NATIONAL SPORTS ACADEMY "VASIL LEVSKI"
"TOURISM, ALPINISM AND ORIENTEERING" DEPARTMENT

Todor Minkov Todorov

METHODOLOGY OF PHYSICAL TRAINING OF PERSONS WORKING THROUGH ROPE ACCESS

ABSTRACT

of a dissertation for award
of educational and scientific degree "Doctor" in
7.6 Sport Sciences

Supervisor: Assoc. Alexander Metodiev Shopov, PhD

Official review by:
Prof. Valentin Georgiev Garkov, PhD
Prof. Malcho Stoyanov Malchev, ScD

SOFIA, 2022

The dissertation contains 140 standard pages. It is illustrated with 33 tables and 28 figures. Literature sources contain 36 titles, of which 18 in Cyrillic, 7 in Latin and 11 websites.

The dissertation defense will take place on January 18, 2023 at 11:30 a.m. in Hall A3 of the National Sports Academy “Vasil Levski”, Studentski Grad, at a meeting of the Scientific Jury.

The defense materials are published on the National Sports Academy “Vasil Levski” website and are available to those interested
in the NSA “Vasil Levski” Library.

INTRODUCTION

Rope access is a popular and widely used method in all areas of our life: construction, telecommunications, power engineering, sports and tourism, food industry, ecology, emergency and rescue activities in industry, civil sites, environment and many others. In this dissertation, we describe the rope access method/technology, training, certification, principle of operation, industries in which it is used, safety and efficiency of the activities performed by its use.

The man is the main component for doing certain work in all these activities. Health and safety and their protection are the most important things we should care about. This is related to training, knowledge, skills, experience, courage and the various motor qualities (strength, endurance, speed, flexibility, agility) that are the basis of safety and efficiency in the work process.

The preliminary requirements to the candidates for initial training are to be physically and mentally fit, and able to tolerate heights. Since the development of motor qualities (strength, endurance, speed, flexibility, agility) is not included in any training programs, we addressed this problem, and through a test battery and approbation of exercise systems, we created a methodology for physical training of hight technicians. We approbated the “self-ascending” test, which is a fundamental element of rope access and provides information on both physical and technical fitness of the technicians.

Good levels of general fitness and functional status of all organs and systems are mandatory conditions for carrying out the exercises, acceleration of recovery processes and minimization of the risk of injuries and other pathological conditions. In rope access, the specific training of the arms and shoulder girdle is important, since these are loaded the most during the work process.

WORKING HYPOTHESIS

Our literature review related to the requirements, training, certification and our personal experience on the problem gives us the reason to formulate the following scientific hypothesis:

We assume that a purposeful implementation of an experimental methodology for physical training will contribute to the development of certain motor skills of rope access techniciants, which are necessary for the correct and safe performance of the work process.

METHODS OF SURVEY

The purpose of this survey is to research, develop and follow up the effect of an innovative author's program and methodology for specific physical training for people employed in professions that require the implementation of the "Rope access" technology.

The topic, working hypothesis and defined objective of the survey predetermined the following research tasks:

1. To explain the scientific problem (question) and describe the most essential elements and factors of the professional activities requiring the implementation of the "Rope access" technology, and to clarify the criteria for training in this profession.

2. To perform a functional and anatomic analysis of the main motor actions in the work operations of technicians who implement the "Rope access" technology, in order to reveal the various participation of the individual muscle groups or muscles and ensure clarity and refine the selection of the tools and methods of the specific physical training of technicians.

3. In accordance with the professiographic characteristics, to develop and approbate an innovative program and methodology for building the specific motor qualities that limit the abilities, quality and occupational safety of those employed in professions based on the "Rope access" method/technology.

The area of this survey is the improvement of the scientific organization of hight technician work by optimizing the basic psycho-physiological requirements for such workers, depending on the specific technical and economic specializations.

The subject of this survey is the process of the specific physical training of height technicians through the implementation of an innovative author's program and methodology, the study and the effect of carrying out a methodology for physical training for rope access technicians.

The object of this survey is the physiometric quantitative and qualitative indicators, which reveal the dynamics of the physical qualities of the hight technicians, as a result of the impact applied through the specialized training methodology.

The population of this survey are the hight technicians in whom the innovative program and methodology for specific physical training was implemented. 58 subjects were included in the survey.

This survey was conducted over a 3-year period (2019 – 2021). The distribution of the population is presented in Figure 1.

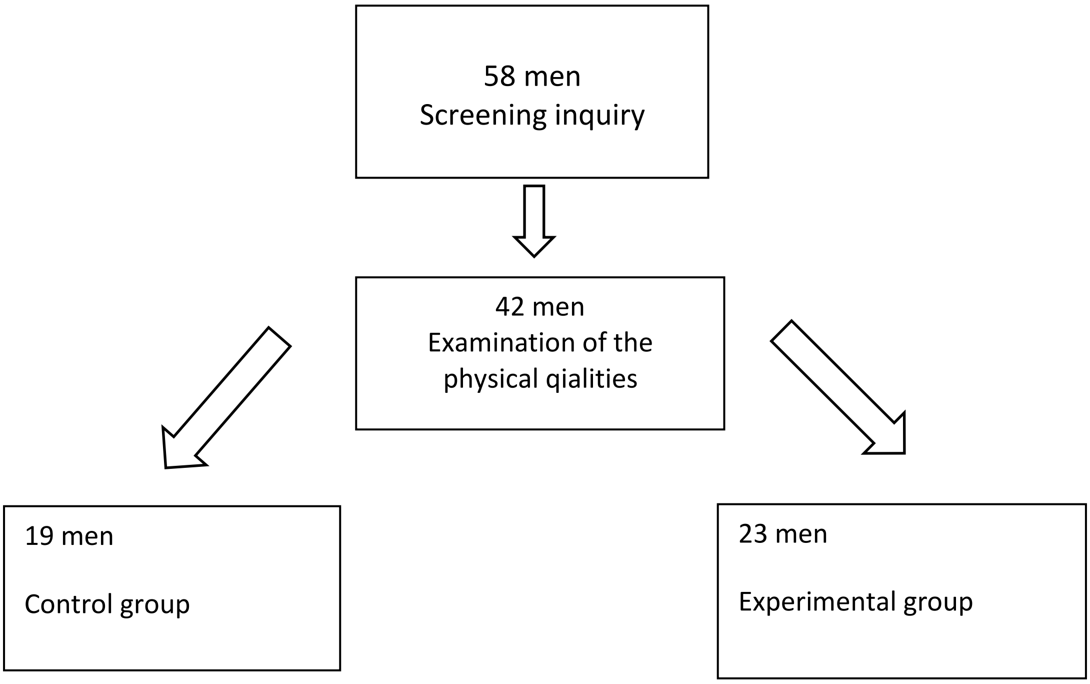


Figure 1. Population distribution

To confirm or reject the hypothesis, as well as to solve the tasks and achieve the objective of the survey, we used a comprehensive methodology, which included the following methods:

◊Theoretical and logical methods;

◊ Sociological methods;

◊ Sports and pedagogical methods;

◊ Mathematical and statistical methods.

The theoretical and logical methods are the method of analysis and the method of synthesis. The analysis was focused on the dynamics of historical, normative and didactic documents dealing with questions and issues from the scientific area of our survey. We mainly used: the meta-analysis, content analysis and system analysis method.

The method of synthesis was actually a theoretical or actual joining together of the parts of the whole separated by the analysis. Our task was to investigate the structural and functional characteristics of the specific physical (conditioning) training of people employed in professions that require the implementation of the "Rope access" method/technology.

The sociological method used was the inquiry. Initially, an inquiry was conducted among 58 male rope access technicians. Its purpose was to gain insight into the opinions and attitudes among the technicians regarding their physical fitness and whether it was necessary for their work.

Of all respondents, 42 people were selected for enrolment in the **main part** of our survey. Selection was made based on the following inclusion and exclusion criteria.

Inclusion criteria:

- *Job experience in the rope access between 3 – 10 years*
- *Completed rope access course level 1 to 3*
- *Willingness to participate in a physical training program for rope access technicians*

Exclusion criteria:

- *Job experience under 3 years*
- *No rope access course completed*

We randomly assigned the 42 men who met the inclusion criteria into two groups. The control group (CG) consisted of 19 subjects, and the experimental group (EG) consisted of 23 subjects. Tables 1 and 2 show the anthropometric data of both groups.

Table 1. Anthropometric data of the control group

No.	Indicator	n	Xmin	Xmax	R	Xcp	S	V%	As	Ex
1.	Age (years)	19	24	43	19	34.7	5.39	15.5%	-0.433	-0.899
2.	Height (cm)	19	171	190	19	180.2	4.36	2.41%	0.235	0.775
3.	Weight (kg)	19	65	96	31	79.9	8.78	10.9%	0.126	-0.422

The average age of the subjects assigned to the control group was 34.7 years. Their average height was 180.2 cm, and their average weight was 79.9 kg. The subjects assigned to the experimental group had an average age of 33.9 years, an average height of 178.0 cm and an average weight of 82.1 kg. According to the coefficient of variation, both the CG and EG were uniform in terms of height and weight, and approximately uniform in terms of age.

