

Studies regarding the structuring of physical effort of rescuers in the process of practical training in the mobile training facility

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Abstract: The rescuer's performance falls into the category of "hard work", in terms of effort, far exceeding the average overall labor consumption of the worker from the active fronts of work. This character, of hard work, is also imprinted by the fact that the professional effort contains several static components and large amplitude oscillations, regarding the level of maximum efforts. The longer they last, the harder is the work. Training is a process of psychophysiological preparation through which an increased performance is obtained in the professional activity of rescuers. The maximum performance is obtained by raising the functional capacity of the body to the highest degree. For this it is necessary to use the systematic and methodical exercise according to pedagogical rules. The paper presents the evolution of physiological parameters, as well as the structuring of the physical effort of rescue personnel in the process of practical training in the mobile training facility, with the aim of preparing rescue teams for situations close to real ones. The mobile training facility consists of a physical training space (endless ladder, impact device, treadmill, elliptical bike, stepper), an indoor training circuit and a control room that allows the coordination of all activities.

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].

Breathing apparatus allow the intervention personnel to move over large areas, regardless of the nature or concentration of toxic gases. Breathing apparatus are used for interventions in areas where the atmosphere has suffered qualitative changes and is not breathable safely without providing airways with protection.

Intervention and rescue in flammable toxic / explosive environments may only be

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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.

The intensity of the performances used during the training are conditioned by:

- the individual possibilities of the rescuer;
- level of training;
- type of exercises;
- external conditions of development.

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 flammable / toxic / explosive surroundings and for efficiency of actions undertaken, intervention personnel must be physically and psychologically prepared and trained. Such training can be achieved by using a modern training facility that can be available to any economic agent, regardless of place and nature of activity carried out [5].

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



Fig. 1. Mobile training facility.

3 Calculation of labour consumption in intervention personnel 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. 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.

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.

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. 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.

The effort performed by intervention personnel 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 and 0,5) experimentally established, based on measurements of energy consumption.

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 photoelectric sensors, safety systems, automatic electronic start and special braking circuit. 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, more people can train successive 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. Climbing the infinity ladder.

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

$$A1 = 0,35 \cdot 100 \cdot 75 = 2625 \text{ Kgm} \quad (1)$$

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 equipment has manual and programmable training programs and 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):

$$A2 = 0,055 \cdot 500 \cdot 100 = 2750 \text{ Kgm} \quad (2)$$



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%. Consumption of oxygen per body Kg, depends on the angle of inclination and the speed of equipment. The device is used effectively for lung function testing, stress tests, bloodstream training, 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 intervention personnel and breathing apparatus, 400 meters - distance travelled within 5 minutes):

$$A3 = 0,055 \cdot 100 \cdot 400 = 2200 \text{ Kgm} \quad (3)$$



Fig. 4. Walking and running on the treadmill.

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

The ergometer is used for training intervention personnel, 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).

A 22 kg weight slides on bearings on a steel frame. A system fitted at the lower end point dims the weight drop. 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):

$$A4 = 22 \cdot 100 = 2200 \text{ Kgm} \quad (4)$$



Fig. 5. Traction on the ergometer.

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 500 watts. The speed range can be adjusted between 5 and 150 rotations / minute (Fig. 6).

The amount of work performed to press the stepper (100 Kg - the weight of intervention personnel and breathing apparatus, 100 meters - distance covered within 5 minutes):

$$A5 = 0,25 \cdot 100 \cdot 100 = 2500 \text{ Kgm} \quad (5)$$



Fig. 6. Pressing on the 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 intervention personnel 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.

On the track are positioned the following types of blockers: oblique blocker, upper horizontal blocker, lower horizontal blocker, right vertical blocker, left vertical blocker, circular hatch, square hatch, 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 - the weight of intervention personnel and breathing apparatus, 22 meters - distance travelled):

$$A6 = 0,5 \cdot 100 \cdot 22 \cdot 3 = 3300 \text{ Kgm} \quad (6)$$

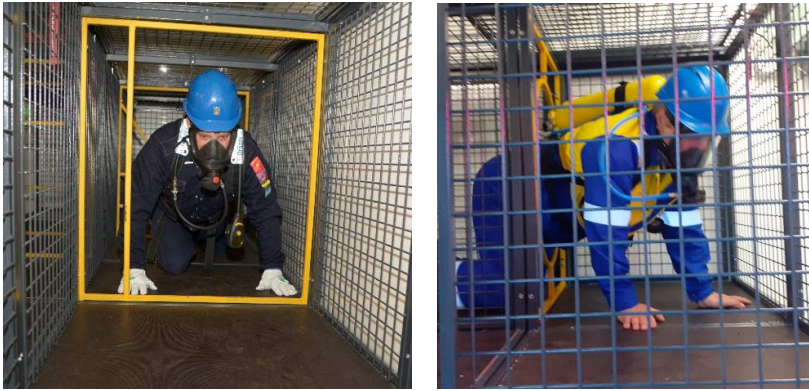


Fig. 7. Cover the confined spaces circuit.

