SECTION – EXERCISE SCIENCES

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RESCUE PROCEDURE EFFECTIVENESS IN TERMS OF RESPIRATORY MUSCLE FATIGUE

Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Introduction: Diagnosis of sudden cardiac arrest in an injured person and taking quick actions to restore vital functions is a critical point of pre-hospital care, carried out not only by medical personnel in civilian, but also in water rescue conditions.

Aim: The purpose of the study is to identify spirometry and cardiopulmonary indices that influence rescue actions at the level of respiratory muscle fatigue, and may have potential impact on the effectiveness and quality of the rescue operation.

Material and methods: The study involved 48 male uniformed soldiers with permission to perform water rescue as part of a training programme regarding tactical activities. Spirometry and cardiopulmonary resuscitation tests were performed before and after lifesaving water tests. The quality of respiratory muscle fatigue at rest and in the condition of fatigue was compared. The recording instrument was the portable Micro Loop spirometer and Ambu Defib Trainer W (Wireless).

Results: The respiratory parameters that may affect the quality and effectiveness of rescue water tests in the area of speed and intensity are: peak exhaust flow, maximal ventilation index, ventilation volume per minute, ventilation rate and maximal respiratory pressure.

Conclusion: The most important spirometric and cardiopulmonary parameters identifying respiratory muscle fatigue level of are: VmV, FEV, FVC, PEF, FEVO FEV3, which total as much as 12.26% of all parameters taken into account, and their improvement may be associated with better rescue performance, both in qualitative and quantitative terms.

Introduction

the quality and effectiveness of rescue operations in water is important, especially within the context of published studies in which data indicate that the main cause of accidental death in the world regards accidents related to water incidents and drowning [1]. Drowning accidents constitute one of the major public health problems. According to an estimate by the World Health Organization (WHO), approximately 400,000 people worldwide die annually for this reason, which accounts for 7% of all deaths as a result of accidents [2].

The degree of fatigue depends on the level of effort and training of the subjects. During long-term efforts of high or maximum intensity, symptoms of muscle fatigue intensify and may be observed even several days after exercise completion. Scientists claim that fatigue of the respiratory muscles is the cause of decreased exercise capacity even in well-trained athletes [3, 4, 5, 6, 7]. In the research by scientists, it has been proven that the introduction of respiratory muscle training into everyday life improves chest expansion, forced vital capacity (FVC), maximum voluntary ventilation (MVV), maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP), and increased values of VE, which correspond to improvement in the endurance and strength of the respiratory muscles. Muscle fatigue can be measured by assessing the differences between the amount of MIP in pre- and post-exercise measurements. After the introduction of this solution, the young swimmers described in one study achieved better results than competitors who trained without the use of SpiroTiger training of the respiratory muscles [3, 8, 9, 10, 11].

Gaps in studies and scientific literature concerning assessment of the quality and effectiveness of rescue operations in water within the aspect of respiratory muscle fatigue, indicate a need to explore this subject. Research conducted by various authors shows that the essence is the impact of CPR procedure quality and the effectiveness of individual elements of the rescue operation on the survival of people who are helped [12, 13, 14].

Therefore, the main objective of this study is to try to determine spirometric and cardiopulmonary indices identifying the level of respiratory muscle fatigue, which may have potential impact on the effectiveness and quality of water rescue operations. In the study, an attempt is also made to identify parameters of CPR, in accordance to the requirements of the 2015 ERC Guidelines for Resuscitation, which deteriorate due to fatigue caused by the rescue action.

Materials and methods

Study group

A total of 48 healthy men with qualifications in the field of water rescue given by the Ministry of the Interior and Administration (MSWiA), including:

- 15 professional Volunteer Water Rescuers (WOPR),
- 17 professional soldiers from the GROM special combat unit - water section,
- and 16 officers of the Central Counter-Terrorist Police Unit (BOA).

The inclusion criterion for candidates in the research project was completion of a qualified pre-medical aid (KPP) course or its recertification within three years prior to the study. Participation in the research was voluntary and selfless. The research project was submitted and approved by the Department of Water Sports of the University of Physical Education in Kraków, respecting the ethical principles of the Declaration of Helsinki. Each participant agreed to provide the necessary data for research tasks in this area.

Research methods

The research method applied in the work was an experiment using the one group technique. In order to solve the research problem, variables were defined, which were selected in accordance with the issues of the work.

- The dependent variable was the effectiveness of rescue operations.
- The independent variable was the controlled level of respiratory muscle fatigue.