Table 2. Anthropometric data of the experimental group

No.	Indicator	n	Xmin	Xmax	R	Xcp	S	V%	As	Ex
1.	Age (years)	23	25	46	21	33.9	6.10	17.9%	0.317	-1.006
2.	Height (cm)	23	169	187	18	178.0	4.43	2.4%	-0.003	0.315
3.	Weight (kg)	23	69	98	29	82.1	7.73	9.4%	0.050	-0.294

To compare anthropometric data between the CG and EG, we used Student's t-test for independent samples (Table 3). No statistically significant differences were observed between the two groups on any indicator.

Table 3. Average values and significance of the differences in the anthropometric data for both surveyed groups

No.	Indicator	CG (n=19)		EG (n=23)		d	t	P%
		X1 mean	S1	X2 mean	S2			
1.	Age	34.7	5.39	33.9	6.10	0.8	0.454	34.8%
2.	Height	180.2	4.36	178.0	4.43	2.2	1.582	87.8%
3.	Weight	79.9	8.78	82.1	7.73	2.2	0.877	61.4%

During the survey, we carried out **sports and pedagogical observation** of 42 subjects participating in the pedagogical experiment. It was carried out during the conduct of diagnostic procedures with the tests for control and assessment of the physical qualities, competence (*knowledge, motor skills and habits*), as well as during some of the training activities conducted for their developement.

The object of the pedagogical observation was the spatial-temporal and strength features of the sports and technical skills for work with the "Rope access" technology. The following tests were used to assess the motor skills of height technicians:

- ***Dynamometry*** of both arms of the subject.
- ***Overhand hang with arm flexion.***
- ***Throwing a thick ball with two hands overhead from a standing position.***
- ***Standing long jump with both feet.***
- ***Canadian – 3 minute step test.***
- ***Self-ascending using two ropes.*** Self-ascending (climbing a rope) is a key element in working at height. It is used when it is not possible to reach a

solid support – land, work site, a strong structure that can bear the load of the technique, equipment, tools and machines that are in use, and does not allow for the technician's safe evacuation (leaving the workplace). And also, when, to reach a working position, it is better for the technician to pull himself up than to make a long or difficult descent. The fast and correct execution of this action and the ability to perform it repeatedly throughout the work process is of utmost importance. There are no research methods related to self-ascending described in the available scientific literature. This is what gave us the reason to create and approbate a suitable test for the measurement of this complex motor activity. Two static/semi-static ropes, freely hanging from 12-14 m height, with a 10-meter marker on the main rope are required for the test. Each of them is fixed on two independent support points. There should not be a wall, column, structure, etc. near them that could serve as a support for an arm or leg. The subject is equipped with: 1 belt for the whole body and for sitting position (harness) with chest self-grip (crol), 1 automatic locking landing gear (ID L), 1 braking device (ASAP LOCK), 1 absorbent safety strap, 1 manual self-grip (left or right), 1 foot pedal, 2 rope safety straps, 3 steel connectors (carabiners) with coupling, 2 aluminum carabiners with an automatic coupling. The baseline position of the subject is standing on the support (floor), equipped with a harness. The chest and hand grips are attached to the working rope. The hand grip is above the chest grip. At the lower end of the manual self-grip with a clutch (carabiner), the pedal is attached and one foot is placed in it. The braking device is attached to the belay rope and is locked to the harness by an absorbent tape and a carabiner with an automatic coupling. On the command "Ready", the subject compensates the elasticity of the rope and hangs on it using the chest self-grip (crol). One lower limb is in contact with the support with the knee joint slightly bent, the foot of the other lower limb is in the pedal and raised as much as possible according to the ability of the subject. The upper limbs are above the head, extended at the elbow joints. One hand holds the handle of the self-grip and the other grips the top attachment of the self-grip to the rope. On the command "Go", the subject begins to pull himself up the rope by pulling with his hands and pushing with his legs and pedal. The movement of the hand grip, the hands and the foot on the pedal, and the hanging on the crol, should be synchronized (Figure 5a and Figure 5b). With a stopwatch, the time from raising the foot off the ground until reaching the 10-meter marker with the self-grip, is counted. The time is recorded to the nearest 1 s. The lower end of the ropes is held stretched by an assistant.

The data obtained from the tests were processed by SPSS 23 statistical processing program using the **following statistical methods**:

1. Frequency analysis

2. Variational analysis – through the standard parameters

3. Hypothesis testing through comparative analysis using Student's T-test for dependent and independent samples with a guaranteed probability of P=99.9%

4. Pearson's $\chi 2$ for comparing independent samples

5. Graphical analysis

SURVEY ORGANIZATION

This survey was conducted for a period of 3 years (2019 – 2021) and included the following **main stages**:

- planning and organizing the survey /development of a concept and specific organization/;
- conducting the survey;
- statistical processing of the empirical results;
- result analysis.

In the first stage of the survey in 2019, the following were outlined: the problem of the study, the subject and object, the objective and tasks, hypothesis, clarification of the concepts and methodology of the survey, and the overall organization of the survey.

The second stage of the survey covered the period from November 2019 until the end of June 2021, with the conduct of the main survey and the planned diagnostic procedures.

Third stage – September 2022, finalization and polygraphic layout of the dissertation.

The key limitations in the process of developing the dissertation were related to the spread of the pandemic caused by Corona virus COVID-19, as its peaks and restrictions imposed by the health authorities coincided with our organization and the course of the sports and pedagogical experiment. This necessitated the use of flexible approaches to overcome the limitations.

We used the strategy of the Ministry of Education and Science, borrowing the idea of remote training of hight technicians and the individual organization of the training process under the unified innovative program and methodology. The planned diagnostic procedures were also in accordance with the requirements of the Ministry of Health and the Regional Inspection for Protection and Control of Public Health.

SPECIALIZED METHOD FOR PHYSICAL TRAINING FOR ROPE ACCESS TECHNICIANS

The methodology for physical training of rope access technicians was divided into three phases:

- **1st month after the end of the active working season**. The purpose is the active physical and psychological recovery. The training program is performed three times a week, with a duration of 40-50 minutes. The exercises are relatively simple and easy to perform. The intensity of performance is low, with a small number of repetitions and a small number of series, with longer resting intervals. In the last week, the repetitions increase and the rests are reduced. The activity density is approximately 60-65%, and at the end of the month it reaches 70%. We used general preparatory exercises with a continuous uniform and continuous variable method of training, with the aim of improving the vegetative functions and aerobic capabilities of the body.
- **2nd month after the end of the active working season.** In this period, the frequency of the activities is maintained as three times a week. The duration of one training is between 45-60 minutes. New exercises are added to the previous exercises, the old ones are becoming more complicated, the resistance is increased. The intensity is low, and from the middle of the period it is moderate, the number of repetitions in the series is increased, the rests are fewer and shorter at the end of the period. The activity density is approximately 70-75%. The training is in the area of aerobic energy provision, and the methods used are continuous variable and continuous interval. Cyclic training (running, veloergometry, cycling and swimming) gradually reach moderate to medium intensity with mixed (aerobic-anaerobic) energy supply.
- **3rd – 4th month after the end of the active working season.**

The trainings take place three times a week with a duration of 50-60 minutes. In this period of preparation, we developed the strength capabilities of the group through exercises with maximum force tensions. At the beginning of this period, we started with the maximum effort training method, by overcoming maximum resistance. We implemented the method of maximum concentric-eccentric tensions with resistance 70-90%, 6-8 repetitions in a series, 3-5 series, rests for 3-5 minutes, mostly with special preparatory strength exercises. Isometric exercises were also included for maximum grip, forearm and brachial plexus strength. From the fifth and sixth weeks of the period, we began to work on developing the power endurance, through the method of repeated efforts with overcoming unlimited resistance until severe fatigue. The training was mainly carried out in a circuit, involving all the main muscle groups with a resistance of 40-70% of Pmax, repetitions in a series – until failure, 3-5 series, rests for 60-90 seconds, rests between the modules for 5-8 minutes. During the last two weeks of the period, we carried oud dynamic strength training for the lower and upper limbs. The exercises were performed around the maximum intensity until failure, rests for 5-7 minutes, 5-7 series, and the other trainings were performed at a moderate intensity.

The cyclic training in the first month was of medium intensity, with mixed (aerobic-anaerobic) energy supply, and in the second month it was within the limits of the Anaerobic Threshold, with a duration of 30-60 minutes.

In the preparatory part of each workout, to warm up the joints and muscles, we used active and passive exercises with enhanced amplitude, with stretching exercises in the final part.

Throughout the program, the subjects worked with elastic bands, with different kilograms of resistance (to lighten or aggravate) the loads, dumbbells, barbells, training rods and their parts, flexbar, training devices for the fingers, personal weight and weights thereto.

The objective of the training program is to achieve a sustainable status of the general and special working capacity of the rope access technicians and a better overall conditioning shape for the upcoming work season. Its achievement is related to the performance of specific tasks distributed during each of the training periods.

An important feature of the implemented methodology is that its exercises are relatively technically familiar to those involved and for the most part do not require any specific equipment. These conditions were necessary for the following reasons:

- Trainees are not bound to visiting sports halls/gyms, i.e. the exercises are accessible and applicable to be performed at home, on open sports grounds, parks, etc. This condition proved to be extremely important due to the epidemiological emergency situation related to COVID-19 that started at the time of the survey and is still continuing.
- Trainees can perform the exercises at any time convenient for them.
- The familiar technique of performing the exercises implies their correct performance. It is the basis for obtaining the desired effect from the given exercise, and also leads to the prevention of controversial traumatism.

