Global Journal of Medical Research: F
Diseases
Volume 22 Issue 7 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Reaction of Cardiovascular System in Children to Specific Loads in Rock Climbing

By A. V. Shuvalov, Sh. Z. Hubbiev & T. I. Baranova

Abstract- The article analyzes the differences in the reaction of the cardiovascular system to specific loads in rock climbing in children aged 9 to 13 at the initial stage of training. The study has revealed that the load intensity corresponds mainly to the aerobic intensity zone when performing lead climbing exercises, speed climbing exercises and endurance exercises. Special exercises have been developed and tested to stimulate the body's performance in combined and glycolytic power zones, considering the specific requirements of rock climbing and the cohort of climbers.

Keywords: rock climbing, children's rock climbing, disciplines in rock climbing, prompt monitoring in rock climbing.

GJMR-F Classification: DDC Code: 796.0922 LCC Code: GV697.A1

Strictly as per the compliance and regulations of:

Reaction of Cardiovascular System in Children to Specific Loads in Rock Climbing

A. V. Shuvalov [α], Sh. Z. Hubbiev [σ] & T. I. Baranova [ρ]

Abstract- The article analyzes the differences in the reaction of the cardiovascular system to specific loads in rock climbing in children aged 9 to 13 at the initial stage of training. The study has revealed that the load intensity corresponds mainly to the aerobic intensity zone when performing lead climbing exercises, speed climbing exercises and endurance exercises. Special exercises have been developed and tested to stimulate the body's performance in combined and glycolytic power zones, considering the specific requirements of rock climbing and the cohort of climbers.

Keywords: rock climbing, children's rock climbing, disciplines in rock climbing, prompt monitoring in rock climbing.

I. Introduction

Climbing is great for children, providing them with a variety of motor activity, extreme activity, play and competitive activities and communication with peers during training sessions. Since many children and their parents are interested in rock climbing training, the issue of further development of children climbing needs to be addressed.

Today, for children's rock climbing in St. Petersburg there is a variety of rock climbing gyms, and indoor rock climbing competitions and festivals (climbing walls), as well as outdoor activities on rock surfaces are held on a regular basis. For competitions, rock climbing coaches have to train climbers to the peak of form using training programs that make it possible to achieve the maximum degree of training and consider working with children. Thus, there is a need for creating a training program at initial stages of training. The training program should be created based on the knowledge of the physiological basics of the child's body performance under various loads [4, 8].

Children's studies have shown that rock climbing is comparable in terms of the level of energy consumption to jogging or outdoor games [22]. These data are consistent with the results of study that shows the level of energy consumption in children when climbing short bouldering routes. It has been shown that in this case, the climbers mainly stay in the aerobic power zone [18]. We have found that such work during rock climbing strengthens upper limbs, increases general endurance and improves movement coordination [6, 8, 10, 11].

Author: e-mail: parbaty@yandex.ru

A survey study of rock climbing effects on the bodies of children and adolescents (aged 7 to 17) reported that no special exercises for developing finger strength were recommended during rock climbing as there was a risk of injury to joints. Furthermore, there are no indications of approaches to children's training which allow to develop strength with a high need for simultaneous development of coordination capabilities [18]. The data from highly qualified young climbers showed differences in the development of their muscles and skeleton from non-climber children. Straightening of lumbar lordosis and greater functional activity of the three-headed muscle of the femur have been observed [1].

A study considering children training in a climbing gym [5] is focused on the use of game and competitive methods in the training process. It provides detailed exercises that are most effective in attracting children's interest and engaging them in the training process on the climbing wall. All the exercises are fun to do which is in line with children's essential need for play activities.

A study of climbers' cardiac function [4] reported the limits of strength loads during training in children's and adolescent gyms. It is recommended for children's groups to include in the training session the general physical exercises in the amount of at least 70% and for adolescent groups in the amount of at least 50% of the total amount of training loads. Exercises involving maximum strength loads are not recommended on the climbing wall. It also provides guidelines on qualifications for climbing gyms and monitoring the cardiac function in order to prevent health disorders.

The use of heart rate indicators to create a training program for climbers and to monitor the climbers' condition is a common practice. There are indications for building the training program and improving its quality using heart rate as a complex indicator of the functional condition, allowing monitoring the reaction of the climber's body to the received load [3, 7]

The available sources provide no data that make it possible to create a training program at the stage of initial training that would consider the physiological reaction of the child's body to loads (various types of exercises) in rock climbing. None of the available literature gives examples of the use of prompt monitoring in rock climbing in order to adjust the

type and volume of loads. No studies have been found directed to the selection of exercises allowing for the growth of results in the training process, considering the ability of the child's body to endure specific loads in rock climbing.

