Журнал «Перспективи та інновації науки»
(Серія «Педагогіка», Серія «Психологія», Серія «Медицина»)
№ 11(29) 2023

UDC 616-001.45:623.443.35

https://doi.org/10.52058/2786-4952-2023-11(29)-648-657

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SPECIFICS OF GUNSHOT RESIDUE DEPOSITION WHEN USING "FORT 9R" AND "FORT 17R" PISTOLS AT DIFFERENT DISTANCES

Abstract. Identification of the distance of the shot, the weapon of the shot, and other circumstances in the case of a gunshot injury are among the key issues facing the forensic medical expert and of greatest interest to law enforcement agencies. The world standard for answering such questions is the use of laboratory-instrumental methods for the identification of the gunshot residue – microparticles that fly out of the barrel of a weapon when a shot is fired. However, for the successful application of this knowledge in practice, it is necessary to perform preliminary experimental shootings. The least researched at the moment are samples of non-lethal firearms, which, despite their name, can lead to lethal consequences and are becoming more and more common among the civilian population. The purpose of

the study was to investigate the peculiarities of the deposition of the residual components of the shot when using the Fort 9R and Fort 17R pistols at contact range, 25 and 50 cm distances. A controlled ballistic experiment was performed in shooting range conditions on 120 gelatin blocks made according to the generally accepted method, which were subsequently covered cotton fabric, denim fabric, leatherette or left bare. The shots were fired from Fort 9R and Fort 17R pistols at contact range, 25 and 50 cm. After the shots, a chromato-mass spectrometric study and infrared microscopy on a combined IR-Fourier spectrometer were performed to detect gunpowder components and X-ray fluorescence spectroscopy to detection of overlays of elements on the trace-receiving object. Statistical processing of the received data was carried out in the license package "Statistica 6.0". The obtained data indicate the existence of numerous reliable differences in the indicators of overlap on the trace-receiving object of lead, iron and zinc, which allows them to be used for the identification of the shot tool and the shot distance. In addition, specific features of the deposition of elements on different clothing materials and bare blocks were revealed, which are most evident in the analysis of blocks covered with leather substitute. Among trace elements, zinc has the greatest practical value, while copper has no practical value in the analysis of shots fired from Fort 9R or Fort 17R pistols. Residual components of gunpowder in the case of the use of these pistols are of limited value and have been detected in some cases when fired at contact range and 25 cm on bare blocks, blocks covered with denim or leatherette.

Keywords: diphenylamine, centralite, gunshot residue, firearm, gunshot injury.

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ОСОБЛИВОСТІ ВІДКЛАДАННЯ ЗАЛИШКОВИХ КОМПОНЕНТІВ ПОСТРІЛУ ПРИ ЗАСТОСУВАННІ ПІСТОЛЕТІВ «ФОРТ 9Р» ТА «ФОРТ 17Р» НА РІЗНИХ ДИСТАНЦІЯХ

