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Analysis of the history of creation and improvement of personal protective equipment: from bronze armor to modern bulletproof vests

Abstract. *In this article, using real historical examples, the authors tried to trace the evolution of personal protective equipment. This has made it possible to perform a comparative historical analysis of the development of scientific research and industrial technologies, which made it possible to manufacture specific personal protective equipment in a certain historical period. Also in this review article, the authors have analyzed the stages of modern technologies that are currently used in the manufacture of various types of bulletproof vest. And given that the overwhelming majority of authors of publications devoted to the history of the creation of bulletproof vests write that: the bulletproof vest does not have a specific inventor, in this review article the authors also talk about specific, undeservedly forgotten now, the creators of the world's first officially patented prototypes of bulletproof vests for the police and VIP-persons, at the beginning of the 20th century, who stood at the origins of the bulletproof vest industry. With the development of the industrial revolution and technological progress, new materials and production technologies have appeared, allowing the creation of more effective bulletproof vest. Bulletproof vest has become lighter and more effective over time, thanks to the use of new materials such as Kevlar, aramid fibers and ceramics. Thus, the history of the development of bulletproof vest includes the contribution of many scientists, engineers and inventors who have contributed to the improvement of protective armor over the years. In the article, the authors show that modern realities put forward new requirements for quality, weight and functional characteristics for design engineers and manufacturers of bulletproof vest. The authors of the article analyze the main directions in which research work is currently underway*



to improve bulletproof vests. The authors of the article show that in different countries of the world there are different standards and classifications for bulletproof vest. Each standard usually has its own classification, which determines the level of protection of bulletproof vest against specific types of threats, such as bullets, shrapnel or stab wounds. Therefore, the task of developing a single standard for modern bulletproof vest is important.

Keywords: body armor; bulletproof; Casimir Zeglen; Jan Szczepanik; Stephanie Louise Kwolek; kevlar

Introduction.

The bulletproof vest (or protective vest), as such, cannot be attributed to one particular inventor. Various forms of armor and protective materials have been used over the centuries to protect against various types of attacks, including attacks using firearms. The bulletproof vest familiar to our contemporaries was developed at the beginning of the 20th century. Several scientists and engineers have contributed to the development of protective vests, and one inventor cannot be unequivocally named.

However, ideas for the creation of protective vests arose long before that time. The ancient Romans used prototype bulletproof vest made of metal plates known as "lorica segmentata" (Fig. 1) during their military campaigns (Bishop, 2002; Argüín, 2006; Tonc, Dizdar, & Vulić, 2022).

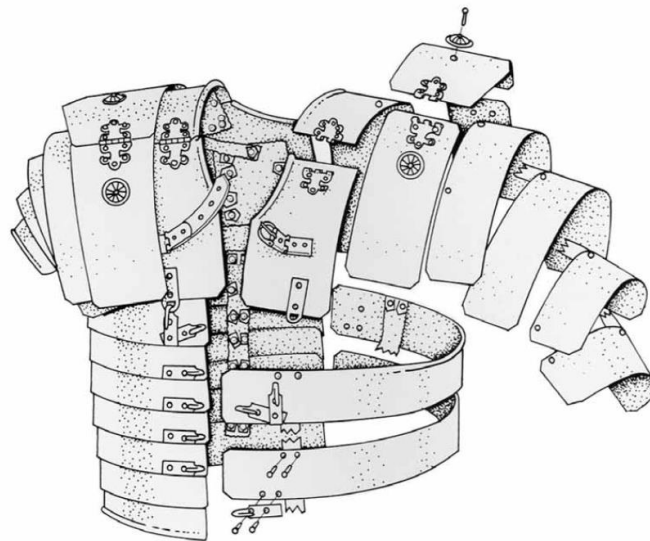


Figure 1. Lorica segmentata tipo «Corbridge». (Argüín, 2006).

Throughout history, there have been many other attempts to develop bulletproof vest and other types of protective equipment. One of the earliest examples of bulletproof vest is mail, which consisted of metal rings tied together. Mail was widely used by various armies in Medieval Europe and other parts of the world.

