

# HEALTH STATUS AND PHYSICAL FITNESS OF MINES RESCUE BRIGADESMEN

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## Abstract

**Objectives:** The aim of the study was to assess health status of regular and part-time mines rescue brigadesmen. **Material and Methods:** A group of 685 mines rescue brigadesmen was examined within the preventive testing – a basic internal, biochemistry and anthropometric examination, physical fitness testing. **Results:** The average age of the subjects was  $41.96 \pm 7.18$  years, the average exposure in mining was  $20 \pm 8.1$  years, out of that  $11.95 \pm 7.85$  years as mines rescue brigadesmen. Elevated levels of total serum cholesterol (T-CH) and low-density lipoprotein cholesterol (LDL-CH) were found in over 1/2 of the subjects. Systolic hypertension (systolic blood pressure (SBP)  $\geq 140$  mm Hg) was confirmed in 34%, overweight (body mass index (BMI)  $\geq 25$ ) in 62.3% and obesity (BMI  $\geq 30$ ) in 20.4% of the examined mines rescue brigadesmen. The metabolic syndrome was found in 15.2% of persons. The highest physical fitness was found in mines rescue brigadesmen and the lowest in mine officers. Limit values of maximum oxygen uptake ( $VO_{2\max}$ /kg) determined by the management of the mine rescue station were not reached by every 3rd of all mines rescue brigadesmen. Compared with the control group of the Czech and Slovak population, the rescuers are taller, have greater BMI, higher percentage of body fat in all age categories and proportionally to that they achieve a higher maximum minute oxygen uptake; however, in relative values per kg of body weight their physical fitness is practically the same as that of the controls. **Conclusions:** The prevalence of risk factors of cardiovascular diseases and  $VO_{2\max}$ /kg in the group of the mines rescue brigadesmen is comparable with that in the general untrained Czech population.

## Key words:

Metabolic syndrome, Cardiovascular diseases, Physical fitness, Coal mining

## INTRODUCTION

The work of mines rescue brigadesmen belongs among highly physically demanding jobs. The energy expenditure of mines rescue brigadesmen during the work under model conditions in the mining environment is reported by various authors to range from 400 up to 700 W;

however, for short periods of time the value may be as high as around 1000 W [1–3]. The heart rate may occasionally climb to 200 beats per min [2,3]. In addition to the physical strain, the mines rescue brigadesmen are also exposed to psychological stress and often to nearly extreme heat stress, whereby their core body temperature can increase

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up to values around 39°C [1,3]. Working conditions are made still more severe if the work must be performed with breathing apparatus [2,4,5].

Mine rescue work can therefore be carried out only by individuals completely healthy, physically fit and mentally stable and their health status must be regularly screened within regular preventive medical examinations. The preventive testing should include strain test for examination of physical fitness [6] and assessment whether mines rescue brigadesmen meet the efficiency criteria for individual age categories and jobs.

The aim of the study was to assess health status of regular and part-time mines rescue brigadesmen in the Ostrava-Karvina Coalfield (OKC), with particular reference to risk factors for cardiovascular diseases (CVD), and to assay their fitness in terms of their ability to pursue the profession of a mines rescue brigadesman in underground coal mines.

## MATERIAL AND METHODS

During 2012 a group of 685 mines rescue brigadesmen was examined within the mandatory periodic preventive testing in cooperation with the Miners Hospital in Karvina. The group included both mines rescue brigadesmen and officers of the Central Mine Rescue Station in Ostrava and also part-time mines rescue brigadesmen who are the permanent staff of mining companies in the OKC.

The examination consisted of anamnesis questionnaire, basic internal examination including a resting electrocardiography (ECG) (12 leads), basic anthropometric and body composition testing. Percentage of fat (% F) was determined by the bioelectrical impedance analysis (BIA) using tetrapolar monofrequency apparatus Omron BF 511. Biochemical tests included determination of total serum cholesterol (T-CH), high-density lipoprotein cholesterol (HDL-CH) and low-density lipoprotein cholesterol (LDL-CH), triacylglycerol (TAG) and fasting blood glucose. The presence of metabolic syndrome was

evaluated according to American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) criteria (2004) [7]. The metabolic syndrome was considered to be present if 3 out of the following criteria were fulfilled:

- systolic blood pressure (SBP)  $\geq$  130 mm Hg or diastolic blood pressure (DBP)  $\geq$  85 mm Hg or the patient is treated for hypertension,
- waist  $>$  94 cm,
- glycemia  $\geq$  5.55 mmol/l or treated for diabetes mellitus,
- HDL-CH  $\leq$  1 mmol/l,
- TAG  $\geq$  1.7 mmol/l.