II. Aim of the Study

The study aims at determining the reaction of the cardiovascular system to various types of loads based on the analysis of heart rate in children during rock climbing.

a) Study hypothesis

Heart rate can permit to assess the contribution of various energy sources to the energy supply of muscular activity under various loads in children's rock climbing.

b) Study objectives

1. To determine the differences in the reaction of the cardiovascular system to the rock climbing loads in children of different sexes.
2. To determine the reaction of the cardiovascular system in children of different degree of training to a competitive exercise involving strength (climbing a bouldering route with the maximum grade possible), climbing a low-grade speed route and climbing a low-grade terrain.
3. To develop and substantiate methods of special strength training in rock climbing.

c) Organization of the study

The study was conducted in the 2020-2021 academic year in St. Petersburg at the premises of the "Lifeguard" teenage and youth gym. The study was conducted on an artificial terrain, i.e. on a climbing wall. The heart rate was measured in children after three different types of load:

1. After climbing a low-grade terrain with an abundance of holds for hands and feet for 2-3 minutes on a 90° wall, the lowest load.
2. After climbing a bouldering route (5-6 movements using certain holds) with a maximum climbing grade possible for a particular child. Climbing grades used ranged in the entire group from 5a to 6b depending on the degree of training [9, 13]. The load corresponds to a high coordination and strength difficulty.
3. After speed climbing on a low-grade terrain over a short distance of no more than 4 m.

Measurements were made twice in November, 2020, followed by averaging the both measurements.

The study enrolled a total of 49 children including 28 boys and 21 girls.

All children have excellent indicators of the development of the cardiovascular system in terms of adaptive potential [2]. Children were admitted to climbing training and have no medical contraindications.

The results obtained in the study were processed using the SPSS 25 software.

d) Study results

Determination of the differences in the reaction of the cardiovascular system to rock climbing loads in children of different sexes.

We compared the values of the reaction to three types of load: climbing a low-grade terrain, climbing a bouldering route and speed climbing on a low-grade terrain separately for each sex. The Friedman test was used to analyze differences. The choice of the test is due to the small group count (the variance analysis is recommended for a group of at least 50 subjects), as well as the need to compare consecutive measurements. As a result, it was found that boys have a significant difference ($p = 0.02$), girls have no significant difference in the reaction of the cardiovascular system to different types of loads ($p = 0.056$).

Confidence interval analysis was employed to determine the spread of heart rate values under different types of loads (Diagram 1).

