Coll. Antropol. **31** (2007) 1: 153–158
Original scientific paper

Simulation of Working Conditions by Maximum Work Load on Firefighters

Hrvoje Lalić[1], Leonardo Bukmir[2] and Mensur Ferhatović[3]

[1] Department of Occupational and Environmental Medicine, Health Center of Littoral – Mountainous County, School of Medicine, University of Rijeka, Rijeka, Croatia
[2] Department of General Practice Medicine, School of Medicine, Health Center of Littoral – Mountainous County, University of Rijeka, Rijeka, Croatia
[3] Public Firefighting Department, City of Rijeka, Rijeka, Croatia

A B S T R A C T

The aim of this research is to find out whether the firefighter manpower is adequate to the requirements in the field under the most severe conditions. It also attempts to test whether firefighters´working ability corresponds to their age. To that purpose 220 Croatian firefighters from the Littoral Mountainous county, 99 professional firefighters from the city of Rijeka, 45 professional firefighters from its suburbs and 76 volunteer firefighters from the suburbs were submitted to load test, fitness test – stepping on the bench for three minutes, repetitive power test – sit – ups lasting 1 minute, and a leap – explosive power test. The fitness test was repeated carrying Dräger's respiratory apparatus PSS 100 with compressed air, so respiratory values were compared before and after the burden of the respiratory apparatus. The results have shown that professional firefighters from the city have the mean increased body mass index (BMI) 26, and professionals from the suburbs BMI 27. In spite of the increased body mass they showed good fitness, spirometric values before and after the load showed neither restrictive nor obstructive ventilation difficulties, which indicates a good condition of cardio respiratory system and also adequate protective equipment. The initial hypothesis has been confirmed: with age, equipped with personnel does not necessarily mean operative equipment, because linear regressive analyses have shown a negative correlation coefficient in relation to repetitive and explosive power. Also, on the average somewhat younger volunteer firefighters are stronger in performing the repetitive power test ($p<0.05$) compared to professional firefighters. Occupational medicine should suggest administrative health measures to improve the accelerated retirement plan and shorten the shifts so that all available firefighters could instantaneously be included in the field intervention.

***Key words**: firefighters, load tests, occupational medicine.*

Introduction

According to professional exposure to burns firefighters besides pilots, furnace workers and those in coke production, bricks and sliced lime are in greatest danger[1]. Also, according to the work-related inhalation of harmful substances firefighters show the highest frequency. The most frequently inhaled substance is carbonmoxide[2]. CO has a great affinity to hemoglobin so the level of carboxihemoglobin is considerably elevated in the plasma of the exposed[3]. Because of a number of dangers that can harm the firefighter's health during interventions, practice and training is an important factor in avoiding injuries[4]. The large firefighting centers carry out severe drills for newcomers with exercises and training that result in higher percentage of injuries than the professional activities later on[5]. Running, steps climbing, rescuing, sit and reach tests, jumping are just some of the exercises for attaining fitness[6]. Such exercises increase aerobic capacity and body strength and decrease body fat and weight[7]. During interventions firefighters wear protective clothing that also help significantly in diminishing the number of injuries[8]. Putting on rubber gloves is already a major step in protecting firemen[9]. Nowadays fire extinguishing is just one of the many tasks the firefighters perform. They often help rescuing people trapped and injured in accidents and other catastrophes. There is additional danger of infections with C hepatitis,

Received for publication December 14, 2006

AIDS and other often fatal viruses[10,11]. Education and information on the importance of vaccination stimulate firemen to undergo vaccination[12]. Besides from the contact with infected blood, gloves protect from various toxical substances, corrosives, acids, alkalis, oxidative and reductive agents[13]. Furthermore, extensive physical strain often results in injuries of the spine lumbar segment[14]. Musculoskeletal injuries occur when the injured are carried in rapid evacuation in unnatural positions but also when landing from a height[15,16]. Besides body injuries firefighters are exposed to increased mental stress, especially when they take part in rescue operations after natural disasters. Mental stress may cause somatic disturbances and heart attack[17]. The occupational medicine physician plays an important role in the timely prevention of PTSD[18]. Disorders in attention and concentration are the best predictors of a chronic PTSD, that is inability to cope with daily stress[19]. Well trained and well equipped operatives will develop fewer symptoms, as well as those with practical stress experience[20].