RESULTS AND ANALYSIS

Inquiry results analysis

The purpose of the inquiry was to establish the attitudes and opinions of the rope access technicians regarding the necessary motor qualities at work and the need for good physical training.

The inquiry was conducted among 58 rope access workers, all male. The average age of the population was 40.0 years. The mean values of the anthropometric parameters height and weight were 178.2 cm and 83.6 kg, respectively. The majority of the population, i.e., 56.9%, had more than 10 years of experience in rope access, followed by 22.4% with experience between 1 and 5 years, and 20.7% between 5 and 10 years (Figure 2).

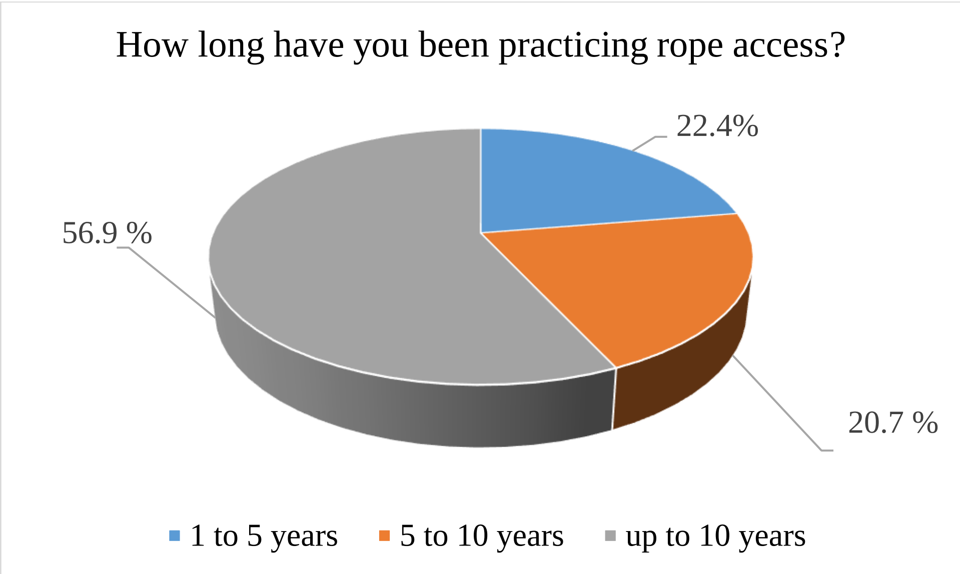


Figure 2. Distribution of respondents' work experience in rope access

Regarding the completion of a qualification course for rope access, it was noticeable that a large part of the respondents had not participated in any course before starting work (51.7%). 43.1% of the population had started working with rope access based on their knowledge and skills from another similar activity –

mountaineering, speleology, sport climbing, etc., and subsequently had completed a course (Figure 3). We associate these results with the fact that there is no mandatory requirement in Bulgaria for a completed qualification level for working with rope access in exercising various activities requiring its use.

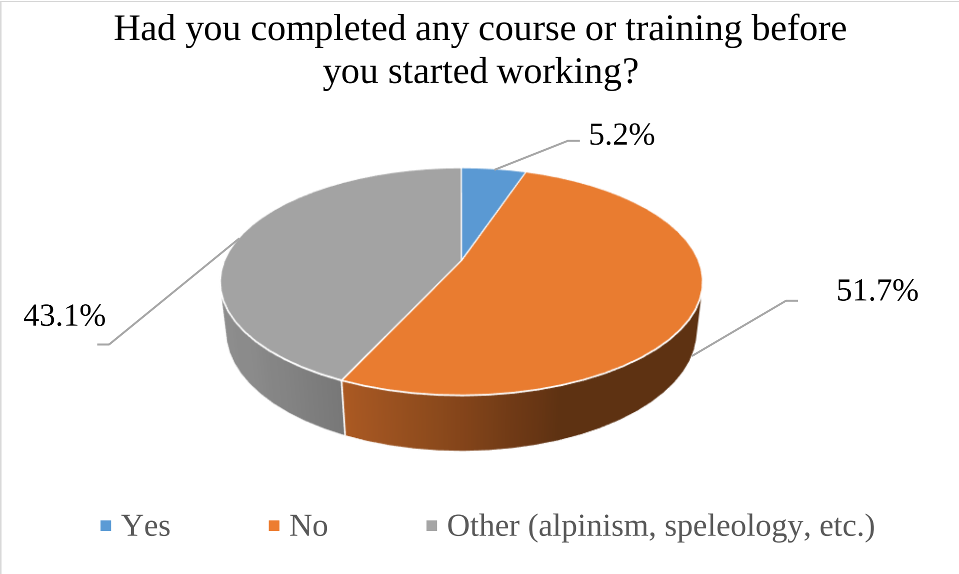
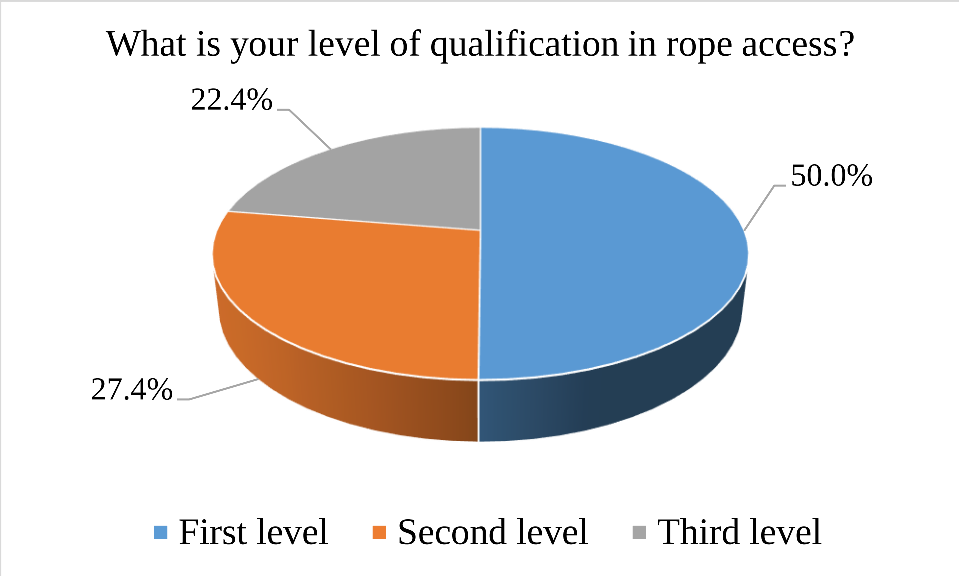


Figure 4. Distribution of respondents according to their completed rope access course

Half of the respondents (50.0%) had acquired “First level” qualification, and the remaining two levels were relatively evenly distributed: 27.4% for the second and 22.4% for the third level (Figure 5). Maintaining a good rate of increase in retraining for the second and third levels was an indicator that the technicians found meaningful, with prospects for development. The basic prerequisite was the better pay.



Fugure 5. Level of professional qualification of respondents

All participants in the inquiry agreed (100%) that good physical fitness was important for rope access technicians, and 94.8% believed it affected the safety and efficiency of their work (Figures 6 and 7)

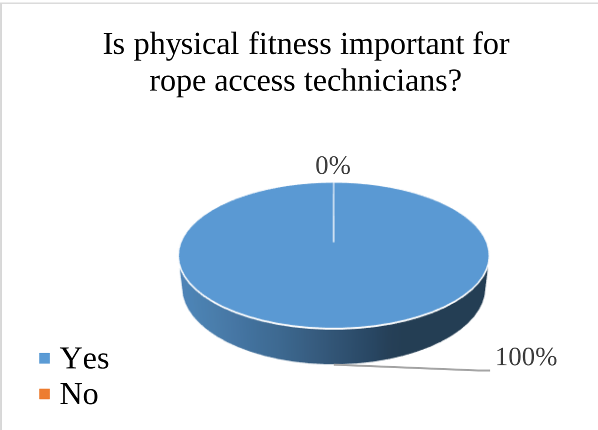


Figure 6.
Importance of physical fitness in rope access

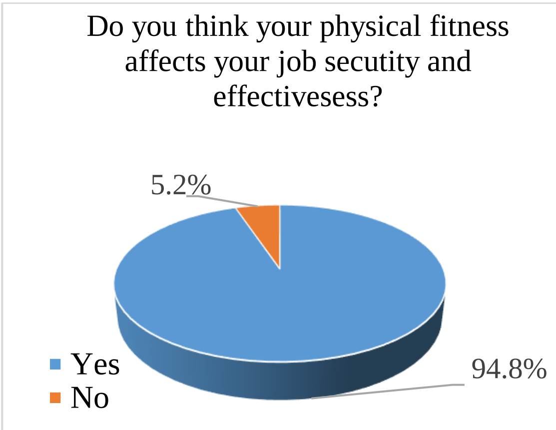


Figure 7.
Impact of physical fitness on job security and effectiveness

A large part of the respondents is training for general physical fitness in the so-called inactive season when they are not busy with work (Figure 8). The largest percentage (44.8%) answered that they exercise "sometimes", which implied sporadic activities including motor activity and a lack of consistency. Only 25.9% defined themselves as regular sportsmen, and 29.3% did not exercise at all. These results indicated that nearly 2/3 of the technicians did not train adequately, which could have adverse effects on the safety and effectiveness during the busy work season.