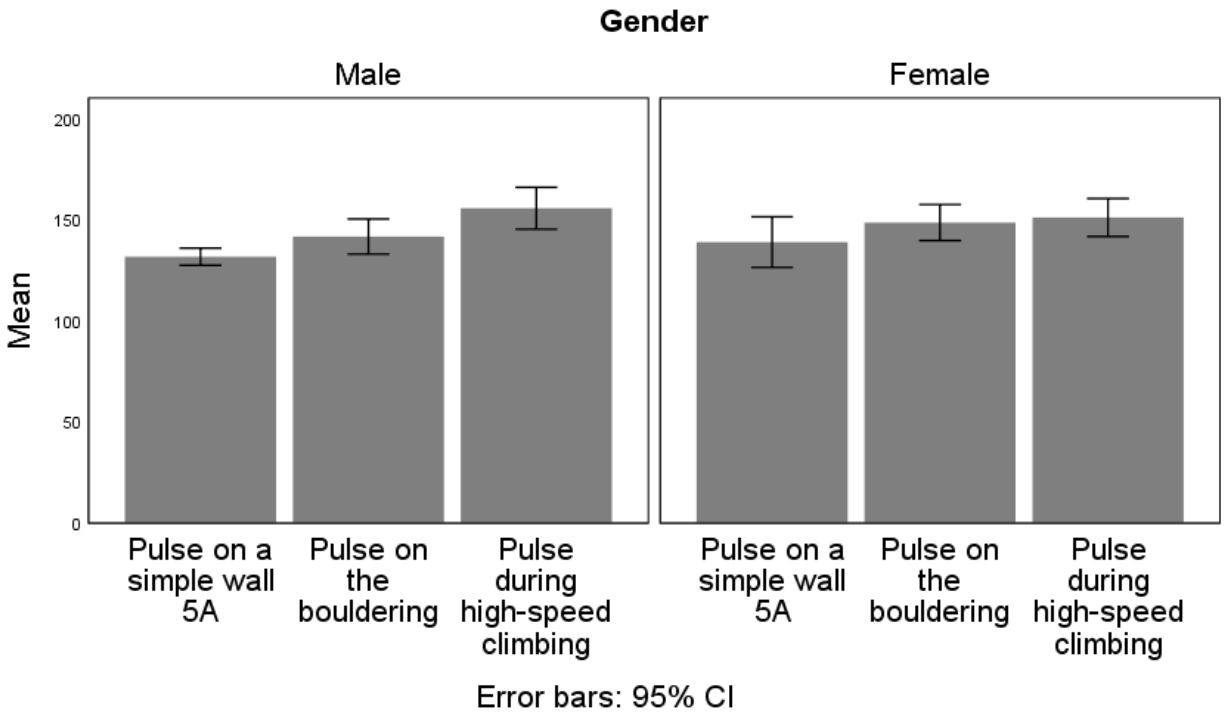

Diagram 1: Reaction to various types of rock climbing loads in children of both sexes n =28 (boys), n= 21 (girls). * p=0.02

The values of confidence intervals indicate a difference in the reaction to different types of loads in boys. When climbing without an emphasis on certain physical quality (climbing on a low-grade terrain with an abundance of holds that are easy to hold/set the legs, not requiring the use of complex techniques, 5a according to the international classification of climbing grades [9, 13]), the heart rate ranges from 128 to 136 bpm; in speed climbing it ranges from 146 to 166 bpm. When climbing a bouldering route, the heart rate in boys cannot be separated from that when speed climbing and climbing a low-grade terrain, due to the crossing of confidence interval boundaries.

In girls, the crossing of confidence interval boundaries has been observed in all the three types of climbing, from 127 to 161 bpm.

The change in the mean values and the shift of the confidence interval boundaries for various types of loads shows a consistent increase in the heart rate with increased load. The load in all the three exercises corresponds mainly to the aerobic intensity zone of training loads.

Determination of differences in the reaction of the cardiovascular system to strength load in rock climbing (climbing bouldering routes with the maximum climbing grade possible) in children of both sexes.

The present study included measuring the children's heart rate immediately following climbing the route with maximum grade possible for each one of the children participating in the study. Due to the fact that among the children attending the gym there are children of various degrees of training (and years of training), the route grades ranged from 5a to 6c (in accordance with the climbing route criteria of the international classification system [9, 13]). The differences between the sexes were determined using the Mann-Whitney U test, which demonstrated the absence of a reliable relationship ($p>0.05$).

When climbing the route with the maximum grade possible, the reaction of the cardiovascular system is the same and ranges from 140 to 150 beats per minute for boys and from 139 to 153 beats per minute for girls, which corresponds to the aerobic intensity zone of training loads [3] (the values were obtained from mean values from two measurements made in November, 2020 and in February, 2021, Diagram 2).