Applied tests:

- a pre-test under conditions of rest,
- and post-test under conditions of fatigue,

allowed to track changes occurring within the value of the dependent variable under the influence of fatigue.

Tools and research techniques were selected and necessary calculations of the level of appropriate indices were performed.

In order to identify spirometric indices determining the level of respiratory muscle fatigue, the Micro Loop wireless diagnostic spirometer was used together with the dedicated PC Spirometry Software and diagnostic equipment (reusable adapter, disposable mouthpieces, nose clip, connection to a laptop computer).

The quality of cardiopulmonary resuscitation (CPR) procedures was assessed using the Ambu Defib Trainer Wireless phantom connected to a computer containing Ambu CPR Software, which allowed for the recording of all CPR effectiveness parameters.

The study participants also completed a questionnaire, which included enquiries regarding information on: age, height and body mass, degree and professional specialisation, date of obtaining rescue licenses and the passage of time since the last training course in the area of first-aid (KPP). The obtained data made it possible to calculate body mass index (BMI), as well as to verify rescue qualifications obtained by the subjects in various years, field units and at various training sessions held by the Ministry of Interior and Administration.

Course of research

The study was divided into two parts. Each part of the study covered a different day and was performed in the order of the tests day-by-day. The entire research

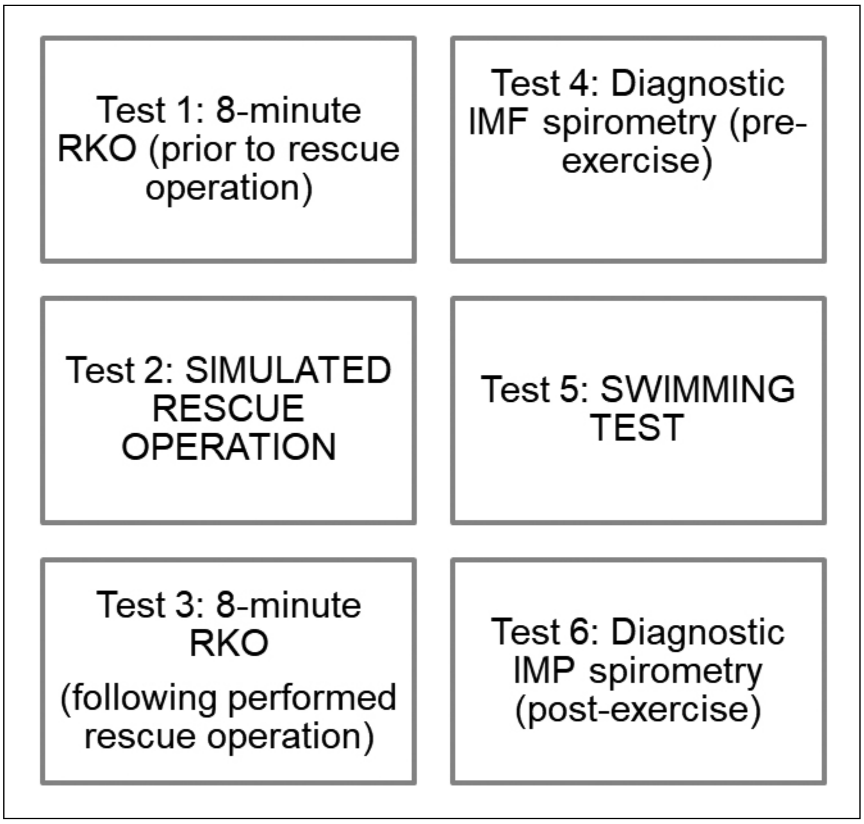

Figure 1: Organisation of research and selected tests

project was carried out at the Znamirowice - Załęże Water Sports Centre of the University of Physical Education in Kraków (2018). The research was performed from May to August, on windless days (the acceptable wind scale was 1-2 degrees on the Beaufort scale), while the air temperature was from 20–26ºC and the water temperature 22–24ºC.

After completing the questionnaire, the subjects participated in the **first part of the study**, which included two tests on a Micro Loop diagnostic spirometer.

- **Test 1** - spirometry test under conditions of rest, measurement of maximal inspiratory pressure (MIP), which was expressed by the force generated by muscles during a short, static contraction, with the airflow closed in the airways. A maximum of 15 and a minimum of 10 breaths were taken, of which the three highest measurements were defined as the maximum.
- **Test 2** - spirometry test, measurement of maximal inspiratory pressure (MIP) in fatigue conditions, performed immediately after the completion of a specialised rescue task.