In the 16th and 17th centuries, the first experiments appeared with metal plates worn on the body to protect against bullets and saber blows. However, these early prototype bulletproof vest were bulky and limited in their effectiveness. In more

modern times, the development of bulletproof vest is associated with the advent of firearms.

With the development of the industrial revolution and technological progress, new materials and production techniques have appeared, allowing the creation of more effective bulletproof vest. Bulletproof vest has become lighter and more effective over time, thanks to the use of new materials such as kevlar, aramid fibers and ceramics (Kathiavelu, 2003; Godara, Yadav, Goswami, & Rana, 2021; Mishra, Madhad, & Vasava, 2021).

Thus, the history of the development of bulletproof vest includes the contribution of many scientists, engineers and inventors who have contributed to the improvement of protective armor over the years.

The main purpose of writing this article is to trace the evolution of personal protective equipment using real historical examples, and to give a comparative historical analysis of the development of scientific research on innovative materials and industrial technologies that made it possible to manufacture personal protective equipment in one or another specific historical period.

Also, the aim of this article is to analyze modern materials and technologies that are currently used in the manufacture of various types of bulletproof vest.

The overwhelming majority of authors of publications devoted to the history of the creation of bulletproof vests write that: the bulletproof vest does not have a specific inventor. This is not entirely true. The authors of this article consider it necessary to analyze the available information and tell about the specific, undeservedly forgotten now, the creators of the world's first prototypes of bulletproof vests for the police and VIPs. Since at the beginning of the 20th century it was they who stood at the origins of the bulletproof vest industry, and their technological developments are still used by design engineers in many countries of the world.

Chronology of the creation of personal protective equipment.

Since ancient times, man has been trying to protect himself during battles by putting on various protective ammunition (Charles, 2012; Nayak, et al., 2018; Manning, 2021). In addition to protective functions, it gives warriors an undeniable advantage over the enemy, if he does not have such protection.

The ancient Greek warriors and legionnaires of the Roman Empire owe their military success to the armor of that time, which reliably protected them: helmets, breastplates, shoulder pads and knee pads, which were made mainly of bronze (Aldrete, Bartell, & Aldrete, 2013).

In the Middle Ages, practically no one could resist the heavy knightly cavalry, because the knights were practically invulnerable thanks to steel armor on top, and chain mail worn under them on the body, made of tightly woven metal circles.

It was at this time in Europe and Japan that a certain prototype of a modern bulletproof vest appeared, which went down in history under the name "brigandine". Plates or various forms of some kind of metal were sewn onto a rough canvas fabric.

Such "brigantides" were worn by warriors under armor, or by civilians under outerwear.

As shown in fig. 2, it exhibits the bascinet of the earliest years of the fifteenth century, a brigandine of few plates, the typical defenses of arms and legs with small "shells" at elbow and knee, the small and separate shoulder defense, and the short-cuffed gauntlets, precisely as one sees them represented in tomb figures of about 1400 (Dean, 1925).



Figure 2. The bascinet of the earliest years of the fifteenth century, a brigandine of few plates, the typical defenses of arms and legs with small "shells" at elbow and knee, the small and separate shoulder defense, and the short-cuffed gauntlets (Dean, 1925).

The development of firearms has made its own adjustments to the evolution of body protection elements. It no longer made any sense to put on heavy knightly armor, because they easily made their way not only with artillery grapeshot, but even with simple bullets fired from muskets, arquebuses and pistols.

Only metal cuirasses remained in the protective equipment of cavalymen in the 17th–18th centuries. Depending on the country where they were used, cuirasses were either only breastplates, or consisted of two parts that protected their owner from two sides: from the side of the chest, and from the back.

As an illustrative example, here we can recall the legendary Polish winged hussars of the Commonwealth, who dressed in segmented metal cuirasses before the battle, and fluttered behind them, fastened to the saddle, huge wooden wings decorated with eagle and falcon feathers, called upon during a swift attack, fluttering in the wind, to intimidate the enemy (Fig. 3).



Figure 3. ArtStation – Battle of Kirchholm. Polish Winged Hussars (Kozik, 2011).

Cuirassier cavalry regiments existed in the armies of European states until the beginning of the 20th century and took an active part in the World War I (Philips, 2011).

Various types of cuirasses and steel breastplates, although not widely used, were used as experimental samples to supplement the ammunition of soldiers during the World War I (Fig. 4) and World War II.

