unauthorized persons at distances not exceeding the range that ensures the lethal effect of the bullet is considered.

But in practice it can happen differently, so it is necessary to consider cases where the action of the bullet on the target is excessive from the point of view of safety, insufficient to hit an outsider, and also uncertain due to the dispersion of the muzzle speed of the bullet. In this case, there are unfavorable probabilities of excessive P_{exc} and indefinite P_{ind} of the bullet on the target. Based on this, the probability of defeat and the first unauthorized person is equal to:

$$W_{UP_i} = 1 - \left[1 - P_{UP_i} (P_{exc_i} + P_{ind_i}) \right]^n, \tag{16}$$

and the probability of defeating at least one unauthorized person is equal to the sum of the probabilities W_{UP_i} :

$$W_{UP} = \sum_{i=1}^m \left[1 - (1 - P_{UP_i} (P_{exc_i} + P_{ind_i}))^n \right], \tag{17}$$

where m – the number of unauthorized persons.

Thus, let's obtain:

$$W_{SWU} = \left[1 - (1 - P_C)^n \right] \cdot \sum_{i=1}^m \left[1 - P_{UP_i} (P_{exc_i} + P_{ind_i}) \right]^n. \tag{18}$$

The probabilities P_{ind} and P_{exc} are calculated in accordance with (8) and (9), and the ranges ΔX_{ind} according to the formula [16]:

$$\Delta X_{ind} = \frac{1}{k \cdot C} \left(\ln \frac{V_m + \Delta V_m}{V_{X_{min}}} - \ln \frac{V_m - \Delta V_m}{V_{X_{min}}} \right). \tag{19}$$

The boundaries of the X_{min} and X_{max} ranges are determined by the formulas [17]:

$$X_{min} = \frac{1}{k \cdot C} \ln \frac{V_m}{V_{X_{min}}}, \tag{20}$$

$$X_{max} = \frac{1}{k \cdot C} \ln \frac{V_m}{V_{X_{max}}}, \tag{21}$$

where V_m – PE muzzle speed; C – PE ballistic coefficient of PE; X_{min} – distance at which the PE has a minimum energy that provides a lethal effect; X_{max} – distance at which the PE has maximum energy can be considered safe; $V_{X_{min}}$ – PE speed at a distance X_{min} ; $V_{X_{max}}$ – PE speed at a distance X_{max} .

The corresponding values of $V_{X_{min}}$ and $V_{X_{max}}$ are calculated by the formulas [17]:

$$V_{X_{min}} = \sqrt{\frac{2E_{k_{min}}}{m}}, \tag{22}$$

$$V_{X_{max}} = \sqrt{\frac{2E_{k_{max}}}{m}}. \tag{23}$$

The minimum and maximum values of the PE energy characteristics are set depending on the nature of the target and the degree of its protection. An analysis of literary

sources shows that the minimum energy that provides a lethal effect is approximately 20 J, and the maximum energy that can be considered safe is about 10 J [18].

The ranges ΔX_{exc} is equal to X_{min} .

For cases of PE reflection from an obstacle, the value V_m is replaced by the value of the PE speed after reflection, and the direction of PE flight is determined from the condition that the angles of its meeting with the obstacle and reflection from it are equal.

The set of expressions (8)–(12) and (18)–(23) constitute a model of the process of performing a fire mission with restrictions on the safety of using weapons.

An analysis of the model shows that a real way to increase the likelihood of performing a fire mission with restrictions on the safety of using weapons is to reduce the P_{exc} value, in particular, at distances exceeding the aiming after PE reflection from the obstacle.

In order to obtain realistic values of the parameters that affect SWU, an analysis was made of cases of the use of weapons by security forces, the level of small arms training of security personnel and the characteristics of small arms.

It is established [19] that in the vast majority of cases (98 %) pistols are used.

The shooting was mainly carried out from unstable positions, namely from a standing position (60 %), in motion (4.4 %) and from a car (20.5 %). In three quarters of the cases, firing was conducted from one hand.

Of the stable positions for shooting (from the knee, lying down, from cover) only about 15 % of the shots were fired.

The distance to the target did not exceed 20 m in 85 % of cases.

In 89 % of cases, the time for shooting was limited, and in 30 % of cases the shooting was fired without aiming (offhand).

In 71 % of cases of the use of weapons, visibility was limited.

The place of use of weapons is distributed as follows: on the street – 80 %, in parks and forests – 8 %, in the premises – 12 %.

More than half of the use of weapons is carried out in adverse conditions: physical activity – 13 %, psychological stress – 29 %, on-target shooting – 10 %.