Анотація. Ідентифікація дистанції пострілу, знаряддя пострілу та інші обставини у випадку вогнепальної травми є одними з ключових питань, що постають перед судово-медичним експертом і найбільше цікавлять правоохоронні органи. Світовим стандартом для відповіді на такі питання є застосування лабораторно-інструментальних методів для ідентифікації залишкових компонентів пострілу – мікрочастинок, що вилітають зі ствола зброї при пострілі. Проте, для успішного застосування даних знань на практиці необхідне виконання попередніх експериментальних відстрілів. Найменш дослідженими на даний час лишаються зразки нелетальної вогнепальної зброї, які не зважаючи на свою назву можуть призводити до летальних наслідків та стають все більше поширеними серед цивільного населення. Метою дослідження було дослідити особливості відкладання залишкових компонентів пострілу при застосуванні пістолетів «Форт 9Р» та «Форт 17Р» на дистанціях впритул, 25 та 50 см. Контрольований балістичний експеримент виконано в умовах тиру на 120 желатинових блоках виготовлених за загальноприйнятим методом, які в подальшому покривали бавовняною тканиною, джинсовою тканиною, шкірозамінником чи лишали голими. Постріли виконували з пістолетів «Форт 9Р» та «Форт 17Р» з дистанцій впритул, 25 та 50 см. Після відстрілів виконували хромато-мас-спектрометричне дослідження та інфрачервону мікроскопію на суміщеному ІЧ-Фур'є спектрометрі для виявлення складових пороху і рентгенфлуоресцентну спектроскопію для виявлення накладань елементів на слідоприймаючому об'єкті. Статистична обробка отриманих даних проведена в ліцензійному пакеті"Statistica 6.0". Отримані дані свідчать про наявність численних достовірних відмінностей у показниках накладання на слідоприймаючому об'єкті свинця, заліза та цинку, що дозволяє застосовувати їх для ідентифікації знаряддя пострілу та дистанції пострілу. Окрім того виявлено специфічні особливості відкладання елементів на різних матеріалах одягу та голих блоках, що найбільше проявляються при аналізі блоків покритих шкірозамінником. Серед мікроелементів найбільше практичне значення має цинк, в той час як мідь не має жодної практичної цінності при аналізі пострілів виконаних з пістолетів «Форт 9Р» чи «Форт 17Р». Залишкові компоненти пороху у випадку використання зазначених пістолетів мають

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обмежену цінність та виявлені в деяких випадках при пострілах впритул та 25 см на голих блоках, блоках вкритих джинсовою тканиною або шкірозамінником.

Ключові слова: дифеніламін, централіт, залишкові компоненти пострілу, вогнепальна зброя, вогнепальна травма.

Statement of the problem. Firearms have become more widespread, as has civilian access to them, and with it, the prevalence of gunshot injuries has increased. In the period from 1993 to 2012, about 32 thousand people died from firearms and twice as many were injured, which led to an increase in annual public costs, which is currently about 48 to 100 billion US dollars [1]. A special type of firearm is the so-called "non-lethal weapon", which is usually used as a weapon of law enforcement agencies or positioned as a weapon for self-defense. However, the "non-lethal" nature of this weapon is the subject of long debates among scientists. Numerous head injuries, including brain damage and loss of sight, were noted for this weapon. Sometimes there are fatalities. It is often emphasized that the lethal nature of this weapon is due to the violation of the rules of its use (shots must be fired from a certain distance into certain anatomical parts of the body, excluding the head, etc.) [2].

In this regard, there is an urgent need for research on the effects of non-lethal firearms. Currently, there are many directions for researching various indicators of this type of weapon, the results of which can serve various practical branches of medicine. Such are studies of the effect of non-lethal weapons on clothing damage [3], which further help with the forensic identification of weapons, works devoted to the study of wound ballistics by analyzing indicators of the temporary cavity on optically transparent media imitating human body tissues [4].

However, it would be most expedient to combine the above types of research into one comprehensive one – where the human body simulator is combined with clothing. Such an experiment would allow a more complete and reliable assessment of the course of wound ballistics. So far, such studies are few in the domestic literature [5]. One of the aspects that would most satisfy the needs of forensic medicine and law enforcement agencies would be the study of the gunshot residue, the main physical evidence when it comes to gunshot injuries [6]. Thus, it is promising to conduct an experimental shooting with the use of non-lethal firearms of the "clothing + human body simulator" complex in order to identify the gunshot residue.

Connection of the publication with planned scientific research works. The work was carried out as part of the research work of the National Pirogov Memorial Medical University, Vinnytsya at the expense of state funding of the Ministry of Health of Ukraine: "Characteristics of damage to human body tissue simulators caused by non-lethal weapons" (state registration number 0121U107924).

The purpose of the article – to establish the peculiarities of the deposition of the gunshot residue when using the "Fort 9R" and "Fort 17R" pistols at different distances during shots at nude non-biological simulators of the human body or covered with different types of clothing.

