Senatorova G. S., Onikiienko O. L. Cardiorespiratory adaptation to sport in young school boys. Journal of Education, Health and Sport. 2018;8(5):399-410. eISSN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.3738550
http://ojs.ukw.edu.pl/index.php/johs/article/view/7725

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part b item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 02.04.2018. Revised: 12.04.2018. Accepted: 31.05.2018.

CARDIORESPIRATORY ADAPTATION TO SPORT IN YOUNG SCHOOL BOYS

G. S. Senatorova, O. L. Onikiienko

Kharkiv National Medical University, Ukraine

Abstract

There is insufficient number of researches dedicated to cardiorespiratory adaptation in various physical activities in general, and especially in children and adolescents for certain types of sport.

The objective: to determine the cardiorespiratory adaptation features in boys of primary school age engaged in football.

Material and method. The study involved data from 92 male children aged 10-11 years, of which 68 children attended sports football schools. The study design included a general clinical examination, a spirometry, condition of cardiovascular system assessed with echocardiography, exercise stress test with cycle ergometer (VEM), 24-hours electrocardiogram (Holter - ECG) monitoring, and ambulatory blood pressure monitoring (ABPM).

Results. Boys 10-11 years of age who play sports have increased values of minute respiratory volume and heart morphology indices, which reflect the myocardial hypertrophy development, although they correspond to normal Z-score values. The frequency of subjective complaints in boys who do not practice football is significantly more frequent when performing the exercise test. According to VEM, Holter-ECG and ABPM results in 57 (83.8%) of 68 football players (p=0.00393) changes were registered.

Conclusions. We obtained statistically significant quantitative differences in the functional state of the cardiovascular system in children-athletes. Satisfactory cardiorespiratory adaptation of boys-athletes is documented during various stages of physical activity with the help of VEM and Holter-ECG and ABPM. The changes found in young athletes may result to further supervision of a pediatric cardiologist, but decision should made individually.

Key words: primary school children; football; respiratory system; cardiovascular system.

Nowadays we have insufficient scientific data on cardiorespiratory adaptation in various physical activities in general, and especially in children and adolescents for certain sports [1]. The most traumatic problem for humanity is the unforeseen death of a young man. Although sudden cardiac death is statistically uncommon in young people, its drama and cascading effects in the family and community make it an important event. Often sudden cardiac death in athletes is associated with “hidden” cardiorespiratory pathology. Therefore, it is recommended to develop evidence-based strategies and expert consensus-based health policies to protect sporting youth from such dramatic events [2]. Such strategies may include cardiovascular screening programs, innovations in the deployment of open access defibrillation, the development of standards for research, and the creation of regional and national registries of sudden deaths in young people. Relevant factors for sudden death include age, gender, presence of comorbidity, geographical area and participation in sports activities [3].

In the recent decades, the search for methods of predicting the occurrence of bronchial obstruction in athletes has been highlighted on the pages of medical publications [4, 5]. Subjective symptoms of exercise-induced bronchoconstriction (EIB), both before and after beta2-agonist administration, have not been shown to correlate with changes in airway caliber in athletes. Therefore, subjective assessments of respiratory symptoms after treatment with inhaled beta2-agonists should not be used as the sole diagnostic tool for detecting induced bronchoconstriction (EIB). [6].

Recent reviews have highlighted the difficulties experienced by general practitioners in diagnosing of respiratory disorders caused by exercise not only due to lack of awareness but also due to lack of access to special tests [7, 8]. However, it is not yet clear how family doctors should diagnose EIB. Moreover, complex diagnosis of bronchoconstriction caused by exercise in athletes may not be well defined in children [9, 10]. According to 2019 recommendations, the American Academy of Family Physicians, the American Academy of Pediatrics (AAP), the American College of Sports Medicine, the American Medical Society for Sports Medicine, the American Orthopedic Society for Sports Medicine, and the American Osteopathic Academy for Sports Medicine, and the recommendations of the American Heart Association and the European Society of Cardiology, before engaging a child in sports, they should be screened for respiratory disease and cardiovascular disease [11, 12].

The objective: to define the cardiorespiratory adaptation features in boys of primary school age engaged in football.

