

Investigation of the condition of firefighters' protective clothing using a questionnaire

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Garment protecting the body from the impact of heat and flame is used at numerous workplaces (in oil refineries, gas industry, foundries, in glass industry, in firefighting, on airplane carriers, oil rigs, by the members of civil defence, army personnel, etc.). It should be manufactured from the materials resistant to high temperatures and burning. The work presented here investigated the characteristics of firefighters' protective clothing under the conditions of actual use. Firefighters are, due to specific working conditions of their job, exposed to the danger of burns and other possible injuries. Adequate clothing systems, employed to protect their health, are essential, together with the overall equipment used to protect from heat and flame, as they influence their efficiency in performing their duty and tasks. The experimental part of this paper includes a questionnaire on using the firefighters clothing, as well as the analysis of the questionnaire. The investigation was performed on 138 respondents, members of the professional and volunteer fire brigades. The interviews involved the members of Public Fire Brigade in Zagreb, Zagreb Centre, Dubrava, the town of Karlovac, as well as the Volunteer Fire brigades in Dubrava and Karlovac. The purpose of the investigation was to acquire data on the type of intervention firefighters' clothing, the methods of its use and care, as well as on the satisfaction of the firefighters and their familiarity with the clothing that they use in accidental and dangerous situations.

Key words: *firefighters' protective clothing, firefighters, questionnaire*

1. Introduction

The most important garment function is to protect human body from basic outer influences, such as wind, rain, sunlight, dust and mechanical influences [1]. People are on everyday basis exposed to various dangerous situations in the course of work,

which asks for adequate protective clothing to be used. Protective workwear protects the body from various injuries and covers or completely replaces personal clothing. It is usually aimed at protecting from one or more harmful influences. By the criterion of use and duration of wearing, it can be permanent (used for the whole pe-

riod of work) or interventional (used in accidental situations) [2].

Most of the hazards and dangers can be relatively accurately predicted in most of work situations and activities, and risks can be evaluated and reduced. However, in firefighting it is only partially possible. It is especially important for the firefighters to be

optimally protected by their clothing systems and by other specialist protective equipment, as they save other lives during their everyday work. Firefighters' protective clothing is used in fire extinguishing or similar situations, where the danger exists of high thermal load and direct flame. Firefighters perform their tasks under specific working conditions and are exposed in their work to outer influences that occur in accidental situations of creating and spreading of fire. This is why their clothing should meet the requirements of other extreme conditions as well, such as protection from rain and water used for firefighting, from mechanical impacts, activities of aggressive and reactive chemicals, of chemical, which are hazard for health etc. [2]. Intervention firefighters' clothing should meet general requirements, such as requirements for thermal protection, requirements for comfort in interventions, requirements for comfort in wearing under normal weather conditions, as well as the requirements properly executed air-conditioning system for releasing the heat generated by natural metabolism of the wearer [3]. To meet these requirements, firefighters' protective clothing should be manufactured of the material resistant to high temperature and flame and waterproof at the same time. Heat transfer through the clothing, which determines its level of protection, depends upon the fabric composition and construction, as well as on the amount of heat and duration of exposure. Various kinds and types of material used to protect from heat and flame are commercially available today. Their quality has been constantly improved and they meet the required norms and standards, and as such are incorporated into protective articles of clothing. Apart from high-quality materials incorporated into the clothing systems, it is necessary, using the functional design elements (outer elements, such as pockets, should be constructed with no sharp peaks and should

not protrude from the garments, while the seams should be optimally strong), to adapt the models of the garment to actual use and protection of health and life. Protective jackets are constructed with additional reinforcements on the elbows and shoulders (the fabric used is PU or meta- and para aramids), sleeve width is regulated by hook-and-loop tape fastener (which should also be fire-proof), the sleeves have knitted cuffs made of aramid fibre, such as Nomex®, there are two breast pockets (for radio device), there are two side pockets, elastic tape is used to regulate the waist, fire-protection collar can be closed in the front with a hook-and-loop tape, zippers are resistant to high temperature, reflecting tapes (e.g. 3M) are fastened around the body and sleeves, hook- and-loop tapes are fireproof. Protective trousers have elastic adjustable shoulder straps, an elastic tape to regulate the waist, a zipper covered with a hook-and-loop tape, side pockets with flaps, additional reinforcements on the knees, sides and legging edges made from PU or para-aramid fibres, replaceable inserts under the knee protectors and reflecting tapes (e.g. 3M) around the leggings [4]. Unfortunately, regardless of the contemporary high-performance fabrics used, the elements of functional design and modern garment making machines, personal protective clothing and equipment are often uncomfortable and ergonomically not adjusted, thus firefighters frequently do not use such equipment, work without it, and expose themselves to health and life hazards. This is why we aimed our investigations to subjective firefighters' perception and their satisfaction with protective clothing used in interventions in accidental situations, as well as to their familiarity with the characteristics of the clothing they use.

2. Methodology

The surface area of the Republic of Croatia is 56 542 km² there are 4.28

million inhabitants, and there are 65 (out of 66 registered) territorial professional public fire brigades and 17 professional fire brigades in various economy. Public fire brigades employ 3 525 professional firefighters. There are also 1 891 volunteer fire brigades in Croatia, with 57 138 volunteer firefighters. In total, there are 60 663 firefighters in Croatia, 94.19 % of them volunteer and 5.81 % professionals [5, 6].