The objective of this research is to find out how able and trained are firefighters in the Littoral Mountainous county in the republic of Croatia to carry out the demanding operative tasks, i.e. whether the number of trained personnel corresponds to operative functions in the field, or if it diminishes with the age making some teams less efficient. Also efficiency of the equipment and closed respiratory systems, as well as the body reaction to the simulated professional load makes an important part of this research.

Material and Methods

The total number of 220 firefighters from the Littoral Mountainous county, as the referential sample for firemen in the Republic of Croatia, were submitted to medical examinations and the load tests on fitness, explosive and repetive power. The firemen were grouped as follows: professional firefighters from the city of Rijeka N=99, professional firefighters from the suburbs N=45 and volunteer firefighters from the suburbs N=76.

Professional firemen from the city of Rijeka were of the mean age 38.15±8.75 (23–58 range), the mean height was 180.61±6.09 cm (170–197 range). The mean weight was 88.80±12.64 kg (65–140 range). The mean body mass index (BMI) was 26.

Professional firemen from the suburbs were of the mean age 39,31±8.73 (24–54 range), the mean height was 179.37±6.79 cm (166–203 range). The mean weight was 89.40±14.57 kg (69–126 range). The mean body mass index (BMI) was 27.

Volunteer firefighters from the suburbs were of the mean age 34.07±11.02 (16–58 range), the mean height was 180.97±6.09 cm (170–189 range). The mean weight was 85.88±13.66 kg (62–134 range). The mean body mass index (BMI) was 25.

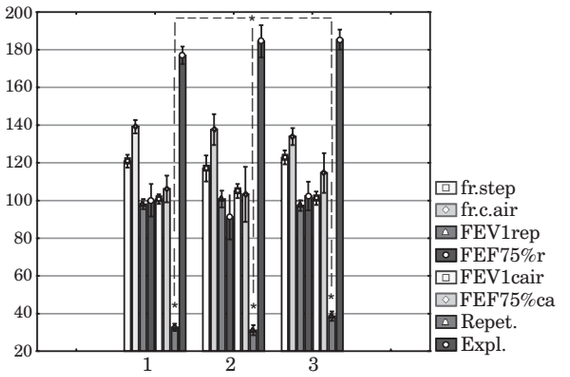
All firemen underwent the fitness test (stepping on 30.5 cm bench for 3 minutes) after which pulse frequency and EKG were taken, the repetitive power tests (sit ups, lifting the body from lying position with ankles fixed lasting 1 minute), where the number of sit-ups per minute was counted, and the explosive power test (the leap). The fitness test was repeated carrying an autonomous respiratory system and the complete firefighting equipment. Before and after the bench fitness test with Dräger's apparatus spirometry was taken by spirometer Mir 1. The computerized 12 channel EKG apparatus Hellige Marquette was used. Firefighters under load used a respiratory mask Dräger Panorama Nova European Standard EN 136:1998 cl 3, CE 0158, a respiratory apparatus with compressed air Dräger PSS 100, with a light bottle of carbon fibers CFK weighting 6.5 kg, capacity 6 liters under the pressure of 300 bar, Bodyguard manometer with scale 0–300 bar, a head-piece Helmet F1 SA12 weighing 1.250 kg CE EN 443:97 and a light assault clothing manufactured by Bristol Uniforms Limited, Fire Technology European Standard EN 469:1995.

Stat Soft statistical program was used, Statistics 6.0. To show relations between specific results Pearson Chi Square test and Kruskal-Wallis test were used as well as correlation matrices and single stream variance analysis, One-way ANOVA analysis.