The specialised rescue task included covering a distance of 400 m, freestyle. The pass criterion was obtaining a time lower than 8 minutes. The measurement was performed with a CASIO HS-6-1EF stopwatch to the nearest 0.001 s. The selection of this trial was due to the fact that in various rescue organisations around the world, it is the most popular test used in the verification procedures of rescuers for rescue steps. The test was conducted in accordance with ILS (International Life Saving Federation) standards. Immediately after the specialist rescue test was performed, the participant began the spirometry test in conditions of fatigue. During spirometric tests, the subjects were motivated to maximise their efforts [9, 11, 17]. Respiratory muscle fatigue was measured by evaluating the differences between the MIP values obtained in the resting and fatigue measurements.

Spirometric tests were performed according to the procedures recommended by the authors Romer, McConnell, and Jones [4], using diagnostic spirometry [16]. The degree of fatigue depended on the effort performed and training experience of the participants.

The **second part of the study** consisted of the two tests carried out on the Ambu Defib Trainer Wireless phantom:

- **Test 3** - 5-minute CPR in resting conditions, performed using the mouth-to-mouth ventilation method according to the 2015 ERC Guidelines for Resuscitation.

- **Test 4** - 5-minute CPR in conditions of fatigue, performed immediately after a simulated water rescue. Cardiopulmonary resuscitation (CPR) was performed in accordance with the current guidelines for resuscitation [18].

The simulated rescue operation took place in a specially designated body of water in a lake, marked with a rescue operation field by lane lines and buoys. The subjects' task was to correctly perform the following elements of the rescue operation:

- cover a distance of 50 m by running to the water edge,
- throw a rescuing line onto a 2.5-m wide track at a distance of not less than 10 m.

Failure to complete this task occurred after three failed attempts, which resulted in:

- the necessity to swim an additional penalty distance of 20 m,
- jumping into the water from a stable shore with a rescue belt or a self-swimming buoy and swimming a distance of 40 m (of which 25 m - freestyle, 15 m - by rescue method),
- swimming a distance of 10 m under the waterline and picking up the dummy,
- towing the dummy over a distance of 20 m by any means and taking it out of the water; after removing the manikin from the water, the subject immediately proceeded to perform 5-minute CPR under conditions of fatigue.

The dummy used for the tests was qualified equipment, used in international water rescue competitions, certified by the International Life Saving Federation.

Before both tests were carried out, rescuers were trained in the algorithm of dealing with a rescued person and immediate feedback, which was supervised by a certified Advanced Life Support instructor. During the tests, the subjects did not receive any feedback.

The effectiveness of the simulated water rescue was assessed both quantitatively and qualitatively.

Based on the results of the rescue operation in water, a point index of the effectiveness of this operation was created. This index was calculated as follows:

- **1 point** was awarded for each well-performed element of the rescue operation,
- while for a badly performed element or its lack, 0 **points** were awarded.

The sum of points obtained by each of the participants allowed to design a rank in terms of the effectiveness of the rescue operation. On the basis of quantitative data, a qualitative index of the effectiveness of water rescue operations was created. The percentage index was calculated as proposed by Kucia, Dybińska, Białkowski, Pałka [15]:

- the number of obtained points was divided by the duration of the rescue action in seconds; the result obtained was multiplied by 100.

Data collection

As a result of the questionnaire, the necessary information was collected on the subjects: age, body height, body mass, BMI, time of the last KPP training, dates of obtaining rescue licenses.

The following data on respiratory system parameters were collected in spirometric tests both in conditions of rest and fatigue:

- forced expiratory volume in the first second (FEV1) - the air volume expelled during the first second of forced exhalation,
- forced expiratory volume in the third second (FEV3) - the air volume expelled during the third second of forced exhalation,
- FEVO - percentage of vital capacity VC (FEV.75/VC),
- maximal expiratory flow for 25% residual FVC (FEF25),
- maximal expiratory flow for 50% residual FVC (FEF50),
- maximal expiratory flow for 75% residual FVC (FEF75),
- forced vital capacity (FVC) - the largest volume of air expelled during maximal expiratory effort,
- percentage of forced expiratory volume during the sixth second (FEV0.75 / FEV6),
- time of forced exhalation between 25-75% capacity (MET),
- duration of forced exhalation (FET),
- peak expiratory flow (PEF) - recorded during the maximal forced exhalation test - the highest flow obtained during the forced exhalation starting immediately after the deepest inhalation,
- maximal voluntary ventilation (MVV) - total maximal ventilation measured during 12 s and converted into ventilation per minute.