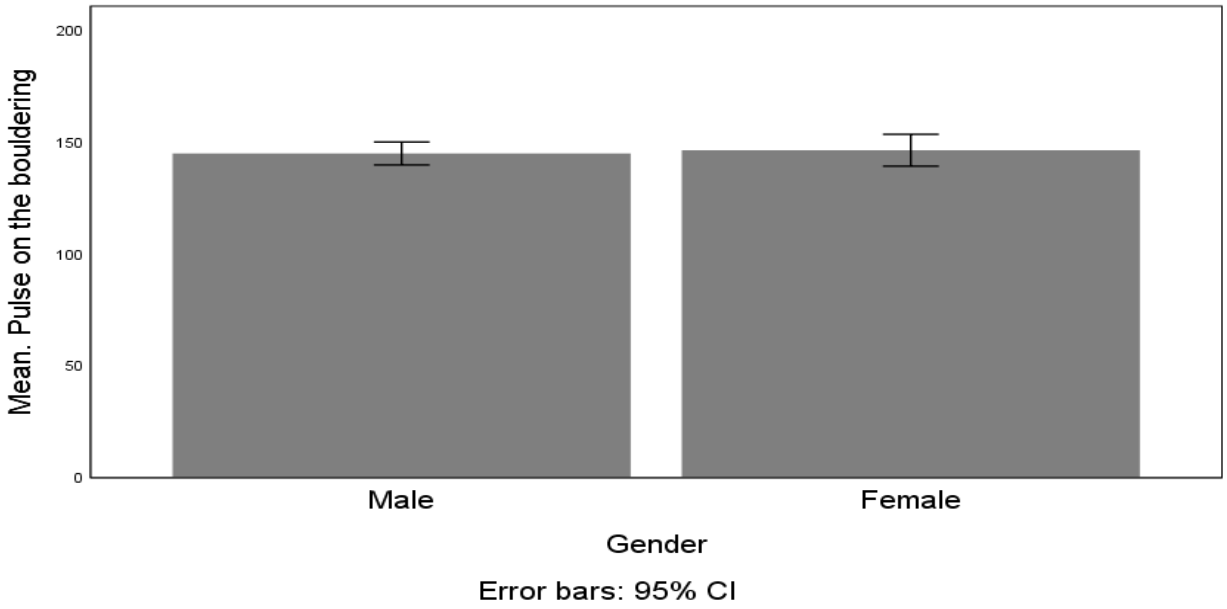

Diagram 2: Mean heart rate during climbing a bouldering route with the maximum grade possible for children of both sexes n=28 (boys), n= 21 (girls).

Development and substantiation of methods of special strength training in rock climbing

As found in this study, the climbing loads corresponding to the main competitive exercises (speed climbing, lead climbing, bouldering) are characteristic mainly of aerobic muscle regimens (mean heart rate does not exceed 150 beats per minute). The solution of the third study objective included developing special exercises to be performed on a climbing wall that consider the requirements for the rock climbing coordination complexity and an infinite number of options for applying strength loads characteristic of rock climbing under the conditions of glycolytic regimens. Heart rate in such exercises should be within 160 to 180 bpm.

Heart rate values in two exercises were investigated.

Exercise 1. A climber positions himself/herself on a vertical climbing wall. The feet should be placed on comfortable holds, the climber should face the wall. The climber makes quick movements with both hands between the holds. An instruction is given to make movements as quickly as possible, with maximum amplitude, to take different holds and to use different grip positions. During the exercise, the climber "jumps" with both hands between various holds. The way this exercise is performed corresponds to the method of shock training for strength endurance.

Exercise 2. A climber should climb a short bouldering route including four holds that are as difficult as possible to hold with his/her hands or require complex coordination techniques to climb. During climbing, the climber can use any holds for feet but with an instruction to use the minimum number of holds for feet (the aim is to load the hands as much as possible). In another variation of the exercise, the climber can use only one leg when climbing the route. The route is climbed by the climber 2-3 times, after which a new route is set. In total, there are 6-8 repetitions with tight intervals (no more than 1 minute). The way the exercise is performed corresponds to the method of near-limit training for strength endurance. The exercise teaches how to climb the key sections of climbing routes that require maximum strength and coordination efforts and places high demands on the strength abilities of the muscles of the hands.

The heart rate was measured immediately following the exercise. Due to the fact that the methods of developing strength (the shock and near-limit training methods) are not recommended for novice athletes, a subgroup of seven people of both sexes, who are in the third year of training and have a good level of physical development, was allocated to perform the both exercises.

The values of the reaction to the five types of loads were compared (climbing a low-grade terrain, climbing a bouldering route, speed climbing on a low-grade terrain, shock training and near-limit efforts on a climbing wall) using the Friedman test. As a result, it was found that there are significant differences between the compared measurement sequences ($p=0.016$). To find differences between each of the five measurements, we employed the LSD post-hoc test recommended for finding differences between five or more groups. The test revealed significant differences ($p<0.05$) between the heart rate when climbing a low-grade terrain and the

heart rate in the other four types of loads. The heart rate also significantly differs during climbing a bouldering route and during shock training on the climbing wall ($p=0.033$), other differences were below a reliable value ($p>0.05$).

Additionally, we analyzed the confidence interval. As can be seen from Table 1 and Diagram 3, the confidence interval boundaries are very slightly crossed between shock/near-limit effort exercises and competitive exercises. Furthermore, the mean heart rate for shock/near-limit effort exercises exceeds 160 bpm.

The survey of all athletes involved in the study confirmed a subjectively higher load when performing shock/near-limit effort exercises, compared with the common competitive exercises.

The analysis of confidence intervals and the results of the post-hoc test confirm that shock/near-limit effort exercises allow performing training activity mainly in the glycolytic mode, i.e. more intensively compared to competitive exercises.