Materials and methods. The study is based on data from 92 male children aged 10-11 years, 68 children attended specialized football schools. Depending on the athletic experience of children, they are divided into groups: 1 group - children who have been engaged in football for more than 4 years, n = 24; Group 2 - children engaged in football from 2 to 4 years, n = 23; Group 3 - children who play football for less than 2 years, n = 21. The control group (group 4) consisted of spirometry data from 24 boys of the same age, who do not play sports and have no health problems. Inclusion Criteria: 10-11 year old boys involved in football. Exclusion criteria: female children, age less than 10 years or more than 11 years, presence of genetic pathology, and acute disorders for 3 months before recruiting. The Bioethics Commission of Kharkiv National Medical University (Protocol No.3 from 4th of April, 2012) found that the research was in accordance with the ethical principles of medical researches.

The study design included a general clinical examination, a spirometry (PFT), condition of cardiovascular system assessed with echocardiography, exercise stress test with cycle ergometer (VEM), 24-hours electrocardiogram (Holter-ECG) monitoring, and ambulatory blood pressure monitoring (ABPM).

The PFT studies were performed using the method of computerized pneumotachography on the devices “Custo-Vit” (Germany) and SpiroCom (“XAI-Medica”, Ukraine) with the measurement of the following parameters: FVC - forced vital capacity (l), FEV1 - forced expiratory volume for 1 sec (l); MRV - minute respiratory volume (l/min).

The echocardiography was performed on the devices “Toshiba-Nemio” (Japan) and “Radmir Ultima PA” (Ukraine). Determined the thickness of the interventricular septum (IVS), mass of the left ventricular myocardium (LVMM) and its index (LVMMi) indexed by the body surface area, which was calculated by Du Boisformula. We determined the stroke volume (SV), and the ejection fraction (EF) of the left ventricle.

VEM was performed using the “CardioLab” system (XAI-MEDICA, Ukraine). Physical activity was offered according to the scheme of intermittent stepped-increasing load (1^{st}stage - 0,5 Wt/kg, 2^{nd}- 1 Wt/kg, 3rd - 1,5 W/kg) with duration of each stage 3 minutes in sitting position at a pedaling speed of 60 rpm. Load periods were alternated with periods of 3 minutes rest. During VEM conduction ECG changes, blood pressure (BP), heart rate (HR), and general clinical condition of the patient were monitored. The values of blood pressure in boys were compared with the referent data of blood pressure values in children [13].

Holter-ECG and ABPM were performed with “CardoSens ECG+BP” (XAI-MEDICA, Ukraine).

Statistical analysis of the data was performed using statistical packages "Excel for Windows", "Statistica 7.0. for Windows". Verification of electoral groups for compliance with the Gauss law was performed using the Shapiro-Wilk test, which proved the need for nonparametric methods. The median (Me), lower (Lq) and upper (Uq) quartiles of distribution were determined. To compare the particles used the method of angular transformation with the evaluation of the F-criterion. Non-parametric analysis of variance Kruskal-Wallis ANOVA [KW] was used to compare samples of more than two. Non-parametric Mann-Whitney criterion [MW] was used to compare two independent samples. The difference in parameters was considered statistically significant at $p <0.05$.

Results. There were no complaints in children and their parents at the beginning of study. Clinical and demographic characteristics of examined children is presented in table 1.

Clinical and demographic characteristics of children in all groups did not reveal any significant difference. In structure of cardiovascular diseases, cases of arterial hypertension and ischemic heart diseases in grandparents were reported. There were no cases of sudden cardiac death in families. Thus in 11 (16.2%) of 68 children that have been trained and in 2 children of control group (8.3%) were found chronic diseases (hydronephrosis, right duplex kidney, retinopathy, umbilical hernia, subependymal brain cyst, chronic urticaria, Arnold-Chiari syndrome, multiple cavernous hemangiomas, scoliosis) (p=0,3329). It is quite understandable that the parents of such children would like to improve their health status with the physical activity.

