VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

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EXAMINATION OF THE CARRIED OVERLOAD FOR FIREFIGHTERS WITH A PHYSICAL LOAD TEST

Abstract

People have been in constant contact with fire throughout the history. During this time, they also learned the beneficial and dangerous effects of fire. Lot of fires generate all over the world, so the science of firefighting needs constant research and development. It is a fact that the physical work of firefighters is tiring. It has a bad affect to the health of firefighters in case of a long time intervention, so the physical performance of firefighters should be increase. In addition, reducing the physical load also provides an opportunity to increase the effective intervention. In the paper, the author points out the limitations of the load capacity of firefighters and demonstrates the need to increase the ability to extinguish with free movement. In order to achieve this objective, the author conducts an own test, which does not require significant resources, but their results can already provide guidance for a tool development. As a result of the test, he proposes to use a novel, innovative technical tool during the firefighting.

Keywords: test, overload, burned energy, elapsed time

TŰZOLTÓK FIZIKAI TERHELÉSÉNEK VIZSGÁLATA A VISELT TÖBBLETTEHER ALAPJÁN

Absztrakt

Az ember a történelem során mindig is kapcsolatban állt a tűzzel. Ennek köszönhetően megismerte annak előnyét és veszélyeit is. A világon mindenhol vannak tűzoltói beavatkozások, ezért a tűzvédelem területén folyamatos a kutatási tevékenység. A tűzoltók fizikai munkavégzése fárasztó. Ez egyrészt hatással van egy hosszabb beavatkozás során a tűzoltók egészségére, ezért fontos lenne növelni a tűzoltók fizikai teljesítőképességét. Másrészt a fizikai teher csökkentése hatékonyabbá teheti a tűzoltást. A cikkben rámutatok a tűzoltók fizikai terhelhetőségének korlátaira és bemutatom a szabad mozgással történő oltás kitolásának szükségét. Ennek érdekében egy olyan saját mérést végzek, amely nem igényel komolyabb erőforrásokat, azonban eredményei útmutatást adnak egy újszerű eszköz fejlesztéséhez. A vizsgálatom eredményeként javaslom egy újszerű, innovatív technikai eszköz alkalmazását a tűzoltás során.

Kulcsszavak: mérés, többletteher, elégetett energia, eltelt idő

1. INTRODUCTION

There is an ongoing research activity in the field of fire protection and firefighting in Hungary. In the field of fire prevention, we can find researches in connection with the BIM and the fire protection [1], with the BIM based sustainable fire safety development opportunities of the hazardous industrial factories [2], and the effects of the actively used reactive and passive fire protection systems established by innovative fire protection methods for whole life-cycle of buildings [3]. In the field of protection against explosion, the industrial safety has been studied in explosive work environment [4]. In the field of firefighting, analytical publications have been prepared on fire, rescue and disaster management [5], on fighting against wildfires [6] [7] and on the solutions for the accessibility of water sources [8]. Based on my various studies of the relevant literatures, I came to the conclusion that research on the development possibilities of technical tools, [9] [10], and analyses to increase the efficiency [11] also play an important role in Hungary. From the above, I conclude that there is a continuing need in case of new technical tools and efficient solutions. Based on it the most important conclusions can be drawn from the research activities [12]. As a result, in addition to the already known tools, I will examine what kind of new tools can be used to increase the efficiency of firefighting in case of wildfires.

2. THE NEED TO WEAR OVERLOAD

Walking is the most basic type of movement. According to Morrison, a person makes an average distance of about 8 km each day. However, the human body is able to perform significantly longer distances without much effort, even under a small load [13]. However, external loads and equipment have an impact on the efficiency of work, as the increased load requires the human body to perform more to achieve the same results. Studies in the military field of science have confirmed the logical conclusion that the more load a soldier wears, the greater his strength and endurance must be. An average soldier must be able to walk with a speed of 6.5 km/h for a long distance of 20 km with a load of more than 30 kg. Based on measurements and experiences, the researchers concluded that a soldier should only fight if he is carrying a load of 16 kg or less [13].

In many cases, firefighters are also exposed to severe physical load due to their daily activities, as their work is very varied and unpredictable. Their load-bearing capacity is affected by the high temperature on the field, the weight and quality of the protective clothing and the weight of the equipment they use during an intervention. Physical load usually occurs on the field during a firefighting. The extent of it depends on the type of the intervention, as not all interventions involve walking long distances or crawling in tight spaces. The extent of physical load is also influenced by the type and the duration of the intervention [14]. Fighting against the most challenging wildfires took several days in Hungary. During the intervention, in addition to the mandatory rest, the firefighters worked continuously. During a whole day work, the firefighters are completely exhausted. This is especially true when personal protective equipment and also firefighting tools must be used [15]. These mean roughly 15-20 kg of extra weight while working. In case of a long intervention, this load is already harmful to the human health. Exhaustion also affects the firefighters' decision-making ability, their thinking may be dulled, and their ability to recognize the situation can deteriorate. A firefighter cannot stop the intervening because of exhaustion, so I suggest to facilitate the working conditions in order to protect the human health.