A survey using a questionnaire was organised in order to define the attitude and satisfaction of the firefighters concerning the clothing they wear in accidental situations. The survey was done on paper in the period from June to September 2015 in Public (professional) Fire Brigades (PFB) in Zagreb and Karlovac, as well as in volunteer fire brigades (VFB) in Zagreb and Karlovac.

The questionnaire was divided into 6 groups of questions:

- general information,
- the type of clothing and equipment the subjects used in interventions,
- design and ergonomic aspects of the clothing and equipment the subjects used in interventions,
- care and maintenance (cleaning, washing, care and repairs) of the clothing,
- history of previous injuries at work,
- additional questions for those who considered themselves familiar with the materials used in the manufacture of personal protective equipment (PPE).

After completing the questionnaire, the results obtained were processed statistically employing the MS Excel software.

3. Results and discussion

Investigations in the experimental part of this paper involved a survey by questionnaire on the usage of firefighters' clothing and the users' satisfaction with the clothing they wore in interventions. The survey was organised among the members of professional and volunteer fire brigades in Zagreb and Karlovac [7]. The inves-

Tab.1 Physical characteristics of the subjects and years of service

	Professional firefighters			Volunteer firefighters		
	MIN	MAX		MIN	MAX	
Age [years]	21	63	39	15	55	36
Weight [kg]	65	128	91	51	105	83
Height [cm]	161	198	180	165	194	178
Service [years]	0.17	40	15	1	39	15

tigation included 138 professional and voluntary firefighters as subjects, members of the following units:

- PFB Zagreb – Centre – professionals (38 questionnaires),
- PFB Zagreb – Dubrava - professionals (33 questionnaires),
- PFB Karlovac - professionals (36 questionnaires), and
- VFB Karlovac - volunteers (15 questionnaires)
- VFB Dubrava - volunteers (16 questionnaires).

There were 107 professional firefighters included, which amounts to 78 % of all the subjects, while 31 volunteers amounted to 22 %.

3.1. General information

The first group of questions in our questionnaire was associated with general information, such as gender, age, body weight, body height, years of service and type of activities the subject is involved in as a firefighter. All the subjects from PFB (professionals) were male, while 28 subjects from VFB (volunteers) were male (90 %) and 3 of them female (10 %). The data on minimum, maximum and average age, body weight, body height and years of service in firefighting for professionals and volunteers can be seen in Tab.1.

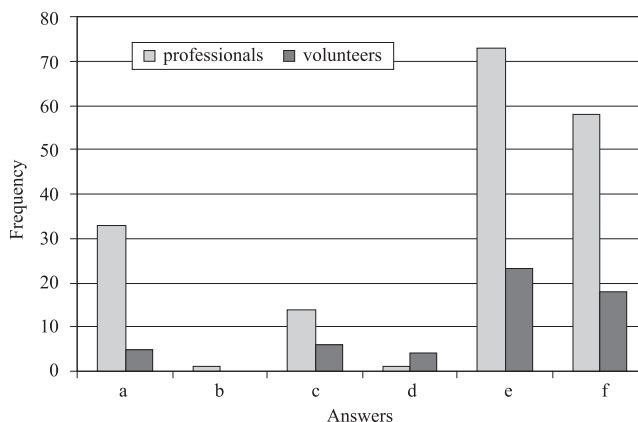
Fig.1 shows frequency graph of the activities and tasks the subjects performed in the course of intervention. It says that most of the subjects took part in extinguishing fires (72 professionals and 23 volunteer firefighters) and saving people (58 professionals and 18 volunteer firefighters). Additionally, 32 professionals and 5 volunteer firefighters took part in preparing the vehicles and/or driving them in the intervention.

3.2. Information on the type of protective clothing, footwear and equipment

Fig.2 shows a graph depicting most frequently worn articles worn in interventions in accidental situations. The graph obviously indicates that firefighters in professional brigades most frequently wore their intervention firefighters' clothing.

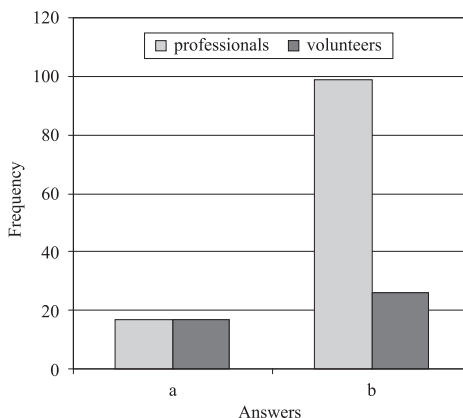
Fig.3 shows a graph of the gloves firefighters wore in interventions. Professionals wore all types of gloves, while the firefighters in volunteer brigades wore fireproof gloves and the gloves that protected them from mechanical injuries and heat.

Fig.4 shows a graph of the types of protective boots worn by firefighters in interventions. Volunteer firefighters wore fireproof boots, while those from professional brigades most often also wore fireproof boots (103 subjects), but sometimes the boots most resistant to aggressive chemicals as well (11 subjects). As it was possible to choose both answers, total number of answers is greater than the number of subjects. It is also important to note that that overboots resistant to chemical agents were commercially available, which could be worn over the firefighters' boots.



