INCREASING THE EFFICIENCY OF THE TRAINING PROGRAMS FOR THE MINE RESCUE TEAMS

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ABSTRACT: *Mining laws in developed countries require trained, equipped mine rescue personnel to be available at all mining operations at surface and underground mining operations. Mine rescue teams must know the procedures used to rescue miners trapped by various hazards, including fire, explosions, cave-ins, toxic gas, smoke inhalation, and water entering the mine. Most mine rescue teams are composed of miners who know the mine and are familiar with the mine machinery they may encounter during the rescue, the layout of workings and geological conditions and working practices. Local and state governments may have teams on call ready to respond to mine accidents. In our paper we have presented some of the newest training methods in countries where mine rescue has more than 100 years history. Also we have presented a few researches made by our collective in 2012 - 2014 year with heart rate monitors and GPS sport watches over 21 mine rescuers trained in the Laboratory for Risk-Rescue Operations of the INCD INSEMEX.*

KEY WORDS: *mine rescuer, training programs, heart rate monitors, increase efficiency.*

JEL CLASSIFICATION: *I18, J81, Y80.*

1. WHAT IS MINE RESCUE? BASIC MINE RESCUE TRAINING PROGRAMS

Mine rescue is a practical science whereby trained personnel, wearing protective breathing apparatus enter a mine during or after a mine fire, explosion, or other disaster to rescue trapped workers, extinguish the fire and restore the mine to its original safe condition. Mine rescue training puts the mine operation in a state of "awareness." The mine is alerted to the possibility of an emergency occurring at any time. This awareness encourages the mine personnel to utilize safe and proper working procedures that will often prevent emergency situations from occurring. The mine has

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a competent and knowledgeable work force able to take the proper action to prevent emergency situations from worsening and endangering lives. It is also equipped with specially trained personnel who can act during the emergency to carry out rescue and recovery operations. When a disaster occurs there are generally several factors contributing to the cause or to the severity, therefore, awareness has to be directed to the various causes

Basic mine rescue certification is considered to be entry level mine rescue training. Potential mine rescue candidates must meet the "Criteria for Emergency Response Personnel". This is to be done prior to participating in aspects of the mine rescue training where they are required to perform demanding work while wearing oxygen breathing apparatus. Basic mine rescue training shall be a minimum of 24 hours (more as required) and must allow participants ample time to become familiar with the course materials and equipment. Instructors will use their discretion to determine if additional time is required to successfully complete the training course. In order to qualify for certification, the participant must demonstrate a satisfactory degree of knowledge, skill, competency and proficiency in the use of mine rescue equipment and must attain a minimum of 80% on a final exam (Manitoba, 2012).

2. MODERN MINE RESCUE TRAINING PROGRAMS

Survey findings (MST&TC, 2006) suggest that better training materials are needed to address significant knowledge and skill gaps. Specifically, additional materials are needed for training miners in the following areas: navigating through smoke, first responder fire fighting, refuge chambers, Self-Contained Self-Rescuers (SCSR's), normal psychological and physiological human response to emergencies such as traumatic incident stress, and emergency communication. Additional training materials on a variety of topics are also needed for mine managers, responsible persons, mine dispatchers or mine-monitoring personnel, crew supervisors, mine rescue teams, and command center personnel.

New computer-based training simulations are needed to provide command center personnel with extensive opportunities to practice handling a wide variety of mine emergency situations. This would lead to improvements in the speed and quality of decisions made by command center personnel. Dynamic decision-making researchers are learning how to train people to make better decisions by observing the choices they make in computer training simulations. Much like the unfolding challenges of managing a mine emergency, these simulations require trainees to continually monitor the goals of the task, learn how to navigate the simulated task space, use their knowledge to diagnose current states and predict future events, form and update strategies, and finally, keep all of these activities connected in a coherent problem solving process. Saner and Gonzalez have identified in 2008 several factors that have an important influence on the quality of decisions made in dynamic situations (Saner & Gozales, 2008).