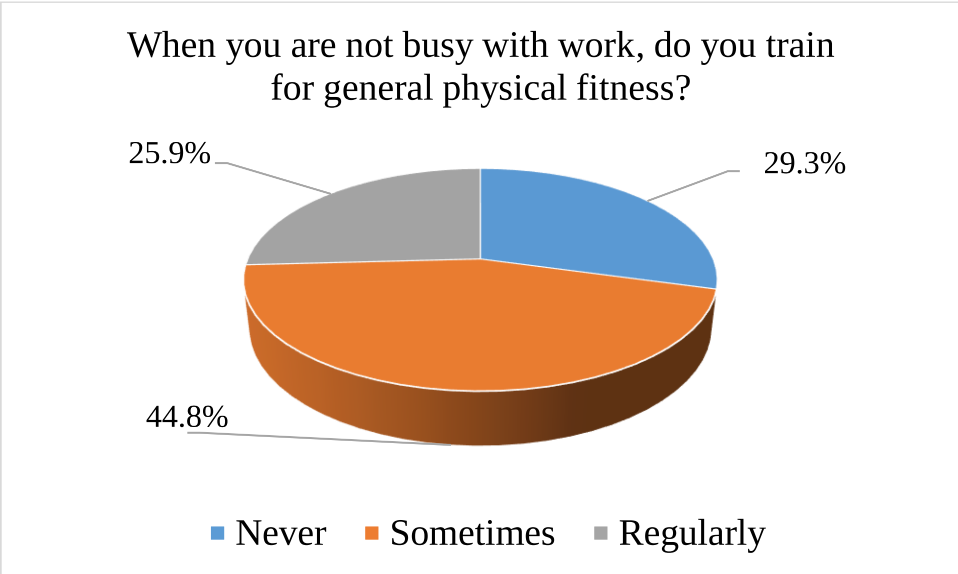


Figure 8. Distribution of subjects training for general physical fitness

To the question of how many times a week they train, most participants answered twice a week (43.1%), and three or more times (20.7%), which is a total of (63.8%). These are very good results for the training subject group. (Figure 9).

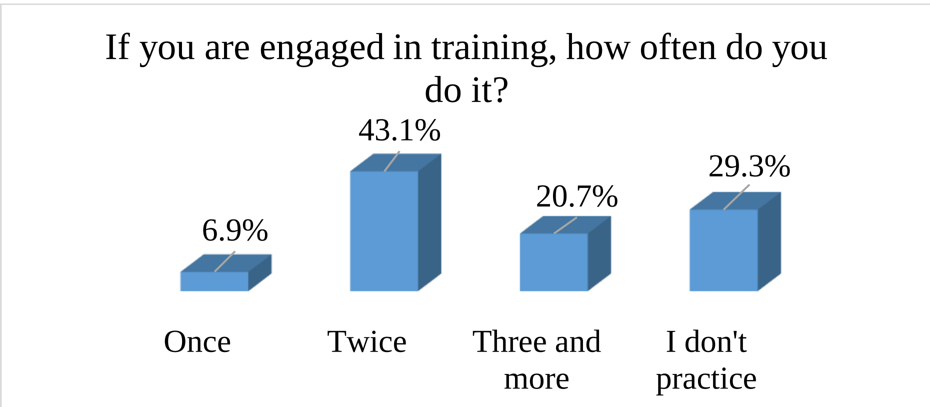


Figure 9. Frequency of activities including general physical training among the respondents

When asked which part of the body they trained most often, the respondents answered that their efforts were most often focused on training the whole body (50.0%), followed by exercises for the upper limbs (24.1%) and abdominal (20.7%) and back muscles. The overall results were good and showed that the training was well distributed among the individual parts of the body by the training technicians (Figure 10).

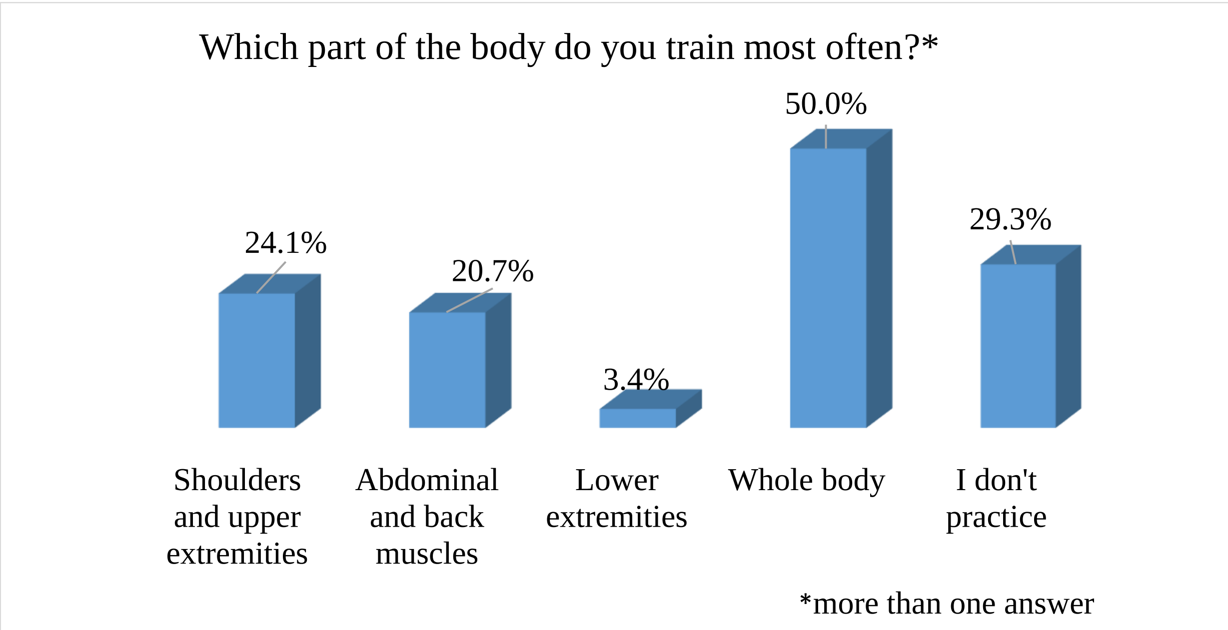


Figure 10. Predominantly trained body areas according to the respondents

When asked the question “Where do you prefer to train?”, the answer “Outdoors” predominates, followed by a gym (24.1%) and at home (10.3%). This result (51.7%) shows that half of the exercisers, in addition to the effect of physical exercise, also relieve themselves psychologically in the beneficial natural environment (Figure 11).

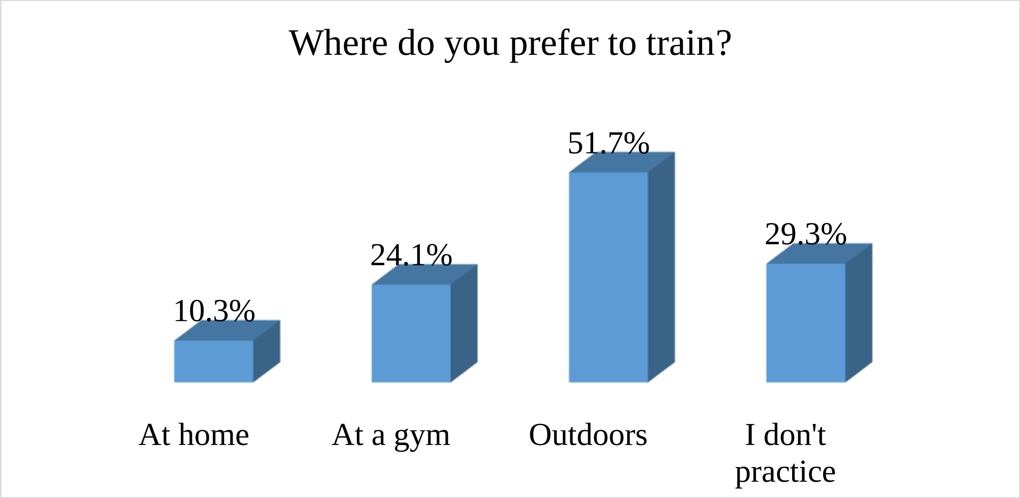


Figure 11. Preferred places for training of the participants

The answers to these questions were important in the selection of the specific exercises included in the methodology. We took into account the opinion of the respondents and included exercises suitable for performance in the gym, outdoors, and at home. For the development of general endurance, in addition to the complex exercises of the methodology, we recommended a cyclic motor activity (running, bicycle ergonometry, cycling and swimming) to which the practitioner had an affinity.

The inquiry also included a question to rank the five basic physical attributes – speed, strength, agility, endurance and flexibility, according to their importance in working at height. The results are presented in Figure 12 (A to E). The subjects undoubtedly defined endurance, strength and agility as the most necessary motor qualities in working at height.

Our theoretical and practical experience also supports these results. For this reason, our methodology is focused precisely on the adaptation and development of these physical qualities in the inactive working season.