Key: a – driving a vehicle and preparing it for the intervention/s; b – firefighter instructor; c – intervention commander; d - liaison (between the call centre and firefighters in the field); e – extinguishing fire; f – saving lives

Fig.1 Frequency of the activities and tasks the firefighters perform in the course of interventions



Key: a – overalls for forest fire fighting b – intervention firefighters' clothing

Fig.2 Firefighters' clothing worn in interventions

Protective helmets worn by firefighters in interventions were firefighting helmets with a protective visor (both professional and volunteer firefighters). Only professional firefighters wore helmets with protective visors

and transmitter incorporated to enable them to communicate, Fig.5.

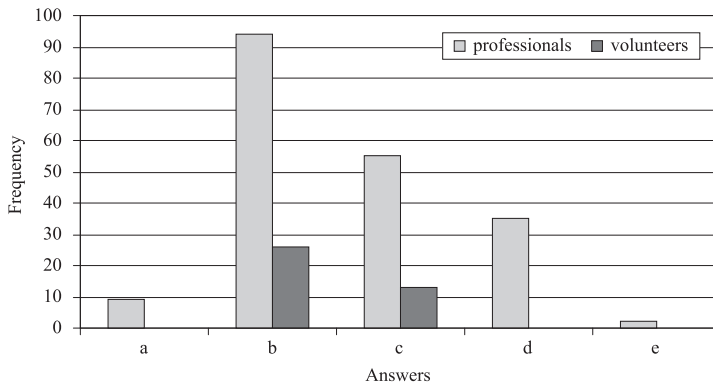
Among the clothing worn by firefighters (Fig.6), the most often encountered combination was trousers and jacket (100 professional and 30 volunteer firefighters), then came overalls (9 professional and 8 volunteer firefighters), followed by trousers and pullover (17 professional and 1 volunteer firefighter).

The graph in Fig.7 shows that the firefighters in professional brigades wore firefighting intervention clothing on everyday basis and/or 2-3 times a week, while the volunteers wore their intervention clothing 2-3 times a week, once a week, or once a month.

Firefighters generally wore their own underwear (Fig.8). Most often, they wore articles such as undershirts and shorts, or T-shirts and shorts (Fig.9).

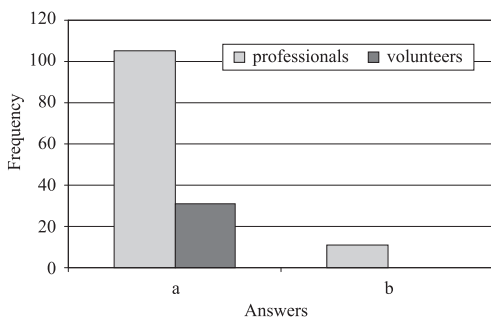
Fig.10 shows the frequency of wearing particular articles of clothing, such as undershirts, T-shirts and long-sleeved undershirts or shirts, as an intermediate layer between underwear and intervention clothing in summer, while Fig.11 shows the frequency of wearing particular articles of clothing as an intermediate layer in winter.

According to the data obtained by the survey, firefighters most often wore T-shirts in summer and T-shirts or long-sleeved undershirts in winter. The results in Fig.11 show that professional firefighters wore shirts (13 subjects) and pullovers (12 subjects).



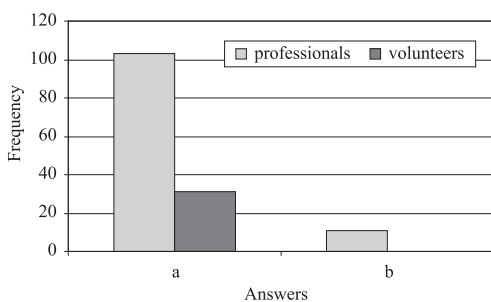
Key: a – aluminium coated; b – fireproof (fire resistant); c – gloves protecting from mechanical injuries and heat (leather); d – gloves resistant to chemicals; e – rubber

Fig.3 Fireproof gloves worn in interventions



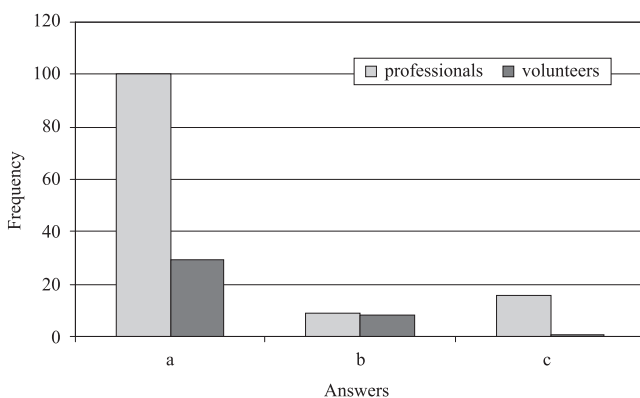
Key: a – firefighters' boots; b – boots resistant to chemical agents

Fig.4 Protective boots worn in interventions



Key: a – firefighting helmets with protective visors; b – firefighting helmets with protective visors and incorporated transmitter for communication

