

Research on labor consumption and rescuers' physiological parameters progress in the case of practical training in a mobile training facility

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Abstract. An important factor in ensuring success in an intervention operation in dangerous environments lays in the training process, in conditions as close as possible to real intervention situations, as well as the manner of setting up rescue teams. In order to organize the intervention process as efficiently as possible, when setting up rescue teams we must take into account work consumption and physiological parameters achieved by members of the rescue teams during practical training carried out within the mobile training facility. In case of special incidents, the rescue intervention can take place in areas with small (limited) sections, spaces with high temperature, in low visibility conditions, which would make rescuers' intervention even more difficult. Conditions mentioned above can be easily created within the rescuers' mobile training facility, endowment of INSEMEX Petroșani, facility that through its equipment and facilities, allows monitoring of labour consumption and physiological parameters of rescuers throughout and in all training situations. The current paper presents training methods of intervention and rescue personnel within the mobile training facility and progress of work consumption / physiological parameters of rescuers throughout these practical exercises, with the aim of preparing intervention and rescue teams for situations close to real ones.

1 Introduction

When toxic gases are released as a result of damage or the air composition is qualitatively changed, it is necessary to protect the airways of persons caught in this area and those who enter the area to evacuate the injured and eliminate the damage, with respiratory protection devices [1].

Respiratory protection devices allow the rescuers to move over large areas, regardless of the nature or concentration of toxic gases. Respiratory protection devices are used for interventions in areas where the air has undergone qualitative changes and is not breathable safely without providing airways with protection.

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Intervention and rescue in flammable toxic / explosive environments may only be carried out by personnel trained and authorized in this respect, by personnel using individual breathing equipment [2].

The decisive factor in ensuring the success of an intervention and rescue operation in toxic or chemical aggressive environments resides in the optimal and efficient design of a rescue personnel's training process including closed-space interventions.

During training, the following psychophysiological objectives are pursued: learning motor skills, developing psychological and physical qualities of motor activity: speed, strength, skill, will, perseverance, self-confidence, courage, determination, initiative [3].

Learning and developing motor skills is achieved with participation of the central nervous system, that ensures efficiency of body functions and through it a high level of activity of the locomotor apparatus. It also represents a "training of the internal organs" that precedes exercise.

The paper presents new types of training methods for intervention and rescue personnel in the mobile workout facility and the determination of work consumption / physiological parameters of rescuers throughout these practical exercises, with the aim of setting up intervention and rescue teams, teams that have rescuers whose physical performance and physiological parameters have close values. This is an determining factor in the success of an intervention in case of a major event [4].

2 Presentation of the mobile workout facility

For safety and health at work of intervention and rescue personnel in toxic/ explosive/ flammable environments and for efficiency of actions undertaken, rescuers must be physically and psychologically prepared and trained. Such training can be achieved by using a modern training facility (mobile facility) that can be made available to any economic agent, regardless of place and nature of activity carried out [5].

The mobile training facility (fig.1) has a complex character, this characteristic being given to the fact that it contains tanks, piping, niches, gas channel, etc. The facility is designed to allow training for rescue in confined spaces.



Fig. 1. Mobile training facility

3 Calculation of labour consumption in rescuers' training exercises

In the conditions of working with the respiratory protection device, there are a number of factors that contribute to the work becoming stressful. Usually, those who work under the protection of the respiratory protection device, in addition to carrying a device that weighs 14-18 kg, are subject to actions of great difficulty, namely ensuring their own security, saving lives, performing urgent and highly qualified activities (insulation of damaged areas, work in areas with water, transport of materials or injured people through low profile workings, etc.) in harsh microclimate conditions (high heat and humidity), toxic environment, smoke [6].

It follows that the physical effort of the rescuers is intense because of conditions mentioned above.

During exertion, body's adaptation is ensured on one hand by nervous control and on the other hand by neuro-hormonal control. As an expression of functional adaptation tendency, a series of changes in body's organs and systems happen, changes that externalize mostly in cardiovascular activity. Cardiovascular adaptation is best observed as accelerated heart rate. In exceptional cases, at great efforts, heart rate can reach 120-150 beats per minute or even 200 beats per minute, from a normal of 60-70 at beats per minute [7].