Table 1: Confidence interval and mean heart rate for various climbing loads n=7 (boys and girls)

			Statistic	Std. Error
Pulse on a simple wall 5A	Mean		133.00	7.804
	95% Confidence Interval for Mean	Lower Bound	113.90	
		Upper Bound	152.10	
Pulse on the bouldering	Mean		146.57	5.004
	95% Confidence Interval for Mean	Lower Bound	134.33	
		Upper Bound	158.82	
Pulse during high-speed climbing	Mean		149.71	3.557
	95% Confidence Interval for Mean	Lower Bound	141.01	
		Upper Bound	158.42	
Pulse during shock workloads	Mean		165.43	6.305
	95% Confidence Interval for Mean	Lower Bound	150.00	
		Upper Bound	180.86	
Pulse during near-limit workloads	Mean		162.71	5.575
	95% Confidence Interval for Mean	Lower Bound	149.07	
		Upper Bound	176.36	

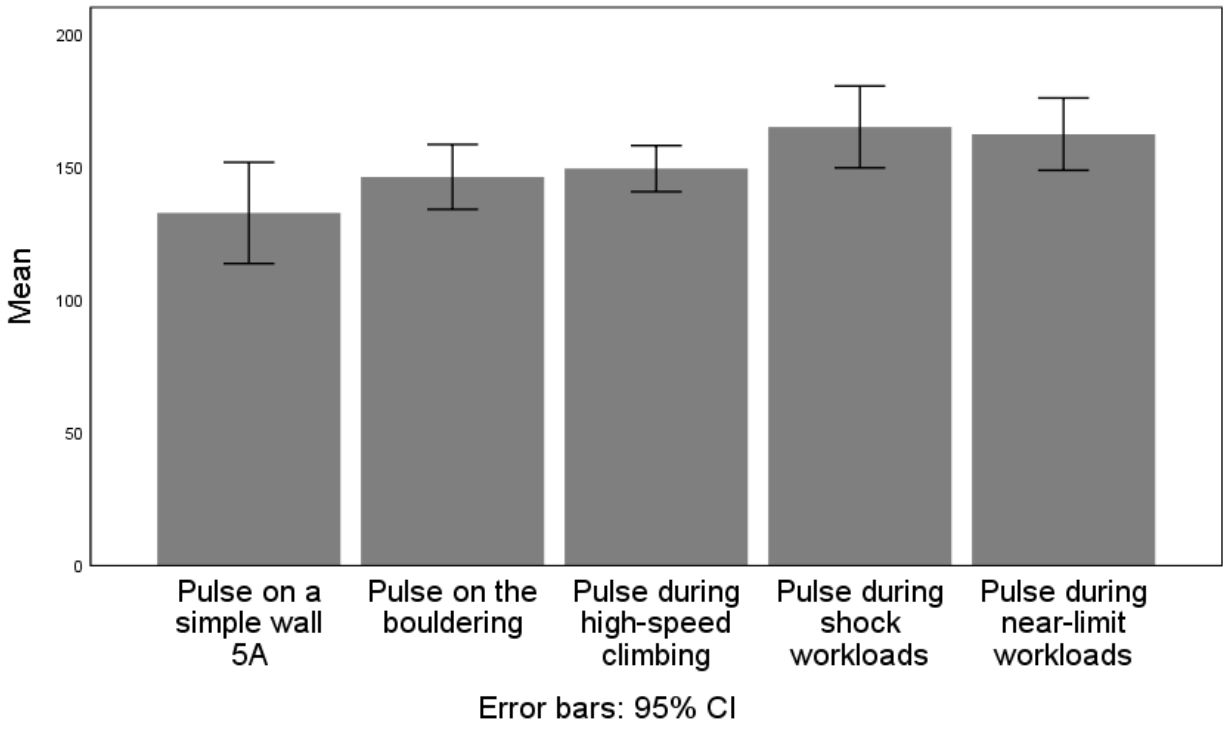

Diagram 3: Confidence interval and mean heart rate for various climbing loads n=7 (boys and girls). * p=0.03

III. Discussion of the Results

The present study demonstrates that the aerobic and cardio-respiratory abilities of novice climbers do not reach extreme degrees when performing exercises on a climbing wall (climbing on a low-grade terrain, speed climbing, and bouldering, i.e. climbing short routes with high strength efforts). Considering the heart rate values obtained, the maximum intensity of work during climbing is not achieved even with the highest possible loads (strength climbing on bouldering routes and speed climbing). This observation confirms previous studies conducted on adult climbers, assessing maximum oxygen consumption during climbing and during running on a treadmill; it was found that the maximum oxygen consumption during climbing is lower than that during running [15].