TABLE 1
REVIEW OF PHYSIOLOGICAL PARAMETERS OF FIREFIGHTERS AT REST AND UNDER FORCED LOAD

Area	N	Age (years) X	H (cm)	W (kg)	BMI	Cond. fr.	Expl. (cm)	Repet. N	Cond. fr.air	FEV1 %	FEF 75 %	FEV1 air%	FEF75 air%
1. City professionals	99	38.15	180.61	88.80	26	120	177	32	139	98	100	100	106
2. Suburb professionals	45	39.31	179.37	89.40	27	117	184	30	137	100	91	105	103
3. Suburb volunteers	76	34.07	180.97	85.88	25	122	185	38	133	97	102	101	114

N – number of examinees, H – height, W – weight, BMI – body mass index, Cond. fr. – pulse after 3 min. bench stepping, Expl. (cm) – explosive power – length of the leap in cm, Repet.N – number of sit-ups in 1 min., Cond.fr.air – pulse after 3 min. bench stepping carrying closed respiratory system with air, FEV1 – forced expiratory volume in the first sec., FEF75 – flow of expiratory air at 75% FVC at rest, FEV1air% – forced expiratory volume in the first sec. immediately after the bench load test carrying respiratory system, FEF 75 air% – flow of expiratory air at 75% FVC after the bench load test and respiratory system.



1 Firefighters from city (professionals), 2 fire fighters from suburb (professionals), 3 firefighters from suburb (volunteers)

*Fig. 1. Differences between physiological parameters of firefighters at rest and under forced load. Fr step – heart frequency after bench load during 3 minutes, fr.c.air – heart frequency after carrying apparatus with air, FEV1rep – FEV1 at rest, FEF75% r – FEF 75% at rest, FEV1 cair – FEV1 after step test carrying apparatus with air, FEF 75% ca – FEF 75% after step test carrying apparatus with air, Repet – one minute sit-ups, Expl – a leap, * p<0.05.*

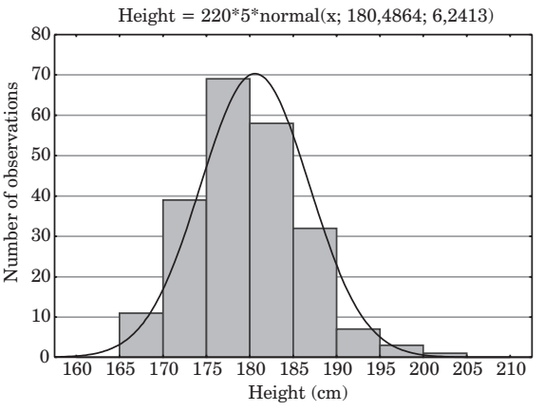


Fig. 2. Changes in the mean height in all examined firefighters.

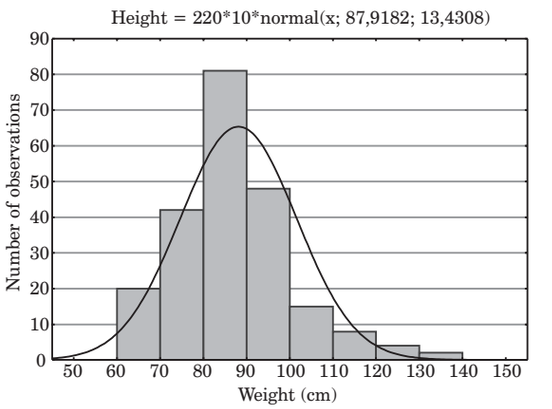
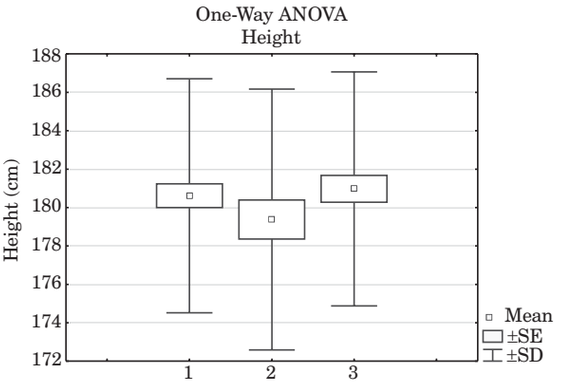


Fig. 3. Changes in the body weight in all examined firefighters.