Several more computer simulations like the Mine Emergency Response Interactive Training Simulation (MERITS) need to be created to provide mine managers the opportunity to practice handling a wide variety of mine emergency

situations. The more experience people gain through participating in such simulations, the better prepared they will be to handle real-world events. Many of the interactive mine emergency training simulations available from NIOSH (National Institute for Occupational Safety and Health) or MSHA (Mines Safety and Health Association) need to be updated and converted to electronic delivery format. MSHA began the process of these conversions a few years ago (see "I Can't Get Enough Air" or "Travel Through Smoke" at http://www.msha.gov/interactivetraining.htm), but many more simulations need to be converted. Training materials and methods developed for other industries and internationally need to be adapted for U.S. mining conditions.

2.1. Australia. The Virtual Reality System developed by the Coal Services

Coal Services has developed the worlds most advanced mine safety training simulator, specifically for the mining industry. These virtual reality systems allow employees to be exposed to dangerous situations and hazardous locations, whilst in a safe and controlled environment. Learning and practicing how to respond in these situations delivers outcomes that could be lifesaving. This virtual reality system is accurate and realistic, having developed an Underground Operating Whole of Mine with over 50km of roadway, covering all regular mining methods and an Open Cut Operating Whole of Mine based off real terrain data. Each of the four Mines Rescue stations are equipped with a fixed 360 degree theatre, as well as a lecture theatre with curved screen and one-on-one training dome facilities. As well as the fixed facilities, the virtual reality system is now portable and can be taken onsite to assist as a training tool to help minimize risk (http://www.minesrescueservices.com/VirtualReality Technologies.aspx).

2.2. USA. Mine Rescue Computer Simulations developed at Colorado School of Mines

It is believed that effective training can incorporate both modern technology and traditional training techniques. This belief has led to the development of the Mine Rescue Computer Simulator. Participants in underground search and rescue training use custom built mine rescue simulation software to practice mine rescue procedures in the safety of a classroom. The software is used in conjunction with an incident command and a fresh air base in order to simulate a mine disaster as accurately as possible. The rescue scenarios address multiple hazards and victims with varying degrees of complexities. The mine model currently used in the simulations is the Edgar Experimental Mine, but they can take place at any mine as long as a 3-D mine model is built. The Target Audience is composed of **e**xperienced and novice mine rescue teams, incident commanders and staff and mine managers and their staff. The objectives of the program are hazard recognition training, decision-making exercise and communication development. The course content: mine disaster simulation, virtual team interaction and team communication with a fresh air base and incident command center for added realism (http://mshp.mines.edu/MSH-rescue-simulations).

2.3. Canada. Virtual Reality Project developed at MASHA and the Faculty of Health Services from the University of Ottawa

Research is a vital component of continuous improvement in mine rescue. The mine rescue identifies areas of research that will provide the greatest benefit to mine rescue teams and emergency preparedness at Canadian mines. Academic institutions are principle research investigators, while MASHA (Mines and Aggregates, Safety and Health Association) ensures the relevance of projects by involving mine operators and ensures the transfer of knowledge back to the workplace. Current research projects include the application of virtual reality to mine rescue, and heat stress as it relates to mine rescue teams. (Grysk, 2007)

Figure 1. Image of Regional Mine – Virtual Reality Project

Virtual reality research is focusing on producing a virtual reality (VR) training environment for mine rescue control groups. Although the model was initially directed at training mine rescue control groups, the technology may prove useful on mine sites as the control center for mine rescue emergency response. The initial phase of the project was to produce a demonstration model. The next phase involves digitizing an operating mine and integrating variable environmental conditions, such as a ventilation system and randomly generated emergencies. The model is being developed with input from control group members and is designed to challenge teams or individuals to make good decisions in emergency situations. The preceding images are extracted from the first phase of the project.

MASHA is engaged in heat stress research as it applies to mine rescue teams with the Faculty of Health Services from the University of Ottawa. Increasing levels of heat and humidity due to extreme mining depths are significant factors affecting our mine rescue teams. MASHA is looking in to the fitness levels of volunteers and exploring nutrition and hydration strategies to minimize the ill-effects on volunteers exposed to elevated temperatures while performing rescue work. The initial phase of this research has focused on studying typical mining tasks and classifying them into

typical activity groups. Laboratory testing has been conducted to quantify energy expenditure of specific tasks and subtasks. Focusing on an extreme task such as mine rescue is being explored as a future target. One desired outcome is to encourage the commercial development of an instrument that will alert individuals, based on their personal characteristics with a given environmental situation, when they become at risk to heat stress.

