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# Examination of the Application of Currently Used, New or Additional Firefighting Personal Protective Equipment[1]

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*The publication focuses on the safety of the damaged environment that arises during firefighting interventions, the protection and ergonomic factors of personal protective equipment currently used in Hungary and internationally, and on increasing and improving the level of protection and other issues related to firefighting interventions. Personal protective equipment must provide the highest level of protection against unforeseen threats in different directions, taking into account proportionality. The basic idea of the publication is to analyse and evaluate the typical sources of danger in the firefighters' work environment in the domestic and international environment, to examine the personal protective equipment in use from several aspects, and to examine the applicability of the currently used personal protective equipment for firefighters. The publication covers the load-bearing capacity of the human body, taking into account age, the concept and interpretation of ergonomics, and the implementation of personal protective equipment in practice. In addition, the author mentions the firefighting accidents of the last 10 years in Hungary and the role of personal protective equipment in them. There is also talk of processing firefighting accidents abroad. Examining the practice of the National Directorate General for Disaster Management settings, maintenance and training will also be one of the topics of the publication.*

**Keywords:** *firefighter, personal protective equipment, ergonomics, accident, the human body*

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## Introduction

People have seen fire as a danger since prehistoric times. The increase in the number of devices used, the population and the number of residential buildings located close to each other led to more and more fire incidents, so it was necessary to organise a squad, a team, which can effectively and quickly put out fires in an urbanised environment.

Firefighting personal protective equipment has undergone many improvements over the past decades, as the number and size of environmental hazards have changed thanks to technological progress. An excellent example within this topic is the appearance of cars at the end of the 1800s; before this period we could not talk about their breakdown or road accidents caused by them as a source of danger.[3] Nowadays, not a day goes by without a car accident that requires the help of firefighters, whether we are talking about technical rescue or firefighting. And this was just one example of all the sources of danger that have become part of our lives in recent decades. The spread of electronic devices (television, computer, laptop, etc.) in addition to its positive, quality-of-life-improving effects also includes dangers that not all users are aware of. Improper use of an electric heater can easily cause a fire in anyone's home, and negligence can even cost human lives.

In addition to technological development, buildings have also changed, since with the appearance of multi-story buildings, not only the personal protective equipment of firefighters but also vehicles and specialised equipment have adapted to more complex interventions.

In addition, the concept of labour protection appeared and gained more and more space, which was meant to protect the lives of workers. By creating a legal environment and with theoretical and practical training that adapts to the constantly changing world, we can reduce the damage caused during interventions and at the same time protect the physical integrity and health of the firefighters who intervene.

## Environmental hazards

Responding firefighters can be at risk from many sources during their work. The first thing that comes to everyone's mind is the heat load since it is one of the most significant sources of danger during firefighting. In such cases, several factors play a role, since, in addition to the high temperature, the time factor is also an important aspect, i.e. it is significant how long the intervening firefighter can withstand the given heat load. The firefighter's personal protective equipment and, of course, the firefighter's health also plays a big role in this.

An accident can also occur during the fire investigation after extinguishing the fire, which mostly results from tripping or slipping since the floor is by no means safe after a fire due to all the materials that have tipped over and fallen on it. In addition, the structure of the building can also weaken, i.e. it can fall on the person who is under it at a careless moment.

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[3] History: Who Built the First Automobile? *History*, 11 December 2012.

In addition to the heat load, the intervening firefighters can face a mechanical hazard, and the personal protective equipment plays a prominent role in preventing or reducing the injury. For example, a case can be mentioned when the building is entered through the window. In such cases, after breaking the window glass, a splinter may remain in the window frame upon entering the room, which may cut the firefighter's skin. The firefighter's protective jacket, protective gloves and protective boots are of course primarily developed for protection against heat and flame, but in addition, due to the quality and thickness of the material, they may be able to provide an adequate level of protection against cuts and punctures.

Road defects, uneven surfaces and liquids spilling onto the road represent an additional source of danger. During a firefighting intervention, be it extinguishing a fire in a building, factory, forest, or other technical intervention, the intervening firefighters work in an unfamiliar place, they do not know the dangers of the given place, so there is a greater chance of tripping and falling. In winter, when the outside temperature drops below freezing, accidents due to slipping on ice can often occur. The number of road accidents increases not only for firefighters, but also for civilians participating in traffic, so the probability of an accident involving firefighters also increases proportionally.

The breathing system of the intervening firefighters is also exposed to danger at the scene of damage. In the case of an established forest fire, the abiotic, biotic and management factors determine the formation of the fire itself, its spread, and the size of the affected area.[4] During combustion, many different chemicals are released into the air, such as carbon monoxide, nitrogen oxides, sulfur dioxide, or hydrogen chloride.[5] These hurt the human body, especially if the person inhales them frequently and/or over a long period. In addition to forest fires, it is also necessary to mention the smoke caused by fires in buildings and various equipment (e.g. electronic equipment), since in such cases substances with a strong toxic effect on the body can enter the air. In such cases, the protection of the intervening firefighters is provided by the compressed air breathing apparatus.