The 5-minute CPR included the following data:

- ventilation per minute - VmV,
- initial ventilation - IV,
- ventilation rate - VR,
- ventilation volume - VV.

Specialised rescue tasks performed by the subjects allowed to estimate the intensity of efforts in the water for the following distances:

- 50-m rescue method <50" - supramaximal effort intensity -V1,
- 75-m rescue action in water <3; 30" - maximal effort intensity - V2,
- 100-m freestyle <1:40" - submaximal effort intensity - V3,
- 400-m freestyle <8' - average effort intensity - V4,

➢ 600-m rescue run <14' - low effort intensity - V5.

Statistical analyses concerning the concept of research quality were very difficult to perform and it was even more difficult to interpret the obtained results. A large number of variables in terms of the research group in tabular form of data was cumbersome in interpretation and it was impossible to read the structure of the analysed variables. Therefore, as a result of the activities undertaken in the work, it was decided to perform analyses using the Pareto-Lorenz diagram. Currently, the general 80/20 rule indicates that about 20% of the elements represent about 80% of the cumulative value [19]. As reported by Kowalik (2018) [20], the use of Pareto analysis allows for taking corrective and preventive actions for a narrow group of identified causes, which will translate, to the greatest extent, into the elimination of errors and improvement of quality level. This means that this analysis allows for indication of the directions of activities (on a small scale and without incurring additional large costs) that will affect the most important issues and thus, contribute to obtaining maximum effects (by influencing the most frequently recurring problems).

The Pareto-Lorenz diagram, built on the basis of Pareto principle analysis, is a bar and line graph that graphically presents the frequency of occurrence of the causes related to a given problem (within bars) and their cumulative value (within the Lorenz curve) in a decreasing manner. It allows to skilfully focus resources on the elimination of one cause, in order to avoid dispersing resources to all at once. Pareto analysis is often used as a traditional quality tool to raise quality and improve various processes [20, 21, 22].

All statistical calculations of the obtained test results were performed using Statistica 7.0 software.

Results

First, the characteristics of the subjects were determined in terms of age, body height and mass, as well as the time of obtaining rescue licenses and duration passed since the last qualified first aid training.

The oldest group comprised professional soldiers of the GROM combat unit, and the youngest were officers of the Central Counter-Terrorism Sub-Unit (BOA), who, at the same, time, made up the group of the heaviest and

Table 1. Characteristics of the study group

Parameters	RW WOPR	GROM	BOA
Age [years]	29.4±1.12	31.2±4.15	26.9±2.26
Body height [cm]	182.86±7.86	184.59±6.60	187.85±7.33
Body mass [kg]	81.14±6.99	83.76±6.71	86.62±5.63
BMI [kg/m2]	24.29±1.75	24.65±2.46	24.63±2.22
Time of last CPR class [in months]	14.2±2.3	10.7±3.2	9.4±1.5
Time from obtaining rescue qualifications [in months]	22.6±4.6	40.8± 3.5	31.7± 3.7

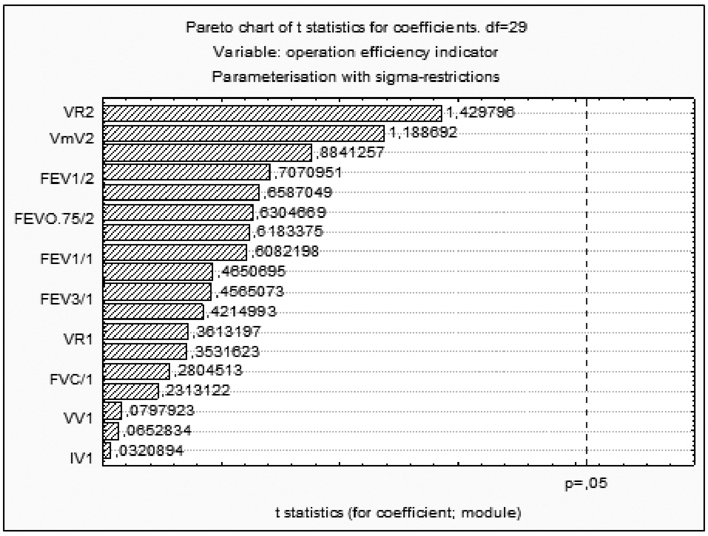

Figure 2: Pareto chart for the dependent variable of the rescue action rate versus spirometry parameters.

tallest participants. The BMI values in all groups turned out to be relatively normal and were within the normal range of 18.5-24.99. Out of the three examined groups, WOPR rescuers had the longest time lapse since the last KPP training, but they belonged to the group that obtained rescue rights the latest. The first and the longest-acquired qualifications in the field of rescue belonged to the professional soldiers of the GROM combat unit.