The present study demonstrates the absence of a relationship between the degree of training in novice climbers and the heart rate under the maximum loads corresponding to the degree of training. If the climber gets the maximum load when climbing a route on the climbing wall, the heart rate is characteristic of the aerobic intensity zone, regardless of the degree of training. This fact is confirmed in studies on adult climbers using maximum oxygen consumption values, which also failed to establish any relationship between maximum oxygen consumption and skill level [12, 14, 17, 20, 21].

The present study shows that when performing an exercise corresponding to the most physically and coordinatively difficult type of climbing (bouldering), the heart rate corresponding to the mixed intensity zone is not reached (heart rate does not rise above 160 bpm). Mixed intensity zone was achieved only in boys during speed climbing. The study shows that rapid progress in the most coordinatively and physically difficult type of climbing (bouldering) can be achieved only when the training program additionally includes strength exercises that are not associated with climbing bouldering routes. To date, strength training in rock climbing is based on the use of strength training exercises that are not related to training on the climbing wall. Weight exercises, gymnastic exercises, exercises using special trainers (campus board (a plywood with wooden slats for develop tenacity), finger board (a board with a complex terrain)) are used. This approach makes it possible to increase the strength of the climber's hands, but the methods used cannot be attributed to special training, as they provide the general development of strength and create prerequisites for development of special strength abilities. Furthermore, there are no studies that recommend the use of special methods of training strength and coordination abilities in children, and consider the sensitive life period.

No relationship between the heart rate and the sexual characteristics in children under various types of rock climbing load has been established. The exception is the difference in boys during climbing on a low-grade terrain (their heart rate does not exceed 136 bpm, corresponding to an aerobic intensity zone) and during speed climbing (their heart rate reaches 166 bpm, corresponding to a mixed aerobic/anaerobic intensity zone). This observation suggests it is possible to divide boys according to rock climbing types (lead climbing and speed climbing) earlier, compared to girls.

The study confirms the need for developing special training methods that, on the one hand, will be rock climbing-specific and promote developing strength abilities considering the coordination complexity of rock climbing, and will also allow to take into account the application of strength when climbing the always new rocky surface (climbing various routes). The training sessions for adult climbers may include climbing with extra weight that gives extra load to the fingers. In the case of children (at the initial training stage), exercises with extra weight on the climbing wall are unwanted as injuries or disorders in the development of the hand/wrist bones may take place [18]. Therefore, the new training methods should focus on developing exercises enabling other methods of developing strength abilities when climbing on the climbing wall. Further, in addition to increasing the load, strength training methods should consider the coordination complexity of rock climbing, i.e. the strength training methods should be employed directly on the climbing wall and should include climbing elements. Thus, it is possible to achieve simultaneously increased strength and improved coordination. Both of these abilities are essential in rock climbing [16].

Based on the results, one could argue that in children's rock climbing, in particular training using basic competitive exercises (typical for disciplines: speed climbing, bouldering climbing, lead climbing), the maximum tension of the cardio-respiratory system is not achieved, thus making it possible to create a training program with frequent training sessions (even daily training in the studied regimens is possible). Children's heart rate is evidence of the fact that muscle work is predominantly in the aerobic power zone during rock climbing [8]. Thus, use of basic competitive exercises in training does not make it possible to achieve the overstrain condition of the cardio-respiratory system and damage thereto.

For children at the stage of initial training, it is practical to use basic competitive exercises because they are associated with aerobic energy supply of muscle activity and are considered combined developing exercises for body strengthening and preparing the body for the loads at the next stage of training.

Climbing on a low-grade terrain, when the children's heart rate ranges from 120-140 bpm may take up a significant portion of training in order to develop the oxygen transport system and specific muscles (forearm muscles, lower leg muscles) that take on a heavy load in rock climbing. Interval and variable regimens [5] with simple climbing seems practical as children are capable of climbing a low-grade terrain for a relatively long time (at least 2-3 minutes). Also, climbing a low-grade terrain in an interval and variable regimen is recommended to professional climbers in the preparatory and transitional periods of year training to change the type of load that primarily includes special exercises related to glycolytic and alactic regimens of energy supply of muscle activity in the preparatory and competition periods of year training. This approach will make it possible to constantly develop and maintain the cardio-respiratory system in a condition that allows the climber's body to withstand increasing loads, while performing special exercises with increasing degree of training at subsequent stages.