3. RESEARCH METHODOLOGY. HEART-RATE BASED TRAINING EQUIPMENT. POLAR PRO TRAINER SOFTWARE

3.1. The training place

We have used for our research the Laboratory for Risk-Rescue Operations of the Romanian National Institute for Research and Development in Mine Safety and Protection to Explosion. Here the INSEMEX researcher aimed at modification of bio-psycho-physiological parameters of intervention and rescue personnel during specific actions. Given the extremely difficult and dangerous conditions in the operating bands of rescue is necessary to conduct more research on how the body and the system respond and adapt to and psyche of rescuers in these environments (http://www.insemex.ro/index.php/en/laboratory-for-risk-rescue-operations.html).

3.2. The instruments

We have used for our research 20 Polar Heart Rate Monitors sport watches and the Polar Pro Trainer Software for evaluating the results.

Figure 2. Polar Heart Rate Monitors and GPS sport watches and Polar Pro Trainer Software

Polar offers some of the most advanced heart-rate based training equipment in the world. It includes heart rate monitors for running, fitness & cross-training, as well as GPS-enabled cycling computers and sports watches for endurance training. We have used these sport watches for measuring the effort of the mine rescuers during the training programs. Polar sport zones offer a new level of effectiveness in heart rate-based training. Training is divided into five sport zones based on percentages of your

maximum heart rate. With sport zones, we can easily select and monitor training intensities and follow Polar's sport zones-based training programs.

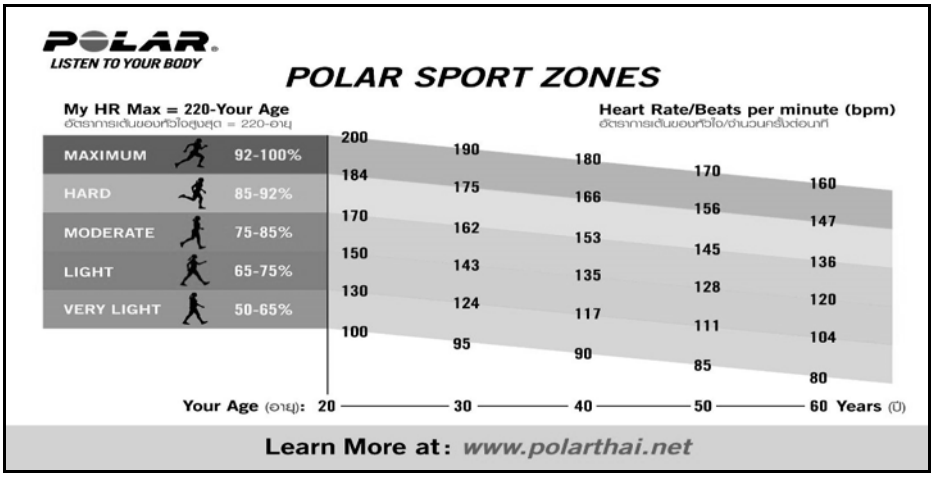

Figure 3. Heart rate beats per minutes, according to age and training intensity

Maximum heart rate (HRmax) is the highest number of beats per minute (bpm) that heart can reach during maximum physical exertion. It is individual and depends on hereditary factors and age. If we wish to reliably measure the intensity of the training, it's important to know how hard the heart can work when it's pumping at its maximum capacity. The more accurately we know the HR max the more accurately we can define the heart rate limits or sport zones needed to use to get the optimal training benefit. If we overestimate the HR max, the heart rate limits within which we train will be higher than they should be. If we underestimate our HR max, then we will be training at too low intensities. Most Polar models allow direct entry of a HR max value. If we don't know our HR max, most models use the age-based formula (220 - age = HR max).