Research objects and methods. To achieve the goal, 120 gelatin blocks were made according to the generally accepted method [7], which, according to their characteristics, imitate the soft tissues of the human body as closely as possible. The blocks were covered with a transparent polyethylene film 200 μm thick to simulate skin. The blocks were further divided into groups according to their covering: bare blocks (BB), blocks covered with cotton fabric (CF), blocks covered with denim fabric (DF), blocks covered with leatherette (LB). In the conditions of the shooting range, the blocks were shot at close range, 25 and 50 cm with the help of "Fort 9R" and "Fort 17R" pistols. In order to identify the components of nitrocellulose (smokeless) gunpowder (nitroglycerin and stabilizers – diphenylamine and centralite), the chromatographic-mass spectrometric method was used on the Shimadzu GC-2010 Plus device and infrared microscopy on the combined IR-Fourier spectrometer Nicolet iN10 of the company "Thermo Fisher Scientific". X-ray fluorescence spectroscopy using the ElvaX Plus device was used to identify the qualitative and quantitative characteristics of the overlay of elements on the trace-receiving surface. Committee on Bioethics of National Pirogov Memorial Medical University, Vinnytsya (protocol № 11 From 03.12.2020) found that the studies do not contradict the basic bioethical standards of the Declaration of Helsinki, the Council of Europe Convention on Human Rights and Biomedicine (1977), the relevant WHO regulations and laws of Ukraine.

The statistical analysis of the obtained results was carried out in the licensed statistical package "Statistica 6.0" using non-parametric estimation methods. The reliability of the difference in values between independent quantitative values was determined using the Mann-Whitney U-test, and between qualitative values – according to the Weber E.

Presentation of the main material.

Research results and their discussion. The analysis of *lead* deposition indicators revealed the following features:

when contact shots from "Fort 9P" significantly lower ($p<0.01$) values of the element when shooting at LB compared to BB, CF, DF (68.40±7.50, 94.00±0.71, 87.60±7.30 and 83.00±6.71, respectively); when shooting from a distance of 25 cm, the element values are significantly lower ($p<0.05$) when shooting in CF compared to BB, DF, LB (51.80±11.23, 73.60±7.02, 71.20±5.81 and 71.20±5.81, respectively); when comparing the values of the indicator when fired from "Fort 9P" from different distances, significantly higher values ($p<0.01$) of the element were found when fired at BB, CF, DF at contact range than at 25 cm (94.00±0.71 and 73.60±7.02, 87.60± 7.30 and 51.80±11.23, 83.00±6.71 and 71.20±5.81, respectively) and contact compared to 50 cm for BB and CF (94.00±0.71 and 62.60±17.24, 87.60±7.30 and 40.60±23.78, respectively);

when firing at contact range from "Fort 17P", the values of the element are significantly lower ($p<0.01$) when firing at LB compared to BB and CF (84.00±1.73, 90.60±3.65 and 91.00±2.12, respectively); when shooting from a distance of 25 cm, the element values are significantly lower ($p<0.01$) when shooting at LB compared to BB, CF, DF (47.20±6.61, 75.00±14.97, 75.00±7.35 and 78.40±4.16, respectively); when shooting from a distance of 50 cm, the element values are significantly lower ($p<0.05$-0.01) when shooting at LB compared to CF and DF (48.20±7.60, 75.40±23.51 and 73.20±11.17, respectively); when comparing the values of the indicator when fired from "Fort 17P" from different distances, significantly higher values ($p<0.05$-0.01) of the element were found when fired at CF, DF and LB at contact range compared to 25 cm (91.00±2.12 and 75.00±7.35, 88.40±3.13 and 78.40±4.16, 84.00±1.73 and 47.20±6.61, respectively) and contact compared to 50 cm (84.00±1.73 and 48.20±7.60, respectively).

When comparing the values of the indicator when fired from "Fort 9R" and "Fort 17R" pistols, significantly higher ($p<0.01$) values of the element were found when fired from "Fort 9R" in LB from distances of 25 cm and 50 cm (71.20±5.81 and 47.20±6.61, 67.20±4.66 and 48.20±7.60, respectively) and significantly higher ($p<0.05$-0.01) values of the element were detected when firing from "Fort 17R" in CF from distances of 25 and 50 cm and LB from contact range (75.00±7.35 and 51.80±11.23, 75.40±23.51 and 40.60±23.78, 84.00±1.73 and 68.40±7.50, respectively).