Within the framework of solving the problem of developing training methods for the initial stages of training, new exercises have been proposed that provide a load corresponding to a mixed and anaerobic intensity zone (more than 160 bpm), which can not be achieved by basic competitive exercises, as found in the present study. The use of special strength exercises using anaerobic energy sources will make it possible to adapt the body to specific loads and intensify the strength training process. The exercises correspond to the shock and near-limit training methods for developing strength. The exercises are very specific for rock climbing and are recommended for children who have been rock climbing for at least a year. The present study revealed no possible restrictions for the use of the new exercises at subsequent stages of training.

In view of the fact that the proposed exercises are special exercises, their use is recommended at the preparatory stage, as part of the year training cycle.

Thanks to easy-to-do measurements, non-invasiveness, informativeness, lack of need to use special equipment and a small amount of time required, heart rate in children engaged in rock climbing can be used for prompt monitoring. Heart rate makes it possible to assess the load received by a young climber when performing basic competitive exercises and depending on the degree of training. Heart rate can be considered when developing and selecting special exercises that allow to achieve greater loads, as compared to the basic competitive exercises, and provide a pronounced effect on the climber's body. This will contribute to an extra adaptability and maintain the body tolerance under increased competitive loads.

IV. Conclusions

It was found that boys have significant differences in the reaction of the cardiovascular system in case of simple climbing (from 128 to 136 bpm) and in case of speed climbing (from 146 to 166 bpm). These differences have not been observed in girls. The heart rate when climbing in the three load regimens (climbing a low-grade terrain, speed climbing and bouldering) ranges from 127 to 161 bpm.

The reaction of the cardiovascular system in children to the strength load in complex climbing (bouldering, climbing a route with maximum coordination and strength difficulty) has been found to range from 140 to 150 bpm in boys and from 139 to 153 bpm in girls, regardless of the degree of training and route grade.

The strength exercises for the climbing wall, which have high specificity and allow the body to work in the glycolytic regimen, have been proposed and substantiated. One of the proposed exercises is the implementation of the shock method for training strength, and the other one is the implementation of the near-limit load method.

The shock load exercise for rock climbing causes a reaction of the cardiovascular system with heart rate ranging from 150 to 180 bpm in children of both sexes.

The near-limit load exercise for rock climbing causes a reaction of the cardiovascular system with heart rate ranging from 149 to 176 bpm in children of both sexes.

Author Contributions: SH.A., KH. SH., T.B. conception and design of the research; SH.A performed experiments; SH.A., KH. SH data analysis; SH.A., KH. SH interpretation of the experimental results; SH.A figure preparation; SH.A drafted the manuscript; KH. SH. and T.B. edited and revised the manuscript; SH.A., KH. SH., T.B. approved the final version of the manuscript.

Funding: This research received no external funding

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Saint Petersburg State University Ethics Review Committee for human studies (No. 40 from 07.03.2012). Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data generated in the present study may be requested from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References Références Referencias

1. Антропов, Е. С., Черкасова, В. Г., Муравьев, С. В., & Крылова, И. В. (2016). Сравнительная

характеристика состояния костно-мышечной и вегетативной нервной систем скалолазов детского и подросткового возраста в зависимости от уровня спортивного мастерства. Педагогико-психологические и медико-биологические проблемы физической культуры и спорта, (4), 195-202. doi:10.14526/01_1111_167