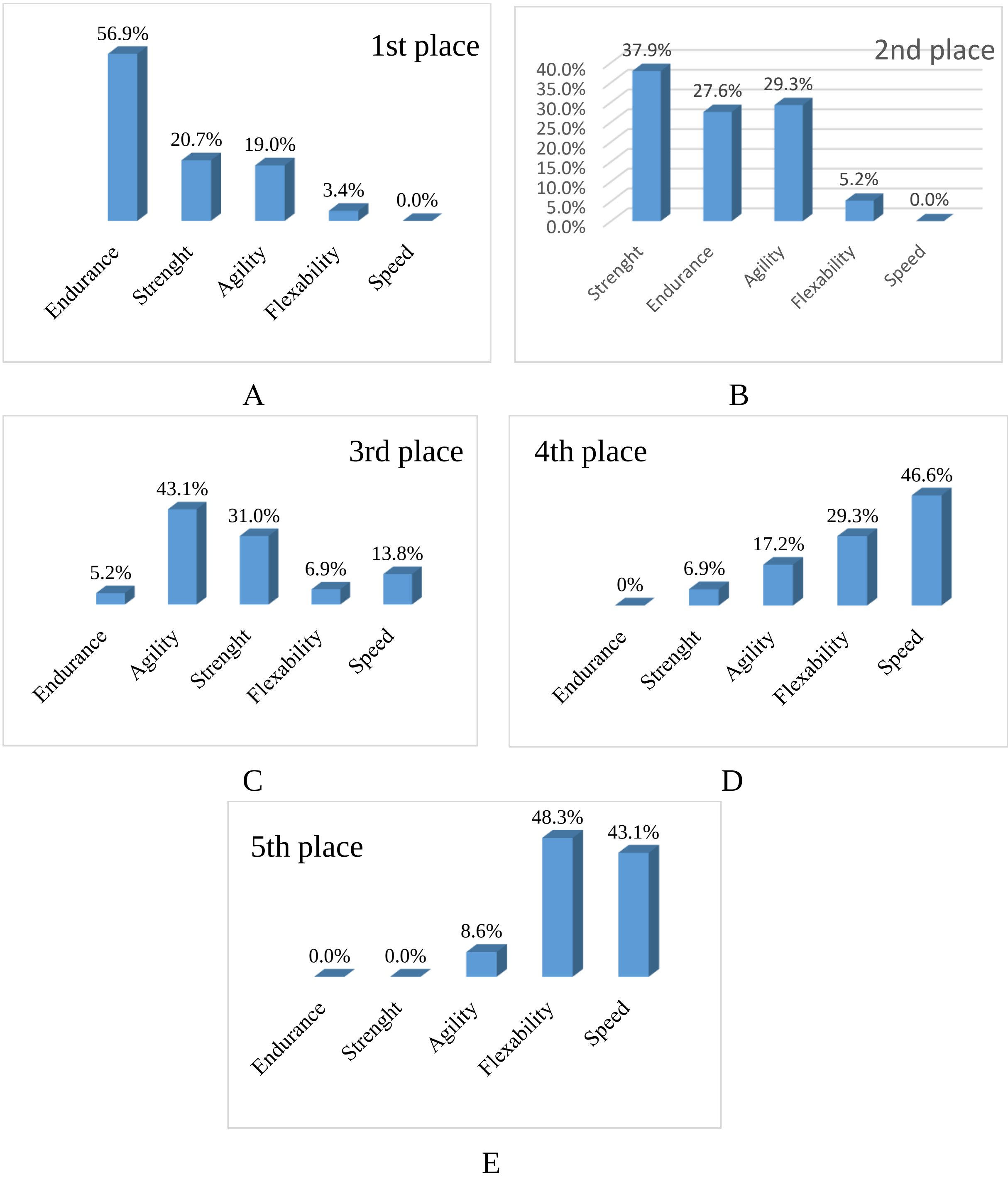


Figure 12. Physical qualities ranked by their importance in work at height according to the respondents

The inquiry conducted clearly shows the need for a targeted methodology for physical training for those working with rope access.

This is also supported by the positive answer of the respondents to the last question in the questionnaire, “Would you take part in the approbation of a methodology for physical training for rope access technicians?” (Figure 13)

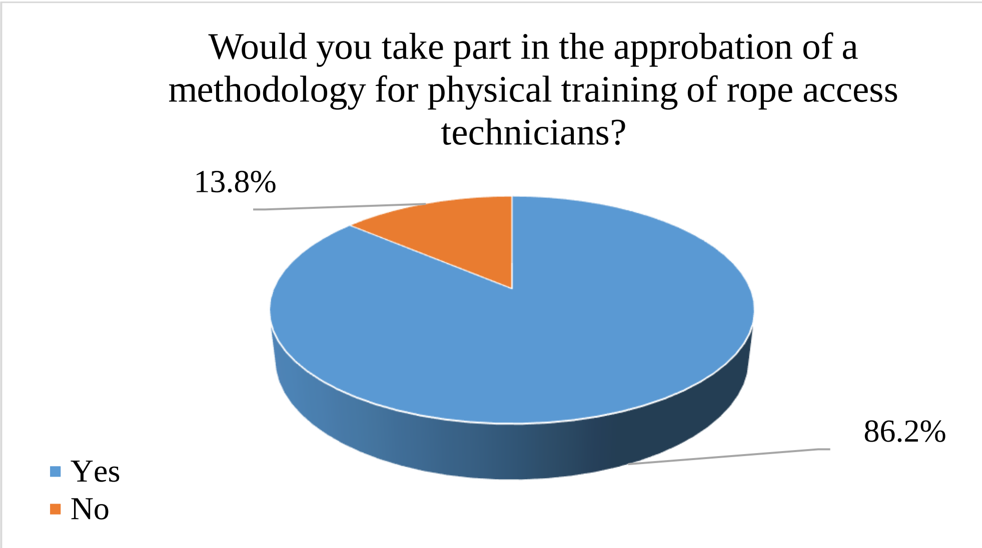


Figure 13. Respondents’ willingness to take part in a specialized methodology for physical workout

It is most appropriate for a method of physical training for rope access technicians to be implemented in the inactive season, and to include tools for developing mainly the strength and endurance. The exercises should be well known to the trainees and applicable on various places convenient for training (gym, crossfit site, home).

Analysis of the maximum grip strength test results

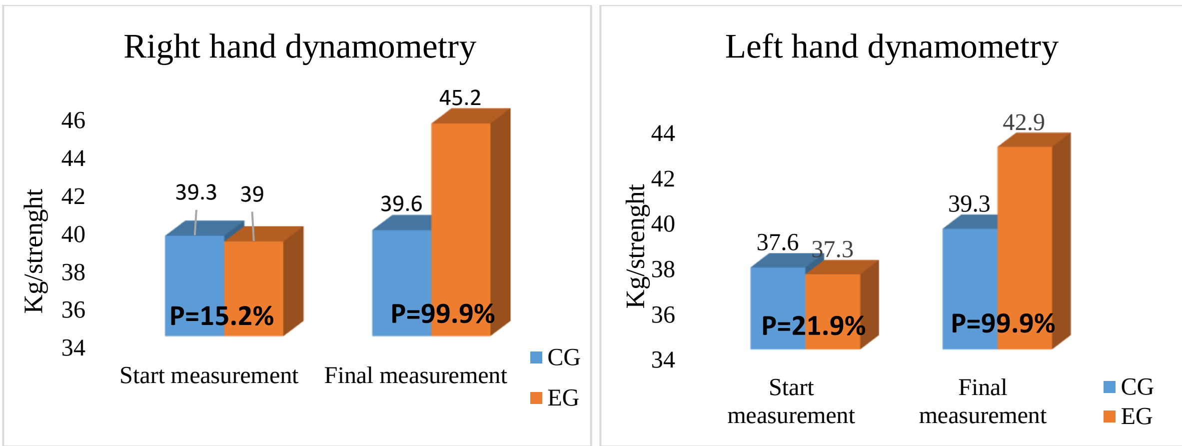
The results of the dynamometric measurement of the maximum grip of the right and left hands in the control and experimental groups are presented in Figure 14.

The control group showed a baseline mean value of 39.9 kg/force for the right hand and 37.6 kg/force for the left hand.

During the baseline measurement of the maximum grip strength, the mean value in the experimental group was 39.0 kg/force for the right hand and 37.3 kg/force for the left hand.

For comparison between the baseline and final measurements in the control group and experimental group, we used Student's t-test for dependent variables. In the CG, no statistically significant differences were reported between the baseline and final measurements in grip strength for either left or right hand. For the EG, a statistically significant increase at the final measurement was noted. For the right hand, the average value was increase by 6.2 kg/force, and for the left hand – by 5.6 kg/force.

To compare the CG and EG, we used Student's t-test for independent variables. The comparison between the CG and EG showed a statistically significant improvement in the grip strength in both hands for the EG.



A B

Figure 14. Results of left and right hand dynamometry for the CG and EG

The enhanced grip strength at the final measurement in the EG is due to several specific exercises from the implemented specialized methodology. Finger flexor strength training exercises with the exercise machines work specifically to increase grip strength. Another factor is the dynamic wrist extensor exercises involved. The ability to keep the wrist in a neutral position and slightly abduct in an ulnar direction ensures a good grip. When working at height (glass washing, chipping, drilling, plastering, etc.) sufficient dynamic stabilization of the wrist is also necessary, which we develop through flexbar exercises. Training involving various types of hanging with different forearm positions also help improve grip strength. In the CG, no statistically significant increase in the grip strength was reported in either the left or the right hand. We believe this is due to the absence of the aforementioned wrist and finger exercises in the standard methodology used in this group.

