RESEARCH REGARDING CHANGES IN RESCUERS'S HEART RATE DURING TRAINING EXERCISES

Daniel PUPĂZAN, Artur George GĂMAN*, Cosmin ILIE*, Alin IRIMIA***

Abstract:

Under conditions of intense effort, physiological parameters (heart rate and blood oxygen saturation) suffer significant changes that depend largely on the functional characteristics of the respiratory system, which in turn is in close correlation with the degree of the body training and physical exertion. Blood oxygen saturation (SpO2) represents an indicator of the overall blood oxygenation, being used in cardiovascular and respiratory monitoring.

Heart rate (pulse) is commonly used in remote monitoring, because it allows an assessment of the overall condition of the rescuer, heart rhythm disturbances being recorded promptly and variations being easily differentiated from abnormal / normal. This parameter provides an indication of cardiovascular function. Pulse sampling is made by automatic devices which are frequently using photoelectric plethysmography method for taking measurements at peripheral arteries level.

Key words: heart rate, blood oxygen saturation, respiratory system, intense effort

1. Introduction

Training is a preparatory psycho physiological process which yields higher (maximum) work efficiency, in the rescuer's professional activity. The maximum efficiency is obtained by raising the functional ability of the body to the highest degree. This requires the use of systematic and methodical exercises, which follow pedagogical rules.

Professional activity asserts a further demand on biological adaptation, defined by the notion of "professional effort."

Professional effort is represented by all adaptive changes of the body during work (motor sensorial and neuropsychological strains).

Professional effort may be classified as follows: physical, sensorial, neuro-psychic, having different weights in the work performed. By type of effort that prevails, work may be classified as physical effort work, sensorial effort work and mental effort work.

Professional physical effort is defined as all motor strains required for maintaining position and performing movements during work.

Among the many vegetative adaptations inherent to physical effort, the most important are those related to the functions of the respiratory, circulatory and thermoregulation systems.

For occupations with predominantly physical effort in which work involves large muscle groups, physiological assessment criteria relate to:

- Size of external mechanical work, the mechanical work done, expressed in kgm;
- Oxygen consumption, effort intensity and energy expenditure, expressed in kcal;
- Changes of physiological indicators during or immediately after effort, particularly the more intensely strained systems and apparatus (cardiovascular, respiratory), compared with baseline values of these parameters at rest or basal conditions.

When analyzing labor mode, changing the work capacity is studied in dynamics at certain spans.

The most rational principle of achieving physiological research would continuous observation using telemetry methods.

Telemonitoring involves remote monitoring of a rescuer's vital functions by means of appropriate devices and techniques.

Conventional monitoring involves sampling biomedical signals or physiological parameters over a period of time, by the order of days, downloading and analysis on a computer system being made at the end of the monitoring period (off-line). Telemonitoring systems sample, store and remotely transmit (through a communication network) biomedical signals or physiological parameters at shorter periods of time, perform their automatically analysis (on-line) and can send alarms if values of monitored parameters exceed certain limits.

Physiological parameters can be sampled automatically via personal monitoring devices, devices that are usually portable and often used in monitoring of vital physiological parameters such as: blood pressure, heart rate, respiratory rate, blood oxygen saturation, etc., which varies according to choice of pathologies, technical and financial possibilities.

Heart rate (pulse) is a physiological parameter commonly used in remote monitoring because it allows an assessment of the rescuer's overall

** Ph.D eng.- INCD INSEMEX Petroşani, Romania*
*** Ph.D stud. eng.- INCD INSEMEX Petroşani, Romania*

condition, heart rhythm disturbances being promptly recorded and variations being easily differentiated from abnormal / normal. The parameter also provides guidance and regarding the cardiovascular function.

Pulse sampling is performed automatically through devices that frequently use photoelectric plethysmography method for measuring the level of peripheral arteries.

2. HRT-SYS telemetry system for pulse measuring

This equipment (fig. 1) is used in the training facility for measuring rescuers pulse and allows continuous monitoring throughout the entire progress of an exercise for six people.