2. Антропова, М. В., Параничева, Т. М., Манке, Г. Г., & Тюрина, Е. В. (2009). Здоровье и функциональное состояние сердечно-сосудистой системы школьников 10 11 лет. Новые исследования, (3 (20)), 15-25.
3. Байковский, Ю. В. (2010). Теория и методика тренировки в горных видах спорта.
4. Гусева, А. А. (2003). Вегетативный статус и функциональное состояние сердца юных скалолазов (Doctoraldissertation, Государственное учреждение" Начный центр здоровья детей РАМН").
5. Колчанова, В. П. (2001). Совершенствование подготовки начинающих скалолазов 9-12 лет. Магистерская диссертация: АФК им. ПФ Лесгафта.
6. Логвина, Т. Ю., Граменицкая, И. Ю., & Кравцов, А. П. (2015). Совершенствование координационных способностей у детей 5-6 лет на занятиях скалолазанием.
7. Пиратинский, А. Е. (1987). Подготовка скалолаза. М.: Физкультура и спорт, 256, 10.
8. Сверкунова, Н. С. (2016). Некоторые аспекты развития координационных способностей детей 10-13 лет в секции скалолазания. Потенциал современной науки, (7), 88-92.
9. Шувалов, А. В., Маркелов, В. В., Баранова, Т. И., & Хуббиев, Ш. З. (2020). Критерии оценки категорий сложности тренировочных и соревновательных трасс в скалолазании. Ученые записки университета им. ПФ Лесгафта, (4 (182)), 517-521.
10. Baláš, J., Strejcová, B., Malý, T., Malá, L., & Martin, A. J. Changes in upper body strength and body composition after 8 weeks indoor climbing in youth. Isokinetics and Exercise Science. 2009 17(3):173-179. doi: 10.3233/IES-2009-0350
11. Baláš, J., & Bunc, V. Short-term influence of climbing activities on strength, endurance and balance within school physical education. International Journal of Fitness. 2007 3(2):33-42.
12. Bertuzzi, R., Franchini, E., Tricoli, V., Lima-Silva, A. E., Pires, F. O., Okuno, N. M., & Kiss, M. A. (2012). Fit-climbing test: a field test for indoor rock climbing. The Journal of Strength & Conditioning Research, 26(6), 1558-1563. doi: 10.1519/JSC.0b013e318231ab37. PMID: 21904243
13. Draper, N., Giles, D., Schöffl, V., Konstantin Fuss, F., Watts, P., Wolf, P.,... & Abreu, E. (2015). Comparative grading scales, statistical analyses, climber descriptors and ability grouping: International Rock Climbing Research Association position statement. Sports Technology, 8(3-4), 88-94. doi:10.1080/19346182.2015.1107081
14. España-Romero, V., Ortega Porcel, F. B., Artero, E. G., Jiménez-Pavón, D., Gutiérrez Sainz, Á., Castillo Garzón, M. J., & Ruiz, J. R. (2009). Climbing time to exhaustion is a determinant of climbing performance in high-level sport climbers. European journal of applied physiology, 107(5), 517-525. doi: 10.1007/s00421-009-1155-x. Epub 2009 Aug 14. PMID: 19680679.
15. Fryer, S. M., Giles, D., Palomino, I. G., de la O Puerta, A., & España-Romero, V. (2018). Hemodynamic and cardiorespiratory predictors of sport rock climbing performance. The Journal of Strength & Conditioning Research, 32(12), 3534-3541. doi: 10.1519/JSC.0000000000001860. PMID: 28301444.
16. Horst, E. (2008). Training for climbing: The definitive guide to improving your performance. Rowman & Littlefield.
17. Michailov, M. L., Morrison, A., Ketenliev, M. M., & Pentcheva, B. P. (2015). A sport-specific upper-body ergometer test for evaluating submaximal and maximal parameters in elite rock climbers. International journal of sports physiology and performance, 10(3), 374-380. doi: 10.1123/ijspp.2014-0160. Epub 2014 Sep 17. PMID: 25230001.
18. Morrison, A. B., & Schoeffl, V. R. (2011). Review of the physiological responses to rock climbing in young climbers (vol 41, pg 852, 2007). British Journal of Sports Medicine, 45(3). PMID: 18037632; PMCID: PMC2658987.
19. PanáČková, M., Baláš, J., Bunc, V., & Giles, D. (2014). Physiological demands of indoor wall climbing in children. Sports Technology, 7(3-4), 183-190. doi: 10.1080/19346182.2014.968251
20. Pires, F. O., Lima-Silva, A. E., Hammond, J., Franchini, E., Kiss, M. D. M., & Bertuzzi, R. (2011). Aerobic profile of climbers during maximal arm test. International journal of sports medicine, 32(02), 122-125. doi: 10.1055/s-0030-1268007. Epub 2010 Nov 25. PMID: 21110282.
21. Rodio, A., Quattrini, F. M., Fattorini, L., Egidi, F., & Marchetti, M. (2006). ERVA M. Med Sport, 59, 313-7.
22. Watts, P. B., & Ostrowski, M. L. (2014). Oxygen uptake and energy expenditure for children during rock climbing activity. Pediatric Exercise Science, 26(1), 49-55. doi: 10.1123/pes.2013-0035. Epub 2013 Aug 29. PMID: 24018310.