Consequently, using the Pareto-Lorenz method, the structure of direct spirometric and circulatory-respiratory parameters were analysed, which may have had impact on the point and percentage rate of the rescue operation effectiveness. A list of all identified parameters with the number of occurrences is presented in Figures 2 and 3.

The percentage share of parameters in first place at the significance level of 0.5 was 6.73% (Fig. 2). These data indicate that the quantitative index of the effectiveness of a rescue operation can be improved in terms of parameters such as:

- ventilation per minute (VmV) constituting 2.62%,
- forced expiratory volume in the first second (FEV1) equal to 2.82%,
- maximal expiratory flow for 75% of residual FVC (FEVO.75) constituting 1.29%,
- forced expiratory volume in the third second (FEV3) equal to 0.93%.

The percentage share of parameters to be improved at the significance level of 0.5 was 5.53% (Fig. 3). These data show how much it is possible to improve the quan-

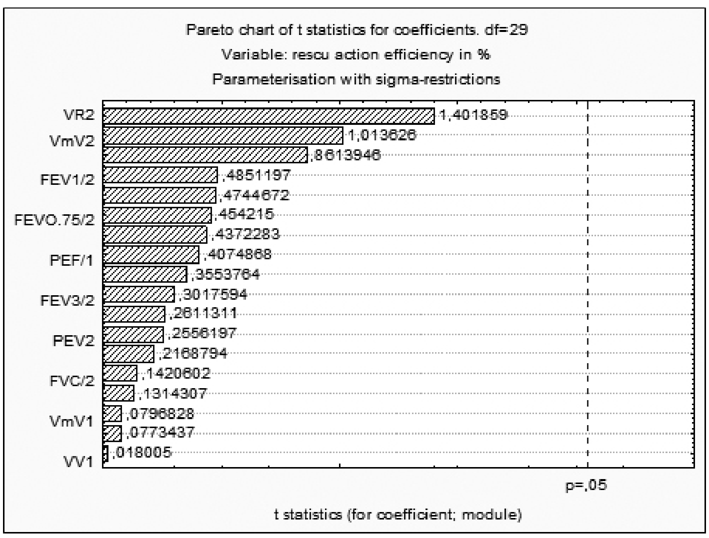

Figure 3: Pareto chart for the dependent variable of the rescue action efficiency in % versus spirometry parameters.

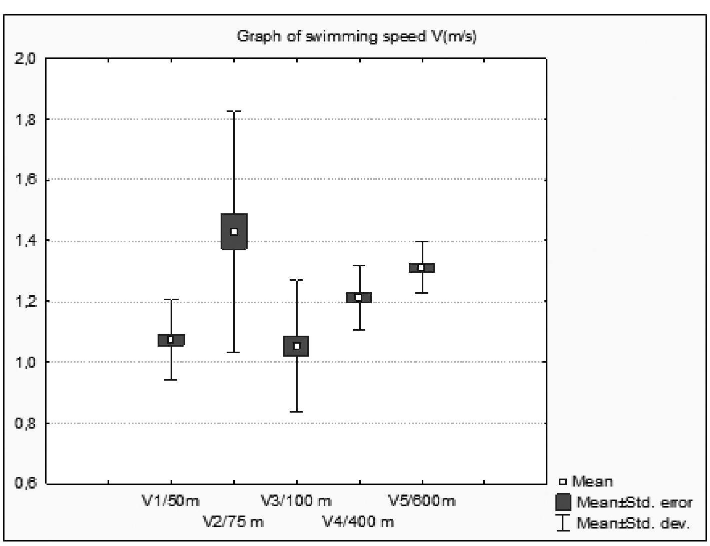

Figure 4: Swimming speed in selected rescue test

titative index of rescue operation effectiveness by improving parameters such as:

- ventilation per minute (VmV) constituting 2.41%,
- forced expiratory volume in the first second (FEV1) equal to 2.07%,
- maximal expiratory flow for 75% of the residual FVC FEVO.75 being 0.92%,
- peak expiratory flow (PEF) of 0.85%.

Both in the case of spirometric as well as cardiovascular and respiratory parameters, the Pareto-Lorenz diagram is very diverse, flatter than the model curve resulting from the 20-80 relationship. This may result in a difference regarding the defect grouped on the basis of quantitative and qualitative factors. Taking qualitative and quantitative factors into account, the group with the most important parameters from both analyses includes six of them: VmV, FEV, FVC, PEF, FEVO and FEV3, which constitute as much as 12.26% of all parameters considered.