In addition to the sources of danger from the environment, I think it is important to mention the sources of psychological danger, since the firefighters who intervene are regularly faced with situations and sights that use up the nervous system to a great extent. First of all, the stress caused by the possible alarm, which keeps the body on constant alert, should be mentioned. In addition, the responsible and dangerous physical work certainly tests their psychological state, since every intervention is different, and they still have to make quick and effective decisions for the sake of themselves, their companions, and the lives of the persons to be rescued. Finally, I would also like to mention the sight of dead

[4] László Bodnár: *Az erdőtüzek oltásának hatékonyságát növelő módszerek kutatása és fejlesztése* [Research and development of methods that increase the efficiency of extinguishing forest fires]. PhD thesis. Budapest, University of Public Service, Doctoral School of Military Engineering, December 2021. 22.

[5] George Broyles: *Wildland Firefighter Smoke Exposure*. United States Department of Agriculture, October 2013. 4.

people – especially children – which requires a strong psychological background so that it does not cause posttraumatic stress[6] and/or other physical illnesses later on.[7]

Finally, it is worth mentioning the mandatory sports activities and the exercises that deepen professional knowledge. As before any sports activity, it is strongly recommended to warm up with adequate quality and time before exercising among firefighters, so that injuries (e.g. torn ligaments)[8] do not occur in the absence of this. Accidents of this nature are usually caused by human error or inadequate prior training.

## Brief presentation of the personal protective equipment for firefighters

In the following section, I would like to describe the personal protective clothing used by the firefighters in Hungary, spiced up with a brief historical introduction. In addition, in the course of the international outlook, the personal protective equipment of firefighters in the United States will also be briefly presented. The presentation can only be of interest to the reader, the aim is no comparison.


*Figure 1: Firefighters' protective clothing*

*Source: Drawn by Anna Veronika Grósz.*

[6] "PTSD (posttraumatic stress disorder) is a mental health problem that some people develop after experiencing or witnessing a life-threatening event, like combat, a natural disaster, a car accident, or sexual assault" (for more information see National Center for PTSD: *Understanding PTSD and PTSD Treatment.* May 2019. 3).

[7] Ágoston Restás: Pszichológia a tűz frontvonalában [Psychology on the Frontline of Fire]. *Védelem Tudomány,* 1, no. 3 (2016). 55.

[8] O. P. Aneja: Warming-up, Cooling Down – Meaning and Significance. *European Journal of Molecular and Clinical Medicine,* 7, no. 8 (2020). 5263.

The personal protective equipment, or more precisely clothing, worn by the firefighters can be grouped according to the areas to be protected (Figure 1).

## *Firefighters' protective helmet*

The standardised firefighters' protective helmets must fit the wearer's head properly. With the help of the straps, or buttons on the helmet, the user will not have any problems adjusting it, even when wearing protective gloves. After proper adjustment to the given head size and shape, long-term wearing does not cause discomfort or pain for the firefighter. Thanks to its material properties, it also withstands high temperatures, thus protecting the firefighter's head. In addition, of course, it also ensures that an object falling on the head from a height does not cause a head injury to its user.

## *Firefighters' protective hood*

Firefighters' protection against extreme weather or increased heat radiation can be increased with the firefighters' protective hood. Thanks to the appropriate material properties (drainage, double-layer), it ensures increased protection of the intervening firefighters.

## *Firefighters' protective clothing*

The firefighters' protective clothing consists of pants and a jacket, which overlap each other at the waist for greater protection. Thanks to their material composition, they provide the necessary waterproofness, as well as adequate heat, flame and mechanical protection for their users.

## *Fire protection gloves*

Firefighters' protective gloves provide a high level of protection to the firefighter who wears them. Thanks to the special material properties, it has excellent heat (contact and radiant) protection, and the reflective strap that may be placed on the wrist increases visibility (e.g. Seiz – Fire-Fighter Premium).[9]

[9] Seiz: Fire-Fighter Premium.

## *Firefighters' safety boots*

All of the regularised firefighters' protective boots have all the protection necessary to preserve the integrity of the intervening firefighters. First of all, it is worth mentioning the protection against thermal radiation, as well as the resistance to chemical and mechanical effects (e.g. piercing, cutting). In addition, it reduces the wearer's risk of a major injury (e.g. broken ankle) during a trip on uneven terrain.

## *Protective gloves against mechanical effects*

Regarding protective gloves, the MSZ EN[10] 388:2016 standard defines several requirements for mechanical hazards, which are as follows: wear, tear, puncture, impact and blade cutting. Based on the standard, the protection levels vary between 1 and 5, where 1 is the lowest and 5 is the highest level of protection. In 2016, the standard was supplemented with regard to protection levels, and resistance to straight blade cutting and impact resistance (A-F level) became an additional aspect. Intervening firefighters belonging to the National Directorate General for Disaster Management (hereinafter: NDG DM) – and those in other positions who wear protective gloves against mechanical effects – may only wear gloves, i.e. gloves that meet the protection level of all regulations at least level 2.[11] These gloves are typically used by the intervening firefighters during technical rescues, i.e. only in the event that heat stress cannot (any longer) be expected at the scene of damage.

## *Personal protective equipment for preventing falls from a height or the impact of a fall*[12]

The firefighters' climbing belt, also known as the work position adjusting belt, provides the intervening firefighter with protection against falling when working at height. Periodic safety reviews and visual inspections before work must be carried out at intervals specified by the manufacturer, as the material may be damaged or aged.

## *Noise protection earplugs*

The noise protection earplugs are part of the accessories on the car engines, which come into play when the firemen are in a hurry e.g. storm damage and the gasoline engine chainsaw are needed, which hurts the ears and damages the hearing if used for a long time.