There were several studies to determine the specific load of firefighters. Among the international literatures, I have found research on the cooling strategy of firefighting [16], the

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study of thermal stress on firefighters [17], and the possibilities of reducing the thermal stress [18]. Within the topic, the Hungarian literatures deal primarily with the assessment of the physical ability of firefighters, the physiological examination of firefighters' performance [19], or the determination of workload and stress in general [20]. When examining the relevant literatures, I found a few overload measurements in the topic. An Italian research team found that a firefighter should be able to intervene effectively with an extra weight of up to more than 42 kg, even if this load is only temporary during an intervention [21]. In Hungary, the physical load on firefighters has not been studied in depth, so I examine the extent to which the extra load can affect the efficiency of the interveners during a wildfire. To achieve this goal, I am conducting my own study that does not require significant resources, but the results can already provide guidance for the development of a tool even if the accuracy of the measurement results is limited.

3. PRESENTATION OF MY OWN TEST

After describing the physical use of firefighters, I present my own test. In order to find out specifically how much more efficient is the work without overload, I made a test with 5 volunteer firefighters

Data and conditions of the test

In order to obtain an authentic study, I recorded the physiological data of the volunteers, such as gender, age group and body mass index. The team of the volunteers consisted of 4 men and 1 woman, two of the members were in the age group 20-29, also two in the age group 30-39 and one in the age group 40-49. Based on the body mass index, two of the volunteers fell into the normal category (18.50–24.99 kg/m^2), as one had a value of 23 kg/m^2 and the other 24.5 kg/m^2. The other three volunteers were in the overweight category (25.00 - 29.99 kg/m^2), as their indices were 27 kg/m^2, 27.5 kg/m^2 and 29 kg/m^2. Based on this, the volunteers have an average body mass index of 26.2 kg/m^2, which can in fact be considered as approaching the limit of normal and slight overweight. The aim of my test was to determine how much the effectiveness of the firefighter decreases when he should to carry overload. During the experiment, I examined the time and energy consumption factor of the efficiency, and I also estimated the possibility of additional capabilities. During my test, I considered as a time factor that how long the firefighter takes a certain distance without load or with carrying an overload. I considered as an energy factor that how much energy uses the firefighter (in this case the volunteer) during the experiment. I give my test data in the unit of energy (joule) used for work in the international system of units of measurement. I made the test as follows.

The test was conducted in the early afternoon on the 24th of April 2020, with the participation of the 5 volunteers I have already mentioned. I considered their physical condition to be average in relation to their age based on my survey. When choosing the date of the test, I also took into account the weather conditions, which were as follows:

Table 1: Weather and field parameters of the test. Created by the Author.

Weather conditions during the test	
Temperature	26 °C
Air pressure	1 016 hPa
Humidity	31%
Wind speed, direction	2 km/h, NW
UV radiation	strong
GPS coordinates	47°36’50”N
	18°52’49”E
	altitude: 220 m

Based on Table 1, I consider the conditions of the experiment to be relevant, as the data of the listed weather factors provided an opportunity to even generate a real wildfire. This is also confirmed by the fact that there was a highly flammable period nationwide on that day in Hungary. Consequently, I consider the circumstances of my test to be acceptable in case of a wildfire study.

The task of the volunteers was to take a distance of 1.5 km twice in complex terrain conditions. For the first, this was done in the traditional way, i.e. without load. For the second time, the task was repeated, but in this case already carrying an extra weight of 25 kg. When choosing the test conditions, I took into account that the participants complete the distance one by one, so that they do not even see each other, thus avoiding that the performance of one participant affects another. In addition to the above, I also determined three check points during the test, in order to be able to analyse the partial results. I selected the first check point at 500 m (one-third of the total distance), the second at 1 km (two-thirds of the total distance), and the third, of course, at the end of the distance. In order to ensure the accuracy of the test, I also recorded the topographic properties of the operation area. To illustrate this, I made a topographic diagram of the test site (Figure 1), in which I indicated the terrain conditions that the volunteers faced during the measurement. The terrain shows a strong slope in the first section, with a total altitude difference of +14 m. In the second section, the opposite can be observed, so the terrain in this case was characterized by downhills. Most of the third section is straight with a small slope at the end.