The statistics provided allow to draw conclusions about the conditions of use of the weapon, the corresponding values of the errors of pointing the weapon at the target and the quality of the shot.

So, in accordance with [20], the error of bringing a weapon to a normal battle is up to 0.05 m at a distance of 25 m.

The size of the median error (B_v and B_b) of pointing the weapon at the target when shooting on the move from a short stop is two thousandths [21], which for a distance of 25 m is also 0.05 m.

When shooting on the go or with a moving error will be even higher. The time limit for shooting also increases the value of the pointing error. The analysis of the re-

sults of high-speed shooting from a distance of 25 m from cadets of various courses of the academy gives the total error of pointing the weapon at the target and bringing the weapon to normal combat $y_{HM}=z_{HM}=0.12-0.27$ m.

Accuracy of shooting from small arms when brought to normal combat is considered acceptable provided that $R100=0.15$ m [13, 14, 20], that is, RME of hitting the target plane is $\sigma=0.025$ m. But when performing fire tasks in traffic conditions and time limits the accuracy of shooting is significantly reduced for the studied groups of cadets $\sigma_y=\sigma_z=0.08-0.20$ m.

The dimensions of the frontal projections of the target and outsiders can vary depending on the growth and physique of individuals. Moreover, taking into account the average dimensions of an adult and the figure factor of a growth target (0.85 [22]), they can be replaced with rectangles with dimensions of 0.46–1.54 m during modeling.

Thus, when assessing the likelihood of performing fire missions by security forces with a limited use of weapons, the following output values are appropriate: $Y_C=1.54$ m, $Z_C=0.46$ m, $X_C=20$ m, $y_{HM}=0.2$ m, $z_{HM}=0.2$ m, $\sigma_y=0.2$ m, $\sigma_z=0.2$ m, $Y_i=1.54$ m, $Z_i=0.46$ m. The values X_i , y_i and z_i should be taken from real conditions.

Fig. 1 shows the placement of unauthorized persons (figures in blue), against which the target can be located (figure in red). The scheme is made according to the photograph and corresponds to the real location of citizens on the station square in Kharkiv (Ukraine).

Fig. 2 shows the dependences of the probabilities of hitting a target and performing a fire mission on the range of the lethal action. The triangular and rhomboid markers reflect the values of W_{SWU} and W_{UP} for the corresponding X_{LE} distances corresponding to the location of unauthorized persons in Fig. 1. The solid curve reflects the dependencies for a similar case, but for uniform distribution of unauthorized persons in distance and lateral direction.

For other values of the number of unauthorized persons, the distance to the target, the distance of the PE lethal action, the accuracy of firing, etc. curves are obtained that are similar in nature to those given above (Fig. 2).

An analysis of the obtained dependencies shows that the increase in the probability of an unauthorized person being injured gradually decreases with an increase in X_{LE} . This is due to the linear dependence of the number of people in the danger zone from X_{LE} and the quadratic dependence of the area of projections of unauthorized persons on the distance to them. So, the increase in the area of the frontal projections of unauthorized persons, taking into account their angular dimensions, lags behind the increase in the distance of the lethal action.

The dependence $W_{SWU}(X_{LE})$ follows from the dependence $W_{UP}(X_{LE})$ taking into account expressions (13)–(15). With a decrease in X_{LE} , the probability of completing a fire mission increases progressively. For the given example, the increase in W_{SWU} for every 50 m of reduction in the distance of slaughter action is given in Table 1.

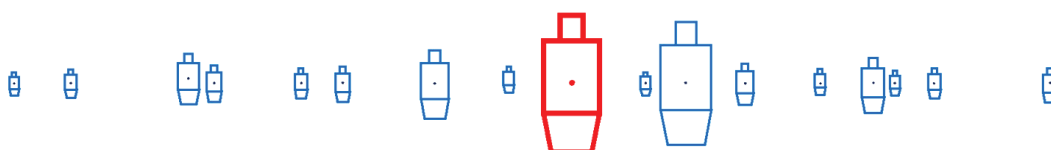


Fig. 1. The option of placing unauthorized persons against which the target is located