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10 Mark of the issuer of Hungarian national standards.

11 Regulation 34/2021 on the provision of personal protective equipment to the personnel of the NDG DM, Appendix.

12 Regulation 16/2018 on the periodic inspection and review of firefighting ladders, personal protective equipment, equipment and firefighting ropes for preventing falls from a height or the impact of a fall of the NDG DM.

### *Breathing mask and compressed air bottle*

The units of the compressed air breathing protection device are as follows:

- compressed air bottle
- carry structure
- lung machine
- mask
- pressure reducer
- safety units (signal, acoustic warning, pressure control)
- additional units[13]

The compressed air breathing cylinders used today are no longer made of steel, but of composite, which means that their mass is also much smaller, making it easier to move with them, which is advantageous from an ergonomic point of view. The composite bottles used by the Disaster Management operate at a pressure of 300 bar, and their internal volume is between 6 and 6.8 litres.[14]

## Brief historical overview of personal protective equipment in domestic and international contexts

In Hungary, in 1834, the Council of Governors distributed to the cities and counties new firefighting personal protective equipment and equipment that provided a higher level of protection for the people involved in firefighting (Figure 2). In addition, many suggestions were made, such as dipping clothing in potash for flame retardant purposes.[15]

[13] László Czikora et al.: *Műszaki ismeretek I. A tűzoltó szakképzésben résztvevők számára.* Budapest, BM Katasztrófavédelmi Oktatási Központ, 2003. 119.
[14] Czikora et al. (2003): op. cit. 120.
[15] János Szilágyi – Károly Szabó: *A tűzrendészet fejlődése az őskortól a modern időkig.* Budapest, BM Könyvkiadó, 1986. 136.

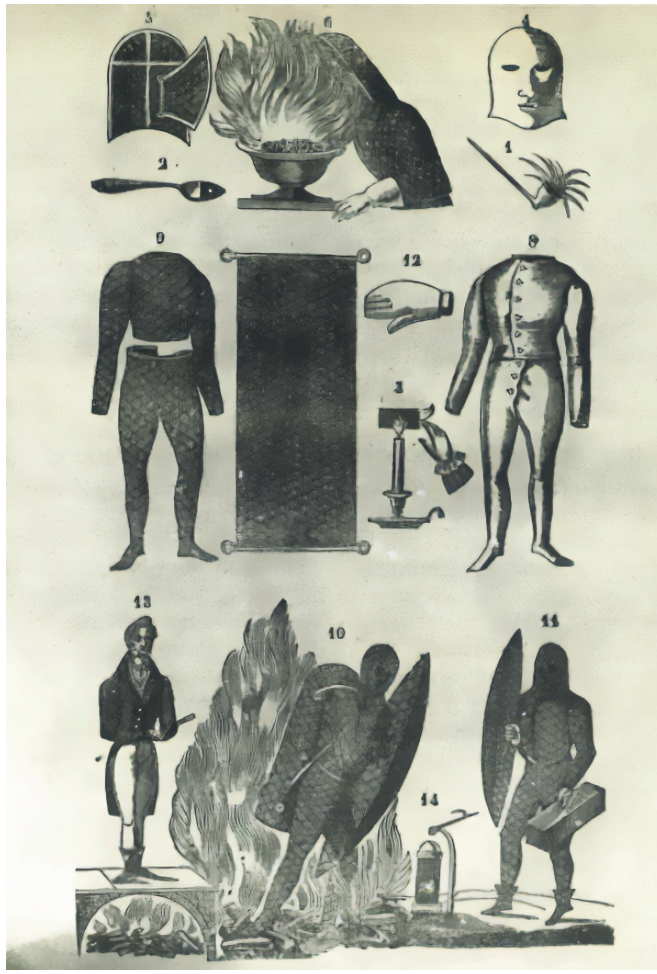


*Figure 2: Recommended personal protective equipment from the past*
*Source: Szilágyi–Szabó (1986): op. cit. 137.*

Later on, this protective equipment was continuously developed to be more resistant to the harmful effects caused by fire. At the same time, of course, changes also took place in the field of professional equipment, thus ensuring more effective intervention and protection. Even if ergonomics was not defined as a concept, comfort and wearability played an increasingly important role. By continuously improving the weight and design of the protective clothing, the firefighter can participate in firefighting for a longer period and can also get closer to the fire.

In Hungary, at the Mosonmagyaróvár Professional Fire Command, the Firefighters exhibition can be viewed at the Command, which provides an introduction to the past and present of firefighters' personal protective equipment and specialised equipment (Figure 3).

*Figure 3: Presentation of firefighting climbing belts*
*Source: Katasztrófavédelem (2020): op. cit.*

Nowadays, the staff of Disaster Management already uses modern personal protective equipment. The deployment of protective clothing complies with the MSZ EN 469 standard, thereby ensuring the appropriate level of protection. An excellent example is the R13 deployment protective clothing, which has several layers that resist the effects of heat and flame, has water-repellent properties, and is also able to withstand a certain level of mechanical and chemical influences.