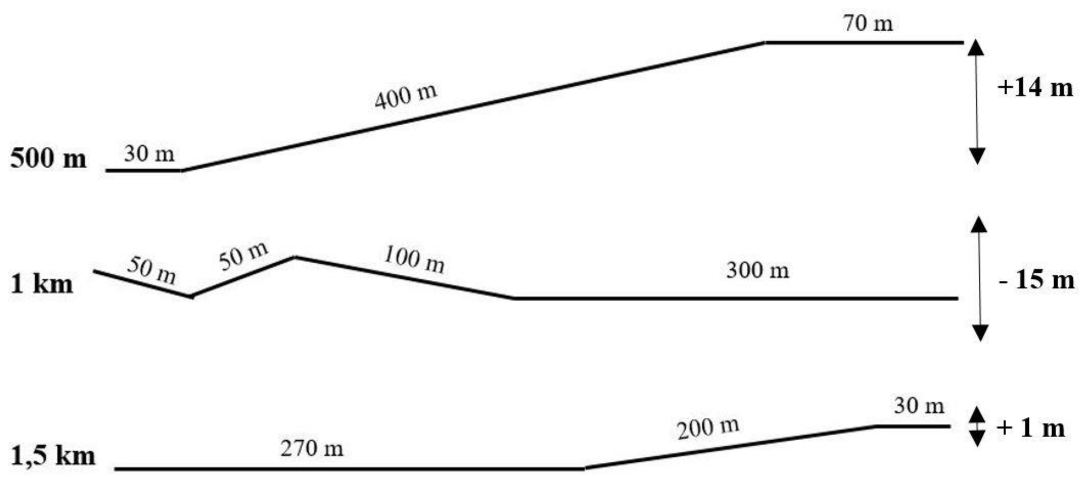

Figure 1 - Terrain conditions on the three checkpoints of the route. Created by the author

During the test I examined how much the overload reduces the speed of the firefighters and how many joules of energy they burn during the work, so how much it burdens the human body. During the test, I provided smart devices (watch, mobile phone) for the firefighters. With these devices, I was able to analyse the characteristics of the experiment. At the end of the test, I asked the volunteers to complete my short questionnaire in order to estimate how much longer they would be able to continue the task with their particular physical condition.

Examination of the temporal factors of the test

The 1.5 km distance was first completed by the volunteers without load. Their results and averages are summarized in Table 2.

Table 2 - Time results after completing the 1.5 km distance without load. Created by the Author. Source: [21]

Time results after completing the 1.5 km distance without load						
	Volunteer "A"	Volunteer "B"	Volunteer "C"	Volunteer "D"	Volunteer "E"	**Averages**
After 500 m	5:36:00	5:03:00	7:22:00	4:45:00	5:41:00	**5:41:00**
After 1 km	10:05:00	9:55:00	11:42:00	8:47:00	11:01:00	**10:18:00**
After 1,5 km	15:01:00	14:53:00	18:32:00	13:26:00	16:12:00	**15:36:00**

Based on Table 2, I established that the volunteers completed the distance on average under normal conditions. The size of the time and the travelled distance increase proportionally. The results of the table are also illustrated in Figure 2.

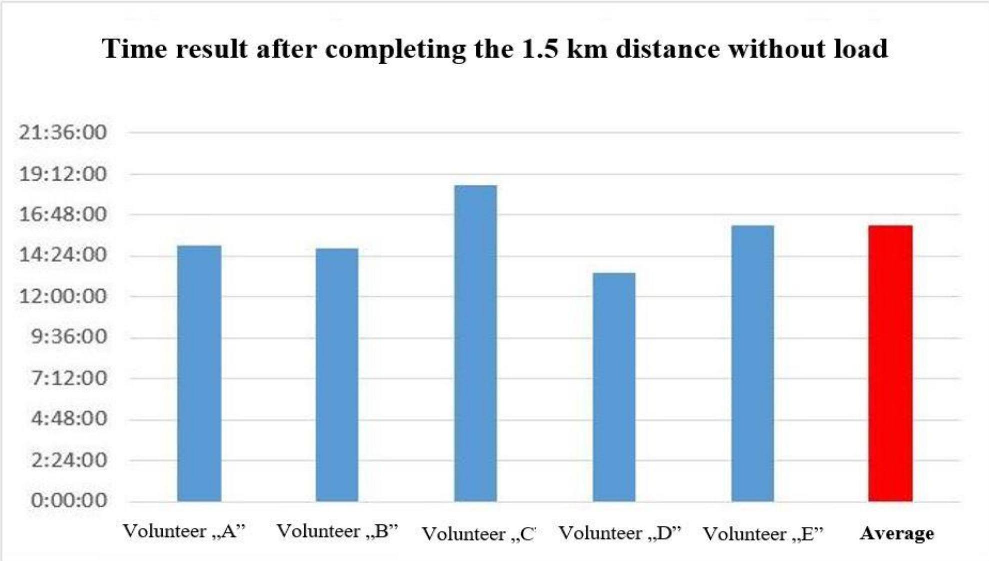

Figure 2 - 1.5 km distance without load on a graph. Created by the Author.

Based on my measurements, I established that the volunteers fulfilled the distance in an average of 15 minutes 36 seconds (936 s). In this case it means an average speed of 5.76 km/h.

$$V_{average_{without}load} = \frac{1000\ m\ x\ 936\ s}{1500\ m} = 624\ s, \text{ in 1000 m, so } \frac{1000\ m}{624\ s} = 1{,}60\frac{m}{s} = 5{,}76\frac{km}{h}$$

This average speed of 5.76 km/h is roughly 1 km/h less than the measurement established that a soldier can walk more than 30 kg at a speed of up to 6.5 km/h over a long distance of 20 km [13]. I explain this difference that the soldiers were specially trained for such a tasks, while the firefighters involved in the experiment volunteered for the task. For this reason, it is logical that the physical fitness of the two groups differs significantly. The volunteers completed the 1.5 km distance for the second time with an overload of +25 kg, and I summarized their results and their average in Table 3.