Due to the fact that the main objective of the analysis was to identify a small group of the most important spirometric and cardiopulmonary parameters that may have potential impact on the point and percentage rate of rescue effectiveness, more complex and in-depth analyses in this regard will be required in the future.

In the final stage of research, the developed swimming speed in individual rescue tests with different swimming intensity was analysed.

As it results from the data in Figure 4, the highest swimming speed in five specialised rescue tests was obtained by the subjects for the 75-m distance (V2), which was characterised by maximal effort and averaged 1.45 m/s. The lowest speed (not at the distance of 600 m with low intensity of effort V5) was obtained during the distance of 100 m, where the submaximal effort V3 should occur and was, on average, 1.05 m/s.

Discussion

The main aim of the study was an attempt to determine spirometric indices identifying the level of respiratory muscle fatigue that may have potential impact on the effectiveness and quality of water rescue operations. In the study, the identification of CPR parameters in accordance with the requirements of 2015 ERC Guidelines for Resuscitation was also assumed. These parameters deteriorate due to fatigue caused by the rescue action.

Spirometry is a method of assessing the functional state of the human respiratory system and, at the same time, it is the most frequently used functional test, which consists in measuring and recording the capacity and volume of the lungs. Few studies have been devoted to non-invasive measurements of respiratory muscle function in the literature. McConnell and Copestake [23] emphasize that the research staff performing testing (experience, correctness of procedures performance) and the motivation of the research participant to perform the maximum possible effort at a given moment in terms of research activities, have huge impact on the measurements.

The quantitative index of rescue operation effectiveness can be improved in terms of spirometric parameters such as: forced expiratory volume in the first second (FEV1), maximal expiratory flow for 75% residual FVC (FEVO.75), and respiratory, such as ventilation per minute (VmV). The overall percentage improvement for this index was 6.73%.

The qualitative index of the rescue action effectiveness can be improved in terms of spirometric parameters such as forced expiratory volume in the first second (FEV1), maximal expiratory flow for 75% residual FVC (FEVO.75) and respiratory parameters such as ventilation per minute (VmV). The overall percentage improvement for this index was 5.53%. The obtained results of the analyses allow to conclude that with supramaximal effort V1, the differentiation of swimming speed among the subjects was small and ranged from 1.00-1.20 m/s. This may indicate that the subject approached this rescue test subliminally, wanting only to meet the time limit of 50 s, but not to develop the highest swimming speed for this sprinting distance. In literature on the subject, it is shown that a world-class swimmer reaches a speed of over 2 m/s for sprinting distances [24, 25].

During the maximal effort V2, one of the greatest speed differences within the research group occurred and it ranged from 1.0 to 1.9 m/s. This indicates that the subjects achieved various maximal speeds depending on the skills in the area of rescue operations and fitness capabilities of individual people. It can be assumed that this is a result of the body's decreased resistance to fatigue [23].

Subsequently, it can be noticed that in the study group, with submaximal effort V3, the differentiation of speed was small and ranged from 0.8-1.3 m/s. This may further indicate that the subjects approached this test subliminally, assuming only to meet the time limit, which was defined as 1 min 40 s. They did not develop maximum swimming speeds for this distance. On the other hand, this may be a result of a decrease in the ability to exercise in an aquatic environment due to fatigue [26].

During exercise of medium intensity V4, the greatest variation in speed was noted in the results within the research group and ranged from 1.15 - 1.45 m/s. The reason for such variation may be the different approach of the subjects as to the distribution of forces when passing this rescue test. The distance had to be covered with an average speed within the time limit of 8 minutes, which was related to time pressure.

In the study group, during exercise with low V4 intensity, there was slight variation in speed which ranged from 1.12 - 1.35 m/s. This may have resulted from the large time limit for completing the task (14 minutes) and, it seems, from the use of flippers for the 300-m distance.

The obtained results of the research concerning the efforts of moderate and low intensity may indicate that the energy cost increases for distances above 400 m. This is related to the higher oxygen demand of muscles [27].

It also seems that the practical objective was achieved in the presented research, as it consisted in the identification of spirometric and CPR indices, the improvement of which may affect the quality and effectiveness of the rescue operation.

According to Zysiak-Christ [28], the level of CPR effectiveness performed by the rescuer or by the witness of the event is of key importance for the victim in cardiac arrest. This applies to both operating in civil conditions and tactical activities.