Heart rate adjustment begins immediately after the initiation of effort, first with an increase over the necessary followed by stabilization at a level that remains constant, if effort is constant. After the effort ends, return to normal is performed in two stages: first by a sudden decrease at the beginning, followed by a slow and progressive, sometimes wavelike, decrease.

Another manifestation of circulatory changes during exertion is the increase in blood pressure, which is proportional to the intensity of exertion, in this situation, both maximum and minimum being of interest. After finishing the training, tension returns to normal, a return that depends on the intensity of effort and fitness of the person who performed the training. In the first minutes, blood pressure values fall below the rest figure, then rise to normal values. In case of inadequate adaptation of the cardiovascular system, maximum blood pressure drops suddenly before the end of the exercise, so the heart is at the limit of its resources [8].

After the effort ends, muscle masses that were in full activity still need a certain period of time to eliminate the substances of wear, a period that is a function of the mechanical work performed.

Repeated physical activity causes the circulatory system to adapt to increased demands, heart increases in volume, the circulatory force increases, and its frequency decreases. As you train, your blood pressure settles to lower and lower values [9].

The phenomenon of fatigue, that occurs during training, represents the totality of subjective and objective phenomena that occur as a result of physical exertion and involves accompanying sensations of effort as well as consecutive repair phenomena. It is characterized by more or less prolonged reduction of work capacity, determined by duration and intensity of effort, being a signal that sets in motion a complex of functional processes. Fatigue shows great differences from individual to individual. When it comes to fatigue, there is a favourable situation, obtained through training and lifestyle, so the possibility of positively influence the phenomenon.

Practical training exercises on ergometer and exercise bicycles were performed in order to determine how pulse, blood pressure and critical frequency of fusion evolve in rescuers equipped with respiratory protection device, performing great efforts (approx. 20,000 kgm a performance which requires the body an intense effort). The effort is intense in these cases and pulse changes must be fall between 150-175 pulses per minute.

In order to cope with such an overload, proper training of rescuers is required and periodic tests to determine the degree and aptitude for effort are performed, tests easily performed by the rescue station's doctor [10].

The effort performed by rescuers in the mobile training facility is expressed in Kgm and, depending on the facilities they work on, is calculated with relationships in which the following are used:

- weight of the rescuer along with the respiratory protection device, (Kg);
- number of repeated passes;
- activity duration, (minutes), without including resting periods;
- length of the training route, (meters);
- weight lifting height, (meters);
- number of tractions.

These calculations also use numerical values (0,055, 0,25, 0,35, 0,5) experimentally established, based on measurements of energy consumption.

The amount of work performed in the mobile training facility must be equivalent to 20.000 Kgm for rescuers having more than 2 years of activity.

During the practical training process, rescue teams performed several types of exercises with different degrees of difficulty, the labour consumption being calculated for each one.

Testing was carried out for 6 activities:

- climbing the infinity ladder;
- cycling on the bicycle - ergometer;
- walking and running on the treadmill;
- traction on the ergometer;
- press on the stepper;
- traversing the closed space circuit.

Blood oxygen saturation and pulse measurements were performed for each rescuer, these being repeated after the end of each activity of the six tested.

3.1. Calculating labour consumption for climbing the infinity ladder

Rescuers will practice climbing on an infinity ladder, having the possibility to electronically measure speed of movement. It has automatic safety systems, photoelectric sensors, special braking circuit and automatic electronic start. A free wheel on the transmission shaft drives the infinity chain only by means of body weight. If the nominal value is reached by the person training, the device automatically stops. Without readjustment of the counter or climb speed, several people can train successively under exactly the same conditions. The climbing speed can be set between 5 and 25 meters / minute according to climbing distance. (Fig. 2).



Fig. 2. Infinity ladder

The amount of work performed for climbing the infinity ladder for 5 minutes (100 Kg - the weight of rescuer and respiratory protection device, 75 meters - distance travelled at a ladder speed set at 15 meters / minute):

$$A_1 = 0,35 \cdot 100 \cdot 75 = 2625 \text{ Kgm} \quad (1)$$

3.2. Calculation of labour consumption for ergometer bicycle

Training programs work on the principle of independent speed resistance so that the pedalling frequency can be arbitrarily chosen without thereby influencing the power. The device has two manual and two programmable training programs as well as an automatic pulse power adjustment program. Pulse adjusting power is guided by pre-set pulses for the training time.