Until the beginning of the 20th century, inventors and design engineers who developed wearable personal protective equipment constantly faced a dilemma that the materials and scientific and industrial technologies of those times that they had at hand did not allow them to solve as rationally as possible. On the one hand: wearable personal protective equipment had to reliably protect its owner from knives and firearms. Therefore, various metals were mainly used for their manufacture. On the other hand, inventors and design engineers were aware that the weight of wearable personal protective equipment should be within reasonable limits and, if possible, not restrict the movements of a person when wearing them.



Figure 4. Result of Ordnance Department body armor test at Fort de la Peigney, Langres, France. Exhibit of body armor, heavy weight, showing effect of pistol, rifle and machine gun fire. (Army Ordnance Department, 1918).

Here it is impossible not to recall the history of the famous Australian gang of (Utley, 2015). At the end of the 1870s, she directed horror on the police of the green continent, robbing banks and killing constables. They could not neutralize the gang for several years, although the Australian police attracted significant forces for this.

During skirmishes with bandits, the police naturally shot to kill, mainly in the chest and heart area. When the gang was finally caught, it turned out that the inventive "gentlemen of fortune" wore homemade steel armor that bullets could not penetrate.

The famous English writer Arthur Conan Doyle was told this adventurous story by one of his acquaintances. The author of the detective Notes on Sherlock Holmes, who was in close contact at that time with representatives of the police and the Ministry of Defense of Foggy Albion, advised British infantry soldiers to be dressed in such armor (Lycett, 2011). But in the military department, such an idea was very skeptical, and tactfully rejected it. Because the home-made steel breastplates and other armor of the Australian "gentlemen of fortune", although they did not make their way through bullets from rifles and revolvers, even almost point-blank, because they were almost 7 millimeters thick, but at the same time they had simply unbearable weight. For example, the "armor" of gang leader Ned Kelly (Fig. 5) weighed 47 kilograms (Utley, 2015).

In addition to the total weight of the personal protective equipment and the mobility of a person when wearing it, inventors and design engineers had to take into account the third important technical aspect when creating them. This is the so-called: armored action from a direct hit by a bullet or a fragment of an artillery shell. A blow of enormous power could lead to a fracture of the ribs or even to the rupture of internal organs.



Figure 5. Ned Kelly armour, located at the State Library of Victoria, Melbourne, Australia (Findlay, 2020).

It is no coincidence that during the World War II, soldiers of the Red Army of the Soviet Union always wore thick padded jackets under steel breastplates (Fig. 6), which, in the event of a bullet or shrapnel hit, significantly softened the force of impact (Melkin, 2019).



Figure 6. Soldiers of the Red Army of the Soviet Union in steel bibs during street fighting in Stalingrad in 1943 (Budanovic, 2017).

Creators of the first officially patented bulletproof vests.

As we noted at the beginning of this article, the vast majority of authors of publications devoted to the history of the creation of bulletproof vests write that: the bulletproof vest does not have a specific creator. This is not entirely true. The first analogues of modern bulletproof vests were created and officially patented in the United States of America by Kazimir Zeglen, and in Europe by Jan Szczepanik (Collins, 2005; Risteski & Srebrenkoska, 2020). By coincidence, these two inventors of the first bulletproof vests have Ukrainian roots.

Because Jan Szczepanik was born in 1872 in the village of Rudniki on the outskirts of the town of Mostyska (in modern Ukraine, this is the regional center of the Lviv region) (Trzaska, 2011).

And his counterpart Kazimir Zeglen in 1869 in Ternopil (the regional center of modern Ukraine) (Łotysz, 2014).

We can say that they are both of them are now undeservedly forgotten, although at the beginning of the 20th century it was they who stood at the origins of the industry for the creation of bulletproof vest for the police and VIPs, and their technological developments are still used by design engineers in many countries of the world.

Jan Szczepanik.

It was he who created and patented the first bulletproof vest in Europe based on a silk multilayer fabric, stitched for reinforcement with the finest metal threads. To do this, he improved the loom, on which it was possible to produce such a fabric on an industrial scale. On Zeglen's commission he developed an industrial method of producing a bulletproof fabric, which not only made it possible to lower its price, but also improved the parameters of its endurance (Łotysz, 2009).