In all tested subjects, a continuous gradual test on a bicycle ergometer was performed up to maximum. The load was increased from the initial 25 W at minute intervals by 25 W up to maximum. Lung ventilation, oxygen uptake ( $\text{VO}_2$ ) and carbon dioxide ( $\text{CO}_2$ ) output were continuously recorded during the entire test by the apparatus OXYCON-PRO (Jaeger – Viasys, Germany). Also ECG was monitored continuously (all 12 leads). Blood pressure was measured at 2 min intervals on the left arm at heart level.

The anthropometric measures and indicators of physical fitness between specific professional groups of mines rescue brigadesmen were compared. The results of biochemical testing were compared with the normative values for the Czech population [8] and with the results of similar studies in various professions of male population in the Czech Republic [9]. The results of anthropometric examinations and the indicators of physical fitness of the mines rescue brigadesmen group are discussed in comparison with the testing of physical fitness of the Czech and the Slovak population in 1976 [10] and with the results of physical fitness study in the Australian mines rescue brigadesmen [11].

## STATISTICS

Statistical analysis was performed using descriptive statistics, t-test, correlation analysis and multivariable linear

regression. Statistical tests were evaluated at a significance level of 5%. Statistical software Stata version 13 was used for data analysis [12].

## RESULTS

The mean  $\pm$  standard deviation ( $M \pm SD$ ) age of the group of mines rescue brigadesmen was  $42 \pm 7.2$  years, the average height  $178.2 \pm 6.6$  cm, the average weight  $88.3 \pm 11.7$  kg, body mass index (BMI)  $27.8 \pm 3.2$ , percentage of fat  $23.8 \pm 5.3\%$  and lean body mass (LBM) was  $66.9 \pm 6.8$  kg. The mean exposure reached in the mining industry was  $20 \pm 8.1$  years, out of that  $11.95 \pm 7.85$  years in the rescue profession. Professional and age composition of the group is shown in Table 1.

### Anamnesis data

As much as 12.4% ( $N = 85$ ) of the personnel were treated for hypertension, of whom 29.2% were officers, 8.6% part-time mines rescue brigadesmen and 8% were regular mines rescue brigadesmen. Regular smoking was declared by 26.9% of rescuers, of whom the prevailing majority (74.6%) smoked up to 10 cigarettes per day, 23.8% smoked from 11 to 20 cigarettes daily and only 3 people smoked more than 20 cigarettes a day. Most of the smokers were in the group of regular mines rescue brigadesmen, while fewest smokers were in the group of officers.

Sport activity of the whole study group was surprisingly low. Nearly 1/2 of the study group (48.6%) did not practice any sport or practiced sports only sporadically. Only 26.9% of the personnel practiced sport regularly, more often than twice a week, while 24.5% of the people practiced sport only once a week. The group of regular mines rescue brigadesmen was relatively most sport-active, while the group of officers was least sport-active.

### Results of physical fitness testing and biochemical testing

Basic anthropometric characteristics and the results of physical fitness testing in the group of mines rescue brigadesmen are shown in Table 2. Compared with the control sample of the Czech and Slovak population from the year 1976 [10] the current rescuers are taller, have greater BMI, higher percentage of body fat in all age categories and proportionally to that, they achieve a higher maximum minute oxygen uptake, while in terms of relative values per kg of body weight, their physical fitness is practically the same (Table 2).