Polar Pro Trainer 5 is dynamic, advanced software that gives a deeper understanding of the training based on heart rate zones, speed, distance, time and increasing/decreasing heart rate. The data analyze in Polar Pro Trainer can review recorded data on the wrist unit display immediately after training. However, once it has been transferred to the Polar Pro Trainer 5 software, that's when we'll get a real understanding of every aspect of your training session in exacting detail. Then we select any point during the training and analyze and compare our data against previous sessions using easy-to-understand graphs.

3.3. Research results

We have tested 15 open pit rescue miners and 6 underground rescue miners during their periodical training session made at INSEMEX Petrosani. Using Polar heart rate monitors watches we could notice a few syncope during the training. In the figure below we have presented the curve for the Heart Rate (HR) during a 90 minutes

training program for two extreme cases of mine rescuers, during the 2012 training session.

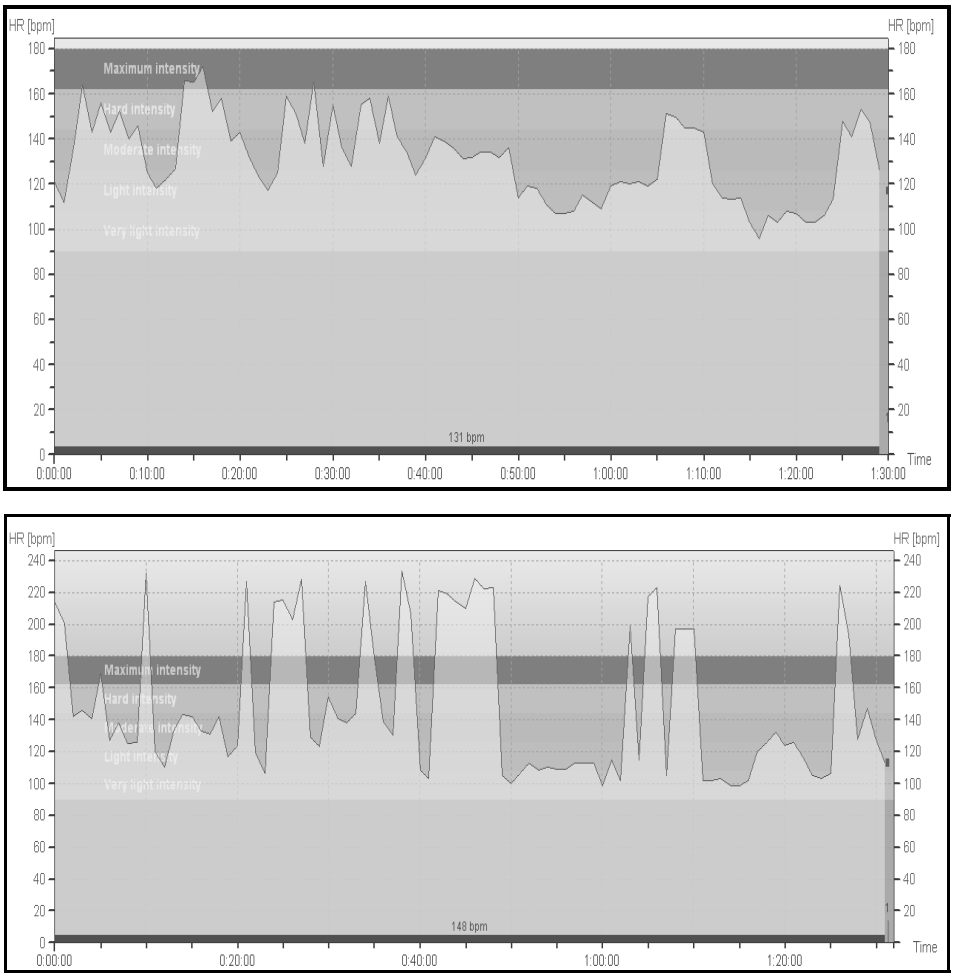

Figure 4. The curve for the Heart Rate (HR) during a 90 minutes training program for two extreme cases of mine rescuers

It is obvious in the above figure that the second mine rescuers has serious problems, his heart rate being during the training session very often above 180 per minute.

He has analyzed also the 90 discontinuous HR results for all the 90 minutes of the exercise for all the 21 mine rescuers.