Fig. 1 *HRT SYS telemetry system for pulse measuring*

The whole device is housed in a mobile kit, allowing its use in different locations. The device is composed of:

- Pulse sensor - mounted on a strip of elastic material, which fastened under the pectoral muscle.
- Transmitter - is connected in the vicinity of the sensor pulse at a distance of maximum 15 cm and is designed to convert all information received from the sensor pulse to be sent to the central unit. Each transmitter is identified by a number which has a channel assigned for wireless communication with the main unit, allowing the view of the monitored wearer's pulse. On the front of the transmitter are two LEDs, one indicating the connection between transmitter and main unit and the second indicating whether transmitter is loaded or not.
- The main unit - displays the pulse for each wearer and connects to an IT system.

Through a USB serial port, the main unit is connected to a computer system having specialized installed software.

For each rescuer, before installing the pulse sensor, in the software will be introduced, as primary data, their name, age, sex, weight and height.

The software allows the compilation of a database based on the carriers of the pulse sensor and their activities. The software:

- Continuously monitors each rescuer's pulse, it being displayed in separate windows;
- Allows for setting of maximum and minimum alarm thresholds and the system highlights their transgression by acoustic signals;
- Records each rescuer pulse over a period of time set by the operator;
- Indicates whether the connection between the central unit and system is on;
- Indicates if one of the transmitters does not work;
- Shows the transmitters workload;
- Depending on the input data and pulse variation calculates burned calories during the conduct of certain activities carried out by rescuers.

For each rescuer, during monitoring period a graph is drawn, highlighting changes in heart rate depending on the activity performed.

3. Pulse measurement using HRT-SYS telemetry system

HRT-SYS telemetric system allows for continuous pulse monitoring, over the entire period of rescuers training.

Monitoring was conducted for a team of three rescuers, found under the protection of protective breathing apparatus with open circuit based on compressed air with negative pressure.

Training included the following activities:

1 – Traction on ergo meters;
2 – Moving on ergo metric treadmill;
3 – Moving on a ladder;
4 – Moving in confined spaces.

The quantities of work put up by rescuers, depending on the specific activity are:

Activity no. 1 - traction on ergo meters

During this activity rescuers performed 4 sessions of traction on ergo meters, each session having 100 pulls-up (fig. 2).

The amount of work put up in order to lift a weight of 20 kg, at a height of 1.2 m, with the activity repeated 100 times in 4 series, is 9600 Kgm.

Fig. 2 *Pull-ups on ergo meters*

Pulse monitoring was conducted prior to the beginning of the activity, for one minute and while rescuers were performing pull-ups on ergo meters.

The software generated two pulse monitoring reports for each rescuer. The values measured before and after the activity are shown in Table 1.

Table 1 *Pulse values before and during pulls-up on ergo meters*

Item no.	Subject	Before exercise- bpm	During exercise - bpm	Variation in pulse- bpm
1	I	81	152	71
2	II	84	102	18
3	III	82	131	49

Activity no. 2 – Moving on ergo metric treadmill

During this activity rescuers simulated walking using an ergo metric treadmill, with the speed of 5 km / h, for 5 minutes (fig. 3).

The amount of work put into moving on the ergo metric treadmill, at the speed of 5 km / h for 5 minutes by a rescuer who weighs approximately 100 kg (including the isolating apparatus) is 2200 Kgm.

Fig. 3 *Moving on the treadmill*

Pulse monitoring was conducted prior to the beginning of the activity, for one minute and while rescuers were performing pull-ups on ergo meters.

The software generated two pulse monitoring reports for each rescuer.

The values measured before and after the activity are shown in Table 2.

Table 2 *Pulse values before and during moving on the treadmill*

Item no.	Subject	Before treadmill - bpm	Walking on treadmill - bpm	Variation in pulse- bpm
1	I	102	144	42
2	II	84	115	31
3	III	102	128	26

Activity no. 3 – moving on a ladder

During this activity rescuers go up and down a 5 steps ladder by repeating 40 times the activity (fig.4).

Fig. 4 *Moving on a ladder*

The amount of work put into climbing and descending the 5 steps ladder, by a rescuer that along with the isolating apparatus weighs approx. 100 kg, with repeating the activity 40 times is 2000 kgm.

Pulse monitoring was conducted prior to the beginning of the activity, for one minute and while rescuers were performing pull-ups on ergo meters.

The software generated two pulse monitoring reports for each rescuer.

The values measured before and after the activity are shown in Table 3.

