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THE RESPIRATORY PROTECTION PRACTICE RANGE OF THE MUNICIPAL FIREBRIGADE OF ZARAGOZA

A SCIENTIFIC STUDY

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INTRODUCTION

The inauguration of a central fire-fighting park in the municipality of Zaragoza in 1983 marked the beginning of a new historical era characterized by improved material, an increase of staff and the provision of equipment, installations and appurtenances which were qualified as the most state-of-the art in the whole of Spain. The respiratory protection practice range is a case in point.

In Spain, there is total ignorance about the effort required from a fireman when running through a practice range. For this reason, a study was carried out with the fire-fighting staff of Zaragoza which, based on stress-testing medecine, was to analyse the exercises with the self-contained breathing apparatus on the firebrigades's practice range.

OBJECTIVES

1. To analyse and define the exercise.

2. To perform an ergonometric examination of the firemen after completion of the exercise.

3. To determine all possible causes that might induce sudden death during the performance of the exercise.

4. To suggest and /or establish precautions, both individual and collective, to ensure that the exercise would not be harmful and would not lead to an increase in morbidity and mortality rates among firemen.

MATERIAL AND APPROACH

A random sample of 100 active firemen (attending emergencies) was chosen from a total population of 300 male persons whose state of health had been examined previously. Data were collected throughout two periods: from September to November 1987 and from March to May 1988 between 11:30 and 12:30; the study was carried out as follows:

1. Before starting the exercise, every fireman was asked to record his age, size and weight and was subjected to the Ruffier test.

2. Measurement of the amount of air in the respiratory apparatus consumed during the exercise and of the time spent on the practice range.

3. *Measurement of arterial blood pressure at rest and immediately after completing the exercise.*

4. *Determination of the Barrach's index and the Double Product before and after the exercise.*

5. *Determination of the maximum theoretic heart rate.*

6. *Determination of the maximum oxygen consumption (VO2 max).*

7. *Completing the entire practice range with the self-contained breathing apparatus:*

A) *Characteristics of the practice range:*

The training labyrinth consists of two levels, one above the other, each with a circuit of 26 metres.

The obstacles in the upper level include a steel door with two locks and a horizontal trap door leading down to the lower level.

The obstacle to be overcome in the lower level was a horizontal cylinder (240 cms long, 57 cms wide).

B) *General conditions on the range*

The exercise was always carried out under the same conditions:

- *general lighting in the room: off,*
- *orientation lights on the range: on,*
- *smoke machine: connected,*
- *heat zone: connected to attain a temperature of 40 degrees C,*
- *noise simulation operating,*
- *compressed-air respiratory apparatus with automatic pulmonary control in "on" position.*

C) *Safety considerations:*

The following safety measures were taken:

- *intercommunication system connected in position "listen-trainer"*
- *visual display of the exercise on TV monitors in the control room,*
- *tracing contacts on the floor,*
- *both a medical doctor and a medico-technical assistant specially trained in advanced cardio-pulmonary resuscitation were always present during the exercise.*

D) *Equipment used for the operation*

The equipment used by the firemen for the operation weighed a total of 19.5 kg and consisted of : working clothes, safety boots, protective nomex vest, helmet and self-contained compressed-air breathing apparatus.

8. *An electrocardiogram was recorded in a state of rest and immediately after the exercise.*

In order to analyse the electrocardiogram parameters, a Hewlett Packard OCR-plotter 9872.A. was used in combination with a desktop computer system 9845 B and a specific electrocardiogram reading and digitalization program developed by Prof. Fabre González and Dr. Romero Alvira, which permitted measuring the following parameters before and after the protocolled test:

- *duration of wave P (milliseconds)*
- *segment PR (milliseconds)*
- *duration of QRS (milliseconds)*
- *interval QT (milliseconds)*
- *heart rate (b.p.m.)*
- *Macruz index (duration of wave P in milliseconds/ segment PR in milliseconds).*

9. *Determination of the volume expired per minute (V.E.M.), the fraction of expired oxygen (FEO2) and the fraction of expired CO2 (FECO2) after completion of the circuit.*

In order to measure the VO2 consumed during the exercise, the fireman, after completing the test, is quickly stripped of his breathing apparatus and clothing, which are an impediment to medical examination; he then lies down horizontally on the stretcher in dorsal position, a two-way mouthpiece which is linked to a Douglas bag being inserted in his mouth.

The air expired throughout one minute (V.E.M) after the exercise was collected in this bag. Subsequently, the FEO2 and FECO2 amounts were examined by gas analysis: Jaeger 02 test and Jaeger CO2 test.

With the "Gas Correction" programme designed by Dr. José Luis Terreros from the municipal sports medical centre of Aragon the following variables were determined:

- *FEO2. Fraction of expired oxygen*
- *FECO2. Fraction of expired CO2*
- *V.E.M. Volume of expired air per minute*
- *heart rate*
- *weight*
- *atmospheric pressure, ambient temperature and humidity.*

The following variables were derived as result:

- FO2%. The concentration of oxygen in the expired air expressed in percentage terms.
- RR. Respiratory ratio
- VO2 l/m. Oxygen consumed in l/m.
- VCO2 l/m. Production of CO2 in l/m.
- VO2/HR. Oxygen pulse.
- VO2 ml/kg/min. Oxygen consumed.
- EQO2. Respiratory oxygen equivalent.
- METS. Basal metabolic rate.