Time	+0:00	+1:00	+2:00	+3:00	+4:00	+5:00	+6:00	+7:00	+8:00	+9:00
0:00:00	121	112	136	164	143	156	143	152	140	146
0:10:00	125	118	122	127	166	165	172	152	158	139
0:20:00	143	132	123	117	125	159	151	138	165	128
0:30:00	155	136	128	155	158	138	159	141	134	124
0:40:00	131	141	139	136	131	132	134	134	132	136
0:50:00	114	119	118	111	107	107	108	115	112	109
1:00:00	119	121	120	121	119	122	151	150	145	145
1:10:00	143	120	114	113	114	103	96	106	103	108
1:20:00	107	103	103	106	113	148	141	153	147	126

Time	+0:00	+1:00	+2:00	+3:00	+4:00	+5:00	+6:00	+7:00	+8:00	+9:00
0:00:00	214	201	142	146	141	169	127	138	125	126
0:10:00	232	120	110	133	143	142	133	131	142	117
0:20:00	124	227	119	106	214	215	203	228	129	123
0:30:00	154	141	138	144	227	179	139	130	233	207
0:40:00	108	103	221	219	214	210	229	222	223	105
0:50:00	100	107	113	108	110	109	109	113	113	113
1:00:00	99	115	102	199	115	217	223	105	197	197
1:10:00	197	102	102	103	99	99	102	120	126	132
1:20:00	124	126	116	105	103	106	224	194	128	147

Figure 5. Listing of heart beats during a 90 minutes training program for two extreme cases of mine rescuers

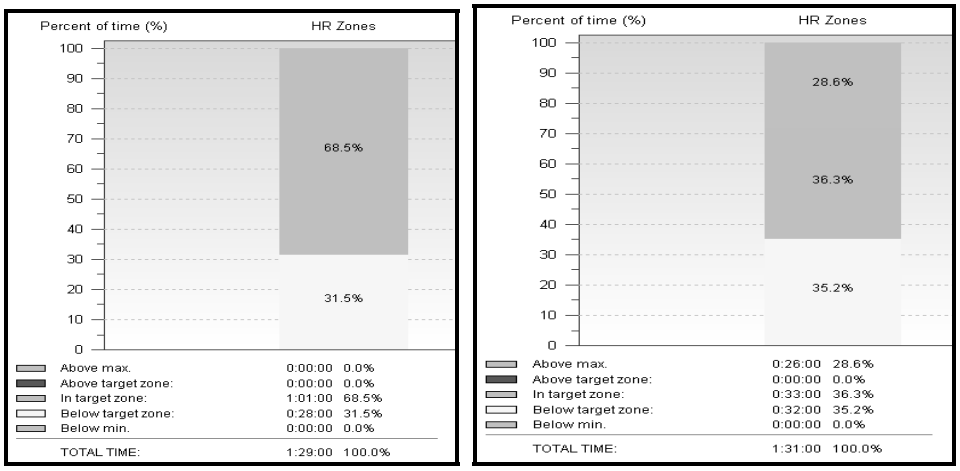

Figure 6. Zone summary for two extreme cases of mine rescuers

In 2014 we have implemented with the INSEMEX support a prerequisite training program to be made by the mine rescuers before the periodical training session. Then we have tested the same mine rescuers at their 2014 periodical training session, and we could observe an average of 7% decrease in the heart rate beating for most of the mine rescuers during the solicitant part of the training.

4. CONCLUSIONS

We have presented in the first part of the paper a few modern mine rescue training programs used in Australia, USA and Canada using virtual reality and simulations programs. We have used also some modern techniques for to improve the mine rescuers training. In 2012 year we have tested 15 open pit rescue miners and 6 underground rescue miners during their periodical training session made at INSEMEX Petrosani. Using Polar heart rate monitors watches we could notice a few syncope during the training. We have proposed a set of training exercises, in fact a prerequisite training program to be made by the mine rescuers before the periodical training session. Then in 2014 we have tested the same mine rescuers and we could observe a 7% decrease in the heart rate beating. This decrease could conduct to a better efficiency in the mine rescuers saving activity.

5. ACKNOWLEDGMENT

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