Figure 7 shows a world's first during tests of bulletproof armor. A shot at Szczepanik bulletproof armor in the courtyard of the Patronage House in Vienna in

1901. Director of the Patronage House Borzhikovsky shoots a clerk from a distance of 3 steps with a 7mm revolver, who is wearing bulletproof armor.



Figure 7. A shot at the bulletproof armor of the Shchepanik system (Głos Narodu, 1901, December 7, p. 13).

Bulletproof fabric woven on the looms of Jan Szczepanik in 1906 during the assassination attempt on Alfonso XIII King of Spain actually saved the life of the monarch (Trzaska, 2011). A powerful bomb was thrown under the king's carriage, the explosion of which killed or injured more than 100 people who were nearby at that moment. The king and all who were in the carriage were not injured, only because from the inside it was sheathed with bulletproof multi-layered fabric for safety reasons. For which Jan Szczepanik was awarded the honorary title of Knight of the Order of Isabella the Catholic. Bulletproof vests created by Jan Szczepanik at the beginning of the 20th century were worn by many European politicians and government officials of the highest rank.

Casimir Zeglen.

He was a Polish Catholic priest who emigrated to America in 1890 (Łotysz, 2014). In 1893, the mayor of Chicago (Collins, 2005), whom Casimir Zeglen respected greatly, was shot dead, and was shocked by his death. This was the reason for the beginning of his active experiments on the creation of bulletproof vest on a fabric basis (Łotysz, 2014).

One day, an article by the famous doctor and medical examiner from Arizona, George Emery Goodfellow, accidentally came across his eyes, in which the case was described in detail when, while examining the corpse, he discovered that one of the revolver bullets that literally riddled the body of the unfortunate man was stuck in the

breast pocket of his jacket in a tightly folded silk handkerchief (Risteski & Srebrenkoska, 2020). Casimir Zeglen noted this interesting detail for himself, and discarding all other materials with which he had worked before, he finally chose silk (Łotysz, 2014).

As a result, it was he who invented an innovative method of weaving silk for a fabric capable of protecting a person from firearms.

The innovative multi-layered silk fabric was woven in factories in Austria and Germany, because only they at that historical moment could guarantee the highest quality of products, which was so necessary for Casimir Zeglen.

Bulletproof multi-layered silk vests, when hit, perfectly stretched at the point of impact and extinguished the energy of lead bullets fired from revolvers almost at close range, as well as steel bullets fired from afar.

In 1897 Casimir Zeglen officially patented his bulletproof vests (Łotysz, 2009).

To establish their industrial production, he was forced to look for business partners in Europe. In the same spring of 1897, Kazimir Zeglen met Jan Szczepanik, who invited him to start the production of bulletproof vests on an industrial scale on the automated looms of his company. They signed a commercial agreement and began to cooperate, but later, due to financial disagreements, their commercial relationship was interrupted. And each went on his own way.

New materials and new technologies.

The USA.

In the 1930s, in the research laboratories of the largest American chemical corporation DuPont, such innovative materials for those times as nylon, neoprene and teflon were synthesized (Singha, Maity, Pandit, & Mondal, 2022).

It was from multilayer ballistic nylon that the United States created the world's first military bulletproof vest M-1951, which was put into mass production and was used by American soldiers during the fighting in Indochina during the Korean War (1950–1953) (Howard, 2020; Melkin, 2019). Statistical data showed that the personnel received the most injuries from fragments of mines, hand grenades and artillery shells Melkin, V. (2019). Up to seventy percent of shrapnel wounds were in the upper torso.

Therefore, the creators of the M-1951 army bulletproof vest were tasked with protecting the marines primarily from fragments (Howard, 2020). Although the developers made the M-1951 universal by providing pockets in it, where aluminum or steel plates could be inserted to cover the chest and heart area. Without metal plates, the M-1951 army bulletproof vest weighed only 3.51 kg, so it did not hamper the movements of the Marines during the battle, even allowing them to move on the ground in a plastun way if necessary.