In an international context, it is worth mentioning the firefighting protective equipment of the United States of America, namely the history of the firefighters' protective helmet. It was a man named Jacobus Turck who developed the protective helmet in the early 1700s, the raw material of which was nothing but leather. In later years, in 1836 to be exact, Henry T. Gratacap designed the helmet, similar to what we can still see on the heads of firefighters in the United States.[16]

In addition, of course, other protective clothing has also undergone development. The raw material used to be mainly wool and cotton, and thanks to the rapid increase in rubber production, they were increasingly replaced by rubber as a raw material. From the middle of the 1900s, fire resistance, and thus the quality of the material, played an increasingly important role. The regulations were included in standards, which was able to unify the regulations.[17]

[16] Salty Dog: Wearing Their Fire Helmets Backwards. *Gettin Salty Apparel*, 09 January 2015.
[17] Paul Hasenmeier: The History of Firefighter Personal Protective Equipment. *Fire Engineering*, 16 June 2008.

In the United States of America, the personal protective clothing used by responding firefighters is also called Bunker Gear or "Turnout Gear".[18] The pants and jacket are made of special materials, multi-layered to provide adequate protection against flames and heat. In the U.S., unlike clothing in Hungary, the colour of the protective clothing is mainly yellowish-brown, but yellow and black are also present. Reflective strips in several places on the clothing ensure visibility.

Firefighters in the United States typically retain the original form of the firefighters' protective helmet. The traditional protective helmet is considered more special due to its design, but there have been several feedbacks from the firefighters who use it, that they cannot look up in full deployment protective clothing, with a compressed air bottle on their back, because the flange of the helmet gets caught in the top of the compressed air bottle[19] (Figure 4). This kind of problem does not arise with European protective helmets.


*Figure 4: Hooking a firefighters' protective helmet into the compressed air bottle*
*Source: Park Huiju et al. (2014): op. cit. Figure 5.*

## The load-bearing capacity of the human body

The human body is structured hierarchically, the smallest unit of which is the cell, which also has an independent life phenomenon. Cells with the same function and similar shapes are assembled into tissue. The next level is the organ, which is made up of tissues, and then

[18] Lynn M. Boorady: Bunker Gear for Fire Fighters: Does It Fit Today's Fire Fighters? *Journal of Textile and Apparel, Technology and Management*, 9, no. 3 (2015). 2.
[19] Park Huiju et al.: Assessment of Firefighters' Needs for Personal Protective Equipment. *Fashion and Textiles*, 1, no. 8 (2014).

the organ system, which is a collection of different organs. Finally, we reach the level of the organism, which consists of organ systems.[20]

The human body consists of a total of 11 organ systems, which perform all body functions with coordinated work. These are the following:

- nervous system
- reproductive system
- muscular system
- cardiovascular system
- digestive system
- endocrine system
- immune/lymphatic system
- respiratory system
- urinary system
- skeletal system
- integumentary system[21]

As life progresses, psychological properties change and transform. As a result of the laws of development, people of the same age show similar characteristics in terms of behaviour, thinking, and emotional experience and they also resemble each other in their way of acting. The similarity is greater at younger ages than at older ages. The common characteristics of each age group are called age characteristics. The sequence of age characteristics is irreversible, they cannot be skipped, in most individuals, they appear in the same year of life, and they follow each other. As age advances, central, essential changes, their appearance, or the lack of them, can also express the level of development and maturity.

The age-specific characteristics change after a certain time and show distinctly different characteristics from the previous one. These transformations create uniform stages of development (periodisation) that can be separated based on their characteristics. Each developmental stage includes similar physical, neurological, cognitive, emotional, behavioural and maturation stages. Unfortunately, this is not a homogeneous process, because the different psychological processes develop unevenly, and the stage boundaries are blurred. The two most important components and processes of age periodisation are biological maturation and socialisation. It should be emphasised that none of them provide the conditions for periodisation by themselves.[22]

In Western societies – as in our country – stereotypes related to the elderly and aging are strong. These are widely accepted beliefs about individuals belonging to different age groups, which appear for people belonging to different age groups and have an impact

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[20] Sarolta Darvay et al.: *Összeállítás a funkcionális anatómia tantárgyhoz csecsemő- és kisgyermeknevelő, óvópedagógus és tanító szakos hallgatók részére* [Compilation for the Functional Anatomy Subject for Students Majoring in Infant and Toddler Education, Kindergarten Teachers and Teachers]. Budapest, ELTE Tanító- és Óvóképző Kar, Természettudományi Tanszék, 2017. 10.

[21] Veterans Law: Human Body Organ Systems and Their Function. *Veterans Law,* 15 October 2021.

[22] István József: *Életkori sajátosságok és fejlődési szakaszok* [Age Characteristics and Developmental Stages]. Lecture notes, s. a.