Table 1

Clinical and demographic characteristics of examined boys

Показник	Group 1 n=24	Group 2 n=23	Group 3 n=21	Group 4 n=24	p
KWANOVA					
Gestational age, weeks Me (Lq; Uq)	37.5 (37.0; 38.0)	37.0 (35.0; 38.0)	38.0 (36.0; 39.0)	38.0 (35.5; 39.0)	0,7512
Weight at birth, kg Me (Lq; Uq)	2950 (2800; 3150)	3050 (2700; 3300)	3100 (2900; 3400)	3100 (2850; 3300)	0,6657
Proportion					
Complicated perinatal history, n (%)	8 (33.3)	6 (26.0)	7 (33.3)	4 (16.6)	$p_{1,2}$=0.5612 $p_{1,3}$=1.0000 $p_{1,4}$=0.2947 $p_{2,3}$=0.9530 $p_{2,4}$=0.5635 $p_{3,4}$=0.2887
Chronic disorders, n (%)	6 (25.0)	4 (17.3)	1 (4.7)	2 (8.3)	$p_{1,2}$=0.5514 $p_{1,3}$=0.2126 $p_{1,4}$=0.2726 $p_{2,3}$=0.4406 $p_{2,4}$=0.5226 $p_{3,4}$=0.9237
History of surgery, n (%)	4 (16.6)	2 (8.6)	4 (19.0)	4 (16.6)	$p_{1,2}$=0.5532 $p_{1,3}$=0.8348 $p_{1,4}$=0.9450 $p_{2,3}$=0.4356 $p_{2,4}$=0.6356 $p_{3,4}$=0.7983
Cardiovascular disorders in relatives, n (%)	13 (54.1)	12 (52.1)	9 (42.8)	12 (50.0)	$p_{1,2}$=0.9525 $p_{1,3}$=0.5835 $p_{1,4}$=0.8747 $p_{2,3}$=0.5741 $p_{2,4}$=0.8718 $p_{3,4}$=0.7243

Using multifactorial Kruskal-Wallis ANOVA test we compare the results of PFT and echocardiography in boys of 10-11 years age. Results are presented in Table 2.

According to multifactorial nonparametric analysis, wed is covered that in 10-11 years old boys of different sport activity duration there were differences in minute respiratory volume and indices of heart morphology that reflects development of myocardial hypertrophy. Despite increased heart morphology indices in children-athletes when comparing them to the control group, these parameters were normal with z-score assessment.

Table 2

The results of spirometry and echocardiography in 10-11 y.o. boys depending on sport activity duration and comparison with Kruskal-Wallis ANOVA test

Показник	Group 1 n=24	Group 2 n=23	Group 3 n=21	Group 4 n=24	p (KW)
FVC, l	2,95 (2,65; 3,25)	3,09 (2,82; 3,32)	3,26 (2,95; 3,41)	2,95 (2,77; 3,05)	0,1104
$FEV_{1,}$ l	2,65 (2,46; 2,95)	2,63 (2,45; 2,93)	2,89 (2,64; 3,05)	2,35 (2,20; 2,59)	0,4066
MRV, l/min	10,70 (9,76; 12,07)	10,80 (8,77; 12,20)	10,50 (8,80;13,60)	7,85 (7,59; 8,42)	0,0075
IVS, mm	7,6 (7,2;8,3)	7,85 (7,0;8,3)	7,9 (7,5;8,1)	7 (6,5;7,5)	0,0018
LVMMi, g/m^2	81,04 (70,0;86,97)	77,75 (71,84;93,44)	82,15 (72,64;90,01	64,17 (53,86;68,90)	0,0048
RV diameter, mm	17,65 (16,80;18,50)	16,55 (15,92;18,15)	16,80 (16,20;17,20)	16,80 (16,10;17,00)	0,2680
SV, ml	52,64 (45,34;57,97)	52,18 (48,23;60,18)	53,60 (48,97;59,8)	45,75 (37,97;51,52)	0,0021
EF, %	66 (61,5;69,5)	67 (63,25;71,75)	70 (66;73)	66 (62;68)	0,0231

Then ext step of cardio respiratory adaptation assessment in athlete boys was investigation of the tolerance to physical load and conducting of Holter-ECG and ABPM (table 3).

The incidence of complaints during stress - test in non - athlete children was significantly higher than in boys who play football. The incidence of automaticity changes was more frequent in athletes and presented with sinusbradycardia. Ectopic heart activity is presented as supraventricular extrasystoles that resolved after physical load. Conduction abnormalities were registered in four children (2 children have second degree atrioventricular block, and 2 cases of right bundle branch block). In 1 boy from the 1st group during the stress - test was detected elevation of systolic and diastolic pressure and elevation of blood pressure during ABPM test. This child has been diagnosed with overweight and has been played in team as a goalkeeper.