In the literature reviewed, there were expectedly no studies conducted to investigate the grip strength in height technicians. Sport climbing could be considered a similar motor activity to work at height. Various authors (Grant et al. 2001; Macleod et al. 2007; Ozimek et al. 2016) reported that average left/right hand grip values of elite climbers were 10 to 15 kg higher than the values of amateur climbers and non-climbers. These are higher than our values; however, we should take into account the survey population. The values mentioned refer to elite athletes and/or active climbers where their power grip is critical to their athletic achievement. In our population, the objective is to improve the grip strength of both hands with a view to optimizing the work process and safety. Based on the achieved results, we believe that we have achieved our objective.

Analysis of the results of throwing a thick ball

Data from the variance analysis of the strength examination for the upper limbs (ULs), the trunk and the lower limbs (LLs) by throwing a thick ball over the head in the CG and EG are presented in Figure 15.

For comparison between the baseline and final measurements in the two groups, we used Student’s t-test for dependent variables. It was found that there was no statistically significant improvement in the dynamic strength of the upper limbs, trunk and lower limbs in the CG (Table 19, Figure 18). A statistically significant improvement in this indicator was observed in the EG (P=99.9%).

To compare the results of measuring the dynamic strength of the ULs, trunk and LLs between the CG and EG, we used Student's t-test for independent samples. Between the two groups, there was a distinct improvement in the upper limb, trunk and lower limb strength in favor of the EG. The increase was 76.4 cm, and the difference was statistically significant (P=99.9%).

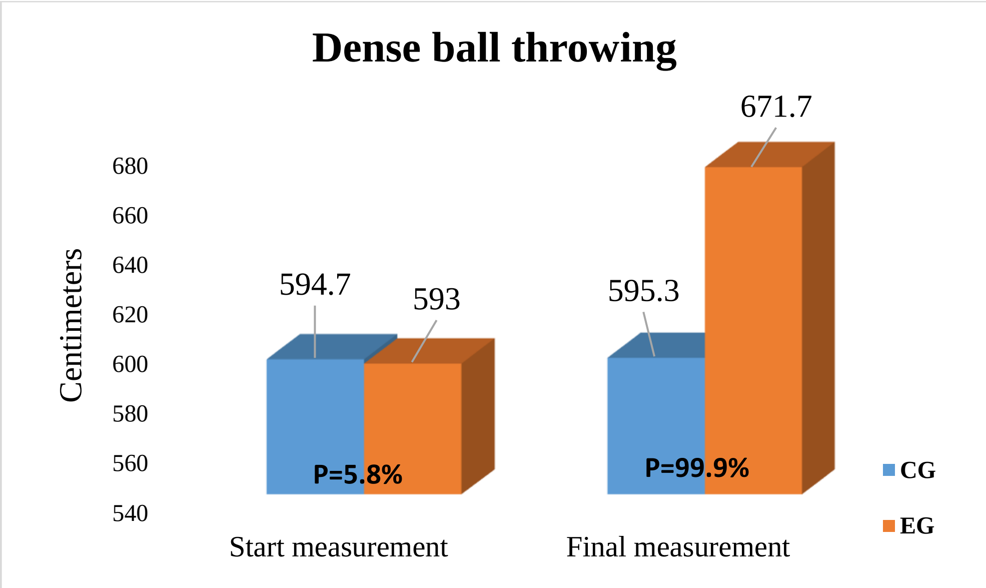


Figure 15. Comparison between thick ball throwing in the control group and experimental group

We associate the obtained positive results with the specific focus of the author's methodology on physical training of hight technicians. When throwing a thick ball overhead, it can be assumed that the strength of the upper limbs, trunk and lower limbs is leading, but good coordination between them is also necessary. Examples of such specific dynamic exercises that exert load on the upper limbs in particular, are the elbow flexion and extension from various starting positions (support, hanging, supported sitting). For the improved coordination in the work of the upper limbs, trunk and lower limbs, the exercises for transitioning from elbow support to frontal support, from side elbow support to frontal elbow support, squat – jumping, and last but not least, the “Burpee” exercise, could be taken as a factor. Our methodology and the classic exercises for developing the flexor and extensor muscles of the elbow, shoulder abductors, etc. definitely had a role for increasing the strength of the upper limbs. These were not primarily implemented by the CG, and did not produce the expected result. The results showed that their combination with specific dynamic exercises lead to a statistically significant improvement in the performance of the “Throwing a thick ball” test in the experimental group.

Analysis of the results of lower limb explosive strength testing

The data of the standing long jump indicator comparison between the CG and EG are presented in Figure 16.

For the statistical processing of the baseline and final long jump results, we used the Student’s t-test for dependent samples. As it can be clearly seen in Table 22 and Figure 19, a statistically significant improvement in the long jump is observed only in the EG (P=99.9%).

For comparison between the CG and EG, the Student’s t-test for independent samples was used. No statistically significant differences were reported from the comparison of the baseline long jump values between the CG and EG. There was also no statistically significant difference between the two groups at the final measurement, but a trend towards improvement in the EG was noted.

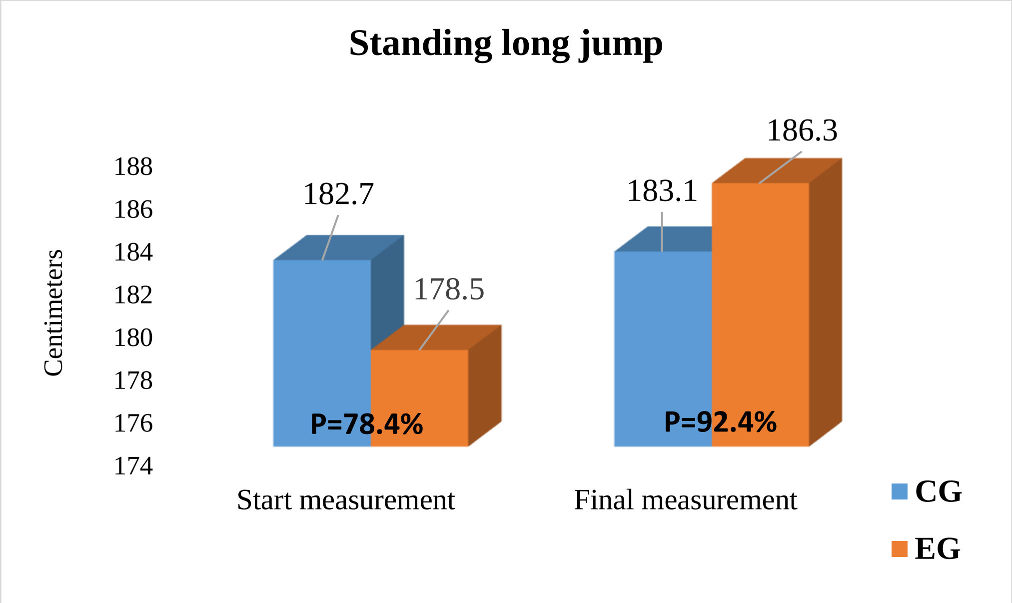


Figure 16. Long jump results in the CG and EG

The long jump is a main test of physical fitness and assessment of the lower limp explosiveness. Good performance depends on all physical qualities, but to the greatest extent on the dynamic strength of the legs, trunk and arms. In our methodology, we included several exercises that should improve the strength of the lower limbs and rebound of the subjects. The obtained results showed that the various squats and lunges, as well as the complex exercises such as “Jumping Jack”, “Mountain Climber”, “Burpee”, etc. gave a statistically significant effect in the EG. It was reflected in the positive trend for improvement of the achievement in the EG, noted after the comparison with the CG. Despite the lack of statistical difference between the two groups, we believe that the achieved results are good.

Analysis of the upper limb strength endurance test results

The results of the upper limb strength endurance study, as measured using the modified "Overhand hang test", are presented in Figure 17.

For comparisons between the baseline and final values from the modified Overhand hang test, we used Student's t-test for dependent variables. In both groups, a statistically significant difference was observed between the two measurements: P=99.4% for the CG and P=99.9% for the EG (Table 25, Figure 20).

For the comparison of the "Overhand hang test" results between the CG and EG, we used Student's t-test for independent variables. After completion of the specialized methodology, a statistically significant difference was found in favor of the EG.