on different areas of life. This is also true for mobile firefighters since a separate study would be worth examining the question of how the size, difficulty, density of service tasks, and the role of territorial (county) distribution are related to the appearance of age characteristics and the cumulative effects of them. The brain undergoes continuous anatomical and functional changes throughout human life. Neurological plasticity is the name given to this ability of the nervous system to change. The importance of plasticity lies in the fact that it enables the adaptation of the nervous system, together with the ability to respond to external and internal processes. The capacity for brain plasticity decreases with advancing age. The mass of the brain decreases by an average of 2–3% every ten years, which is a natural consequence of cell death observed in certain brain areas. These cells cannot regenerate, the natural process of cell death is therefore associated with a natural loss of function. The perception of the aging generation in the labour market is mostly unfavourable, which raises the question of what kind and how uniform changes are justified as the age of employees increases, and what effect does all this have on their ability to perform work? This is an extremely important factor for firefighters on mobile duty. Age-related decline can be detected in three main areas of memory processes. This is even more true for firefighters on mobile duty. One such area is the slowdown in memory processes, especially in situations where information processing and speed are important. During an intervention, performance deterioration in working memory can play a major role. A measure that is not considered in time and with insufficient thoroughness can seriously endanger the safety of life and property. Another area of decline is the necessary in-depth processing of new information, which is a consequence of the lack of cognitive control and suboptimal strategy selection. Elaboration, that is, the healthy and efficient processing of information and emotional impulses stored in our memory and subconscious mind, is damaged in this case. To manage the information appropriately, it is necessary to maintain control not only when the information is blocked, but also when it is activated, and there seems to be a decreasing trend in both control processes with aging. Another area adversely affected by aging is the retrieval of memory contents. The decline is most evident in the fact that retrieving the content requires an increased effort on the part of the person.[23]

According to a finding reported by Warr in 2000, there is no obvious difference between the performance of young and older workers, and the variability within the age is even greater than the average difference between ages. Warr's results are contrary to the results obtained in laboratory conditions, which primarily show deterioration of cognitive functioning. This may be due to the essential difference between the laboratory state and practical life, i.e. the world of work since the effectiveness of work is influenced by motivational and social interpersonal factors in addition to cognitive functioning. In addition, it also attempts to set up a four-factor model, based on which jobs can be categorised by taking age characteristics into account, and thus it becomes possible to determine which jobs can be recommended for older employees. The model integrates

[23] Karina Ágnes Szászvári: *Fejlődés egy életen át. Az idősödő munkavállalók sajátosságai és lehetőségei* [Lifelong Development. Characteristics and Choices of the Aging Employees]. Budapest, Budapesti Gazdaságtudományi Egyetem, 2017. 8–9.

the cognitive, physical, and sometimes emotional characteristics of aging workers.[24] Appropriate team spirit and professional awareness can also positively influence the age characteristics of the firefighting staff on mobile duty.

Skeletal and muscular system diseases that develop in connection with special firefighting work can develop as a result of the work's special loads that do not occur elsewhere, or they can cause an aggravated condition due to the nature of the work. In the medical field, these conditions are more often called rheumatic and musculoskeletal diseases. Unfortunately, ergonomics is not given enough weight in terms of fire departments, it is not included as a specialist field in countless developments in the field, even though its application to the sub-processes affecting the work, even during the planning and implementation of firefighting techniques at the idea level, could help with so many beneficial properties during the subsequent implementation of health protection of mobile firefighters.

According to the Occupational Musculoskeletal Disorders, chronic musculoskeletal disorders are chronic problems that affect the muscles, bones, joints and soft tissues. Disorders that cannot be traced back to the exact cause, such as chronic back pain or chronic upper extremity disorders, which can occur during the execution of both firefighting and technical rescue activities, and whose exact origin can only be determined with great certainty in connection with an accident. In countless cases, the causes of these diseases can be traced back to injuries done in a forced situation or caused by one-sided loading. Rheumatic diseases and degenerative conditions, such as osteoarthritis or osteoporosis, can develop as the human body ages, possibly due to genetic predisposition or disease. Based on the European Working Conditions survey of 2010, the Hungarian situation in terms of diseases of the musculoskeletal system – that is, back, neck and upper limbs – is unfavourable even in comparison with the European Union (EU), these diseases represent significant health and outstanding cost burden. This is no different in the case of the Disaster Management since musculoskeletal diseases resulting from work are also at the top of the list of retired firefighters.[25] The latest European research conducted in this area also proves that diseases of the musculoskeletal system are still a significant health and cost problem, and their importance is increasing. Ensuring the physical ability of the personnel performing military service is also a very important factor in terms of preserving the ability to perform work since the physical strain resulting from service and the performance of service tasks can lead to injuries and illnesses. The result of excessive exertion or repetitive movements can be an accident or injury, which can lead to illness or, in more serious cases, loss of fitness for duty.[26]

Act XCIII of 1993 on labour protection in Hungary, under Section § 54 (2) of the Act, "the employer is obliged to qualitatively and, if necessary, quantitatively evaluate

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[24] Szászvári (2017): op. cit. 22.

[25] Ildikó Vásárhelyi-Nagy: A beavatkozó állomány kondicionális képességei fejlesztésének új irányai, különös tekintettel a proprioceptív módszerek alkalmazására [New Ways to Improve the Fitness Ability of the Intervening Personnel, Most Importantly with the Use of Proprioceptive Methods]. *Hadmérnök*, 13, no. 4 (2018). 411.

[26] Gyula Szabó: Krónikus váz-izomrendszeri megbetegedések a munkában [Chronic Musculoskeletal Diseases at Work]. *Magyar Ergonómiai Társaság*, 01 April 2021. 4–5.

the risks endangering the health and safety of employees". Therefore, the management of ergonomic risks is also a legal requirement.