1 – Professional firefighters from city, 2 – professional firefighters from suburb and 3 – volunteer firefighters from suburb

Fig. 4. Comparison of heights in three groups of firefighters

Results

The body mass index (BMI) worked out on the basis of anthropometrical measurements has shown that there are no significant differences among the tested firemen, although the mean BMI 25 was the lowest in the group of volunteer firefighters whom are somewhat younger than their professional colleagues. The tested firefighters´ spirometric values, forced vital capacity (FVC), forced expiratory volume in first second (FEV1), FEV1% and flow of expiratory air at 75% FVC (FEF 75) did not change considerably either at rest or after the bench load with Dräger´s apparatus with compressed air (Table 1).

The results have shown that the groups of firemen differ statistically significantly in the repetitive power test ($p<0.05$), i.e. the highest count of sit-ups was achieved by volunteer firefighters (Figure 1).

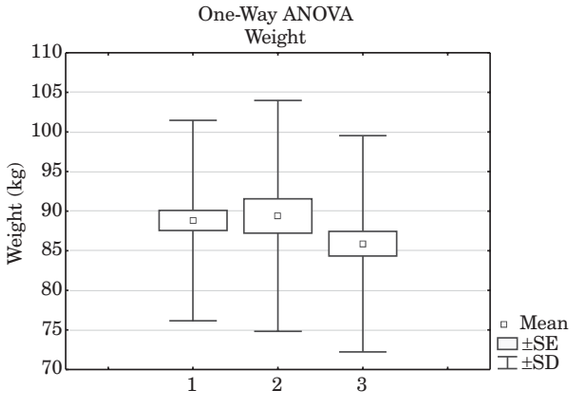
The firemen do not differ significantly either by height or weight while the widest range of St. Dev. of these values was found in professional firemen from the suburbs (Figure 4 and 5).

Linear regression analysis has shown a negative correlation coefficient regarding the relation between the age and repetitive power (Figure 6).

A negative correlation coefficient was also found in the relation between the age and explosive power (Figure 7).

Discussion

Various toxical substances, physical, chemical and biological above the tolerated values in the environment may cause multiple body damage[21]. Extreme loads that firemen may experience in combination with CO can diminish the lung respiratory capacity and increase the risk of cardiac ishemia[22]. Such risk could be substantially decreased by enhanced physical condition and reducing body mass. The Eurofit Croatia study had shown that generally economically active population in Croatia has low aerobic capacity, high obesity and poor locomotive



1 – professional firefighters from city, 2 – professional firefighters from suburb and 3 – volunteer firefighters from suburb

Fig. 5. Comparison of weights in three groups of firefighters

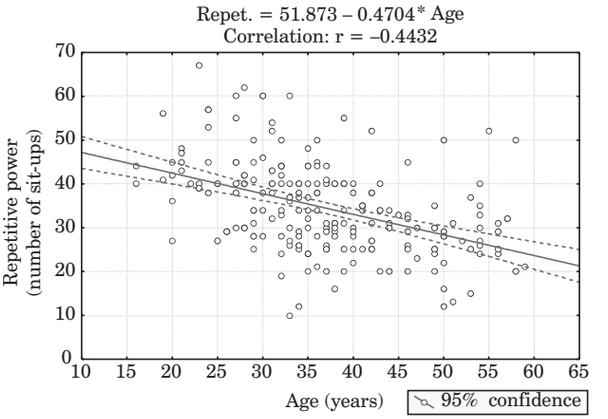


Fig. 6. Linear regression analysis and correlation coefficient between the age and repetitive power