The support frame is a welded, robust construction, which incorporates a silent pedal drive system, consisting of chain and timing belt (Fig. 3).

The amount of work performed for cycling for 5 minutes (500 watts - the average power of the bicycle, 100 meters - the distance covered within 5 minutes):

$$A_2 = 0,055 \cdot 500 \cdot 100 = 2750 \text{ Kgm} \quad (2)$$



Fig. 3. Ergometer bicycle

3.3. Calculation of labour consumption for walking and running on the treadmill

Treadmill is a device for testing the load condition with an adjustable travel speed between 1 and 25 km / h and with a variable inclination between 0 and 30%. Oxygen consumption per body Kg, depends in this case, on the speed and angle of inclination. The device is effectively used for bloodstream training, lung function testing, stress tests and orthopaedic performance testing. (Fig. 4).

The amount of work performed for walking on the treadmill, at a speed of 5 km / h, for 5 minutes (100 Kg - the weight of rescuer and respiratory protection device, 400 meters - distance travelled within 5 minutes):

$$A_3 = 0,055 \cdot 100 \cdot 400 = 2200 \text{ Kgm} \quad (3)$$



Fig. 4. Treadmill

3.4. Calculation of labour consumption for performing traction on the ergometer

The ergometer is used for training rescuers, the workload performed allowing a correct analysis of the physical capacity of person being trained. The weight is scanned by magnetic switches at the top and bottom. This ensures that the counter includes only those tests in which the weight reaches the stop (Fig. 5).

On a steel frame, a 22 kg weight slides on bearings. The weight drop is attenuated by a system fitted at the lower end point. The 1-meter-long traction cable is directed over a roller.

The amount of work performed to lift a weight on the ergometer (22 kg – weight lifted, 100 - number of repetitions 50 pulls and 50 descents):

$$A_4 = 22 \cdot 100 = 2200 \text{ Kgm} \quad (4)$$



Fig. 5. Ergometer tractions

3.5. Calculation of labour consumption for pressing on the stepper

The performance level for pressing on the stepper can be adjusted between 0 and 600 watts. The speed range can be adjusted between 1 and 130 rotations / minute (Fig. 6).

The amount of work performed to press the stepper (100 Kg - weight of the rescuer and the respiratory protection device, 100 meters - distance covered within 5 minutes):

$$A_5 = 0,25 \cdot 100 \cdot 100 = 2500 \text{ Kgm} \quad (5)$$



Fig. 6. Stepper

3.6. Calculation of labour consumption to cover the confined spaces circuit

The training space is built of metal structure, on several levels in the form of interconnected cells, so that training tracks with varying degrees of difficulty can be created.

The confined spaces track within the mobile training facility is provided with pressure sensors placed in the floor, so that presence of rescuers on route is monitored.

The confined spaces track consists of horizontal, vertical and inclined movement areas with a length of 800 mm, a width of 900 mm and a height of 1000 mm.

The training area in confined spaces comprises 28 individual cells interconnected with each other, superimposed on 2 levels, the lower level - level zero, comprises 14 cells and the upper level - level one comprises 14 cells, resulting in a training route length of 22 meters.

The following types of blockers are positioned on the track: circular hatch, square hatch, oblique blocker, upper horizontal blocker, lower horizontal blocker, right vertical blocker, left vertical blocker, circular tunnel with a minimum diameter of 600 mm and minimum length of 1200 mm, circular blocker. These types of blockers are interchangeable, so that several training routes with different degrees of difficulty can be configured (Fig. 7).

The amount of work performed to cover the track, on all fours, with 3 repetitions (100 Kg - weight of the rescuer and the respiratory protection device, 22 meters - distance travelled):