In the present study, it is shown that both GROM soldiers, BOA policemen and WOPR rescuers performing activities in conditions of fatigue are able to successfully carry out a rescue operation in water and effectively perform cardiopulmonary resuscitation, even if these activities are performed after tasks that significantly increase fatigue.

According to the available literature on the subject, the conducted research is the first observation made in the field of classifying factors that may have potential impact on the quality and effectiveness of water rescue operations.

The obtained positive results of previous studies carried out by the authors of this study [15] indicated that it is worth continuing them with the participation of an increased number of subjects and extending the area of the variables taken into account. These were pilot studies conducted under controlled conditions in a swimming pool. The research results of the present work were carried out in realistic conditions, as close to those natural as possible - in a lake. In the used and designed tests, the authors wanted to simulate the worst-case scenario that a rescuer may encounter in civil or military conditions.

It seems that the need to carry out a safe and effective rescue operation, and then to perform effective cardiopulmonary restitution in conditions of fatigue, is of key importance for a person requiring help following cardiac arrest.

Highlighting the significance of the activities performed by various groups of uniformed services prepared for this purpose, as well as to improve the quality of rescue training, the results of research in this area may have positive impact on the effectiveness and quality of saving lives of people at risk of drowning. In the research conducted by other authors in this field, the importance of individual factors, such as training, awareness, technique, fatigue, is emphasized as key elements affecting both the quality and effectiveness of the rescue operation [29].

It is also indicated by other researchers [30] that the introduction of obstacles to a simulated rescue operation in the form of an additional underwater task increases the effectiveness of the entire operation and can be used as a tool to assess and verify the effectiveness of rescue operations.

Conclusions

The conducted research allowed for the selection of spirometric indices, identifying the level of respiratory muscle fatigue, as well as resuscitation parameters that may have potential impact on the effectiveness and quality of a rescue operation.

1. The spirometric and respiratory parameters that can be used to improve the quantitative index of rescue operation parameters are:
   - forced expiratory volume in the first second (FEV1),
   - maximal expiratory flow for 75% residual FVC (FEVO.75),
   - ventilation per minute (VmV).
2. The following spirometric and respiratory parameters may have potential impact on the qualitative index of rescue action effectiveness:
   - forced expiratory volume in the first second (FEV1),
   - maximal expiratory flow for 75% residual FVC (FEVO.75),
   - and respiratory, such as ventilation per minute (VmV).
3. It seems that the accumulation of fatigue caused by rescue actions, in conditions of stress overload of the respiratory muscles, reduces the quality of ventilation procedures performed during cardiopulmonary resuscitation.

The group of the most important spirometric parameters identifying the level of respiratory muscle fatigue includes: VmV, FEV, FVC, PEF, FEVO FEV3, which accounts for as much as 12.26% of all parameters taken into account, and their improvement may be associated with better performance and execution of a rescue operation, both in terms of quality and quantity.

Applicative conclusions

In order to obtain a more complete image of the presented issue and to indicate directions of corrective or preventive actions in rescue operations, this type of research should be continued on a larger number of participants, in more extreme weather conditions and different waters (seas, lakes, rivers). This research may also inspire further considerations regarding the identification of factors causing fatigue among rescuers and affecting the effectiveness and quality of rescue operations.

References:

[1] Peden M, Oyegbite K, Ozanne-Smith J: *World report on child injury prevention*. Geneva: World Health Organization; 2008.
[2] Halik R, Poznańska A, Seroka W, Wojtyniak B: *Wypadkowe utonięcia w Polsce w latach 2000-2012. Zakład Centrum Monitorowania i Analiz Stanu Zdrowia Ludności Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny.* Zdrowie Publiczne: Przegl Epidemiol. 2014; 68:591– 594.
[3] Lemaitre F, Coquart JB, Chavallard F: *Effect of Additional Respiratory Muscle Endurance Training in Young Well-Trained Swimmers*. JSSM. 2013; 12(4):630–638.
[4] Romer LM, McConnell AK, Jones DA: *Inspiratory muscle fatigue in trained cyclists: effects of inspiratory muscle training*. Med. Sci. Sports Exerc. 2002; 34(5):785–792.
[5] Walker DJ, Ertl T, Walterspacher S: *Respiratory muscle function during a six-week period of normocapnic hyperpnoea training.* Neurobiol. 2013;15:188(2):208–13.
[6] Powers SK, Coombes J, Demirel H. Exercise training-induced changes in respiratory muscles Sports Med. 1997;24(2):120-31.
[7] Fischer G, Tarperi C, George K: *An exploratory study of respiratory muscle endurance training in high lesion level paraplegic hand bike athletes*. J Sport Med. 2014; 24(1):69–75.
[8] Boutellier U, Biichel R, Kundert A: *The respiratory system as an exercise limiting factor in normal trained subjects*. Eur J Appl Physiol. 1992;65:347–353.
[9] Mueller G, Perret C, Spengler CM: *Optimal intensity for respiratory muscle endurance training in patients with spinal cord injury*. J Rehabil Med. 2006;38(6):381-6.
[10] Uemura H, Lundgren CEG, Ray AD: *Effects of Different Types of Respiratory Muscle Training on Exercise Performance in Runners*. Mil Med. 2012;177(5):559-66.
[11] Perenc L, Kaczmarek–Borowska B, Tymczak M: *Endurance training of the respiratory muscles –literature research*. Medical Review. 2016;(2): 193-208.
[12] Jalali A, Simpao A, Gálvez J, Berg R, Nadkarni VM, Nataraj CA: *Dynamic model of rescuer parameters for optimizing blood gas delivery during cardiopulmonary resuscitation.* Comput Math Methods Med. 2018: 3569346. DOI: 10.1155/2018/3569346.
[13] Cha KC, Kim YW, Kim TH, et al.: *Comparison Between 30:1 and 30:2 Compression-to-ventilation Ratios for Cardiopulmonary Resuscitation: Are Two Ventilations Necessary?*. Acid Emerg Med. 2015;22(11):1261-1266. 15.
[14] Yeh ST, Cawley RJ, Aune SE, Angelos MG: *Oxygen requirement during cardiopulmonary resuscitation (CPR) to effect return of spontaneous circulation*. Resuscitation. 2009;80(8):951-955.
[15] Kucia K, Dybińska E, Białkowski T, Pałka T: *The impact of respiratory muscle fatigue on the quality and efficiency of rescue action.* JKES. 2017; 80 (27): 65-75.
[16] Gondrowicz K, Siergiejko Z: *Zalecenia Polskiego Towarzystwa Ftyzjopneumonologicznego dotyczące wykonywania badań spirometrycznych*. Warszawa: PTF; 2004. (Pneumonologia i Alergologia nr 72).
[17] Tamplin J, Berlowitz DJ: *A systematic review and meta – analysis of the effects of respiratory muscle training on pulmonary function in tetraplegia*. Spinal Cord. 2014; 52(3):175-80.
[18] Arends J: *Wytyczne resuscytacji*. Kraków: Europejską Rada Resuscytacji, Polską Radą Resuscytacji; 2016.
[19] Bociąga M, Klimecka-Tatar D: *Narzędzia zarządzania jakością w branży cementowej*. Archiwum Wiedzy Inżynierskiej 2016;1:3638.
[20] Kowalik K: *Diagram Pareto-Lorenza w teorii i praktyce zarządzania jakością*. Archiwum wiedzy inżynierskiej. 2018;3(1):22-24
[21] Knights P: *Rethinking Pareto analysis: maintenance applications of logarithmic scatterplots*. Journal of Quality in Maintenance Engineering. 2001;7:252-263.
[22] Hamrol A: *Zarządzanie jakością z przykładami*. Warszawa: Wyd. PWN; 2005.
[23] McConnell AK, Caine MP, Sharpe GR: *Inspiratory muscle fatigue following running to volitional fatigue: The influence of baseline strength*. Int J Sports Med. 1997;18(3):169-73.
[24] Troup JP*: The physiology and biomechanics of competitive swimming*. Clin Sports Med. 1999;18(2):267-85.
[25] Rakowski M: *Nowoczesny trening pływacki*. Rumia: Centrum Rekreacyjno-Sportowe Rafa; 2008.
[26] Johnson BD, Aaron EA, Babcock MA, Dempsey JA: *Respiratory muscle fatigue during exercise: implications for performance.* Med Sci Sports Exerc. 1996 Sep;28(9):1129-37.
[27] Sheel AW: *Respiratory muscle training in healthy individuals for exercise performance*. Sports Med. 2002; 32:567–581.
[28] Zysiak-Christ B: *Effectiveness of performing cardiopulmonary resuscitationby officer cadets after actions of a tactical nature*. Emerg Med Serv 2019; VI, 1: 7-12.
[29] Ong EH: *Improving the quality of CPR in the community*. Singapore Med J. 2011;52(8):586-91.
[30] Wiesner W and Niedziela M: *Underwater task performance during an examination.* PolHypRes 2013;44(3):79 – 96

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