Summarizing the data obtained from cycling ergometry, Holter-ECG and ABPM we received changes in 57 (83.8%) of 68 children which play football and in 13 (54.2%) of 24 children that don’t take part in the sport activity (p=0.00393). Thus, we received statically significant differences of cardiovascular system’s functional condition in young athletes based on cycling ergometry, Holter-ECG and ABPM.

Table 3

Incidence of abnormalities according to VEM, Holter - ECG and ABPM in 10-11 years old boys depending on sport activity duration

Characteristics	Group 1 n=24	Group 2 n=23	Group 3 n=21	Group 4 n=24	p (KW)
VEM1 -1,5 Wt/kg (2-3 stage)					
Arrhythmia	2 (8,3)	0	1 (4.7)	1 (4.1)	$p_{1,2}$=0.2570 $p_{1,3}$=0.2751 $p_{1,4}$=0.2481
Blood pressure elevation	2 (8,3)	2 (8.6)	0	0	$p_{1,2}$=0.9027 $p_{1,3}$=0.2751 $p_{1,4}$=0.2481 $p_{2,3}$=0.2385 $p_{2,4}$=0.2112
Subjective complaints	0	0	1 (4.7)	6 (25.0)	$p_{1,4}$=0.0172 $p_{2,4}$=0.0194 $p_{3,4}$=0.0246
Holter-ECG					
Changes in automaticity	11 (45.8)	6 (26.0)	7 (33.3)	1 (4.1)	$p_{1,2}$=0.1607 $p_{1,3}$=0.3793 $p_{1,4}$=0.0006 $p_{2,3}$=0.6132 $p_{2,4}$=0.0150 $p_{3,4}$=0.0055
Ectopic heart activity	4 (16.6)	2 (8.6)	2 (9.5)	2 (8.3)	$p_{1,2}$=0.4205 $p_{1,3}$=0.4998 $p_{1,4}$=0.3508 $p_{2,3}$=0.9059 $p_{2,4}$=1.0000 $p_{3,4}$=0.9049
Changes in conduction	4 (16.6)	0	1 (4.7)	0	$p_{1,2}$=0.0742 $p_{1,3}$=0.0865 $p_{1,4}$=0.0688
ABPM					
Non-dipper < 10	4 (16.6)	2 (8.6)	0	0	$p_{1,2}$=0.4047 $p_{1,3}$=0.0865 $p_{1,4}$=0.0688 $p_{2,3}$=0.2774 $p_{2,4}$=0.2496
Over-dipper > 20	3 (12.5)	2 (8.6)	2 (9.5)	3 (12.5)	$p_{1,2}$=0.6639 $p_{1,3}$=0.7554 $p_{1,4}$=1.0000 $p_{2,3}$=0.9105 $p_{2,4}$=0.6639 $p_{3,4}$=0.6725
Night-peaker < 0	1 (4.1)	0	0	0	$p_{1,2}$=1.0000 $p_{1,3}$=1.0000 $p_{1,4}$=1.0000

Discussion

Sudden cardiac death is a tragic event that occurs in people around the world. Recently, attention has been focused on preventing these deaths, especially in the extremely vulnerable contingent, such as patients with psychiatric illnesses and children and young people involved in sport. But today, whether young athletes have an increased risk of sudden death remains unknown [14]. In Denmark, a population survey of the incidence of sudden death among all Danish children aged 1-18 years was conducted in Denmark in 2000-2006. The incidence of sudden death was 7.5%, with heart disease being known to die in 18% of all sudden deaths. The most common symptoms preceding fatal outcomes were convulsions, shortness of breath and syncope [15].

And in 2018, a Danish population study of sudden death in young people 1-35 years old with congenital heart disease conducted during 2000-2009 was published. Sudden death rate was 11% [16].

A similar study on the incidence, causes and tendency of cardiovascular cardiac arrest in children and young people aged 0 to 35 have been conducted in the United States for 30 years [17]. The most common causes of sudden death were congenital abnormalities aged 0 to 2 years (84.0%) and 3 to 13 years (21%), cardiac arrhythmias at the age of 14 to 24 years (23.5%) and coronary artery disease in people aged 25 to 35 years (42.9%). Therefore, heart rhythm disorders are associated with the sudden death appearance. In our study, we did not observe cases of sudden death among boys of 10-11 age involved in football. But we aimed to identify the features of cardiorespiratory adaptation of young school-age boys involved in football. We have more frequently reported deviations in the function of automaticity such as decreased heart rate in boys 10-11 years of age who have been involved in football for more than 3-4 years. This can be explained by the vagal influence on the automatism function which is common in athletes. Therefore, it can be considered as a physiological bradycardia in sport, since it was not accompanied by subjective complaints or syncope [3].