In May 1943 the Dow Chemical Company laminated a fibrous glass fabric which immediately proved very promising (Pike, 2011). The initial product consisted of layers of glass filaments of Fiberglas bonded together with an ethyl cellulose resin under high pressure. Some of the individuals working with Col. (later Brig. Gen.)

Georges F. Doriot, then director of the Military Planning Division, Office of the Quartermaster General, decided that the project should be known as the "Doron Project" in his honor. Therefore, the glass fiber laminate manufactured by the Dow Chemical Company became known as and continued to be called doron. The production of the M12 vest was slated to continue to a certain degree after August 1945. The M12 vest was made of thick aluminum plates and had layers of nylon cloth. It weighed 12 pounds and 3 ounces and provided an area protection of 3.45 square feet. The design had been modified to provide greater protection for the anterior portion of the thorax both by increasing the width of the main frontpiece and also by increasing the size of the anterior flap over the heart and great vessels. It was not until the Korean War that it was utilized in the field. With the rebirth of body armor during the Korean War, the M12 vest was used initially by American troops in conjunction with the newer all-nylon-type vest. Following the completion of the initial surveys and standardization of the final end item, all US frontline troops were equipped with the newer all-nylon or doron vests, and the M12 vests were used by Republic of Korea troops.

Figure 8 shows a soldier displays a piece of shrapnel that lodged in his armored vest during frontline action in Korea on March 30, 1952 (Morrell, 2014). The impact knocked him to the ground, but the vest, reinforced with Doriot's "Doron," was credited with saving him from serious injury (source Associated Press).



Figure 8. A soldier displays a piece of shrapnel that lodged in his armored vest during frontline action in Korea on March 30, 1952 (Morrell, 2014).

During the Korean War, several more modifications of army bulletproof vests were released, in particular, the M-1952 (Prat, Rongieras, Sarron, Miras, & Voiglio, 2012). In their advanced anti-fragmentation equivalent of the M-1969 (which weighed 3.85 kg), most American soldiers went through the Vietnam War (1964–1973), because its wearing was mandatory for all personnel of any units participating in the hostilities in that country (Howard, 2020). Since 1967, the US Marines have been able to insert not only metal, but also fiberglass and ceramic plates into the breast pockets of their bulletproof vests to enhance protection.

Perhaps the biggest paradox in the field of scientific and technological progress in such a militaristic industrial branch as the creation of personal protective equipment is that a small and fragile woman, Stephanie Kwolek, made a significant contribution to its development. She ran a research laboratory at the American chemical corporation DuPont. Another oil crisis was approaching the world. So her lab was tasked with synthesizing a fiber that was light, flexible, versatile, yet strong enough to be used in the production of car tires. The result of the work of her research laboratory exceeded even the wildest expectations (Jethy, Paul, Das, Adesina, & Mustakim, 2022).

Kevlar was invented in 1964 (Melkin, 2019). In 1965, the technology for its industrial production was developed. And since the beginning of the 1970s, the production of various experimental products from Kevlar has begun, including Kevlar bulletproof vest.

It was the appearance of Kevlar, and also, along with it, high molecular weight polyethylene that opened the era of creating not only anti-fragmentation type PASGT, but also more reliable bulletproof vests, which in various modifications, constantly updated year after year, from the beginning of the 1980s, they began to massively enter service with the special services, the police and the US army (Marchenko, 2017).

PASGT (abbreviated from Personnel Armor System for Ground Troops), the system of individual armor protection of the ground forces) is an armor protection kit consisting of a bulletproof vest and an armored helmet (Roberts & Bullian, 1993).

PASGT was adopted by the US Army in 1980 (however, the start of delivery to the troops was scheduled for October 1981, after the completion of the production of the first batch of 130 thousand sets), and was officially in service until 2003 (in fact, a replacement for more perfect samples of personal armor protection occurred gradually, in 2004–2009) (Roberts & Bullian, 1993). Nevertheless, PASGT helmets and bulletproof vest are still in service with a number of US allied countries and are used by US private military and security companies. Although, according to American military doctrine, for a long time (until 1999), the marines were dressed in anti-fragmentation, and not in anti-bullet Kevlar bulletproof vest.

The USSR.