Fig.5 Protective helmets worn in interventions



Key: a – trousers and jacket; b – overalls; c – trousers and shirt + pullover

Fig.6 Firefighters' clothing combinations worn by firefighters

3.3. Information on the satisfaction with protective clothing, from the point of view of ergonomics in garment construction

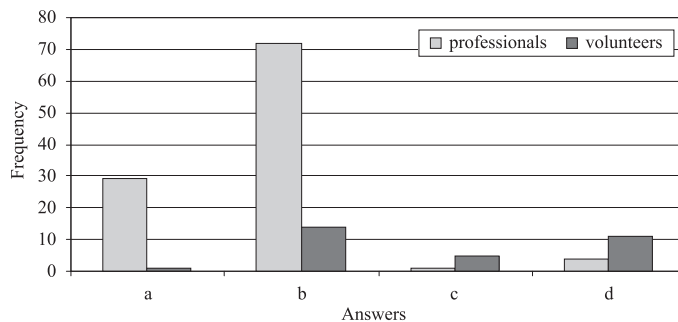
The investigations of ergonomics and ergonomic principles employed in design was done with the subjects who wore the whole of the clothing system (garments, footwear, equipment) under conditions of work. The aim was to determine the degree of functionality, level of protection and security, to evaluate mobility or the degree of freedom of movement, design (overlapping individual articles

of clothing in wearing, e.g. jacket and trousers, sleeve and legging length) as well as the compatibility with the rest of the equipment [8]. The investigations related to the design of protective clothing, footwear and equipment, from the point of view of ergonomics, indicated that the clothing used met the needs of the users well or very well [9, 10].

The graphs in Fig. 12-16 show the degree of user (firefighters) satisfaction with the appearance, cut and garment size of their firefighting clothing, as well as with the size of pockets on jackets, trousers and overalls. Most of the subjects (from 80 % to 93 % of the professionals and from 80 % to 94 % of the volunteer firefighters) were satisfied with the above characteristics of firefighting protective clothing they wore, grading their clothing with 3, 4 or 5 (out of 5).

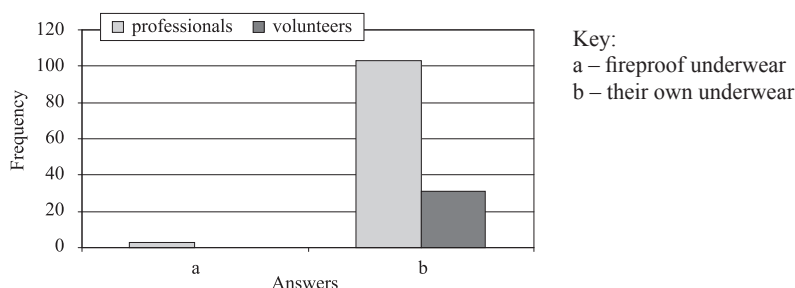
In order to determine the level of fit and functionality of protective clothing from the ergonomic point of view, it was necessary to see whether the positioning of the pockets, as well as the sleeve and legging length match the dynamic movements of the user under the conditions of performing the planned work. This is why human body characteristics and particular function, as a part of the ergonomic approach, should be taken into account when designing and constructing products. It is necessary to be familiar with the movements a person makes in performing everyday working tasks, and also know static and dynamic bodily measures (static and dynamic anthropometry), together with movement amplitudes in joints, field of reach and muscular strength in various body postures [11]. Graphs in Figures 17-19 show the satisfaction of the firefighters with the position of jacket, trouser and overalls pockets, as well as with sleeve and legging lengths.

According to the information acquired, 93 % of the firefighters from professional brigades and 100 % of them from volunteer brigades were satisfied with the position of the pockets. Sleeve length was satisfactory for 92



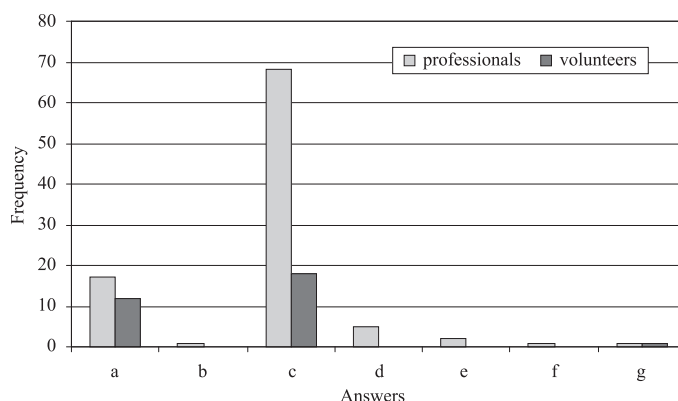
Key: a – every day; b – 2-3 times a week; c – once a week; d – once a month

Fig. 7 The frequency of wearing firefighting intervention clothing



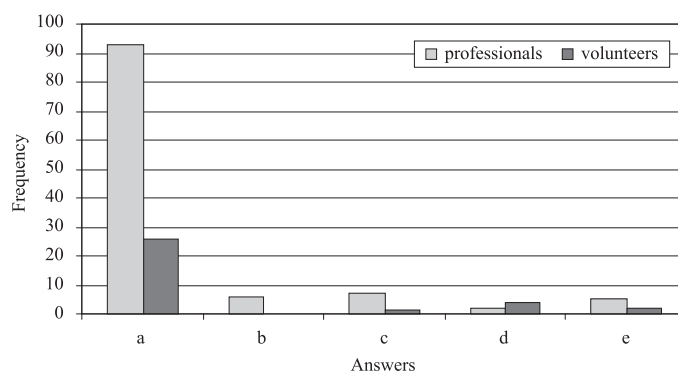
Key: a – fireproof underwear b – their own underwear