Table 3 represents the relative numbers of persons with overweight and obesity in the specific professional groups. Whereas the percentage of obese personnel was practically the same in the both groups of rescuers, the percentage of obese officers was significantly higher ( $p = 0.034$ ). The number of obese individuals increased

**Table 1.** Age structure of the group of mines rescue brigadesmen

Profession	Respondents ( $N = 685$ ) [n (%)]				total
	21–29 years old	30–39 years old	40–49 years old	50–59 years old	
Regular mines rescue brigadesman	4 (2)	72 (37)	109 (55)	12 (6)	197 (100)
Part-time mines rescue brigadesman	33 (9)	135 (38)	158 (45)	25 (7)	351 (100)
Officer	2 (1)	10 (7)	83 (61)	42 (31)	137 (100)
Total	39 (6)	217 (32)	350 (51)	79 (12)	685 (100)

**Table 2.** Basic anthropometric characteristics and the results of physical fitness testing of mines rescue brigadesmen and comparison with Czech and Slovak population

Age group	Mines rescue brigadesmen (2012)			Czech and Slovak population (1976) [10]			p
	respondents [n]	M	SD	respondents [n]	M	SD	
21–29 years old	39			100			
height [cm]		179.8	8.6		177.00	6.80	0.0457
weight [kg]		84.6	13.9		75.80	8.90	< 0.001
body fat [%]		21.9	6.2		13.50	4.40	< 0.001
LBM [kg]		65.6	8.6		63.20	6.20	0.1183
BMI [kg/m <sup>2</sup> ]		26.1	3.3		24.19	1.90	0.0013
VO <sub>2max</sub> [l/min]		3.7	0.6		3.24	0.51	< 0.001
VO <sub>2max</sub> [ml/kg/min]		44.0	4.7		43.20	8.00	0.4451
30–39 years old	217			100			
height [cm]		178.8	6.3		175.80	6.80	< 0.001
weight [kg]		88.0	11.5		78.40	8.90	< 0.001
body fat [%]		23.0	5.4		16.00	4.40	< 0.001
LBM [kg]		67.3	6.5		64.80	6.20	0.0015
BMI [kg/m <sup>2</sup> ]		27.5	3.2		25.40	2.90	< 0.001
VO <sub>2max</sub> [l/min]		3.6	0.5		3.01	0.50	< 0.001
VO <sub>2max</sub> [ml/kg/min]		40.9	4.2		39.30	8.00	0.0685
40–49 years old	350			100			
height [cm]		177.9	6.3		174.20	6.80	< 0.001
weight [kg]		88.6	11.2		79.10	8.90	< 0.001
body fat [%]		24.2	4.9		18.00	4.50	< 0.001
LBM [kg]		66.8	6.4		65.80	6.20	0.1836
BMI [kg/m <sup>2</sup> ]		28.0	3.0		26.10	1.90	< 0.001
VO <sub>2max</sub> [l/min]		3.3	0.4		2.75	0.51	< 0.001
VO <sub>2max</sub> [ml/kg/min]		37.9	4.4		35.80	8.00	0.0136
50–59 years old	79			100			
height [cm]		176.8	7.3		172.50	6.80	0.0001
weight [kg]		89.6	12.7		79.50	8.90	< 0.001
body fat [%]		25.1	5.3		15.60	4.50	< 0.001
LBM [kg]		66.7	7.9		66.70	6.30	0.9999
BMI [kg/m <sup>2</sup> ]		28.6	3.5		26.70	1.90	< 0.001
VO <sub>2max</sub> [l/min]		3.0	0.5		2.49	0.51	< 0.001
VO <sub>2max</sub> [ml/kg/min]		34.3	5.7		32.60	8.00	0.1075

M – mean; SD – standard deviation; LBM – lean body mass; BMI – body mass index; VO<sub>2max</sub> – maximum oxygen uptake.

**Table 3.** Persons with a normal weight, an overweight and obesity

Profession	Respondents (N = 685) [n (%)]			
	normal weight (BMI < 25)	overweight (BMI = 25–29.9)	obesity (BMI ≥ 30)	total
Regular mines rescue brigadesman	36 (18.3)	124 (62.9)	37 (18.8)	197 (100)
Part-time mines rescue brigadesman	68 (19.4)	219 (62.4)	64 (18.2)	351 (100)
Officer	14 (10.2)	84 (61.3)	39 (28.5)	137 (100)
Total	118 (17.2)	427 (62.3)	140 (20.4)	685 (100)

BMI – body mass index.

with age ( $p = 0.015$ ). The overweight was found in 56.4% of the age category < 29 years in the whole study group and obesity in 10.3% of rescuers. In the age category > 50 years, 58.2% of mines rescue brigadesmen were affected by overweight and 29.1% by obesity.