Different service groups have different health requirements, so a person unfit for one position may be perfectly fit for another. A more precise definition of the health requirements imposed on firefighting candidates is necessary for the professional use of the given agents and firefighting techniques. Protection against harmful effects occurring during firefighting work and the efficient use of human resources play an increasingly important role in everyday life. Regularised personal protective equipment that ensures safe and healthy working conditions must be available in sufficient numbers and an appropriate composition for the outgoing personnel of the fire department. During firefighting interventions – firefighting, technical rescue – this personal protective equipment plays a prominent role. The intervention at the site of the damage places extraordinary physical and ergonomic strain on the firefighter's body – which can range from a fire that can be extinguished in 1–2 minutes to a sustained strain that lasts for several hours. The physical stress on the human body during firefighting work and its effects on the reduction of the ability to perform work is difficult to prove without conducting medical and other expert tests, but the physiological limitations of firefighter interventions in protective equipment are real problems, to reduce them, the continuous development of this personal protective equipment is justified. The measurements must be separated from the assessments for sports purposes, since maximum performance is not required during a given work, as in a sports competition.[27]

From an ergonomic point of view, the movement of a firefighter often consists of running, climbing, crawling, carrying loads, etc. However, a part of its functional load capacity is used by external load forms other than work, e.g. the load and heat load caused by flue gases, and poisons, as a result of which it can perform less external work. It is possible to increase this load capacity by using the most effective personal protective equipment.

With interventions using today's modern firefighting techniques, it can no longer be stated that the firefighter can only be loaded up to the limit of his functional capacity. Ergonomics must also play a prominent role in this, since the loads on the whole body can be significantly reduced by using well-designed personal protective equipment, thus increasing functional performance. The firefighter's protective equipment makes the wearer almost completely independent from the external environment, protecting the body from external heat effects. Factors that generally put a burden on the wearer of the protective equipment can be the following: breathing protection, the weight of the protective equipment, limited movement due to the clothing, narrowing of the field of vision, and difficulty in understanding (communication difficulties). Additional stress is caused by increased work performance and/or heat retention and heat congestion that affect the body's heat balance due to the increase in external temperature. In addition, it is necessary to take into account possible disturbances in the body's salt and water balance. I

[27] Ferenc Kanyó – Ildikó Vásárhelyi-Nagy: A beavatkozó tűzoltói állomány kompetencia alapú fizikai állapotfelmérése [Competence-based Physical Test for Firefighters]. *Védelem Tudomány,* 6, no. 1 (2021). 207.

would also supplement this with the ergonomic stress that occurs due to work performed in a forced situation, which may lead to earlier fatigue and loss of functional performance.[28]

## Training of firefighters in the domestic context

In Hungary, the Disaster Management Education Centre organises the training and further training of firefighters in the area of Disaster Management. The education system has been changed from 01 January 2022, so currently it is *Firefighter Training.*[29] People who want to become firefighters and who have not yet dealt with firefighting apply for the Firefighter Vocational Training. During the training, they get to know both the theoretical and practical aspects of the profession, by learning about firefighting, technical rescue, the correct use of professional equipment, the proper use of personal protective equipment, communication and other law enforcement regulations.[30]

During the training, the future firefighters only use professional equipment, vehicles and personal protective equipment that have already been regulated.[31] In addition, of course, here as well as in the departments, mandatory periodical safety inspections are carried out regularly, as stipulated in Act XCIII of 1993 on labour protection, under Section § 23 (1).

## Case studies

### *International case No. 1*

Firefighters were called to a family home in a city in the United States, whose bedroom windows were open and flames were coming out. The fire chief was the first to arrive at the scene, where he was informed that the house was empty and all its residents had escaped. The crew began spraying with the syringe through the garage towards the living room. When they managed to reach the kitchen, they started towards the corridor. It was then that they saw the bedroom had almost flashed over and the flames were already overhead. While they were trying to extinguish the fire, one of the firefighters indicated that he felt burned. Shortly after, they stopped fighting the fire and left the building, after which

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28 Ferenc Kanyó: *A tűzoltók fizikai alkalmasságának felmérése az új évezredben, Laboratóriumi és pályavizsgáló teljesítménydiagnosztikai eljárások alkalmazási lehetőségei a tűzoltók teljesítménymérésében* [Assessing the Physical Fitness of Firefighters in the New Millennium. Application Possibilities of Laboratory and Field Testing Performance Diagnostic Procedures in Measuring the Performance of Firefighters]. Doctoral thesis. Budapest, Zrínyi Miklós Nemzetvédelmi Egyetem, 2008. 4–24.

29 Katasztrófavédelem: Szakmai képzések (2021. január 1-től indított) [Professional Training Courses (launched from 1 January 2021)].

30 Zsolt Huszka et al.: Tűzoltói beavatkozások veszélyforrásai és munkabiztonsága [Hazards and Occupational Safety of Firefighting Interventions]. Védelem Tudomány, 7, no. 2 (2022). 34.

31 Regulation 15/2010 (V.12.) on the applicability of fire protection techniques related to firefighting and technical rescue activities. Regularization based on the ÖM decree: "Authorization of the unrestricted use of fire protection technology for the professional disaster prevention organization and the municipal fire department."

another team continued to fight the fire. The burned firefighter suffered second-degree burns to his neck and ears. He was transported by ambulance to the hospital for further examination and treatment of the injury. He was only able to go back to work after nearly two months.[32]

In such cases, it is typical that due to the high heat load, the intervening firefighters sweat profusely, as a result of which burns occur in the areas where the personal protective equipment is less covered (i.e. the area under the strap of the breathing mask around the face). The accident could have been avoided if the firefighter had made sure that the personal protective equipment he was wearing had been put on as prescribed, and before entering the building, colleagues should have checked each other's eyes. It is also possible that the practical training is not adequate or that their repetition is not regular so that the firefighters acquire knowledge about the correct use of personal protective equipment poorly or incompletely. In addition, it is important to mention the psychological factor, since in such a case – if the firefighter is not prepared – human error can easily occur, simply due to inattention or lack of concentration.