Fig. 8 Types of underwear worn by firefighters



Key: a – undershirt / shorts; b – undershirt / long underpants; c – T-shirts / shorts; d – T-shirts / long underpants; e – long-sleeved undershirts / long underpants; f – long-sleeved undershirts/ shorts; g – nothing of above

Fig. 9 Articles of underwear worn by firefighters



Key: a – T-shirt; b – long-sleeved undershirt; c – shirt; d – undershirt; e – nothing

Fig. 10 Frequency of wearing particular articles of clothing as an intermediate layer between the underwear and the intervention clothing in summer

% of the professionals and 80 % of the volunteers, while rousers legging length satisfied 87 % professional firefighters and 74 % of the volunteers. The subjects not satisfied with sleeve length stated that the sleeves were too long and leggings too short (8 % professional and 7 % volunteer firefighters) or too long (5 % professional and 19 % volunteer firefighters).

3.4. Information on the manner of firefighters' clothing care and repairs

Attention should be paid to the methods of care of the clothing used to protect from heat and flame, having in mind the protection and characteristics such clothing should have, as well as to what happens to such clothing in the course of use. Depending

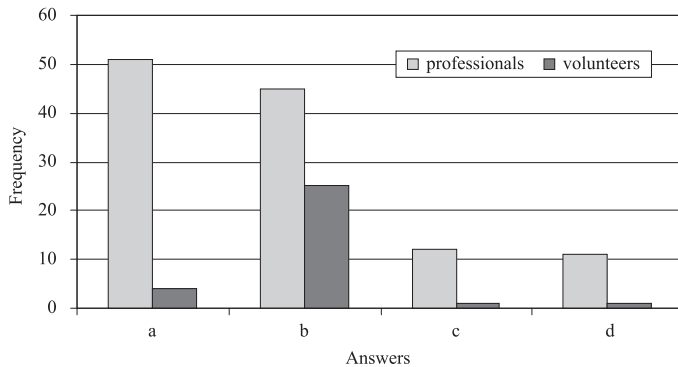
upon the materials incorporated in the protective clothing and additions included, it is necessary to pay special attention to the care of this clothing, its washing and cleaning, following the manufacturers' instructions in the process. To monitor the life cycle of the clothing used for protection from heat and flame, it is necessary to fill-in the form after each cycle of use, i.e. keep a diary of the use of firefighting clothing [12, 13].

Fig.20 shows a graph depicting the frequency of the firefighters keeping the diary of the clothing they wore in interventions. Most of the firefighters, 93 % of the professionals and 84 % of the volunteers, did not keep the diary, while 4 % of the professionals and 13 % of the volunteers kept the diary occasionally, and only 3 % regularly.

The graph in Fig.21 shows that most of the firefighters, both professional and volunteer, took care of their protective clothing at home (77 % professional firefighters and 75 % volunteers). As regarding the frequency of washing or cleaning the firefighters' clothing (Fig.22), professional brigades cleaned the clothing after every intervention (36 % of the subjects), as they considered it necessary (56 % of the subjects) or once a year (8 % of the subjects). Volunteer firefighters washed their clothing once a year in most cases (42 % of the subjects), or when necessary and after every intervention (23 % of the subjects).

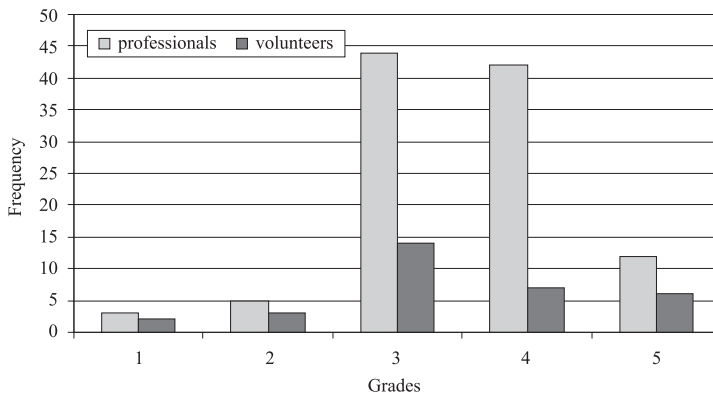
The intervention firefighters' clothing was inspected after every intervention most often (36 subjects in professional brigades and 5 in volunteer ones) or once a month (59 subjects in professional brigades), Fig.23.

Repairs of small damages that could occur in wearing and usage of the firefighters' protective clothing were done by the manufacturer or provider in professional fire brigades (42 % of the subjects), or by the users themselves (42 % of the subjects), while 5 % of the subjects said the repairs were done by their tailors, and for 11 % the repairs were organised by their brigades. Firefighters most often do their repairs by themselves in volunteer fire brigades.