Table 3 - 1.5 km distance with extra load. Created by the Author.

Time results after completing the 1.5 km distance with a load of 25 kg						
	Volunteer "A"	Volunteer "B"	Volunteer "C"	Volunteer "D"	Volunteer "E"	**Averages**
After 500 m	6:18:00	6:50:00	8:02:00	5:19:00	6:19:00	**6:33:00**
After 1 km	11:30:00	13:58:00	13:10:00	9:36:00	12:21:00	**12:07:00**
After 1,5 km	17:54:00	20:41:00	21:05:00	15:22:00	18:36:00	**18:44:00**

The results in Table 3 also confirm the logic that volunteers completed the distance more slowly compared to the first attempt. The size of the time and the travelled distance increase proportionally in this case too. I also illustrated the results in Figure 3.

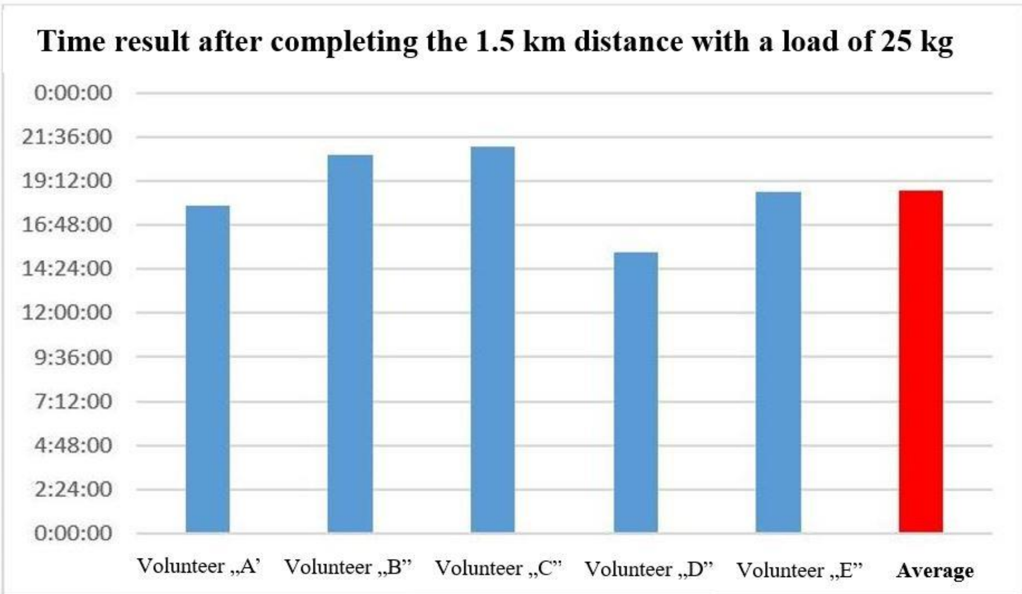

Figure 3 - Completed time results of the 1.5 km distance with extra load on a graph. Created by the Author.

Based on the above mentioned results, I conclude that the volunteers covered the distance in an average of 18 minutes 44 seconds (1124 s), which means in this case an average speed of 4.8 km/h.

$$V_{average_{withload}} = \frac{1000\,m\,x\,1124\,s}{1500\,m} = 749{,}33\,s \text{ in 1000 m, so } \frac{1000\,m}{749{,}33\,s} = 1{,}33\,\frac{m}{s} = 4{,}8\,\frac{km}{h}$$

I compare the results of the two measurements in Figure 4. In the figure, I illustrated the time results of each volunteer at the end of the 1.5 km distance. I marked the time without load in green, the time results with +25 kg overload in red, and as well as the average result.