Table 3 *Values of heart rate before and during the ascent and descent of the ladder*

Item no.	Subject	Before exercise- bpm	During exercise- bpm	Variation in pulse- bpm
1	I	112	144	32
2	II	91	112	21
3	III	102	118	16

Activity no. 4 – moving in confined spaces

During this activity rescuers are moving indoors, using 3 types of movement (crawling - in a section of 0.54 m², on palms and knees - in a section of 0.9 sq m and bended in a section of 1.5 m²) per a length of 12 m by repeating 3 times the activity (fig. 5).

The amount of work put into moving in confined spaces is 3150 kgm.

Pulse monitoring was conducted prior to the beginning of the activity, for one minute and while rescuers were performing pull-ups on ergo meters.

The software generated two pulse monitoring reports for each rescuer.

Fig. 5 *Moving in confined spaces*

The values measured before and after exercise are shown in Table. 4.

Table 4 *Values of heart rate before and during movement in confined spaces*

Item no.	Subject	Before exercise-bpm	During exercise - bpm	Variation in pulse-bpm
1	I	112	156	44
2	II	93	138	45
3	III	102	140	38

As far as pulse is concerned, increases were observed for all activities, the highest values being recorded for the activity with the highest amount of the work, respectively the ergo meters.

4. Blood oxygen level monitoring

The method of measuring arterial blood oxygen saturation, oximetry, presents a theoretical and practical interest.

Oximetry is performed using the spectrophotometric method based on spectral features of hemoglobin. It represents a method for studying the global respiratory functioning, allowing for direct measure of the existence and degree of respiratory failure.

Determination of arterial blood oxygen saturation can be performed in vitro or in vivo. In occupational health practice in vivo oximetry is preferred. Normal saturation of arterial blood is 96-98%. At work, this parameter undergoes significant changes that depend largely on the functional characteristics of the respiratory system which in turn are in strong correlation with the body's training degree and the physical strains. In this connection it should be noted that, in different cases, the effect of exercise on blood oxygen saturation is different.

During a pronounced dynamic effort, usually, there can be noted a progressive decrease in the degree of blood oxygen saturation. Static effort, accompanied in most cases by breathing disorders, is characterized by a pronounced reduction in blood saturation. The value of this parameter decreases also when the working mode is characterized by low oxygen concentration.

Oximetry is performed as follows: the oximeter emitter is secured to the rescuer's finger. The value in state of rest, free breathing conditions, is measured. Also the pulse and respiration rate are determined. Afterward the rescuer is proposed to conduct a dynamic work (lifting weights), while determining the mentioned parameters. After analyzing the process of blood oxygen saturation, during the restoration period a static work is performed (maintaining a marked weight) and also the above-mentioned parameters are assessed.

Apnea causes a decrease in arterial blood O2 saturation, decrease dependent on whether the apnea is inspiratory or expiratory; the lower the lung air supply and the higher the body's oxygen usage, the higher the speed of decrease is. Expiratory apnea produces a more abrupt and accentuated descent than inspiratory apnea, at the same oxygen use. Lung – capillary circulation time represents the period of time from the beginning of the first breath after the apnea until the increasing of the saturation (four seconds in atmospheric air).

SpO2 device measures the blood concentration of O2 in a non-invasive manner (O2 is bound to hemoglobin in the blood and only a small part of it is dissolved in plasma). the pulse oximetry operating principle is based on spectrophotometric absorbance (Lambert-Beer law), by measuring changes in light absorption of the two forms of hemoglobin (HBO 2 - oxyhemoglobin and Hb - reduced hemoglobin).

The oximeter uses two light sources: a source in the infrared spectrum (IR - 910nm) and a source in the visible spectrum - red (R - 660nm) and a photo detector (PIN diode). The light sources and photoreceptor (optical sensor) are fixed on a torque that is attached to the fingertip or earlobe. As background radiation absorption by venous blood, subcutaneous tissue and skin are practically constant, the only variable is the amount of Hb (pulsating wave) in the vascular bed.

WK-50 D oximeter

Easy to use, the oximeter (fig. 6) is used for a proper management and dosage of the work put up by the rescuers in the training facility.

Fig. 6 *WK-50 D oximeter*

For each determination of blood oxygen saturation, information related to the subject, name, age, height, weight, gender are entered into the software, so that a database containing all the subjects, will be formed.