## *International case No. 2*

In a locality in the United States, a resident of an apartment building woke up at dawn to the sound of a smoke alarm, after which he noticed thick smoke in the living space, on the second floor. He called his roommate, who was on his way home, then went out onto the second-floor porch and called the fire department. Later investigations established that the place where the fire started was the kitchen, where newspapers and books placed too close to the stove caught fire next to the gas burner that was left alone. It was roughly thirty minutes until the room was filled with smoke, and when the resident upstairs opened the porch door, the airflow started in the smoke-filled room. In addition, the other roommate also arrived, who by opening the front door let even more air into the space in question, so the fire broke out and spread to the rest of the house. Firefighters arrived at the scene within 5 minutes of receiving the call and immediately noticed the resident trapped on the second-floor veranda and the thick smoke, which by then had completely covered the wooden house. Firefighters set up a ladder to the side of the porch and began rescuing the person stuck there. During the rescue, two firefighters suffered burns and smoke inhalation, so they had to be taken to the hospital. They were only able to perform their duties again one to three months after the incident. During the rescue, a third firefighter was also injured, he sprained his ankle, but he only received one day of relief.[33]

During the incident, it is believed that the injured firefighters did not wear breathing masks when they entered the smoke-filled building, so they suffered smoke poisoning. The reason for this shortcoming may be human inattention, the inadequacy of preliminary

[32] Richard Campbell: Firefighter Injuries on the Fireground. *National Fire Protection Association*, September 2021.

[33] Hylton J. G. Haynes – Joseph L. Molis: U.S. Firefighter Injuries. *National Fire Protection Association*, November 2016. 27–28.

and repeated training, or professional inexperience. In my opinion, the presumed causes of burns include lack of knowledge of personal protective equipment and human inattention or distraction caused by psychological stress.

## *Statistics in Hungary*

In Hungary, there are also many fire incidents in residential buildings, factory buildings, or even forests and fields. The number of fire incidents in 2012–2019 developed as follows (Figure 5).

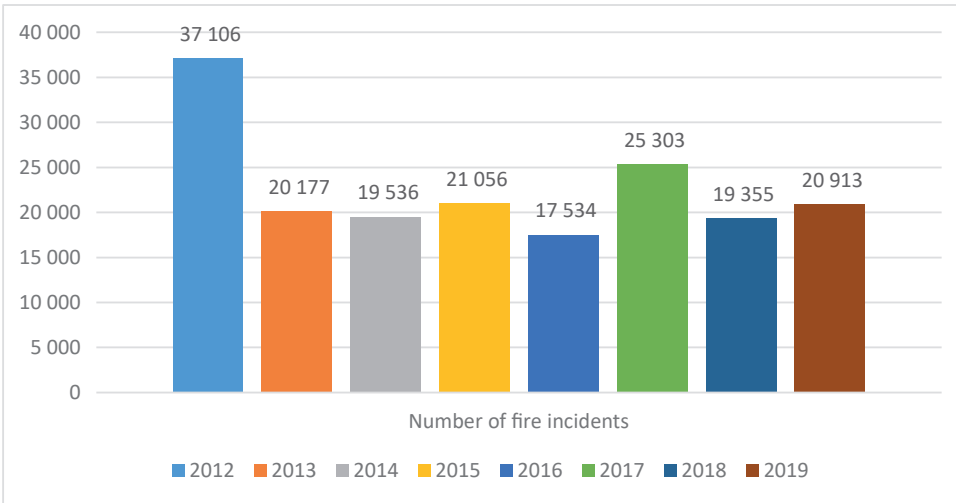


*Figure 5: The number of fire incidents in Hungary between 2012–2019*

*Source: Compiled by the author based on CTIF public data.*

The number of fire incidents was almost the same except for the spike in 2017. The outliers were mainly caused by the increase in the number of outdoor fires. These data only include fire incidents, not technical rescues and other alarms. Regarding firefighting accidents in 2015–2019, the figures were as follows (Figure 6).