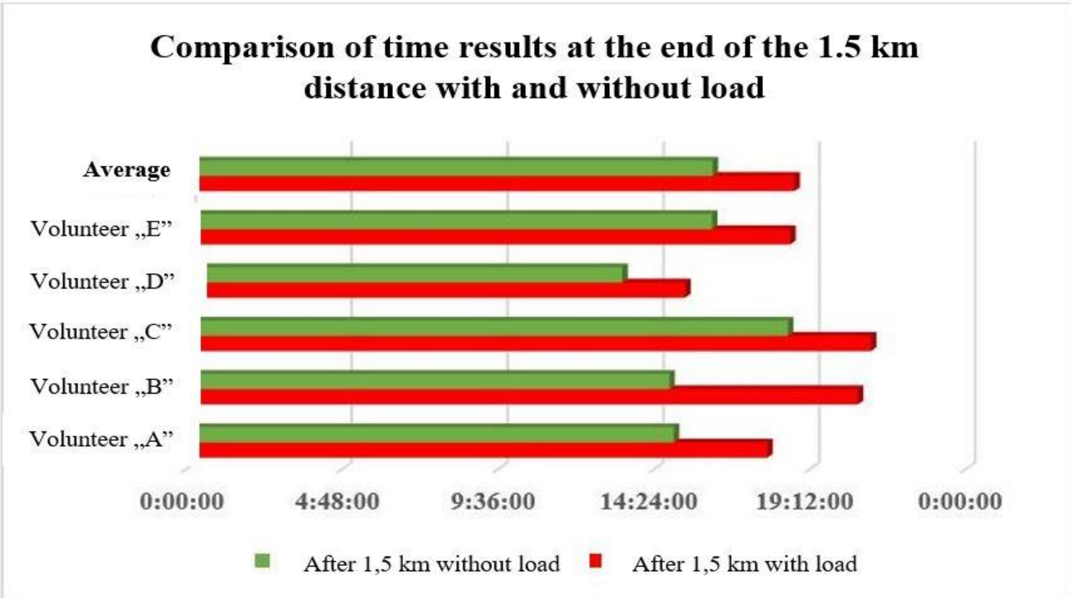

Figure 4 – Comparison of time results at the end of the 1.5 km distance with and without load. Created by the Author.

From the results, I conclude that working with overload was slower in all cases, but the extent of this varies from each other. In addition, I calculated the average time difference between the measured points and at the end of the whole distance (Table 4).

Table 4 - The average of time differences in the given sections. Created by the author.

Distance	Time
500 m	0 min 52 s
1 km	1 min 49 s
1,5 km	3 min 08 s

Examination of the work factors of the test

During the measurement, in addition to the time factors, I also examined the energy consumption factor, i.e. how much joule of energy the firefighters burn during the execution of distance at the various checkpoints. I present this in Table 5.

Table 5 - Burned energy without load. Created by the author.

Amount of burned energy without load (kJ)						
	Volunteer "A"	Volunteer "B"	Volunteer "C"	Volunteer "D"	Volunteer "E"	**Averages**
After 500 m	100,8	79,8	96,6	92,4	92,4	92,40
After 1 km	184,8	163,8	155,4	189	197,4	178,08
After 1,5 km	285,6	243,6	243,6	273	310,8	271,32

From the results in the table, I conclude that the volunteers fulfilled the distance by burning relatively little energy (as a rule of thumb, 2-2.5 times that the calories burned at rest). The magnitude of the time and the travelled distance increase proportionally relative to each other at the measured points. The result of the table is also illustrated in Figure 5 below.

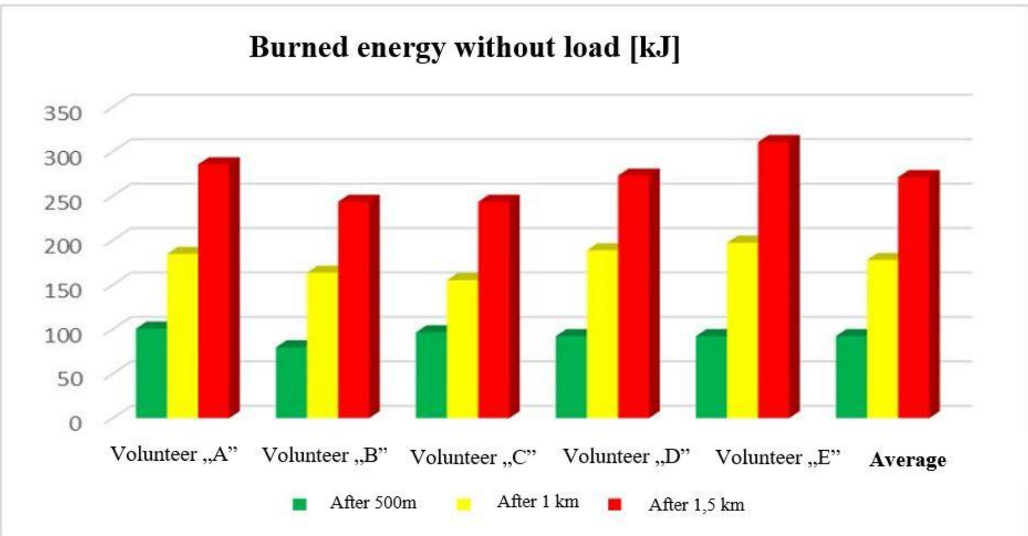

Figure 5 - Diagram of burned energy without load. Created by the author

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The 1.5 km distance was fulfilled by the volunteers for the second time with an overload of +25 kg, and I show the amount of energy burned there with the help of Table 6.

Table 6 - Amount of energy burned with extra load. Created by the author.

Amount of burned energy with 25 kg overload (kJ)							
	Volunteer "A"	Volunteer "B"	Volunteer "C"	Volunteer "D"	Volunteer "E"	**Averages**	**Differences**
After 500 m	142,8	113,4	130,2	100,8	126	**122,64**	**+30,24**
After 1 km	252	226,8	210	210	273	**234,36**	**+56,28**
After 1,5 km	390,6	340,2	340,2	336	428,4	**367,08**	**+95,76**

From the results in the table, I conclude that the volunteers could only fulfilled the distance by burning more energy. The magnitude of time and distance increased proportionally relative to each other at the check points. The results of the table are also illustrated in Figure 6.