$$A_6 = 0,5 \cdot 100 \cdot 22 \cdot 3 = 3300 \text{ Kgm} \quad (6)$$

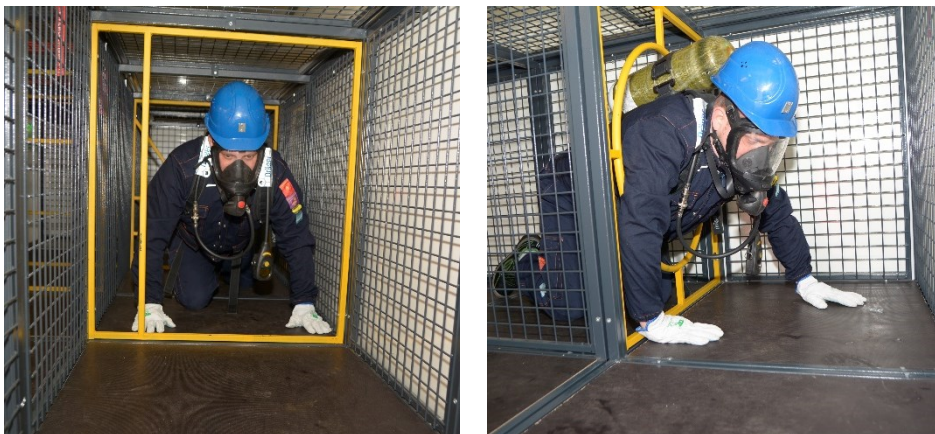


Fig. 7. Confined spaces track

The total amount of work performed by each rescuer in the mobile training facility is:

$$A = \sum A_1 \div A_6 = 2625 + 2750 + 2200 + 2200 + 2500 + 3300 = 15.575 \text{ Kgm} \quad (7)$$

During the training of rescuers in the fitness compartment and in the confined spaces circuit, the rescuers had constantly monitored the physiological parameters (heart rate, blood oxygen saturation, etc.) using the telemetry system. The measurements were repeated after the end of each activity.

The quantification of the physiological parameters was performed by means of the Zephyr™ BioModule type sensors, which record data during the training / simulation and allow the download of the data through the software.

The physiological parameters monitored during a training were:

- Heart rate (expressed in beats / minute);
- Respiration rate (expressed in breaths / minute);
- Skin temperature (expressed in °C);
- Oxygen saturation in the blood.

For this particular track, blood oxygen saturation and pulse are represented in table no. 1, and graphically shown in Figures 8 and 9.

Table 1. Blood oxygen saturation and pulse measurements

No.	Activity	Subject 1		Subject 2		Subject 3	
		Pulse	SpO ₂	Puls	SpO ₂	Puls	SpO ₂
1	Climbing the infinity ladder	101	96	116	96	113	97
2	Ergometer bicycle	144	98	107	97	116	98
3	Treadmill	120	96	103	97	120	96
4	Ergometer tractions	162	98	138	97	115	96
5	Stepper	127	97	121	99	135	98
6	Confined spaces track	133	98	137	98	126	98