The oximeter is applied to the index finger and within seconds the measured values appear on the screen. The device can connect to your PC or laptop via a USB connection thereby facilitating storage and processing of data on computer with the help of specialized software. The software allows monitoring blood oxygen saturation and pulse rate in real time for four subjects (Fig. 7).

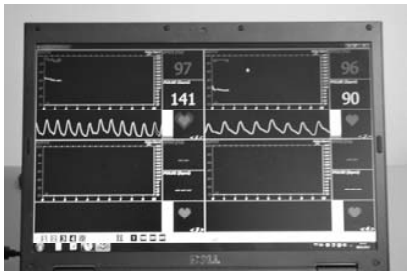

Fig. 7 *Blood oxygen saturation monitoring*

It also allows recording and presenting these data as diagrams (fig. 8).

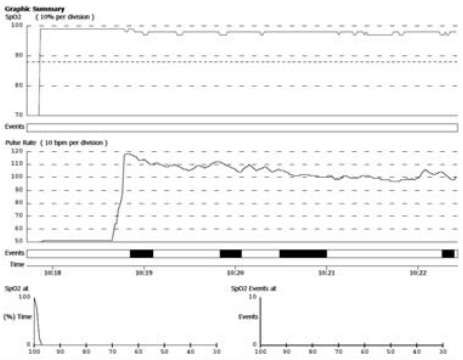

Fig. 8 *Blood oxygen saturation diagram*

Determination of blood oxygen saturation using WK D50 oximeter

Determination of this parameter has been performed at the beginning and end of each activity within the training.

Specialized software has been installed on three information systems. Connection between the oximeter and the computer system has been done through the USB slot. In order to reduce primary data registration time (name, age, weight, etc.) to each system have been connected two oximeters.

Testing was conducted for four activities:

1 – Traction on ergo meters;

2 – Moving on ergo metric treadmill;

3 – Moving on a ladder;

4 – Moving in confined spaces.

Activity no. 1 – traction on ergo meters

During this activity rescuers performed 4 sessions of traction on ergo meters, each session having 100 pulls-up.

The amount of work put up in order to lift a weight of 20 kg, at a height of 1.2 m, with the activity repeated 100 times in 4 series, is 9600 Kgm.

Blood oxygen saturation was measured for each rescuer before starting the activity as well as after finishing it. (fig. 9).

Fig. 9 *Measuring blood oxygen saturation*

For each rescuer the software allows the printing of a report, both before starting the activity and after finishing it, report that contains information related to changes in blood oxygen saturation during testing.

For this activity, blood oxygen saturation is shown in table no. 5.

Table 5 *SpO2 determinations on ergo meters*

Item no.	Subject	Before activity %	After activity %	SpO2 Variation Ergo meters %
1	I	98	96	2
2	II	95	94	1
3	III	97	95	2
4	IV	95	93	2
5	V	99	97	2
6	VI	94	93	1

Activity no. 2 – Moving on ergo metric treadmill

During this activity rescuers simulated walking using an ergo metric treadmill, with the speed of 5 km / h, for 5 minutes.

The amount of work put into moving on the ergo metric treadmill, at the speed of 5 km / h for 5 minutes by a rescuer who weighs approximately 100 kg (including the isolating apparatus) is 2200 Kgm.

Blood oxygen saturation was measured for each rescuer, both before starting the treadmill and after stopping it (fig. 10).

Fig.10 *Measuring blood oxygen saturation*

For each rescuer the software allows the printing of a report, both before starting the activity and after finishing it, report that contains information related to changes in blood oxygen saturation during testing.

For this activity, blood oxygen saturation is shown in table no. 6.

Table 6 *SpO2 determinations on ergo metric treadmill*

Item no.	Subject	Before activity %	After activity %	SpO2 Variation Ergo metric treadmill %
1	I	90	94	-4
2	II	92	94	-2
3	III	92	95	-3
4	IV	95	95	0
5	V	95	95	0
6	VI	92	93	-1

Activity no. 3 – moving on a ladder

During this activity rescuers go up and down a 5 steps ladder by repeating 40 times the activity.

The amount of work put into climbing and descending the 5 steps ladder, by a rescuer that along with the isolating apparatus weighs approx. 100 kg, with repeating the activity 40 times is 2000 kgm.