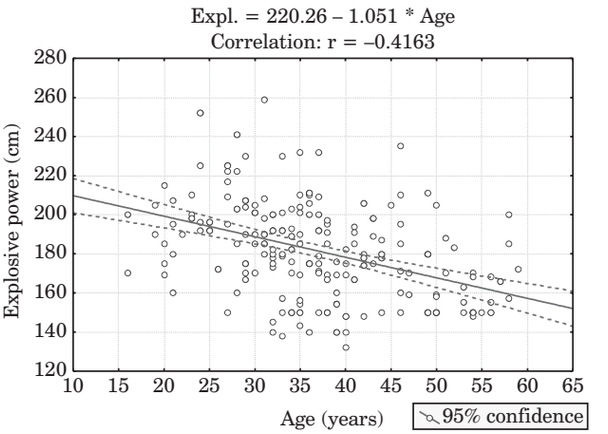


Fig. 7. Linear regression analysis and correlation coefficient between the age and explosive power

performances[23]. Our study has shown that the tested professional firefighters have mean increased BMI, 26 in the city of Rijeka, and 27 in the suburbs. BMI 25 of the volunteer firemen would speak in favor of the tolerated body mass. As regards obesity the tested professional firefighters are within the results of the Croatian study but also of the new international study[24]. Even the young generations show the worrying increase of obesity in the last decade that can be seen at recruits´ examinations[25]. Nevertheless, thanks to specific training, regardless of the increased body mass, firefighters are expected to have an adapted cardiovascular system[26]. Spirometric findings of all firemen were normal and there were no signs of obstructions of upper respiratory tracts. In rare cases spirometry had to be repeated, the findings of restrictive difficulties in ventilation was annulled, i.e. by correct blowing into the spirometer normal respiratory values were obtained. The research departs from some earlier researches in which FEF 75 was considerably decreased in firemen, which indicated a general presence of upper respiratory tract obstruction in firefighters[27]. FEV1 with FEF 75 indicate obstructions of smaller respiratory tracts, but in our subjects the results reached the predicted values. In fact, the spirometric values for FEV1 and FEF 75 were on the average somewhat higher compared to the values obtained only after the fitness step test without carrying a respiratory apparatus with compressed air, which corresponds with the previous studies with spirometric check after carrying a breathing apparatus[28]. It is important to ensure a safe and unobstructed operation of the oxygen regulator system, especially in the field where there is a possibility of catching fire[29]. Generally, as it is well known among the tested firemen, it is important during the action in the field to carry complete protective clothing from elements to chemical protective suit systems (CPSSs)[30,31]. Also small details, like wearing shorts under the protective suit, could reduce a heat stress[32]. Considering the heart frequency, blood pressure, loss of liquid, it has been worked out that the suggested time for carrying a protective suit with a respiratory system is 20 minutes[33]. During the 3 min. step test with Dräger´s apparatus, by which we simulated a quick climbing in a skyscraper in case of fire intervention, cardiovascular system was considerably burdened and firefighters felt intensified fatigue. Besides increased pulse frequencies in sporadic cases extrasystoles occurred registered by EKG and felt manually on artery radialis in the form of superficial pulse especially in older firemen. Therefore the recommended time for carrying a chemical protective suit with a respirator should be taken with a qualified acceptance and definitely shortened if besides wearing the suit heavy manual labor is performed, although the suits are manufactured on the basis of most modern ergonomic principles[34].

In their work firefighters are regularly exposed to mental stress. It is known that it is in the mentality of professional firefighters that they do not like to speak openly or confirm psychical difficulties. To the Perception Stress scale (PSS) question all the subjects answered

that they never or very seldom felt stress, while to the Cope (coping orientation to problems experienced) test to distinguish the styles of coping with stress regarding help and compassion of others in stress situations, almost all the subjects answered that they never or very seldom ask for such help. But in practice the chief of fire department has a long talk with his people to help them disburden themselves and overcome accumulated problems. Critical incident stress debriefing is a known method used by policemen, firefighters and members of rescue efforts[35]. Psychological group therapy enables overcoming stress that occurs almost daily when people are trapped and traumatized in traffic accidents[36,37]. Besides mental difficulties, fireman may show symptoms of fatigue, proneness to infections, feeling of sand in the eyes, myalgia, symptoms that imitate autoimmune disturbances[38]. It is also augmented because firemen work in shifts[39].