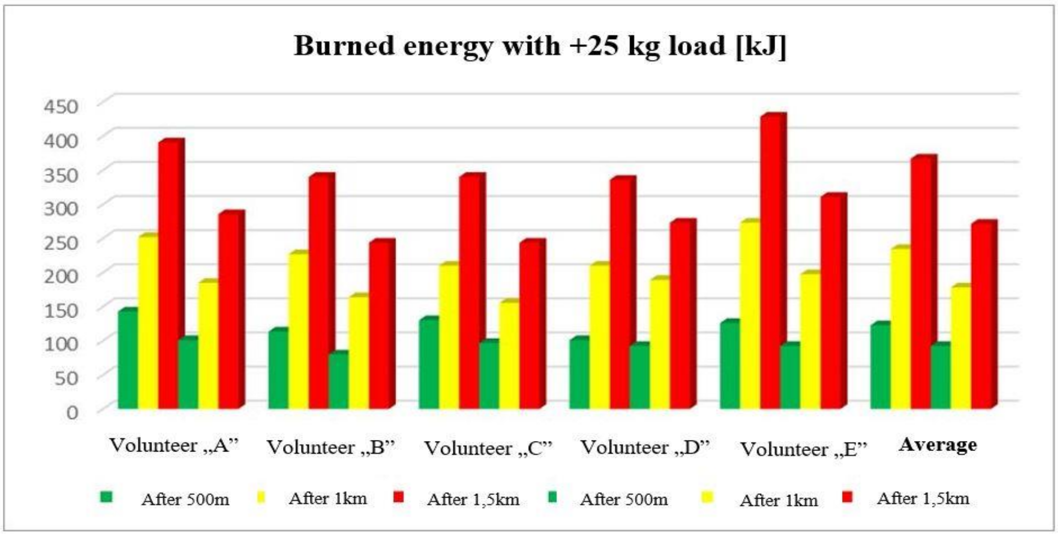

Figure 6 -Diagram of burned energy without load. Created by the author.

I show that at the first checkpoint the volunteers burned an average energy of 30.24 kJ, at the second checkpoint 56.28 kJ and at the end of the distance 95.76 kJ more energy during a distance which can be fulfilled approximately in 20 minutes. This 95.76 kJ at first glance is not much, but in case of firefighting against wildfires is much longer than 20 minutes based on previous experiences. As a result, I logically examine the additional amount of the burned energy as a function of the elapsed time, as shown in Figure 7.

Intervention time	Burned energy (kJ)
0:20:00	392,7
1:00:00	1178,1
2:00:00	2356,2
5:00:00	5890,5
10:00:00	11762,1

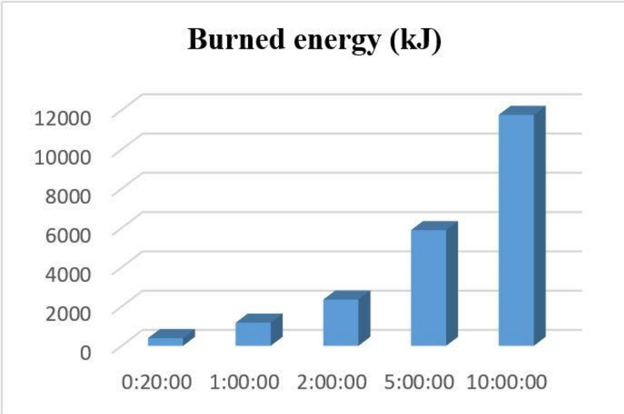

Figure 7 - Amount of the burned energy as a function of the elapsed time. Created by the author.

Based on the time results of the volunteers and the test conditions, I make the following consequences. The average energy consumption was the lowest in the second section, but considering that there was a negative level difference here (-15 m), it cannot be considered as the part with the lowest energy consumption. The difference between the second and third section is the largest, despite the fact that in this case the distance was almost without level difference. Based on the above, I justified that energy consumption is constantly growing, and the rate of growth is exponential according to my assumption. I could not prove the latter because both the number of participants was small and the test conditions included too much variance. I suggest further studies to determine the extent of the change.

Analysis of the study questionnaire

At the end of the experiment, I wanted to determine how tired are the volunteers after the test and how long they would have been able to continue the task in similar circumstances. For this purpose I first asked them - in the form of a questionnaire - that how difficult it was to complete the distance without overload. 60% of the volunteers answered that the task was *very easy*, while 40% felt it was *easy* to complete it without overload. The task was not considered difficult by anyone, so I conclude that the physical condition of the volunteers is adequate.