We have received an adequate response of blood pressure and electrical function of the heart in children who do sport during cycling ergometry with the load of 1-1.5 Wt/kg in the absence of subjective complaints. On the contrary, in non-sports children, the physiological processes of adaptation to physical activity were accompanied by subjective complaints. Consequently, in athletic children an increase in minute respiratory volume is the mechanism to increase oxygen transport in the blood [9]. Although it is well known that physical activity can affect lung volume, the impact of sports activity on pulmonary function testing has never been investigated [11]. In 2016, a study was published that examined differences in functional respiratory parameters in athletes of different sports by measuring lung volumes and influencing the factors that most affect respiratory function. But this study, unlike ours, included men 18-35 years old. The authors concluded that they correlated with respiratory parameters and participation in sport is associated with respiratory adaptation, and the degree of adaptation depends on the type of activity. Endurance athletes have higher lung capacity than athletes involved in sports that requires strength.

Another problem that has been studied in recent years is the impact of physical activity on the development of bronchial asthma and the development of a condition such as physical activity induced bronchospasm [13, 15].

We did not observe any case of bronchoconstriction in boys of 10-11 age engaged in football.

But another KOALA study that examined the relationship between physical activity and the development of asthma in 838 children aged 5-10 years with FEV1 and FVC assessment found that exercise at an early school age was not associated with a reported asthma development in later life. However, the results of pulmonary function showed that the time of sedentary activity was associated with a decrease in FEV1 and FVC. Although it is the first longitudinal study with objectively measured physical activity and lung function, it requires replication in other populations of children [17].

We obtained statistically significant quantitative differences in the functional state of the cardiovascular system in children-athletes using cycling ergometry, Holter - ECG and ABPM.

Children who had changes in the function of automatism, excitability, and conductivity according to the Holter - ECG, as well as children who had elevated blood pressure at night according to the ABPM were taken under the supervision of a pediatric cardiologist, but recommended to continue to play sports with periodic monitoring of the detected changes [14]. According to the results of Swedish researchers, the positive effects of sports are achieved primarily through physical activity, they bring health benefits, enhance psychosocial and personal development. Physical activity has significant positive effects for the prevention or alleviation of many diseases, promotes biological and psychological maturation of children [11, 17].

The limitation of our study is a small sample, a short observation time for boys 10-11 years of age who are engaged in football.

Conclusions. In boys of 10-11 age who are engaged in football, there are no signs of bronchoconstriction according to spirometry. The elevation of minute respiratory volume in their progress is used to increase the transport of oxygen in the blood under physical activity. We obtained statistically significant quantitative differences in the functional state of the cardiovascular system in children-athletes. Satisfactory cardiorespiratory adaptation of boys-athletes was documented by using of different physical load steps of cycling ergometry, Holter-ECG and ABPM. The identified changes should be estimated individually in each case and therefore recommendation to continue playing sports under the supervision of a pediatric cardiologist.

Further research prospective. The study of the adaptation of the respiratory system in athletes of different sports is an urgent problem and the subject of further research and discussion, especially in childhood. Prospects are to determine the impact of different physical activities, different sports, on the respiratory system, depending on the age of the children. It is promising to determine the prognostic criteria for the formation of pathological changes by the cardiovascular and respiratory systems in athletes.

References

1. Michael Ackerman, Dianne L Atkins, and John K Triedman. Sudden cardiac death in the young: Circulation. 2016 Mar 8; 133(10): 1006–1026. doi: 10.1161/CIRCULATIONAHA.115.020254

2. Maron BJ, Murphy CJ, Haas TS, Ahluwalia A, Garberich RF. Strategies for assessing the prevalence of cardiovascular sudden deaths in young competitive athletes. Int J Cardiol. 2014;173:369–372. doi: 310.1016/j.ijcard.2014.1002.1021.