The analysis of indicators of *iron* deposition revealed the following features:

when fired at contact range from "Fort 9P", the values of the element are significantly lower ($p<0.01$) when fired at BB compared to LB (4.400±0.548 and 20.40±5.81, respectively); when shooting from a distance of 25 cm, the values of the element are significantly higher ($p<0.05$) when shooting in CF compared to DF and LB (24.80±6.83, 15.20±3.35 and 15.20±3.35, respectively); when shooting from a distance of 50 cm, the values of the element are significantly higher ($p<0.05$) when shooting in CF compared to LB (36.20±19.92 and 9.800±8.955, respectively); when comparing the values of the indicator when fired from "Fort 9P" from different distances, significantly lower values ($p<0.05$-0.01) of the element were found when fired at BB and CF at contact range, compared to 25 and 50 cm (4.400±0.548, 17.60±3.36, 25.40±18.06 and 10.40±8.26, 24.80±6.83, 36.20±19.92, respectively);

when firing at close range from "Fort 17P", the element values are significantly higher ($p<0.05$-0.01) when firing at LB compared to BB, CF and DF (13.60±1.52, 8.200±2.588, 7.200±2.280 and 8.800±2.490 in accordance); when shooting from a distance of 25 cm, the values of the element are significantly higher ($p<0.01$) when shooting at LB compared to BB, CF, and DF (45.00±7.58, 18.20±12.21, 19.40±2.61, and 12.80±1.92, respectively) and CF compared to DF (19.40±2.61 and 12.80±1.92, respectively); when shooting from a distance of 50 cm, the element values are significantly higher ($p<0.05$-0.01) when shooting at LB compared to BB, CF and DF (42.40±7.16, 14.40±15.11, 20.00±18.43 and

14.60±8.73, respectively); when comparing the values of the indicator when fired from "Fort 17R" from different distances, significantly lower values ($p<0.05$-0.01) of the element were found when fired at CF, DF, LB at contact range compared to 25 cm (7.200±2.280 and 19.40±2.61, 8.800±2.490 and 12.80±1.92, 13.60±1.52 and 45.00±7.58, respectively) and LB closely compared to 50 cm (13.60±1.52 and 42.40±7.16, respectively).

When comparing the values of the indicator when fired from the "Fort 9P" and "Fort 17R" pistols, significantly higher ($p<0.05$) values of the element were found when fired from the "Fort 9P" in LB from contact range (20.40±5.81 and 13.60±1.52, respectively) and significantly higher ($p<0.05$-0.01) values when shooting from "Fort 17R" in BB at contact range (8.200±2.588 and 4.400±0.548, respectively) and LB from distances of 25 and 50 cm (45.00±7.58 and 15.20±3.35, 42.40±7.16 and 9.800±8.955, respectively).

The analysis of *zinc* deposition indicators revealed the following features:

when fired from a distance of 25 cm from "Fort 9P" significantly lower ($p<0.05$-0.01) element values were found when fired at BB compared to CF, DF and LB (6.200±3.899, 21.20±4.868, 13.40±2.61 and 13.60±2.70, respectively), and significantly ($p<0.05$) higher values of the element when firing in CF compared to DF and LB (21.20±4.868, 13.40±2.61, and 13.60±2.70, respectively); when fired from a distance of 50 cm from "Fort 9P", significantly lower ($p<0.05$-0.01) element values were found when fired at BB compared to CF and LB (12.00±2.35, 23.20±7.22 and 23.00±4.85, respectively); when comparing the values of the indicator when fired from "Fort 9P" from different distances, significantly lower values ($p<0.05$-0.01) of the element were found when fired at CF and DF at contact range compared to 25 cm (2.000±2.000 and 21.20±4.868, 3.400±4.775 and 13.40±2.61, respectively), BB, CF and LB when shooting at contact range compared to 50 cm (1.600±0.548 and 12.00±2.35, 2.000±2.000 and 23.20±7.22, 11.20±7.50 and 23.00±4.85, respectively), at shots in BB and LB from 25 cm compared to 50 cm (6.200±3.899 and 12.00±2.35, 13.60±2.70 and 23.00±4.85, respectively);