I asked the volunteers the same question after the second round of the task fulfilled it with +25 kg overload. I determine that because of the overload, it was a much more serious challenge to complete the task. 80% of the participants answered it was *difficult* and 20% found it *very difficult* to complete the task with the + 25 kg overload. This also confirms the practical experience that firefighting with overload significantly reduces the work ability of firefighters in a short period of time. Then I asked the participants to estimate how long they would be able to work without a longer rest with and without an overload. Based on the answers, I conclude that the firefighters - on their own assessment - would be able to intervene on average for an additional 4 hours without overload (light physical work) and for an additional 1 hour with overload (heavy physical work). I chose the amount of overload (25 kg) for the test, so I also asked how much more overload they could wear in addition to 25 kg. Based on the answers of the questionnaire, I state that, on average, firefighters still consider it only tolerable to carry an extra weight of 5 kg above the 25 kg. This is a total of 30 kg, which is the weight of a backpack water pump full of water. As a result of it, I conclude that a volunteer firefighter can work effectively with a 30 kg overload in addition to his own body weight. A heavier weight has a significant influence on the effect of the firefighter's work. Tasks and solutions like these serve sustainable development within the field of the disaster management [23] [24] and engineering sciences [25].

4. CONCLUSIONS

My test showed that the top of the physical load of firefighters in case of long work is approximately 30 kg. Working with a heavier load than this is on the one hand no more effective and on the other hand it can lead to health consequences. In order to increase the efficiency of firefighting, a technical tool would be needed that can reduce the load on firefighters, while maintaining the freedom of movement. The physical loads appear on firefighters in case of free movement by using traditional technical tools. Vehicles and technical tools tested in general cannot simultaneously maintain the free movement and the reduce of the physical load, therefore I am looking for a tool that can meet both conditions at the same time. For this purpose, I have found an external wearable mobile machine (so called exoskeleton) that is already used in military and civilian fields. This machine allows the wearer to carry extra load and to carry only minimal additional load on the body. As an energy source for the machine, an electrical system is logically proposed, which moves the structure through hydraulically driven pistons through the data of the sensors. It also detects the wearer's movements and the extra load, balances it by following the movements and takes over the wearer's physical load. The exoskeleton is effective, because the user does not have to lift an additional load in addition to his body weight, because it is already sensed by the exoskeleton itself and is lifted based on the wearer's movements. As a result, the user of the machine is able to work with overload even for a long time, as he does not actually feel the extra weight, so he does not need more effort, as the frame does it instead. It makes the machine almost the part of the human body, which helps the movement with a direct contact. I suggest to systematize such a special machine like this exoskeleton in order to increase the efficiency of the firefighting. With such a tool, a weight of 30 kg can easily be lifted without harming the human body. Due to the huge number of interventions [26], it will be necessary to use such an equipment in the future. Its application requires further research in the field of the disaster management. However, I do not explain this in this paper, but I intend to analyse it in the future.

REFERENCES

[1] Érces Gergő: A BIM és a tűzvédelem. (The BIM and the Fire Protection part III.) *Védelem Tudomány*, (2019), IV. 4. pp. 1-16.

http://www.vedelemtudomany.hu/articles/01-erces.pdf Download: 27.01.2021.

[2] Érces Gergő - Vass Gyula: Veszélyes ipari üzemek fenntartható tűzbiztonságának BIM alapú fejlesztési lehetőségei. (BIM based sustainable fire safety development opportunities of the hazardous industrial factories) *Védelem Tudomány*, IV. 1. (2019), pp. 131-161.

http://vedelemtudomany.hu/articles/07-erces-vass.pdf Download: 27.01.2021.

[3] Érces Gergő – Bérczi László – Rácz Sándor: The effects of the actively used reactive and passive fire protection systems established by innovative fire protection methods for whole

life-cycle of buildings. *Műszaki Katonai Közlöny*, XXVIII. 4. (2018), pp. 47-58 https://dev2.uni-nke.hu/document/mkk-uni-nke-hu/PDF_2018_4sz.pdf Download: 28.01.2021.

[4] Király Lajos - Restás Ágoston: Industrial safety in explosive work environment view for Hungary. *Ecoterra Journal of Environmental Research and Protection*, XIV. 4. (2017), pp. 15-22. http://www.ecoterra-online.ro/files/1524347009.pdf Download: 27.01.2021.

[5] Pántya Péter: Fire, Rescue, Disaster Management. Experiences from Different Countries. *AARMS – Academic and Applied Research in Military and Public Management Science*, XVII. 2. pp. 77–94.

https://folyoirat.ludovika.hu/index.php/aarms/article/view/1062/385

Download: 28.01.2021.

[6] Rácz Sándor: Firefighting problems in case of large outdoor fires. *Műszaki Katonai Közlöny*, XXVIII. 4. (2018), pp. pp. 23-32. https://dev2.uni-nke.hu/document/mkk-uni-nke-hu/PDF_2018_4sz.pdf Download: 17.01.2021.

[7] Bodnár László – Pántya Péter: The Threat of Forest and Vegetation Fires and the Possibilities of Intervention in Hungary. *Academic and Applied Research in Military and Public Management Science*, XVIII. 3. (2019), pp. 21-31.

[8] Herczeg Gergely – Restás Ágoston: Solutions for the Accessibility of Water Sources for Fire Extinguishment. *Academic and Applied Research in Military and Public Management Science*, XIX. 1. (2020), pp. 55-63

https://folyoirat.ludovika.hu/index.php/aarms/article/view/770/3925

Download: 02.02.2021.