The total amount of work performed by each intervention personnel in the training mobile polygon is:

$$A = \Sigma AI \div A6 = 2625 + 2750 + 2200 + 2200 + 2500 + 3300 = 15.575 \text{ Kgm} \quad (7)$$

During the training of rescuers in the fitness compartment and in the confined spaces circuit, the rescuers had constantly monitored the physiological parameters 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.

Blood oxygen saturation and pulse, for this particular track, are represented in table no. 1.

Table 1. Blood oxygen saturation and pulse measurements.

No.	Activity	Subject 1		Subject 2		Subject 3		Subject 4	
		Pulse	SpO ₂	Pulse	SpO ₂	Pulse	SpO ₂	Pulse	SpO ₂
1	Climbing the infinity ladder	121	96	126	96	123	97	122	98
2	Ergometer bicycle	144	98	137	97	126	98	131	97
3	Treadmill	120	96	113	97	121	96	118	97
4	Ergometer tractions	142	98	138	97	135	96	132	99
5	Stepper	127	97	121	99	128	98	124	98
6	Confined spaces track	133	98	137	98	126	98	131	97

Blood oxygen saturation and pulse, for this particular track, are represented graphically in figures 8 and 9.

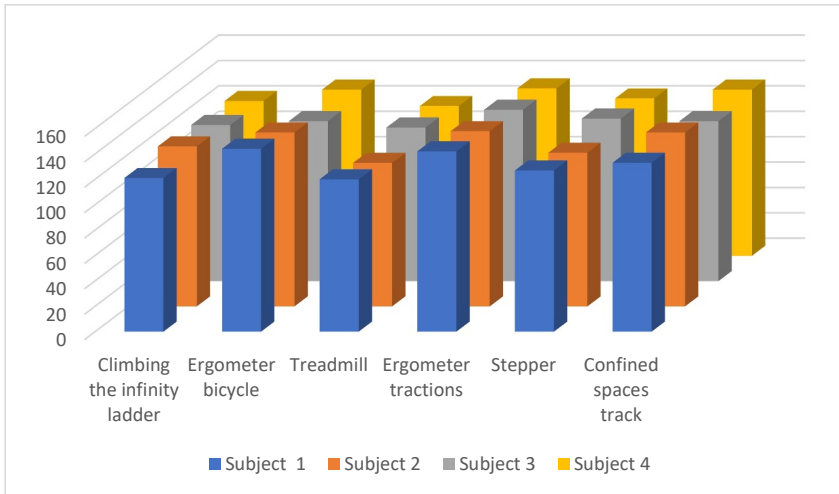


Fig. 8. Pulse variation.

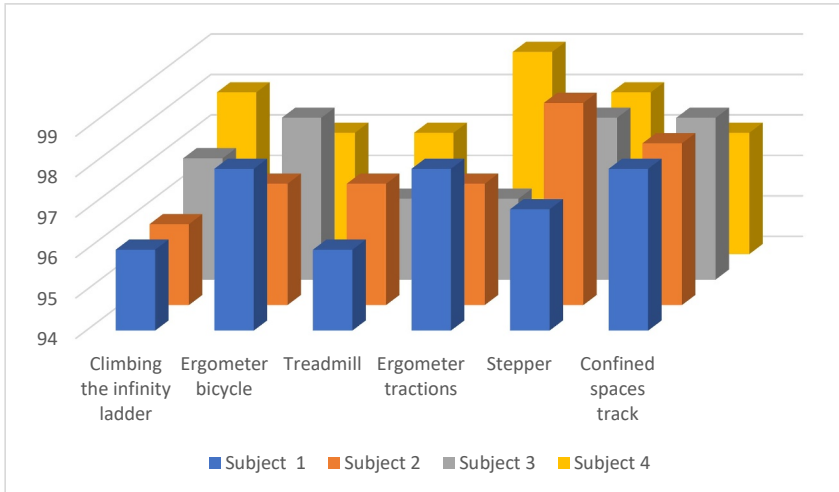


Fig. 9. SpO₂ variation.

4 Conclusions

Intervention personnel 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 intervention personnel physiological parameters (blood pressure, heart rhythm, blood oxygen, etc.) during training, with the help of devices provided by the training mobile polygon.

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 explosive / toxic / flammable environments which, by using the training mobile polygon, 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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