In the conclusion, the tested firefighters have shown that despite the increased body mass they do well in the tests checking forced physiological parameters, and that official conditioning is done adequately, as the increased physical activity in itself does not automatically mean an increase in physical fitness[40]. The linear regression analysis has shown that with the age repetitive and explosive power diminishes, which proves the initial doubt, i.e. that the number of operatives does not necessarily guarantee effectiveness. That it is to say that though all firefighters are considered operatives, in an emergency not all can be mobilized. Therefore the program of health protection should include the so-called administrative measures, i.e. an increase of accelerated retirement plan and shortening of shifts.

REFERENCES

1. QUINNEY B, MCGWIN G, CROSS JM, VALENT F, TAYLOR AJ, RUE LW, J Burn Care Rehab, 23 (2002) 305. — 2. VALENT F, MCGWIN G, BOVENZI M, BARBONE F, Chest, 122 (2002) 1865. — 3. DUBICK MA, CARDEN SC, JORDAN BS, LANGLINAIS PC, MOZINGO DW, Toxicology, 176 (2002) 145. — 4. BYLUND PO, BJORNSTIG U, Work, 12 (1999) 117. — 5. SZUBERT Z, SOBALA W, Int J Occup Med Environ Health, 15 (2002) 49. — 6. WILLIFORD HN, DUEY WJ, OLSON MS, HOWARD R, WANG N, Ergonomics, 42 (1999) 1179. — 7. ROBERTS MA, ODEA J, BOYCE A, MANNIX ET, J Strenght Cond Res, 16 (2002) 271. — 8. RABBITTS A, ALDEN NE, SCALABRINO M, YURT RW, J Burn Care Rehabil, 26 (2005) 348. — 9. EDLICH RF, WINTERS KL, MARTIN ML, LONG WB, WERNER CL, GUBLER KD, J Long Term Eff Med Implants, 15 (2005) 161. — 10. RISCHITELLI G, LASAREV M, MCCAULEY L, J Occup Environ Med, 47 (2005) 1174. — 11. CRUTCHER JM, LAMM SH, HALL TA, Am Ind Hyg Assoc J, 52 (1991) 14. — 12. SILK BJ, RIO C, IVANSCO LK, WETTERHALL SF, AUGUSTINE JJ, BLUMBERG HM, BERKELMAN RL, South Med J, 98 (2005) 876. — 13. EDLICH RF, FARINHOLT HM, WINTERS KL, BRITT LD, LONG WB, WERNER CL, GUBLER KD, J Long Term Eff Med Implants, 15 (2005) 303. — 14. WALTON SM, CONRAD KM, FURNER SE, SAMO DG, Am J Ind Med, 43 (2003) 454. – 15. LAVENDER SA, CONRAD KM, REICHELT PA, JOHNSON PW, MEYER FT, Appl Ergon, 31 (2000) 167. — 16. KNAPIK JJ, CRAIG SC, HAURET KG, JONES BH, Aviat Space Environ Med, 74 (2003) 768. — 17. CSEF H, HEFNER J, MMW Fortschr Med, 147 (2005) 147. — 18. MORREN M, YZERMANS CJ, VAN NISPEN RM, WEWERS SJ, J Occup Health, 47 (2005) 523. — 19. WAGNER D, HEINRICHS M, EHLERT U, Am J Psychiatry, 155 (1998) 1727. — 20. DUCLOS P, VIDONNE O, BEUF P, PERRAY P, STOEBNER A, Eur J Epidemiol, 7 (1991) 365. — 21. POTROKHOV OI, DOLGIKH DV, KASIANOVSKIAIA VP, SHEVCHENKO OI, Med Tr Prom Ekol, 7 (1997) 14. — 22. GUIDOTTI TL, Int Arch Occup Environ Health, 1 (1992) 1. — 23. HEIMER S, MISIGOJ DURAKOVIC M, RUZIC L, MATKOVIC BR, PRSKALO I, BERI S, TONKOVIC LM, Coll Antropol, 1 (2004) 223. — 24. SOTERIADES ES, HAUSER R, KAWACHI I, LIAROKAPIS D, CHRISTIANI DC, KALES SN, Obes Res, 10 (2005) 1756. — 25. LALIC H, KALEBOTA N, KABALIN M, Coll Antrop, 30 (2006) 585. — 26. SMITH DL, MANNING TS, PETRUZZELLO SJ, Ergonomics, 3 (2001) 244. — 27. MUSTAJBEGOVIC J, ZUSKIN E, SCHACHTER EN, KERN J, VRCIC M, KEGLEVIC S, HEIMER S, VITALE K, NADA T, Am J Ind Med, 1 (2001) 55. — 28. DONOVAN KJ, MCCONNELL AK, Eur J Appl Physiol Occup Physiol, 80 (1999) 107. — 29. WASHENITZ F, STOLTZFUS J, NEWTON B, KUBINSKI L, Inj Prev, 7 (2001) 34. — 30. PREZANT DJ, BARKER RL, STULL JO, KING SJ, ROTANZ RA, MALLEY KS, BENDER M, GUERTH C, KELLY KJ, J Burn Care Rehabil, 22 (2001) 165. — 31. ILMARINEN R, LINDHOLM H, KOIVISTOINEN K, HELISTEN P, Int J Occup Safe Ergon, 10 (2004) 215. — 32. MCLELLAN TM, SELKIRK GA, Ergonomics, 47 (2004) 75. — 33. RICHARDSON JE, CAPRA MF, J Occup Environ Med, 43 (2001) 1064. — 34. HAVENITH G, HEUS R, Appl Ergon, 35 (2004) 3. — 35. SMITH CL, DE CHESNAY M, Med Law, 13 (1994) 185. — 36. EID J, JOHNSEN BH, WEISAETH L, Int J Emerg Ment Health, 3 (2001) 145. — 37. KANZ KG, SCHMOLLER G, ENHUBER K, HOLZL G, STURM JA, MUTSCHLER W, Unfallchirurg, 105 (2002) 1015. — 38. SLOTTJE P, BIJLSMA JA, SMIDT N, EWISK JW, HUIZINK AC, LEMS WF, VAN HOOGSTRATEN I, WITTEVEEN AB, VAN MECHELEN W, SMID T, Arch Intern Med, 165 (2005) 2278. — 39. TAKEYAMA H, ITANI T, TACHI N, SAKAMURA O, MURATA K, INOUE T, TAKANISHI S, SUZUMURA H, NIWA S, Ergonomics, 48 (2005) 1. — 40. RUZIC L, HEIMER S, MISIGOJ DURAKOVIC, M, MATKOVIC BR, Occup Environ Med 60 (2003) 983.