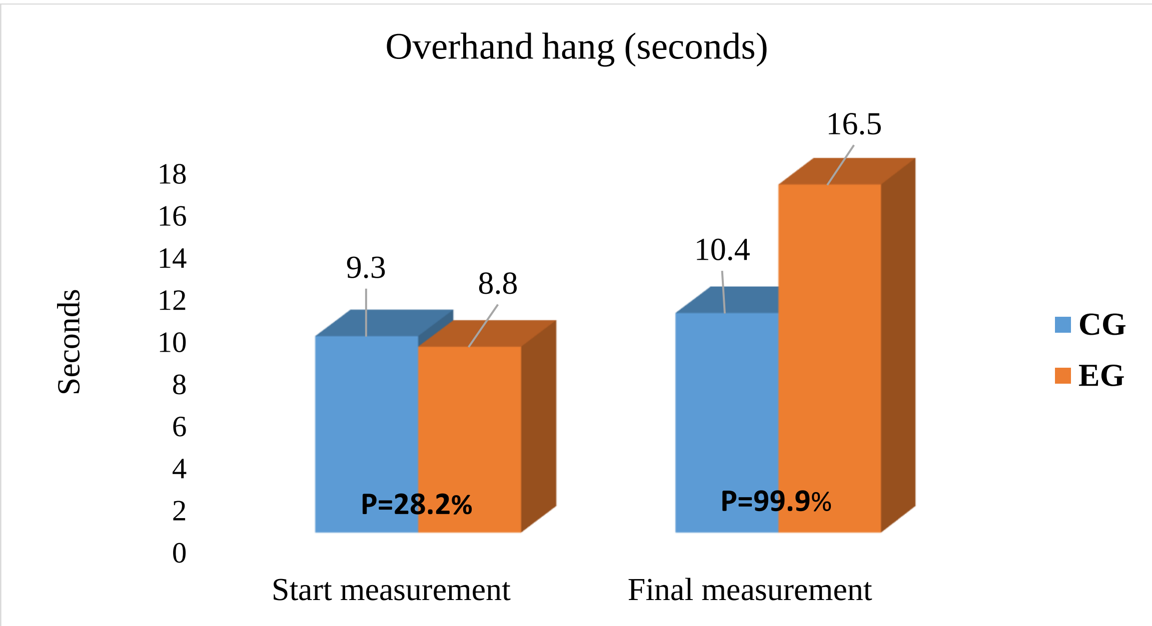


Figure 17. Modified "Overhand hang test" results in the CG and EG

Holding the final position in the modified "Overhand hang test" is the result of the coordinated action of several large muscle groups. The weak baseline times shown in the test in both groups can be explained not only by the reduced endurance of the mentioned muscle groups, but also by poor coordination between the execution of the movement and the subsequent holding of the given position. In our methodology, we emphasized on the development of strength endurance of the flexor muscles in the elbow joint, the latissimus dorsi muscle, the pectoralis major muscle, etc. through complex exercises. These are the different types of hangs, elbow flexion from hanging position and, last but not least, exercises to develop grip strength. The adequate progression of the included exercises and their exact dosage contribute to the improvement of the execution technique. All this can reasonably be pointed out as the reason for the increased time to hold the final position in the modified "Overhand hang test" after completing the author's specialized methodology for physical training of height technicians.

Analysis of the complex strength endurance results through the "Timed self-ascending" test

The "Timed self-ascending" test results are shown in Figure 18.

The baseline and end indicators in each group were compared using Student's t-test for dependent samples. A statistically significant improvement in the self-ascending time was found in both groups (P=99.9%).

For comparison between the CG and EG, Student's t-test for independent samples was used. No statistically significant differences were reported in the comparison of the baseline self-ascending time values between the CG and EG. The final measurement showed a better self-ascending time in the EG, the improvement being statistically significant (Table 28, Figure 21).

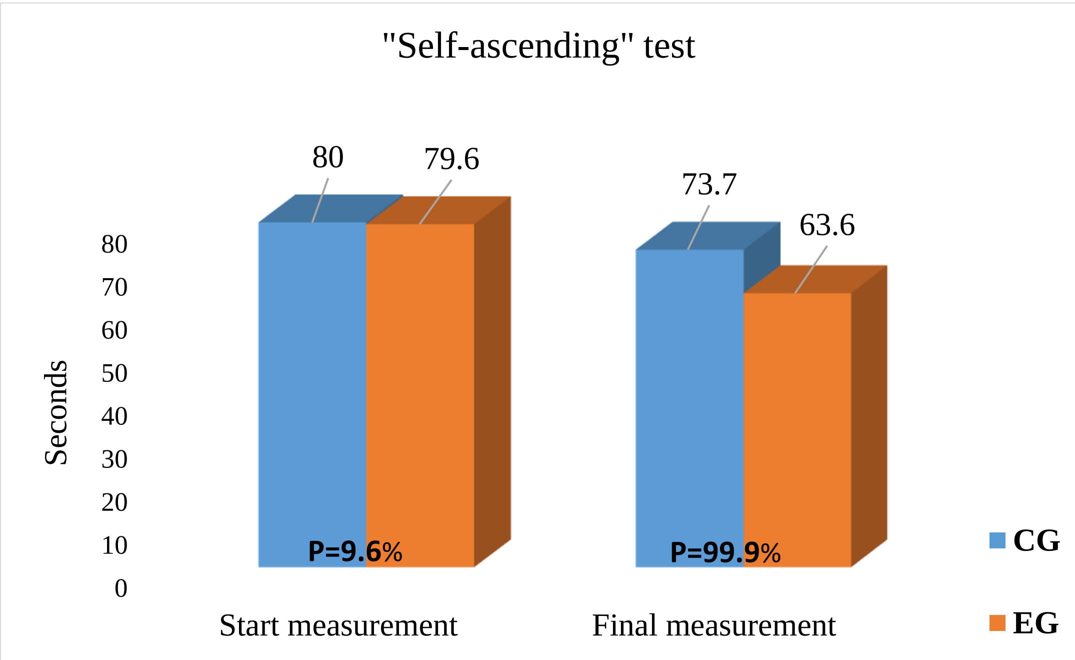


Figure 18. "Timed self-ascending" test results in the CG and EG

Self-ascending is a complex and basic movement in rope access. Despite the availability of facilitating equipment (self-grips and pedal), good physical and technical qualities are necessary for its economical implementation. We associate the positive impact on the self-ascending time in the EG with the overall comprehensive approach in preparing the training program. During self-ascending, the movement of the lower limbs is cyclic and close to squatting – standing up. In our methodology, the focus is on different types of squats in order to influence their dynamic strength. The movements of the upper limbs are also cyclic, but sufficient strength and endurance are required in the grip, forearm, brachial plexus and dexterity in handling the self-grip. The upper extremity exercises included in the training program (flexion and extension of the elbows from hanging and support positions, the analytical exercises for the flexor muscles in the elbow joint, etc.) and the exercises to improve the grip strength and stability of the wrist improved the strength endurance and hence also affected the performance of self-ascending. The status of the abdominal and back muscles is also related to the self-ascending technique.

In our methodology, the training is mainly carried out by static and dynamic exercises as different variants of the so-called "abdominal press", elbow support combined with movements, burpee, etc., which also gives a favorable reflection in the overall movement of self-ascending.

In the CG, there was a reduction in the performance of the "Timed self-ascending" test as well, which could be attributed to the complex whole-body training approach.

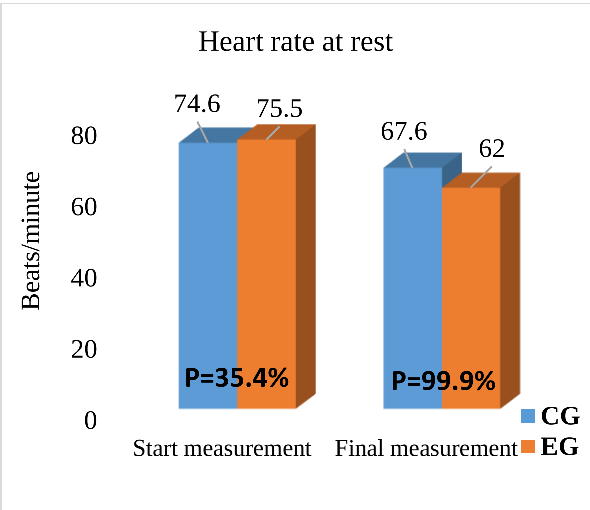
In the available scientific literature, we could not find any publications or scientific reports presenting the results of a test similar to the one we described. Our test is entirely proprietary and is closely specialized for assessing the physical fitness of hight technicians. We hope that over time it will be implemented in practice and that these results will be used as a starting point for future scientific research in the area.

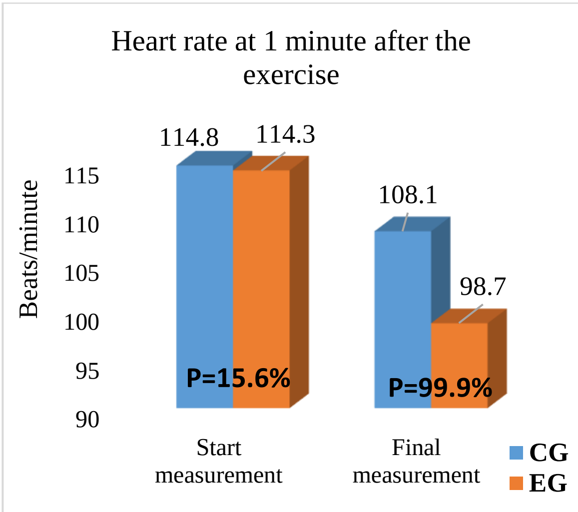
Analysis of the general endurance test results

The Home Step Test results of the CG and EG are summarized in Figure 19.

Student's t-test for dependent samples was used for processing the statistical data for the heart rate changes between the baseline and final measurements in both groups. Statistically significant changes were observed in the final values compared to the baseline values in both groups.

Student's t-test for independent samples was used to compare changes in the heart rate for the CG and EG. A statistically significant difference was found in both heart rate measurements (at rest and at 1 minute after the exercise) in favor of the EG.





A B

Figure 19. Heart rate examination findings for the CG and EG

The Home Step Test provides an opportunity to make a qualitative assessment of the heart rate of the subjects. To compare the obtained scores for the CG and EG, we used Pearson's $\chi 2$-test for comparing independent samples. The results are presented in Table 4.