The results of biochemical testing and resting values of blood pressure in the group of mines rescue brigadesmen are shown in Table 4. The high percentage of mines rescuers brigadesmen achieved values of T-CH (54.2%), LDL-CH (65.2%) and TAG (42.5%) beyond the range of the normative values valid for the Czech population [8].

Systolic blood pressure exceeding 139 mm Hg was found in 29.4% of persons and diastolic blood pressure higher than 89 mm Hg was detected in 140 persons (20.4%). New-detected cases of hypertension included systolic hypertension in 148 (21.6%) and diastolic hypertension in 95 (13.9%) of the rescuers. Metabolic syndrome was found in 15.2% of persons.

The multivariate analysis showed high statistically significant positive correlation between maximum oxygen uptake ( $VO_{2max}$ ), BMI and sport activity. Conversely,  $VO_{2max}$  was in statistically significant negative correlation with

**Table 4.** Biochemical testing and resting values of blood pressure in the group of mines rescue brigadesmen

Variable	M	SD	Upper reference level	Respondents	
				total [n]	with the value poorer than the norm [n (%)]
T-CH [mmol/l]	5.26	1.20	≤ 5.00	681	369 (54.2)
LDL-CH [mmol/l]	3.44	0.97	≤ 3.00	679	443 (65.2)
HDL-CH [mmol/l]	1.23	0.32	> 1.00	681	162 (23.8)
TAG [mmol/l]	1.90	1.33	≤ 1.70	680	289 (42.5)
Glycemia [mmol/l]	5.01	0.93	≤ 5.55	680	102 (15.0)
SBP [mm Hg]	129.10	11.97	≥ 140.00	680	200 (29.4)
DBP [mm Hg]	80.20	7.68	≥ 90.00	681	141 (20.7)

T-CH – total serum cholesterol; LDL-CH – low-density lipoprotein cholesterol; HDL-CH – high-density lipoprotein cholesterol; TAG – triacylglycerol; SBP – systolic blood pressure; DBP – diastolic blood pressure. Other abbreviations as in Table 2.

**Table 5.** Multivariate linear regression on the predictors of physical fitness ( $VO_{2\max}$  [l/min]) of mines rescue brigadesmen

Variable	Multivariate linear regression			
	coefficient $\beta$	p	95% CI	
Body mass index	0.096	< 0.001	0.080	0.111
Age [years]	-0.027	< 0.001	-0.032	-0.023
Fat [%]	-0.019	< 0.001	-0.028	-0.010
Smoking				
no	0.000	(base)		
yes	-0.114	0.001	-0.179	-0.048
Sport activity				
no	0.000	(base)		
yes	0.174	< 0.001	0.116	0.232
Profession				
professional rescuer	0.000	(base)		
voluntary rescuer	-0.118	0.001	-0.185	-0.050
technician	-0.243	< 0.001	-0.331	-0.155
Constant	2.394	< 0.001	2.060	2.728

Base – base category; CI – confidence interval.

age, smoking, and percentage of fat. Significantly large age adjusted differences in physical fitness were found between the individual professions. The fitness declined from the highest in regular mines rescue brigadesmen through medium in part-time mines rescue brigadesmen to the lowest in the officers (Table 5).

#### Physical fitness and risk factors of cardiovascular diseases

Table 6 presents correlations between the indicators of physical fitness ( $VO_{2\max}$  and  $VO_{2\max}/kg$ ), percentage of body fat and the value of BMI on one hand and the level of blood lipids and level of blood pressure on the other hand. A significant negative correlation between  $VO_{2\max}$  and T-CH, LDL-CH, TAG, SBP and DBP, and a significant positive correlation with HDL-CH and the ratio HDL-CH/T-CH was found. The percentage of body fat and BMI showed a significant positive correlation with T-CH, LDL-CH, TAG, SBP and DBP, and a negative correlation with HDL-CH and the ratio HDL-CH/T-CH.