In the Soviet Union, which was the main military adversary of the United States, the All-Union Institute of Aviation Materials in 1954 developed the first Soviet anti-fragmentation and anti-bullet bulletproof vest with the abbreviation name 6B1 (Melkin,

2019). Small aluminum plates sewn into separate “pockets” were used as armor protection throughout the bulletproof vest. The overall cut was made of synthetic fabrics. Inside there was a soft cotton lining to reduce the armor effect of bullets and shrapnel. In 1957, an experimental batch of only 1,500 units entered service. But during the Cold War, the party and military leadership of the USSR relied on nuclear weapons of mass destruction. Rocket troops and long-range strategic aviation were considered priority. Therefore, large-scale production of the first Soviet bulletproof vest 6B1 was not started. Their mass production was planned to begin only in case of war.

In 1971, at the All-Union Research Institute of Steel, a specialized vest was created for KGB officers, police officers and prosecutors with the ZhZT-71 index (Melkin, 2019). At the very beginning of the war in Afghanistan (1978-1985), all 1500 of the first Soviet 6B1 bulletproof vests were transferred to units of a limited military contingent of Soviet troops. In the difficult mountainous terrain where the fighting took place, its operation immediately showed that it was too heavy (5.5–5.3 kg, depending on its size).

In 1979, the All-Russian Research Institute of Steel promptly developed the first Soviet Kevlar bulletproof vest 6B2, based on its own ZhZT-71 vest for law enforcement agencies (Marchenko, 2017).

The cut was made of TSVM-J fabric (analogous to American Kevlar). Armor protection was provided by with either 1.25 mm titanium plates inserted into the pockets (Cameron, 2017). The Soviet Kevlar bulletproof vest 6B2 weighed 4.2–4.8 kg (depending on its size) (Galeotti, 2023; Melkin, 2019). Bulletproof vest 6B2 became the main one for the entire Soviet-Afghan war for airborne and motorized rifle units. He provided reliable protection even with a direct hit on him by bullets fired from a pistol and shrapnel from mines and shells. But practically could not protect against rifles and machine guns.

Therefore, the military leadership of the USSR decided on the need to create an anti-bullet vest that can withstand the hit of automatic, rifle and machine-gun bullets with maximum all-round protection of the torso: from the chest and from the back.

The developed bulletproof vests with indexes 6B3TM (with either 6.5 mm titanium armor plates (Cameron, 2017) and a total weight of 12.2 kg), and 6B4 (with ceramic armor plates weighing 12 kg) held automatic bullets fired from a distance of 10–15 meters (Melkin, 2019). But because of their heavy weight, they could not be used by paratroopers and motorized riflemen for a long time. Since the fighters had to constantly move and move a lot during active combat.

An innovation in the design of the 6B3TM model was the appearance of cases/pockets for placing spare machine gun stores, hand grenades, and a portable radio in them (Melkin, 2019). But they did not abandon the idea of creating a powerful, reliable combined-arms bulletproof vest. On the basis of models 6B4 and 6B3TM in the mid-1980s, two bulletproof vests were developed and put into service in the USSR: 6B3-01 (Zh-85T) weighing 8.2 kg, and 6B4-01 (Zh-85K) weighing 7.6 kg. The reduction in the total weight of these two bulletproof vest was achieved by reducing

the thickness of the armor plates on the back. As a result, bulletproof vests were still bulletproof in front, and from the back they were anti-fragmentation.

Taking into account the experience of the Soviet-Afghan war in 1986, the All-Russian Research Institute of Steel developed a series of universal bulletproof vest 6B5 "Beehive" (Dragobetskii, Shapoval, & Zagoryanskii, 2015). They could provide a different level of protection, depending on what armor plates from what materials and what thickness they were equipped with.

The current stage of development of personal protective equipment.

In the 1990s and at the beginning of the 21st century, thanks to the latest technologies and the ultra-modern innovative materials obtained with their help, the production of bulletproof vests becomes massive.

They are beginning to be produced not only by state-owned enterprises of the military-industrial complex, but also by private firms. In order to avoid chaos in the production of personal protective equipment and streamline their production, in particular, bulletproof vests, every country in the world has a government organization that introduces certain standards, ensures compliance with them so that bulletproof vests meet these standards and bulletproof classifications (Nayak, et al., 2018; Kumar, Saxena, Sharma, Gangolu, & Prabhu, 2023).