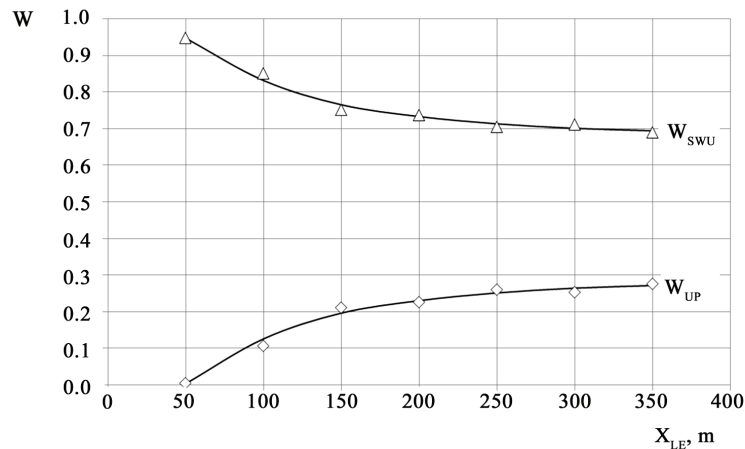


Fig. 2. The dependences of the probabilities of hitting a target and performing a fire mission on the range of the lethal action

Table 1
 $W_{SWU}(X_{LE})$ dependence for the 9 mm Makarov pistol

X_{LE} , m	W_{SWU}	Increase in W_{SWU} for every 50 m, the reduction in X_{LE} , %
50	0.947	13.9
100	0.831	8.6
150	0.765	4.5
200	0.732	2.7
250	0.713	1.9
300	0.700	0.9
350	0.694	–

In the case when the energy characteristics of PE exceed the values that are necessary for a reliable hit of the target of the above danger of hitting an outsider due to a miss by the target, the danger of hitting it with a bullet that pierced the target through and through can be added.

It should be noted that the ΔX_{ind} value significantly affects the stability of the muzzle speed of a bullet, follows from expression (19). The expansion of the ΔX_{ind} range negatively affects the efficiency of the fire mission. The value of V_m depends on a number of factors, in particular, on the values of the charging parameters [23]. Therefore, to ensure the stability of the values of the charging parameters, considerable attention should be paid. Possible ways to increase the stability of the muzzle speed of the striking elements of kinetic weapons are given in [24].

7. SWOT analysis of research results

Strengths. Strengths of research are the use of well-tested classical approaches in the field of external ballistics and firing efficiency, which ensures high reliability of forecasts. In practical terms, a significant positive effect is expected from the ability to reduce the likelihood of hitting unauthorized persons and increase the effectiveness of the performance of fire missions by security forces.

Weaknesses. Weaknesses include the difficulty of practical implementation of the requirement to minimize the difference between the aiming range of a weapon and the range at which the bullet maintains a lethal effect. This is due to the low stability of the muzzle speed of a bullet when using insufficiently high-quality ammunition (long-term storage, various manufacturers, etc.).

Opportunities. Studies of the opportunities of abruptly reducing the bullet speed at the aiming distance of the weapon seem to be promising, which will minimize the difference between the aiming range of the weapon and the range at which the bullet preserves the lethal effect.

Threats. The practical implementation of the ideas is associated with the need to improve the quality of ammunition or develop new cartridges with an abrupt decrease in bullet speed, which requires additional material costs.

8. Conclusions

1. The analysis of known studies shows that the existing scientific and methodological apparatus for determining the effectiveness of firing does not allow to determine the effectiveness of the execution of the fire mission, taking into account the safety of the use of small arms due to the imperfection of the corresponding models. Therefore, the model of the process of performing the fire mission is improved by taking into account the influence of the ballistic characteristics of the weapon on the likelihood of hitting unauthorized persons. This creates an opportunity to assess the safety of the use of weapons.

2. The influence of the ballistic characteristics of the weapon on the effectiveness of firing, taking into account the safety of the use of small arms, is investigated. It is established that the nature of the dependence of $W_{SWU}(X_{LE})$ indicates the need to minimize the difference between the aiming range of the weapon and the range at which the bullet maintains a lethal effect. Excessive energy of a bullet increases the likelihood of hitting an outsider due to an increase in the area of the danger zone of its destruction as a result of through penetration of the target. The probability of performing a fire mission with a limitation on the safety of using weapons is positively affected by increasing the stability of the muzzle speed of a bullet.

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Bilenko Alexander, Doctor of Technical Sciences, Associate Professor, Department of Doctoral and Adjuncture, National Academy of the National Guard of Ukraine, Kharkiv, Ukraine, ORCID: <http://orcid.org/0000-0001-6007-3330>, e-mail: albilenko@ukr.net

Kyrychenko Alexander, Faculty of Operations, National Academy of the National Guard of Ukraine, Kharkiv, Ukraine, ORCID: <http://orcid.org/0000-0002-9107-5002>, e-mail: Kirikalexio@ukr.net

Kaidalov Ruslan, Doctor of Technical Sciences, Associate Professor, Department of Combat and Logistic Support, National Academy of the National Guard of Ukraine, Kharkiv, Ukraine, ORCID: <http://orcid.org/0000-0002-5131-6246>, e-mail: kaidalov.76@ukr.net