#### DISCUSSION AND CONCLUSIONS

The cardiovascular diseases are the major cause of death in the Czech Republic and are also on a top among causes of long-term sickness [13]. The reasons are seen primarily in the life style, inappropriate quantitative and qualitative composition of the diet, increased mental stress [14] and a lack of time for relaxation and sport activities.

Chaloupka and Wolfová (2008) examined a sample of 6387 male Czech population of various professions at the prevailing age of 36–42 years [9]. The highest prevalence of cardiovascular risk factors was found in drivers, fire-fighters and the construction workers, while the lowest in administrative staff and military professionals. A high percentage of individuals with the levels of T-CH (54.2%) and TAG (42.5%) exceeding the norms is consistent with the levels reported by Chaloupka and Wolfová in the most vulnerable professions of fire-fighters and construction workers [9].

Obesity is generally considered to be a significant risk factor for cardiovascular disease. The percentage of body

**Table 6.** Correlation between the indicators of physical fitness and percentage of body fat and risk factors of cardiovascular diseases

Parameter	Correlation coefficient			
	VO <sub>2max</sub> [l]	VO <sub>2max</sub> /kg [ml]	fat [%]	BMI
T-CH [mmol/l]	-0.123*	-0.266*	0.208*	0.172*
LDL-CH [mmol/l]	-0.102*	-0.251*	0.229*	0.190*
HDL-CH [mmol/l]	0.075	0.112*	-0.201*	-0.238*
TAG [mmol/l]	0.044	-0.237*	0.239*	0.223*
HDL-CH/T-CH	0.034	0.276*	-0.310*	-0.303*
SBP [mm Hg]	0.028	-0.211*	0.229*	0.197*
DBP [mm Hg]	0.016	-0.244*	0.252*	0.221*

Abbreviations as in Table 2 and 4.

\*  $p < 0.05$ .

fat, BMI and number of obese persons increased significantly with age in all groups of mines rescue brigadesmen, but the highest increase was noted in the group of officers. The most of obese individuals regardless of age were identified, as expected, in the group of officers (28.5%), the least in part-time mines rescue brigadesmen and regular mines rescue brigadesmen (18.2%, 18.8%, respectively). The number of obese persons in the group of officers exceeds the national average of male 2008 population (23.9%), is the same as the national averages of European countries with the highest percentage of obesity (Greece – 27.9%, and Scotland – 26.6%), [15] but is lower than the percentage of obese Czech drivers (45%) [9].

In comparison with the 2005 Czech population average [13] the average value of SBP in the total group of mines rescue brigadesmen (129.1 mm Hg) was identical. The average value of T-CH (5.26 mmol/l) in the group of mines rescue brigadesmen was slightly lower than the national average. Comparing the group of mines rescue brigadesmen with the group of fire-fighters [9], the mines rescue brigadesmen achieved more favorable levels both of SBP and T-CH. The same prevalence of metabolic syndrome as in our mines rescue brigadesmen (15.2%) was found by Donovan et al. in American fire-fighters [16].

A higher prevalence of metabolic syndrome (20%) in various professions of American male and female population was indicated by Levis et al. [17].

During the recent years, an increasing number of references have reported a positive correlation between obesity and low capability of the cardiopulmonary system and premature death from cardiovascular disease [18–25]. Bucksch et al. (2010) investigated the effect of physical activity on mortality in a group of 3724 men and 3445 women aged 30–69 years [18]. Physical activity decreased mortality of both sexes in persons with normal weight, the same as in persons with overweight and obesity compared to the control group. The results of the study demonstrate the prevalence of physical activity over weight reduction. The faster decline of age related cognitive function in persons with low value of VO<sub>2max</sub> was pointed out by Wendel et al. [26].