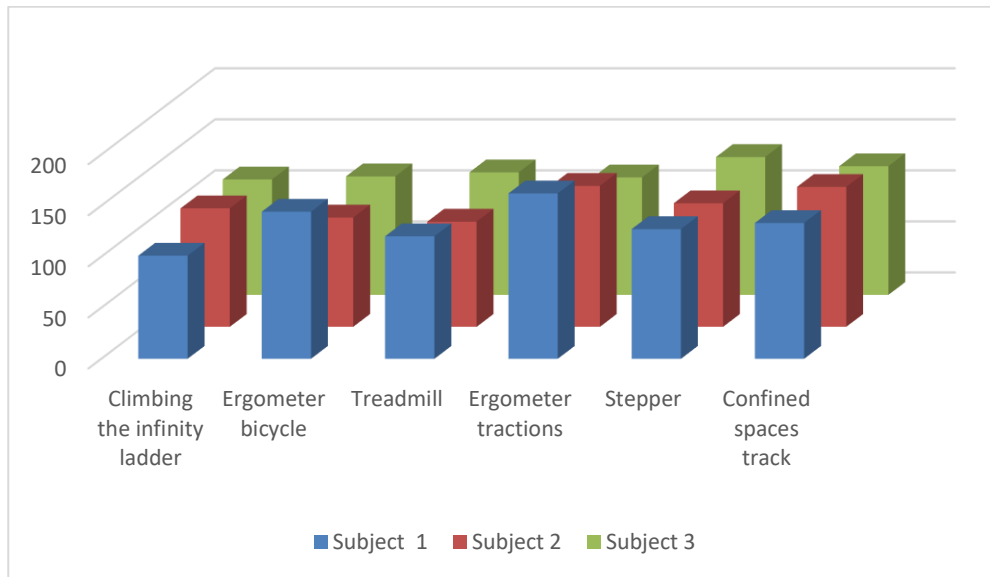


Fig. 8. Pulse variation

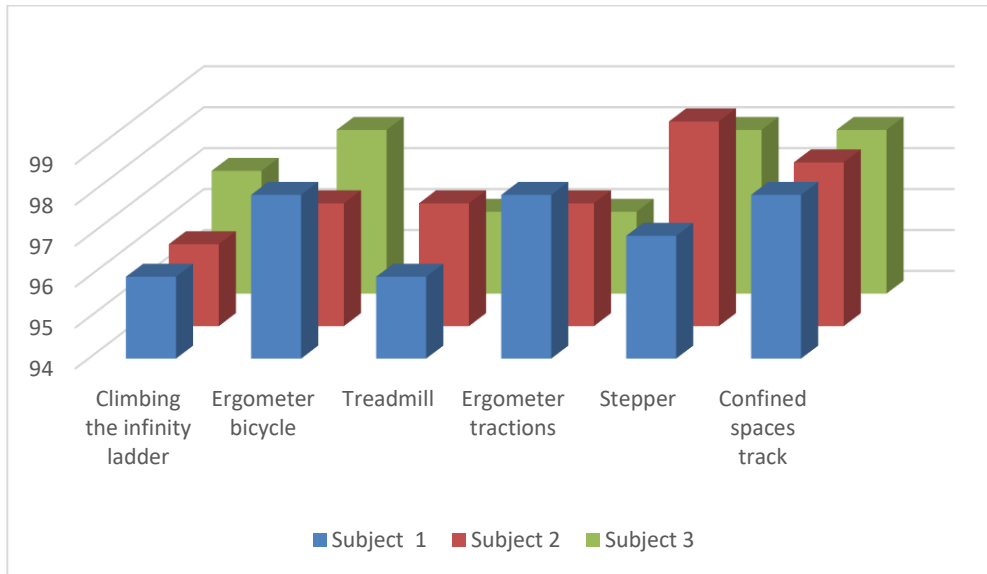


Fig. 9. SpO₂ variation

4 Conclusions

Rescuer's training within the mobile training facility leads to increased levels of safety and health at work, by increasing the capacity to act in high safety conditions, in case of damages, accidents, disasters, etc.

Development of a mobile training facility led to development of the practical training infrastructure of intervention and rescue personnel in toxic/ explosive/ flammable environments, allowing for research studies with the final objective of elaborating and implementing selection and mobile facility training procedures for intervention and rescue teams working in confined spaces, both within INCD INSEMEX as well as at economic agent's rescue stations.

Various training scenarios with various degrees of difficulty can be created within the mobile facility, allowing simulation of intervention activities in limited, horizontal and vertical spaces, environment with low visibility, high temperature and humidity, etc., aiming at the training intervention and rescue teams for situations close to real ones.

The possibility of constant monitoring of rescuer's physiological parameters (heart rhythm, blood pressure, blood oxygen, etc.) during training, with the help of equipment provided by the mobile training facility.

During the practical training process, the rescue teams performed several types of exercises with different degrees of difficulty, labour consumption being calculated for each one. Testing was carried out for 6 activities: climbing the infinity ladder, cycling on the ergometer bicycle, walking and running on the treadmill, traction on the ergometer, pressing on the stepper and going through the confined spaces track.

Blood oxygen saturation and pulse measurements were performed for each rescuer. Measurements were repeated after the end of each activity. Analysis of these measurements, showed that subject no. 3 had a smaller variation in pulse and blood oxygen saturation.

By using the mobile training facility endowment of INCD INSEMEX Petroșani, measurements of physiological parameters can be made for an entire team of intervention and rescue personnel and by comparing them, rescue teams with similar parameters can be set up to streamline the intervention and rescue activity.

Benefits achieved by the economic agents, beneficiaries of the training - authorization activity of intervention and rescue personnel in toxic / explosive / flammable environments which, by using the mobile facility, will ensure an increase in health and safety at work, accident prevention capabilities, and more effective protection of patrimony susceptible to being destroyed or disabled by accidents or break-downs.

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