Table 4. Home Step Test heart rate assessment for the CG and EG

Measurement	Assessment	CG (n)	EG (n)	Σ	$\chi 2$	α
Baseline	Above average	3	2	5	0.621	0.892
	Average	2	3	5		
	Below average	7	10	17		
	Poor	7	8	15		
	Σ	19	23	42		
Final	Good	1	9	10	14.359	0.002
	Above average	5	10	15		
	Average	4	3	7		
	Below average	9	1	10		
	Poor	0	0	0		
	Σ	19	23	42		

The comparison of both groups by the Pearson's $\chi 2$-test for comparing independent samples showed that the difference in the improvement of the heart rate results in the EG versus CG was statistically significant (α=0.002) (Table 4).

Figures 20 and 21 present the rate distribution of the results for the CG and EG. At the baseline, both study groups had heart rate measurements ranging between "Poor" and "Above average". For the CG, the most subjects had measurement results "Poor" (7 subjects) and "Below average" (7 subjects). For the EG, the result “Below average” prevailed during the baseline measurement (10 subjects).

During the final measurement, there was no “Poor” result in either group. For the CG, the most common result was “Below average”, and for the EG, the most common result was “Above average”.

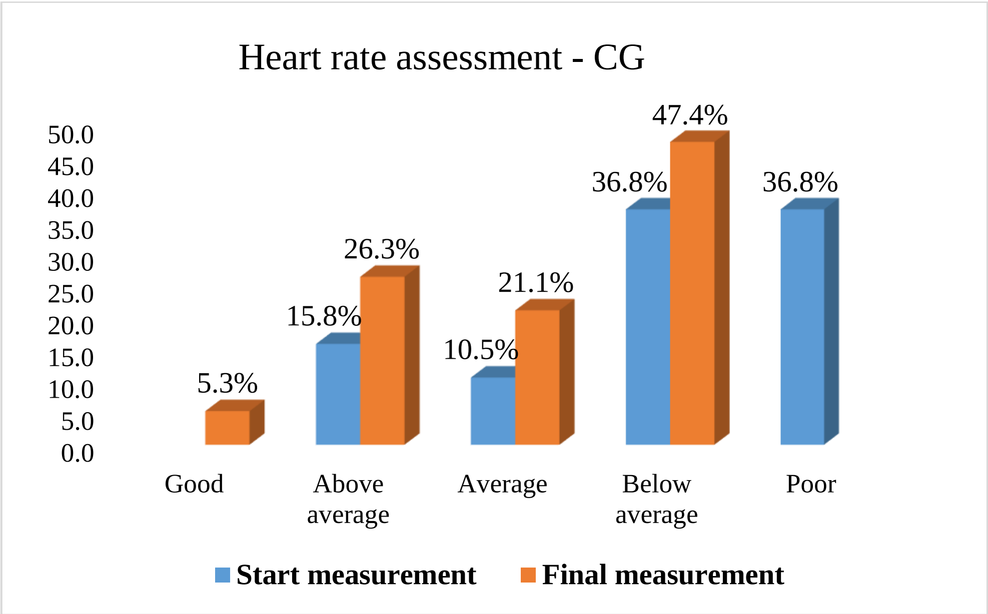


Figure 20. Heart rate assessment in the CG

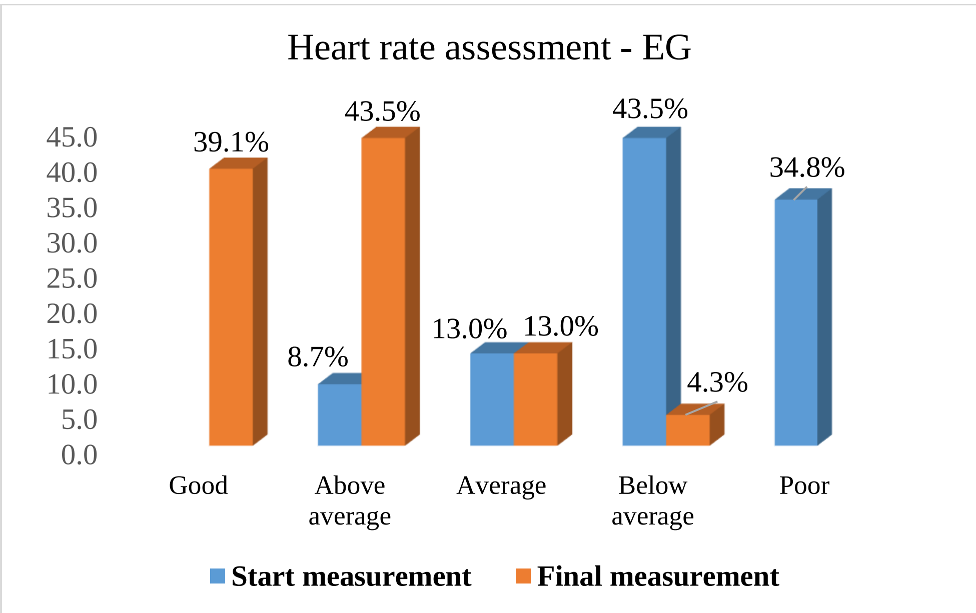


Figure 21. Heart rate assessment in the EG

The results presented clearly show an improvement in the general endurance based on the heart rate measurement in both surveyed groups.

During the baseline measurement of the pulse rate at rest, both groups showed normal values, approximately 75 beats/min. A decrease in the heart rate at rest was reported in both the CG and EG groups upon completion of our study. In this case, we could not talk about sports bradycardia; those positive changes were rather a sign of the initial phase of adaptation.

During the final measurements, the pulse frequency measured at 1 minute was also reduced after the exercises. This means that the heart rate returns more quickly to the baseline values after the execrcise, which indicates a better adaptation of the recovery processes.

The general endurance is developed primarily by practicing aerobic activities such as running, swimming, cycle ergometry, etc. with a duration of over 40 minutes. For the CG, these were the activities recommended to influence this feature. In the EG program, in addition to a single workout with only the mentioned activities, high-intensity exercises working on the large muscle groups (“Jumping Jack”, “Mountain Climber”, squat jump, “Burpee”) were also added in the remaining 2 training days. Therefore, we can claim that it was that approach that lead to better results in the EG.

In the literature reviewed, different groups of authors prefer other post-exercise heart rate monitoring tests, and such where maximum oxygen consumption can be indirectly calculated. In most cases, these tests require specialized equipment such as a bicycle ergometer, a mouthpiece, or the testing is running a certain distance. Our survey was conducted in “field” settings during the conduct of qualification courses and therefore, a test requiring minimum equipment was preferred. Because of these differences, it is not correct to compare our results with the reported data in the available scientific literature on that isuue.

CONCLUSIONS

Based on the information presented and the results obtained, we can formulate the following conclusions:

1. The developed and approbated test battery evaluates well enough the tested physical qualities for rope access work.
2. The comprehensive approach used to train the grip strength, strength and endurance of the upper limbs, is an effective method to develop these qualities in hight technicians in view of their work activities.
3. The inclusion of targeted exercises to improve the status of the trunk muscles and the explosive power of the lower limbs help optimize the work process.
4. The combination of classic methods for developing general endurance and high-intensity circuit training for the large muscle groups is a good method for influencing the endurance in hight technicians.

RECOMMENDATIONS

The survey conducted and the analysis of the results gives us a reason to make the following recommendations:

1. Before starting a course to obtain or increase the qualification, the trainers should test and assess the physical capacity of the candidates. The same recommendation is made to the future employers of the trainees.
2. During the training, the participants should be informed about the importance of the physical fitness for the work process and be trained by targeted exercises for its improvement.
3. Employers should stimulate the motor activity of height technicians during the off-season.

CONTRIBUTIONS

- An in-depth analysis of the positive and weak points of the data from the literature review was made, the unsolved issues related to the physical training of hight technicians were clarified.
- The approbated and implemented methodology for developing the motor skills of height technicians, fully tailored to their work technique, is original and scientifically justified.
- An algorithm for a comprehensive survey of the motor qualities has been developed, which ensures a sufficiently good and adequate evaluation for their objectification in hight technicians.
- The "Self-ascending" height technique has been modified as a test to assess the general physical fitness of height technicians, and has been approbated in the course of the scientific survey.

SCIENTIFIC PUBLICATIONS ON THE DISSERTATION TOPIC

1. Тодоров, Т. (2020). Съвременни аспекти на въжения достъп. Дванадесета научна конференция „Съвременни тенденции на физическото възпитание и спорта“, ISBN 1314-2275, Университетско издателство „Св. Климент Охридски“, с. 374-378
2. Todorov, T. (2022). TESTING METHODS OF THE PHYSICAL QUALITIES FOR ROPE ACCESS WORKERS. Socio Brains Journal. Issue 91, p. 1-6, ISSN 2367-5721 (online), Publisher: SMART IDEAS – WISE DECISIONS, Ltd., Sofia, Bulgaria
3. Todorov, T. (2022). SURVEY OF ATTITUDES AND OPINIONS ABOUT PHYSICAL QUALTIES AND MOTOR ACTIVITY IN WORK-AT-HEIGHT TECHNICIANS. Socio Brains Journal. Issue 96, p. 27-32, ISSN 2367-5721 (online), Publicher: SMART IDEAS – WISE DECISION, Ltd.,Sofia,Bulgaria