In different countries of the world there are different standards and classifications for bulletproof vests. Some of the more common standards are listed below:

NIJ (National Institute of Justice) standards (USA). The NIJ is an agency under the US Department of Justice that develops standards for evaluating bulletproof vest. The most common classifications include NIJ Standard-0101.06 for ballistic bulletproof vest and NIJ Standard-0115.00 for stab protection. For example, NIJ 0101.06 standards define protection levels such as NIJ Level IIA, II, IIIA, III, and IV, where level IV provides the highest protection against high caliber bullets.

EN (European Norm) standards (Europe). European EN standards define the requirements for bulletproof vest in various European countries. For example, EN 1522 and EN 1063 define protection classes against firearms and fragments. Classifications include levels BR1, BR2, BR3, BR4, BR5, BR6 and BR7, where BR7 provides the highest level of protection.

VPAM (Vereinigung der Prüfstellen für angriffshemmende Materialien und Konstruktionen) standards (Germany). VPAM is a German organization that develops standards for bulletproof vests and anti-ballistic protection. They provide a classification for evaluating protection against firearms and other forms of attack.

ISO (International Organization for Standardization) standards: ISO develops international standards for various areas, including security technologies. Some ISO standards may be applicable to bulletproof vests and performance testing.

In Ukraine, the standards are developed and approved by the state enterprise "Ukrainian research and training center for problems of standardization, certification and quality". In Ukraine, the main legal act on which the protection classes of

bulletproof vests are determined by bullet resistance is the document DSTU 8782:2018 “For individual protection. Bulletproof vests. Classification. Global technical mind”.

These are just a few examples of the standards used in different countries to evaluate bulletproof vest. Each standard usually has its own classification, which determines the level of protection of bulletproof vest against specific types of threats, such as bullets, shrapnel or stab wounds.

A single world standard – a global classification – for bulletproof vests does not exist today, because in different countries of the world different ammunition and different methods are used when testing bulletproof vests.

The use of such ultra-modern synthetic materials as, for example, Kevlar, aramid, high-modulus polyethylene for the manufacture of a fabric base for bulletproof vests makes them easy to wear, reliable in a difficult combat situation and durable in storage (Kathiervelu, 2003; Arora & Ghosh, 2018; Buckner, 2021; Mishra, Madhad, & Vasava, 2021).

Most models of modern bulletproof vests for the police and the army, thanks to external covers/pockets for placing spare automatic magazines, hand grenades, and other ammunition in them, combined in their design the protective function of combat bulletproof vest with the function of a civilian unloading vest, which is used in everyday life by ordinary fishermen or utility workers/emergency services (Conroy & Park, 2022; Kukić, Janković, Dawes, Orr, & Koropanovski, 2023)..

Taking into account that in the manufacture of armor plates for modern bulletproof vest, various innovative synthetic polymers, metals and composite alloys, as well as ceramics are used, this allows manufacturers to complete their bulletproof vest with armor plates universally, depending on their areas of application (Godara, Yadav, Goswami, & Rana, 2021; Pathak, Patel, Gupta, & Bandaru, 2023; Rudi, Syahid, & Hayat, 2023).

Therefore, modern bulletproof vest can be:

- or universal, for example, light bulletproof vests of primary protection classes for security guards of various institutions and supermarkets.
- or, also as an example, heavy combat bulletproof vests of high protection classes for police special forces and special forces.

Considering modern realities, in the armies of the whole world and police special forces today, in addition to bulletproof vest, a helmet and other protective elements are used for additional comprehensive protection (Risteski & Srebrenkoska, 2020; Kukić, Janković, Dawes, Orr, & Koropanovski, 2023).

Therefore, in official documents of the defense departments of various countries today, such a definition as “modular bulletproof vest” is often used. That is, in addition to the bulletproof vest itself, a protective kit may include several other components (Fig. 9): a helmet, shoulder pads, knee pads, etc. (Marchenko, 2017).



Figure 9. US Marines in modern protective ammunition (Nemenov, 2007).

Modern realities put forward new quality requirements for design engineers and manufacturers of bulletproof vest, so today work is being carried out in three main areas.