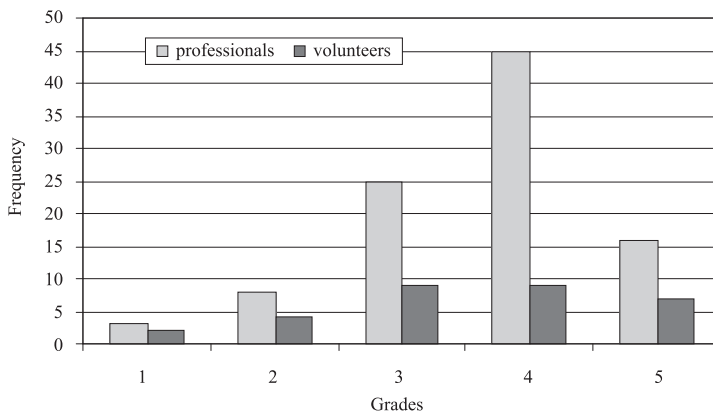
Key: a – T-shirt; b – long-sleeved undershirt; c – shirt; d - pullover

Fig.11 Frequency of wearing particular articles of clothing as an intermediate layer between the underwear and the intervention clothing in winter



Key: 1 – lowest grade, complete dissatisfaction; 5 – highest grade, complete satisfaction

Fig.12 Satisfaction with the firefighters' clothing appearance and cut



Key: 1 – lowest grade, complete dissatisfaction; 5 – highest grade, complete satisfaction

Fig.13 Satisfaction with garment size of the firefighters' clothing

3.5. Information on injuries at work

While performing their tasks in saving lives and firefighting, firefighters often suffer injuries, because of hazards in accidental situations in which they find themselves. Thus, to the question whether they had been injured at work, 28 professional firefighters and 3 volunteers answered positively (Fig.25). Firefighters who were injured also stated the type of injuries they suffered, such as burns on the back, sprained joints, smaller burns, burn of the second and third degree, smaller scratches and burns on the ankles. Additionally, 48 subjects from professional brigades and 5 from volunteer ones said they had suffered a thermal stress in the interventions.

The questionnaire also asked whether the firefighters wore protective clothing after direct exposure to the flame, where 99 subjects from the professional brigades and 21 subject from volunteer brigades answered positively, which could be a possible cause for the injuries.

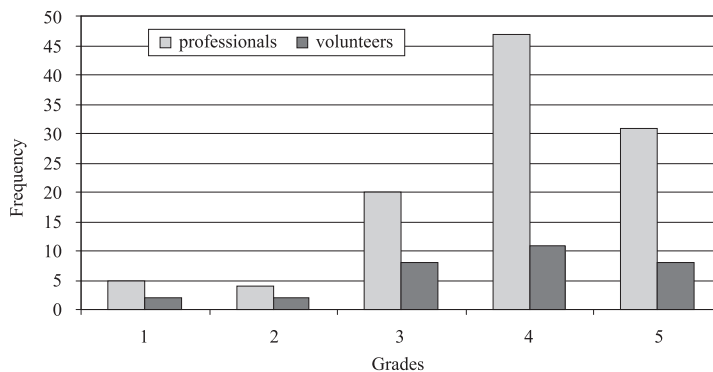
The subjects also stated their opinions on the clothing they wore in interventions, stating that:

- it was necessary to use hook-and-loop tapes in garment construction, able to close the pockets more firmly,
- the clothing they used was old and should be replaced by new ones more often,
- the clothing should be more resistant to wearing,
- the clothing was too thick for summer conditions of use,
- the clothing was of satisfying quality.

The results of the survey obtained generally confirmed that the firefighters were satisfied with the quality and protection offered by the clothing they wore. However, they thought that the clothing should be replaced by new one more often.

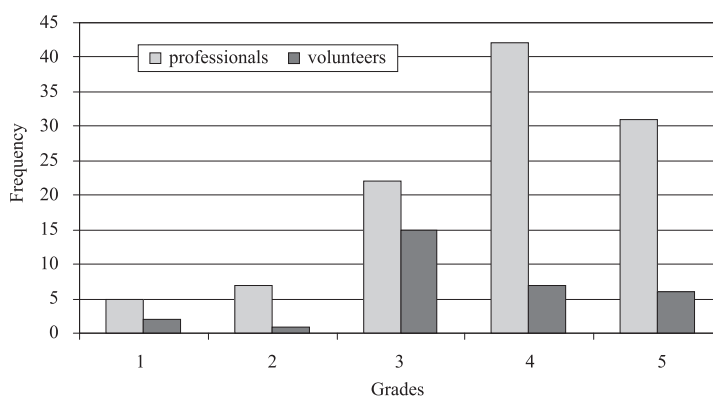
4. Conclusion

In their everyday work, firefighters are confronted with numerous hazards, especially during fire extinguishing and in accidental situations,