Blood oxygen saturation was measured for each rescuer, both before starting the activity and after finishing it, reports that contain information regarding changes in blood oxygen saturation being generated in both cases.

For this activity, blood oxygen saturation is shown in table no. 7.

Table 7 *SpO2 determinations on ladder*

Item no.	Subject	Before activity %	After activity %	SpO2Variation Ladder %
1	I	92	93	-1
2	II	94	95	-1
3	III	94	95	-1
4	IV	94	95	-1
5	V	96	95	1
6	VI	96	95	1

Activity no. 4 – moving in confined spaces

During this activity rescuers are moving indoors, using 3 types of movement (crawling - in a section of 0.54 m², on palms and knees - in a section of 0.9 sq m and bended in a section of 1.5 m²) per a length of 12 m by repeating 3 times the activity (fig. 5).

The amount of work put into moving in confined spaces is 3150 kgm.

Blood oxygen saturation was measured for each rescuer, both before starting the activity and after finishing it, reports that contain information regarding changes in blood oxygen saturation being generated in both cases.

For this activity, blood oxygen saturation is shown in table no. 8.

Table 8 *SpO2 determinations in confined spaces*

Item no.	Subject	Before activity %	After activity %	SpO2 Variation Confined spaces %
1	I	91	94	-3
2	II	92	94	-2
3	III	95	95	0
4	IV	96	95	1
5	V	93	98	5
6	VI	94	90	4

The analysis of blood oxygen saturation values for all activities in this training shows that there has been a decrease only for those activities where the amount of work had the highest values, such as traction on ergo meters.

5. Conclusions

Heart rate (pulse) is a physiological parameter commonly used in remote monitoring because it allows an assessment of the overall condition of rescuer, heart rhythm disturbances being promptly recorded and variations being easily differentiated from abnormal / normal. Parameter provides an indication of cardiovascular function. Pulse sampling is performed automatically through devices that frequently use photoelectric plethysmography method for measuring the level of peripheral arteries.

For pulse measuring a HRT-SYS telemetry system was used, this being the only device which allows continuous monitoring of the parameter. Equipment uses specialized software that allows continuous recording of rescuers pulse via wireless technology, up to a distance of about 100 meters from the central unit.

Blood oxygen saturation (SpO2) represents an indicator of the overall blood oxygenation (the amount of oxygen bound to hemoglobin in arterial

blood) being used in cardiovascular and respiratory monitoring in state of rest and state of effort. Oximetry is performed using the spectrophotometric method based on spectral features of hemoglobin. It represents a method for studying the global respiratory functioning, allowing for direct measure of the existence and degree of respiratory failure.

For blood oxygen saturation monitoring a WK D50 type oximeter was used, due to the benefits it presents:

- The possibility of using a specialized software for recording data;
- Blood oxygen saturation determination through a non-invasive method;
- Real time determination of blood saturation.

Pulse and blood oxygen saturation determinations were performed for a team of rescuers (six persons – for blood oxygen saturation and three persons – for pulse). The measurements were performed in state of rest, before starting the activities and after finishing them – for oxygen saturation and in state of rest, and before and during the activities – for pulse.

After analyzing these measurements it was found that a significant change in blood oxygen saturation (approximately 5% decrease) takes place only fore those activities where the amount of work had the highest values; for the rest of the activities no special changes were observed. Increases of the pulse were noted for all activities, the highest values being recorded for the activity where the amount of work had the highest values, respectively on ergo meters.

Real time remote monitoring allows:

- Determining the degree of difficulty of training routes based on changes in heart rate and blood oxygen saturation;
- Alarm thresholds for achieving the minimum and maximum for the measured vital parameters;
- Real-time identification of rescuers whose vital parameters are exceeded during training exercises;
- Possibility for the instructor which supervises the exercises to stop this activity for those above the maximum or minimum, avoiding possible undesirable events;
- Data storage for each person and the possibility to follow up their evolution during the next workout.

Refrecences

1. Rotariu, C.
Remote monitoring of vital parameters using embedded systems, 2010.

2. Mesina, V.
Analysis and evaluation of the operational status of the body while working with physical exertion, 2013.

3. ELGO, Germany
Technical prospectus, Pulse monitoring system.