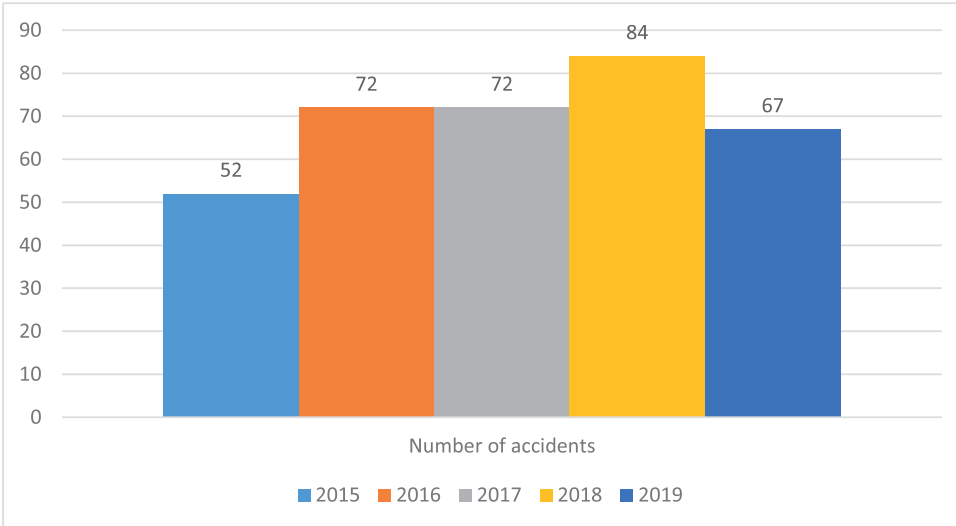


*Figure 6: The number of firefighter injuries in Hungary 2015–2019*

*Source: Compiled by the author based on CTIF public data.*

The number of injuries showed a slight increase in 2018, but not significantly. In case of accidents involving firefighters belonging to the Disaster Management, based on the available public data, the firefighting accident does not have a direct cause-and-effect relationship with the fault or failure of the personal protective equipment. Presumably, this is due to regular inspections, mandatory safety reviews, and effective training and further education.[34] It is likely that the data in the used source table were not entered according to uniform system of criteria, so they can probably reflect the trend for the given country, not the exact figure.

## Solutions and suggestions

Several measures can serve as a basis for maintaining and preserving the health and working capacity of firefighters suffering from chronic musculoskeletal diseases.

Maintaining appropriate safety and health protection standards and good ergonomics is an important task that can make firefighting work easier, safer, and, in some cases, healthier for all firefighters. When designing workplaces and work tools, where necessary, the role of individualised adjustments could also increase. Ergonomic improvements aimed at personal protective equipment can also help firefighters assigned to the Disaster

[34] Péter Pántya: A Katasztrófavédelem beavatkozó hatékonyságának fejlesztése a tűzoltósági területen [Developing the Efficiency of the Intervention Part of the Disaster Management in the Field of Fire Service]. *Hadmérnök*, 13, "KÖFOP" issue (2018). 121.

Management Authority to be able to perform their duties for a long time (decades) without harming their health.

In my opinion, it would be worthwhile to focus on prevention, that is, to intervene as early as possible, not to wait for health problems to appear, and to focus on keeping firefighters at work, not on returning them back after being out of employment.

I would also consider it important to provide continuous training in the knowledge material related to the health status of employees, as well as updating their workplace knowledge with up-to-date knowledge material regarding support for continuing work or returning to employment, specifically for human resources staff, members of the occupational health service, and occupational health and safety professionals. These measures could greatly contribute to the fact that it is easier for firefighters with impaired work ability to remain in the system, the extent of the workers' mainly physical workload is reduced, and their harmful effects can be effectively prevented and managed.

During professional training and further training, it would be recommended to use close-to-reality or mobilised version[35] options, which on the one hand continuously update the knowledge of firefighters, and on the other hand, the exercises could be carried out under controlled conditions, which would give more space to empirical and instrumental observation, thus the health status, as well.

Thanks to the appropriateness of the employer's attitude and the changes in the workplace, with the support of the occupational health system, many work-related diseases could be prevented, and employees with chronic diseases could continue to work under possibly easier conditions. Improving ergonomics to create better working conditions for the entire workforce can reduce sickness absence and make it easier to continue working or return to work.

In addition, I would find it useful to review the design and weight of the personal protective equipment used, as the international examples described in the article also show that the weight and design of the personal protective equipment play a key role. Clothing that fits the body, protective gloves, in which it is easier to hold the given tools, and a lightened compressed air bottle would be of great help in ensuring that the health of the person who intervenes remains high in the long term. The negative effects of climate change are currently felt by almost everyone. As a result of rainless periods and higher ambient temperatures, the number of forest and bush fires that the intervening firefighters have to fight also increases. Due to the higher outdoor temperature and the increased number of outdoor firefighting, in my opinion, it would be worthwhile to examine the material composition of the protective clothing of firefighters and to develop a new material mixture that allows firefighters to carry out interventions for a longer period, while not subjecting their bodies to as much heat stress.

[35] Péter Pántya: Fire, Rescue, Disaster Management. Experiences from Different Countries. *AARMS*, 17, no. 2 (2018). 93.

## Conclusion

In the first part of the article, the reader was able to get a glimpse of typical environmental hazards, and the author also made a short detour in the area of psychological hazards. From all of this, it emerged that the intervening firefighters are exposed to very high risk during their daily work, and in this, the personal protective clothing they wear provides protection on the one hand, but on the other hand, it can even be a burden if the equipment or clothing in question is not ergonomically appropriate. After that, a brief historical background of personal protective equipment (mainly protective clothing) in the United States of America and Hungary was presented, followed by the personal protective equipment still in use today. Concerning the United States, the mistake brought out by experience, i.e. moving in a firefighters' protective helmet and breathing apparatus was highlighted.

After that, the author briefly described the human body and its structure, then detailed the relationship between load capacity and age, especially concerning the work of firefighters. In the case studies, the author described two accidents in which it can be assumed that the intervening firefighters did not use their personal protective equipment properly or that their training and further training were not effective enough for safe work. The author of the article considers it essential that both preliminary and repeated theoretical and practical training is of considerable importance, as they add to the professionally founded knowledge and skills, which are essential during interventions.

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