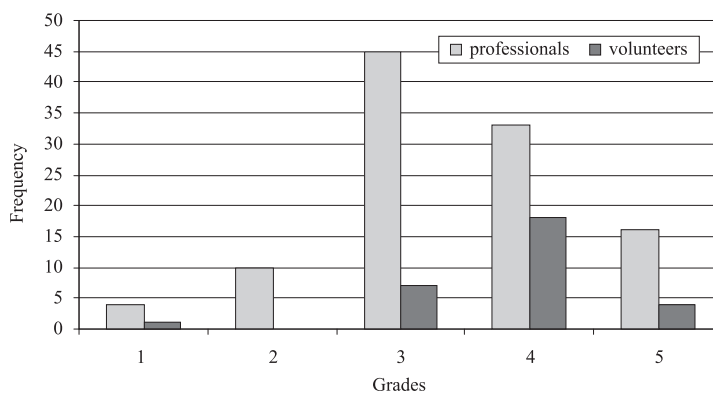
Key: 1 – lowest grade, complete dissatisfaction; 5 – highest grade, complete satisfaction

Fig.14 Satisfaction with jacket pocket size



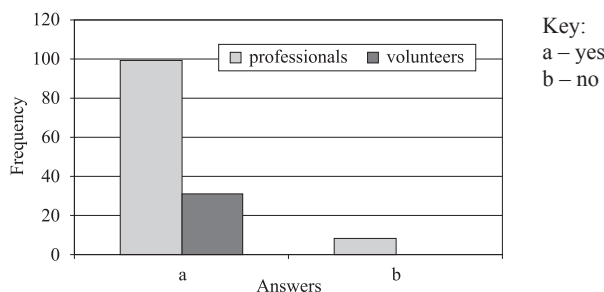
Key: 1 – lowest grade, complete dissatisfaction; 5 – highest grade, complete satisfaction

Fig.15 Satisfaction with trouser pocket size



Key: 1 – lowest grade, complete dissatisfaction; 5 – highest grade, complete satisfaction

Fig.16 Satisfaction with overalls pocket size



Key:
a – yes
b – no

Fig.17 Satisfaction with the position of upper / lower pockets

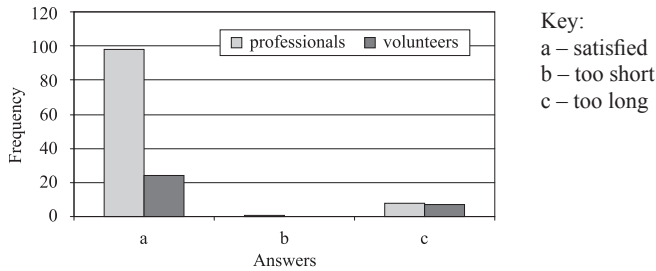


Fig.18 Satisfaction with sleeve length

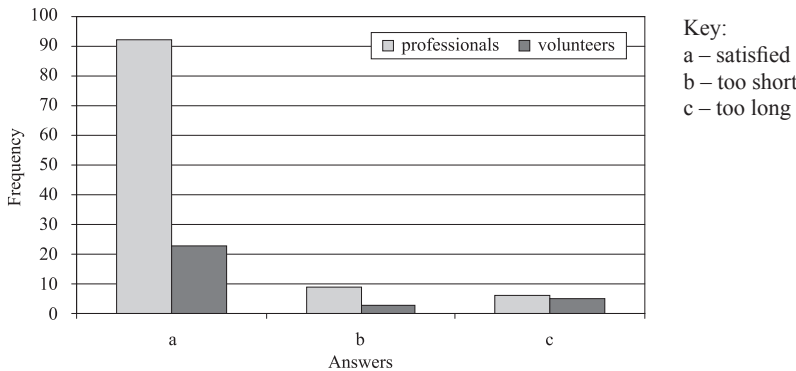


Fig.19 Satisfaction with trouser legging length

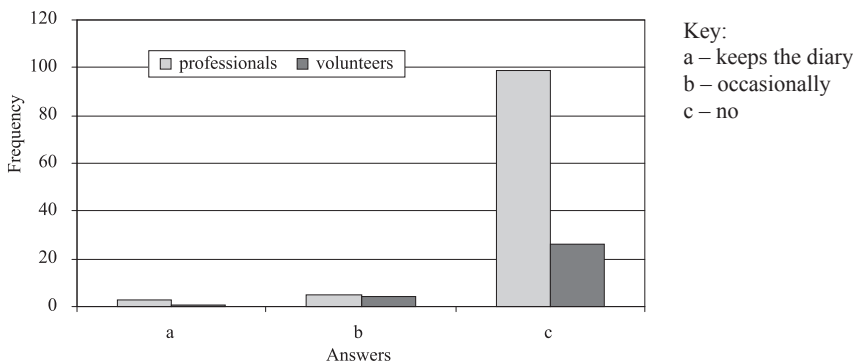


Fig.20 Graph depicting the frequency of keeping diary on the usage of firefighters' clothing