10. Computerized statistical processing of the data

Computerized statistical processing of the data was carried out with the help of the Statview II statistics programme on a MacIntosh II computer.

From the statistical point of view, the quantitative variables were summarized as medians, standard deviations, standard error, variance, variation coefficient, by computing also position measurements such as percentiles 10, 25, 50 (median), 75 and 90; and form measurements such as curtosis and skewness.

In a comparative analysis of the mean values – after having verified their normality and existence – two groups of mean values were compared by using Student's t–test for the correlated data and, as alternative, the Wilcoxon rank sum test.

The significance level was determined at $\alpha = 0.05$.

In order to study the possible interrelation of the variables – different as they may be at two different moments – a regression and correlation analysis were carried out to obtain data such as correlation coefficient and determination coefficient, standard error of correlation and the right–side parameters. Similarly, the statistical significance of the correlation coefficient is verified with
$p = 0$.

RESULTS

The age class distribution was the following:

– from 20 to 29 years	30 firemen
– from 30 to 39 years	30 firemen
– from 40 to 49 years	30 firemen
– from 50 to 59 years	30 firemen

The following variables are described for all test persons and for the age classes 20–29, 30–39, 40–49, 50–59:

RR, VO2/HR, VO2 l/m. VO2 ml/kg/min.
heart rate before and after the exercise
T.A.S before and after the exercise
Double Product before and after the exercise.

In one study, the consumption of air and VO2 ml/ kg/ min for all test persons and all age classes were related.

Another study compared the following variables for all test persons and for the age classes 20-29, 30-39, 40-49, 50-59:

- *maximum VO2 and VO2 ml/ kg/ min.*
- *maximum theoretic heart rate and post-exercise heart rate.*

This work resulted in representative graphs.

CONCLUSIONS

1. Morbidity and mortality in the study were found to be zero, which proves that the exercise on the practice range with respiratory equipment performed by previously selected healthy firemen is innocuous, provided that appropriate precautions and safety measures are taken.

2. With respect to the level of tachycardia observed relative to the maximum theoretical heart rate, and with respect to the values for oxygen consumed (VO2 ml/kg/min) compared to the maximum amount of oxygen consumed (VO2 max), the exercise can be classified as sub-maximal.

3. The results obtained for the respiratory ratio leads us to define the exercise as aerobic.

4. Regarding the data analysed for the consumption of oxygen when accomplishing the practice circuit with self-contained respiratory equipment, the exercise was found to be within the "easy walking to slow running" field for the average values, and within the "slow to fast running" field for the peak values.

5. Changes in intraventricular transmission were not assessed.

6. The methodology used for the present study allows us to determine a number of variables, which enable an ergonometric evaluation of the population studied. Once these variables have been analysed, training guidelines can be formulated with the aim of improving the exercise conditions for the firemen on the practice range.

7. The oldest group (50 to 59) showed a significant increase in the consumption of oxygen during the exercise in the practice range with respiratory equipment, compared to the other age classes, which differed slightly from one another. One may conclude that the stated age group performs the exercise less effectively than the other age classes.

8. The analysis of variables such as post-exercise heart rate, CO2 production (VCO2) and respiratory oxygen equivalent (EQU2) corroborate the findings presented in the preceding conclusion.

9. The amount of compressed air consumed from the bottles of the respiratory apparatus during the performance of the exercise does not give any indication as to the energy consumption during the exercise.

10. During the exercise, a highly significant increase in systolic arterial pressure was noted, which has a considerable influence on the Double Product and Barrach's index, both indicators of myocardial oxygen consumption. These results suggest that there is a risk of coronary ischemia for persons suffering from organic troubles, which affect myocardial oxygen consumption.

11. The levels of tachycardia observed in the firemen during the exercise confirm the risk of coronary ischemia for persons suffering from organic troubles, which affect myocardial oxygen consumption.

12. The mean and maximum values of heart rate and oxygen consumption during the performance of the exercise which are closest to the maximum theoretical heart rate and the maximum consumption of oxygen were found with the 50 to 59 year old. This is indicative of a higher risk involved for this population to develop myocardial ischemia.

13. In line with conclusions no. 10 and 11, every person subjected to the exercise in the respiratory protection practice range should undergo prior medical examination less than one year before. Special attention should be given to cardiovascular and respiratory functions and, if possible, a stress electrocardiogram should be recorded. Consequently, all persons with suspected and/or proven cardiovascular and/ or respiratory troubles should be withdrawn from the exercise.

14. Whenever an exercise on the practice range is performed, medical staff (a medical doctor and /or a medico-technical assistant) specifically trained in cardio-pulmonary resuscitation should be present and provided with adequate equipment to carry out advanced cardio-pulmonary resuscitation.

15. Currently, there is no legislation in Spain governing the performance of exercises on respiratory-protection practice ranges. This leads to situations where training is carried out without appropriate medical precautions. It is therefore necessary to draw up a set of legal provisions guaranteeing safe performance of training exercises.

16. Pending the implementation of appropriate statutory provisions it is necessary and obligatory to comply with the requirements stated in conclusions 13 and 14 when performing similar exercises.