3. James H. Hull, Les Ansley, Oliver J. Price, John W. Dickinson, Matteo Bonini. Eucapnic Voluntary Hyperpnea: Gold Standard for Diagnosing Exercise-Induced Bronchoconstriction in Athletes?Sports Med. 2016; 46: 1083–1093. Published online 2016 Mar 23. doi:10.1007/s40279-016-0491-3

4. The effect of nebulized salbutamol or isotonic saline on exercise-induced bronchoconstriction in elite skaters following a 1,500-meter race: study protocol for a randomized controlled trial Jean MM Driessen, MargrytGerritsma, Jaap Westbroek, Nick HT ten Hacken, Frans HC de Jongh Trials. 2013; 14: 204. doi: 10.1186/1745-6215-14-204

5. Andrew j. Simpson, Lee M. Romer, and Pascale Kippelen.Self-reported Symptoms after Induced and Inhibited Bronchoconstriction in Athletes Med Sci Sports Exerc. 2015 Oct; 47(10): 2005–2013. doi: 10.1249/MSS.0000000000000646

6. Schwartz LB, Delgado L, Craig T, Bonini S, Carlsen KH, Casale TB, Del GS, Drobnic F, van Wijk RG, Ferrer M, et al. Exercise-induced hypersensitivity syndromes in

recreational and competitive athletes: a PRACTALL consensus report (what the general practitioner should know about sports and allergy) Allergy. 2008; 63:953–961. doi: 10.1111/j.1398-9995.2008.01802.x.

7. James H Hull, Peter J Hull, Jonathan P Parsons, John W Dickinson, and Les Ansley. Approach to the diagnosis and management of suspected exercise-induced bronchoconstriction by primary care physicians. BMC Pulm Med. 2009; 9: 29.doi: 10.1186/1471-2466-9-29

8. Campbell RM, Berger S. Preventing pediatric sudden cardiac death: where do we start? Pediatrics 2006; 118:802.

9. Carek PJ, Mainous AG 3rd. A thorough yet efficient exam identifies most problems in school athletes. J Fam Pract. 2003; 52:127.

10. Maron BJ, Levine BD, Washington RL, et al. Eligibility and Disqualification Recommendations for Competitive Athletes with Cardiovascular Abnormalities: Task Force 2: Preparticipation Screening for Cardiovascular Disease in Competitive Athletes: A Scientific Statement from the American Heart Association and American College of Cardiology. Circulation 2015; 132:e267.

11. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. Pediatrics. 2005 Mar;115(3):826-7;

12. Risgaard B. Sudden cardiac death: a nationwide cohort study among the young. Dan Med J. 2016 Dec; 63(12). pii: B5321.

13. Winkel BG, Risgaard B, Sadjadieh G, Bundgaard H, Haunso S, Tfelt-Hansen J. Sudden cardiac death in children (1-18 years): Symptoms and causes of death in a nationwide setting. Eur Heart J. 2014;35:868–875. doi: 810.1093/eurheartj/eht1509.

14. Winkel BG, Holst AG, Theilade J, Kristensen IB, Thomsen JL, Ottesen GL, Bundgaard H, Svendsen JH, Haunso S, Tfelt-Hansen J. Nationwide study of sudden cardiac death in persons aged 1-35 years. Eur Heart J. 2011;32:983–990. doi: 910.1093/eurheartj/ehq1428.

15. Meyer L, Stubbs B, Fahrenbruch C, Maeda C, Harmon K, Eisenberg M, Drezner J. Incidence, causes, and survival trends from cardiovascular-related sudden cardiac arrest in children and young adults 0 to 35 years of age: A 30-year review. Circulation. 2012;126:1363–1372. doi: 1310.1161/CIRCULATIONAHA.1111.076810. Epub 072012 Aug 076810

16. Bianba, Sveinung Berntsen, Lars Bo Andersen, Hein Stigum, Ouzhuluobu, Per Nafstad, Tianyi Wu, and EspenBjertness. Exercise Capacity and Selected Physiological Factors by Ancestry and Residential Altitude: Cross-Sectional Studies of 9–10-Year-Old Children in Tibet. High Alt Med Biol. 2014 Jun 1; 15(2): 162–169. doi: 10.1089/ham.2013.1084

17. Lazovic B, Mazic S, Suzic-Lazic J, Djelic M, Djordjevic-Saranovic S, Durmic T, Zikic D, Zugic V. Respiratory adaptations in different types of sport. Eur Rev Med Pharmacol Sci. 2015;19(12):2269-74.