Firstly, a modern bulletproof vest should have as large a protection area as possible, covering as many parts of the human body as possible, and at the same time remain relatively light and not restrict a person's movements during long-term movement (Marchenko, 2017; Risteski & Srebrenkoska, 2020; Conroy & Park, 2022).

Secondly, the armor plates in modern bulletproof vests must have the maximum degree of protection in terms of bullet resistance, and at the same time be thin in thickness and light in weight (Yadav, Naebe, Wang, & Kandasubramanian, 2016; Nayak, et al., 2018; Rudi, Syahid, & Hayat, 2023).

Thirdly, in order to reduce the armor effect in the event of a direct hit of a bullet or fragment in the armor plate, the fabric base from which the bulletproof vest is sewn must be multi-layered and must have one or more shock-absorbing linings from the inside (Cameron, 2017; Melkin, 2019).

Therefore, the history of the creation of personal protective equipment continues and today enters a new phase of its development.

Let's also hope that someday, finally, the day will come when manufacturers of bulletproof vests from different countries of the world will be able to agree among themselves, and the long-awaited unified system/method for classifying modern bulletproof vests by their bulletproofness will appear in the world.

Conclusions.

In this review article, using real historical examples, we have tried to trace the evolution of personal protective equipment. This has made it possible to perform a comparative historical analysis of the development of scientific research and industrial technologies, which made it possible to manufacture specific personal protective equipment in a certain historical period.

Also in this review article, we have analyzed the stages of modern technologies that are currently used in the manufacture of various types of bulletproof vest.

And given that the vast majority of authors of publications on the history of the creation of bulletproof vests write that: the bulletproof vest does not have a specific inventor, in this review article we also talk about specific, undeservedly forgotten now, the creators of the world's first officially patented prototypes of bulletproof vests for the police and VIP-persons, at the beginning of the 20th century, who stood at the origins of the bulletproof vest industry.

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Conflicts of interest.

The authors declare no conflict of interest.

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Аналіз історії створення та вдосконалення засобів індивідуального натільного захисту: від бронзових обладунків до сучасних бронежилетів

Анотація. У цій статті на реальних історичних прикладах автори спробували простежити еволюцію засобів індивідуального захисту. Це дало змогу виконати порівняльний історичний аналіз процесу розвитку наукових пошуків та промислових технологій, які дозволяли у певний історичний період виготовляти конкретні засоби індивідуального натільного захисту. Також у цій оглядовій статті автори проаналізували етапи сучасних технологій, які використовуються на сьогоднішній день при виготовленні різних видів бронежилетів. І враховуючи, що в переважній більшості автори публікацій присвячених історії створення бронежилетів пишуть, що бронежилет не має конкретного винахідника, в цій оглядовій статті автори також розповіли про конкретних, незаслужено забутих нині, творців найперших у світі офіційно запатентованих прототипів бронежилетів для поліції та VIP-персон, на початку XX століття, які стояли біля витоків галузі створення бронежилетів. З розвитком промислової революції та технологічним прогресом, з'явилися нові матеріали та технології виробництва, що дозволяють створювати більш ефективні бронежилети. З часом бронежилети стали все більш легкими та ефективними завдяки використанню нових матеріалів, таких як кевлар, арамідні волокна та кераміка. Таким чином, історія розвитку бронежилетів включає внесок безлічі вчених, інженерів та винахідників, які вносили свій внесок у вдосконалення захисної броні протягом багатьох років. У статті автори показують, що сучасні реалії висувають перед інженерами-конструкторами та виробниками бронежилетів нові вимоги до якості, ваги та функціональних характеристик. Автори статті аналізують основні напрямки, за якими на сьогодні ведуться науково-дослідні роботи з удосконалення бронежилетів. Автори статті показали, що у різних країнах світу існують різні стандарти та

класифікації для бронежилетів. Кожен стандарт зазвичай має свою класифікацію, яка визначає рівень захисту бронежилету від конкретних видів загроз, таких як кулі, уламки або ножові удари. Тому важливим є завдання розробки єдиного стандарту для сучасних бронежилетів.

Ключові слова: доспіхи; бронежилет; Казимир Зеглен; Ян Щепаник; Стефані Луїза Кволек; кевлар

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