Good physical fitness is an important precondition for the performance of some physically demanding occupations, in particular of rescue brigades, such as mine rescuers, fire-fighters and others. Physical fitness is declining with age by about 1% per year both in untrained and in trained individuals. Regarding job retention, it is important for rescuers to keep good physical fitness necessary

for the effective performance of their profession until retirement [6,27]. As shown by numerous studies, a hard physical work itself is not enough to achieve a good physical fitness [11,25]. Work in the industry does not have a character of training load. Training effect can be reached only from physical activity of a dynamic nature and sufficient intensity performed by large muscle groups at least 3 times a week for 20 min [28–30]. Also walking or bicycling to work can bring beneficial effect on physical fitness, but not gardening or work at a cottage [31]. Smoking, on the other hand, is associated with a lower physical fitness [31,32].

A comparison of physical fitness between different populations is difficult due to the considerable differences attributable to the character and arrangement of the strain tests. Based on our experience, the highest values of  $VO_{2\max}$  are reached in continuous gradual tests on a treadmill or a bicycle ergometer in which the load is increased in one minute intervals up to a maximum. The values lower by 5–7% are reached in loads with the particular grades duration of 2–3 min, while the results of the indirect methods might differ in the same tested persons in relationship to the number of grades used by 10 and even more percent [29,33].

The most recent data on physical fitness of the Czech and Slovak adult population was published in the 70s of the last century [10]. In comparison with the control Czech and Slovak population sample from the year 1976 [10], the contemporary mines rescue brigadesmen are taller and heavier and reach higher levels of  $VO_{2\max}$  in the individual age categories. In the relative values per kg of body weight, the physical fitness of the current mine rescuers does not differ from the Czech and Slovak population in 1976.

The same conclusion is valid for the present population aged 17–20 that is taller, heavier and has proportionally better physical fitness in comparison with the population of the same age from the year 1976. However, in

the relative values per kg of body weight, the physical fitness of both populations is identical [34].

Comparable anthropometric values and physical fitness detected by extrapolation of the last grade of the step-test in Australian mines rescue brigadesmen were found by Stewart et al. [11]. Rather lower values of  $VO_{2\max}$  detected by the indirect method in the Indian miners ( $42.4 \pm 2.03$  ml/kg for the age group 20–29 and  $34.2 \pm 3.38$  ml/kg for the group 50–59 years), have been reported by Saha et al. [35]. Comparable values of  $VO_{2\max}$ /kg were indicated using linear extrapolation of sub-maximal values in a large population of American men and women aged 18–59 by Lewis et al. [17].

Cardio-pulmonary fitness varied according to occupation. Professions with the lowest physical activity at work (administrative staff) included the highest number of individuals with a low fitness; in contrast, the highest values of  $VO_{2\max}$ /kg were found in the construction workers ( $49.5$  ml/kg) [17]. Even higher values of  $VO_{2\max}$  found by maximum gradual test on a bicycle ergometer ( $53$  ml/kg) in mountain rescuers aged  $45 \pm 8.9$  were reported by Callender et al. [36]. The highest values of  $VO_{2\max}$ /kg that are reached in the top high endurance-trained sportsmen varied around 80–90 ml/kg [29]. On the other hand, reports are accessible suggesting a potential risk of more frequent prevalence of atrial fibrillation in high-endurance-trained sportsmen [37,38].

The work of mine rescuers demands oxygen uptake ranging from  $1.12 \pm 0.3$  to  $2.16 \pm 0.6$  l/min during emergency situations in mines, depending on the task being performed [1]. But in short term periods it may reach up to around 3 liters per min [2]. This corresponds to the value of  $VO_{2\max}$ /kg  $\geq 38$  ml/min for an average rescuer who is 180 cm tall and has the total body weight of 80 kg, % F  $\leq 20\%$ , LBM 64 kg and BMI  $\leq 25$ . The limit quoted above was not fulfilled by 30% of the total group of rescuers. It is necessary to implement measures intended to improve health status and physical fitness of mine rescuers,

such as changes in lifestyle and dietary habits, including regular endurance training as part of the training program. According to Kampmann et al. (1977) a regular training is necessary for keeping a required physical efficiency during the whole productive age of a rescuer, and the intensity of the load during the training must be comparable with the load during an actual intervention [3].

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