[9] Komjáthy László – Kós György: Thermographic cameras in the service of fire departments. *European Science*, III. 4. (2019), pp. 27-31.

[10] Hesz József: A műszaki mentés eszközeiről tudományosan. (Scientific approach to the technical rescue tools) *Florian Press*, VI. (2009), pp. 244-245.

[11] Himmer Krisztián – Pántya Péter: A különböző tűzoltó sugarak összehasonlító vizsgálatának eredményei. (Comparing results of different fire hoses analyzes) *Hadmérnök*, XIV. 2. (2019), pp. 179-190. http://hadmernok.hu/192_15_himmer.pdf Download: 11.10. 2020.

[12] Vass Gyula - Bleszity János: The analysis of thr process of rehabilitation following disasters. Védelem Tudomány, V. 1. (2020), pp. 98-117

https://vedelemtudomany.hu/articles/07-vass-bleszity.pdf Download: 01.28.2021.

[13] Morrison Nate: The Soldier's Ideal Speed. https://spotterup.com/the-soldiers-ideal-speed/ Download: 15.10.2019.

[14] Urbán Anett – Restás Ágoston: Making body temperature lower to raise the safety level of firefighters' intervention. *Ecoterra Journal of Environmental Research and Protection*, XIV. 1. (2017), pp. 47-51. http://www.ecoterra-online.ro/files/1496321961.pdf Download: 19.05.2019.

[15] Restás Ágoston: *Tűzoltó védőruházat ergonomikus vizsgálata és fejlesztésének lehetséges irányai a beavatkozók komfortérzetének javítása érdekében az éghajlatváltozás hatásainak enyhítésére*. (Ergonomic examination of the protective clothing in case of firefighting and the possible directions for its development in order to improve the comfort of the interveners in order to mitigate the effects of climate change) In. Berek Tamás; Csurgai, József; Farkas Andrea (szerk.): Adaptációs lehetőségek az éghajlatváltozás következményeihez a közszolgálat területén. Nemzeti Közszolgálati Egyetem. Budapest. 2019. pp. 320-350

[16] David Barr - Warren Gregson: A practical cooling strategy for reducing the physiological strain associated with firefighting activity in the heat. Ergonomics, LII. 4. (2009), pp. 413-420.

[17] Jay Carter - Paul Rayson - David Wilkinson: Strategies to combat heat strain during and after firefighting. Journal of Thermal Biology, XXXII. 2 (2007), pp. 109-116

[18] David Degroot – Richard Gallimore- Shawn Thomson: Extremity cooling for heat stress mitigation in military and occupational settings. Journal of Thermal Biology, XXXVIII. 6 (2013), pp. 305–310

[19] Kanyó Ferenc: *A tűzoltók fizikai alkalmasságának felmérése az új évezredben - Laboratóriumi és pályavizsgáló teljesítménydiagnosztikai eljárások alkalmazási lehetőségei a tűzoltók teljesítmény mérésében*. (Assessing the physical fitness of firefighters in the new millennium - Application possibilities of laboratory and career test performance diagnostic

procedures in measuring the performance of firefighters) PhD értekezés. ZMNE. Budapest. 2008.

[20] Varga József: A munkaterhelés és igénybevétel meghatározás lehetséges módszerei. (Possible methods for determining workload and use) Családorvosi Fórum 2003.

[21] Storeshr: https://www.storeshr.com/product_detail.php?c=kaciga%20za%20decu%20duga%20dodatna%20oprema%20vozila%20za%20decu%20na&p=36 Download: 01.05.2020.

[22] Bodnár László: *Az erdőtüzek oltásának hatékonyságát növelő módszerek kutatása és fejlesztése*. (Research and development of methods to increase the effectiveness of firefighting in case of wildfires) PhD értekezés. Nemzeti Közszolgálati Egyetem, Budapest. 2021.

[23] Teknős László: Sustainability aspects of disaster management. *Georgikon for Agriculture: Multidisciplinary Journal in Agricultural Sciences*. XXIV. 4. (2020), p. 103-116.

[24] Ambrusz József – Vass Gyula: Katasztrófavédelem a hadtudomány és a rendészettudomány határán. In: Gaál, Gyula; Hautzinger, Zoltán (szerk.) A hadtudománytól a rendészettudományig társadalmi kihívásoka a nemzeti összetartozás évében. Pécs, Magyarország: Magyar Hadtudományi Társaság Határőr Szakosztály Pécsi Szakcsoport (2020), p. 41-50.

[25] Blesztiy János - Földi László - Haig Zsolt - Nemeslaki András - Restás Ágoston: Engineering science researches and effective government (Part 1.). American Journal of Research Education and development. I. 3. (2017), p. 17-34.

[26] Hesz József – Kovács Zoltán: Mentő tűzvédelem 2019 – legmelegebb év több káreset. *Védelem-Katasztrófavédelmi Szemle*, XXVII. 1. (2020), pp. 32-34

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