H. Lalić

Department of Occupational Medicine, Medical School, University of Rijeka, Braće Branchetta 22, 51000 Rijeka, Croatia.
e-mail: hlalic@inet.hr

IZAZIVANJE MAKSIMALNIH OPTEREĆENJA VATROGASACA SIMULIRANJEM RADNIH UVJETA

S A Ž E T A K

Ovim istraživanjem željelo se ustvrditi da li dobra kadrovska ekipiranost profesionalnih i dobrovoljnih vatrogasaca odgovara operativnoj na terenu, te da li radna sposobnost ostaje zadovoljavajuća porastom godina života s obzirom na često teške i opasne radne uvjete. U tu svrhu 220 vatrogasca u Republici Hrvatskoj Primorsko-Goranske županije, podijeljenih na 99 profesionalnih vatrogasaca iz grada Rijeke, 45 profesionalnih vatrogasaca iz okolnih mjesta i 76 dobrovoljnih vatrogasaca iz okolnih mjesta podvrgnuto je testovima opterećenja, step testu, testu repetitivne i eksplozivne snage. Step test je ponavljan uz nošenje respiracijskog aparata, te je pravljena usporedba spirometrije prije i poslije opterećenja, koja nije pokazala znatne razlike. U izvođenju testa repetitivne snage vatrogasci su se razlikovali ($p<0.05$) uz najbolje ostvarene vrijednosti kod nešto mlađih dobrovoljnih vatrogasaca. Linearna regresijska analiza pokazala je negativni korelacijski koeficijent u odnosu životne dobi i repetitivne, kao i eksplozivne snage, što je potvrdilo početnu sumnju u stvarnu operativnu sposobnost svih prisutnih vatrogasaca za sve, pa i najteže uvjete na terenu.