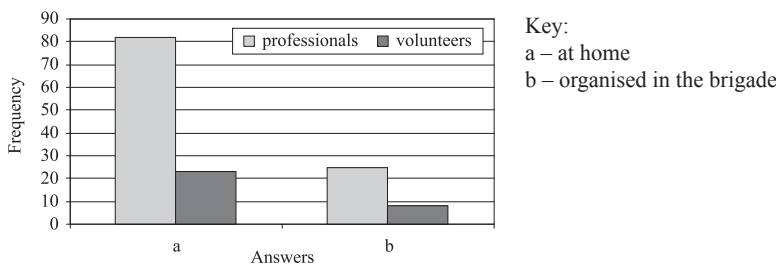


Fig.21 Manner of firefighters' clothing care

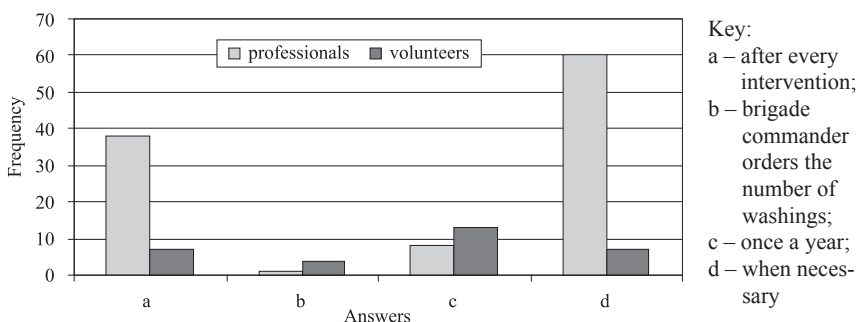
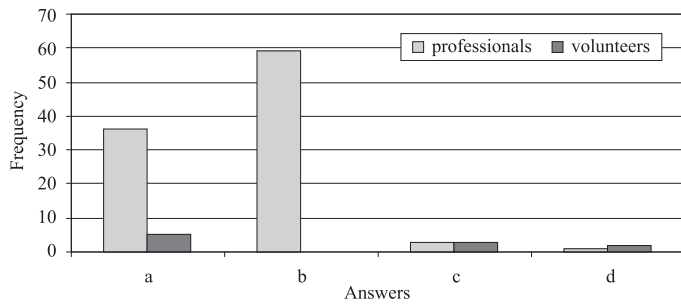


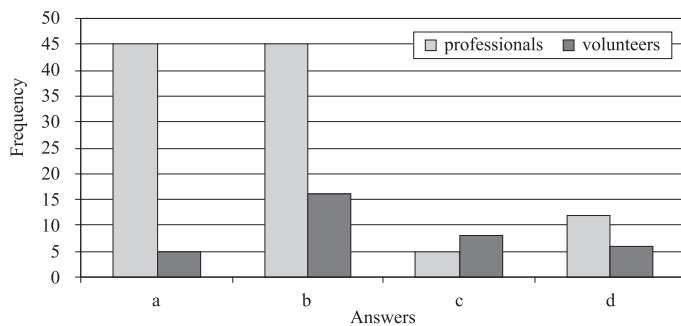
Fig.22 Frequency of cleaning the firefighter's clothing

where firefighters' intervention clothing is supposed to offer adequate protection. The survey conducted in public professional fire brigades and volunteer fire brigades offers information on the satisfaction with the protective intervention clothing used. The results obtained indicated that most of the subjects were properly or very much satisfied with their clothing size, the location and size of pockets, as well as with the length of sleeves and leggings. Additionally, most of the subjects were satisfied with the quality of the clothing they wore. However, some of the subjects thought their equipment was too old and could not stand all the stresses they were exposed to. Having in mind all the results obtained by the questionnaire, firefighting protective clothing should be improved regarding functional design and garment fit. Precise pocket location and adequate sleeve and legging length could easily be determined by static and dynamic measurement of the firefighters' bodies, meaning the garment should be manufactured individually for each user. This would result in adequate fit and the garment would not be neither too tight not too wide. The results showed that the subjects were not satisfied with the size of the pockets on the overalls. The pockets should be larger and in garment design attention should be paid to the need that pocket seams should not protrude and are stuck in wearing and use. The results also indicate that most of the firefighters wash their clothing at home. Protective clothing should be washed in an organised way in the brigades, so that the conditions of washing and care could be identical for all the types of clothing. Most of the firefighters repair their protective clothing at home or visit a tailor, both of which should be avoided. Garment repairs should be provided by the supplier, as the clothing is highly expensive and is supposed to offer a high level of protection. Firefighters should also keep diary for the clothing, so that the frequency of use and number of usages should be known, together with the number



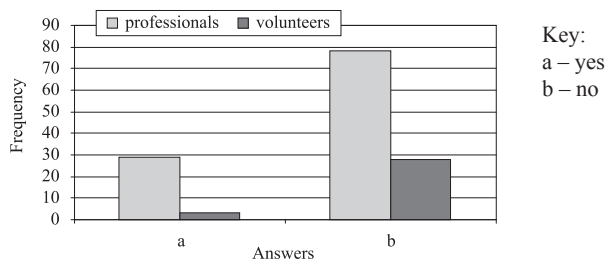
Key: a – after every intervention; b – once a month; c – once in 6 months; d – once a year

Fig. 23 Frequency of inspection for intervention firefighters' clothing



Key: a – done by the manufacturer/provider; b – do themselves; c – repaired by a tailor; d – organised in the brigade

Fig. 24 The manner of making smaller repairs



Key:
a – yes
b – no

Fig. 25 Injuries at previous work

of washing cycles, the number of repair etc., since this information can be used to predict the need for purchasing new protective clothing.

The results of the survey and questionnaire used offer the possibility of improving the design and manufacture of the intervention firefighters' clothing, using new high-performance materials, resistant to burning and wear, with the manufacture of the clothing following the individual bodily measures of each firefighter.

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