when fired at contact range from "Fort 17P", the element values are significantly higher ($p<0.01$) when fired at BB compared to CF, DF, and LB (0, 1.800±0.837, 3.600±2.074, and 2.400±0.548, respectively); when shooting from a distance of both 25 and 50 cm, significantly lower ($p<0.05$) values of the element were found when shooting at BB compared to DF and LB (3.400±2.510, 8.200±1.643, 7.800±1.924 and 5.800±1.924, 10.40±2.07, 8.600±0.894, respectively); when comparing the values of the indicator when fired from "Fort 17P" from different distances, significantly lower values ($p<0.05$-0.01) of the element were found when fired at contact range compared to 25 and 50 cm for BB, DF and LB (0, 3.400± 2.510, 5.800±1.924 and 3.600±2.074, 8.200±1.643, 10.40±2.07 and 2.400±0.548, 7.800±1.924, 8.600±0.894, respectively).

When comparing the values of the indicator when fired from "Fort 9R" and "Fort 17R" pistols, significantly higher ($p<0.05$-0.01) values of the element were

found in all cases when fired from "Fort 9R": BB at contact range and at a distance of 50 cm (1.600±0.548 and 0, 12.00±2.35 and 5.800±1.924 respectively), CF 25 and 50 cm (21.20±4.868 and 5.600±7.701, 23.20±7.22 and 4.600±7.057 respectively), DF 25 cm (13.40±2.61 and 8.200 ±1.643, respectively) and LB 25 and 50 cm (13.60±2.70 and 7.800±1.924, 23.00±4.85 and 8.600±0.894, respectively).

During the analysis of *copper* deposition indicators, no significant differences or trends to differences between the studied groups were found.

The analysis of indicators for *centralite* and *diphenylamine* revealed that the deposition of these components coincides and is observed when fired at contact range and 25 cm in BB, 25 cm in LB from the Fort 9R pistol, and from a distance of 25 cm in DF when fired from the Fort 17R pistol.

X-ray fluorescence analysis has found widespread use in forensic medicine, and especially in the part that studies ballistics. As an example, studies have shown that it is possible to successfully use indicators of barium and lead on the hands to identify the shooter [8]. At the same time, it is necessary to remember about false-positive results. Australian scientists [9] during SEM-EDS analysis of samples from the hands of persons who have no business with firearms found a characteristic combination of lead, stibium and barium in 0.3 % of subjects, in 8 % of people a combination of lead and stibium and in 7 % one of three elements. In general, the residual components of the shot remain on the skin in significant quantities for 3 hours, and in the future their number begins to decrease significantly, but they are determined up to 6 hours [10].

Experimental controlled shootings followed by laboratory research on the peculiarities of the accumulation of residual components of the shot are the world standard for identifying the distance of the shot in cases where such factors as: unknown distance, angle of the shot, pose of the shooter, type of weapon used, type of ammunition are unknown to the investigation [11]. In this way, the residual components of the shot remain the most valuable and key material evidence in the case of forensic medical examination related to firearms and require taking into account the maximum number of accompanying factors [12].

Conclusions. When analyzing the indicators of lead, iron and zinc, numerous reliable differences were found between the studied comparison groups regarding the distance of the shot, the features of the coating and the weapon of the shot. At the same time, copper indicators cannot be used for the above-mentioned purpose due to the absence of any reliable or trends to differences in all the studied comparison groups.

The most expedient for identifying the shot tool in the case of using Fort 9R and Fort 17R pistols is the use of zinc indicators, which are significantly higher in all comparison groups for shots fired from Fort 9R, regardless of the cover of the blocks; in cases of a shot at blocks covered with leather substitute, it is advisable to use indicators of any elements.

The components of gunpowder (centralite and diphenylamine) are mostly found in Fort 9R pistol shots, but are of less interest for identifying the shot distance or the shot weapon than the stacking of elements.

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