Comprehensive use of cardiopulmonary exercise testing in pediatrics
Wszechstronne zastosowanie testu spiroergometrycznego w pediatrii

Filip Wołoszyn, Artur Mazur

Department of Human Physiology, Institute of Medical Sciences, Medical College of Rzeszow University, Rzeszow, Poland
Department of Pediatrics and Pediatric Endocrinology and Diabetes, Medical College of Rzeszow University, Poland

Abstract
Cardiopulmonary exercise test (CPET) is a kind of method that enables an integrated response to the physical effort of the different systems of children and adolescents organism. The field of clinical applications on children and adolescents is widen to assess impairment of physical capacity with an unclear cause and to objectively determine functional capacity. The higher consciousness of better interdependence between exercise tolerance and health condition than with resting measurements is crucial.

Key words: cardiopulmonary exercise test, pediatrics, exercise, effort.

Streszczenie
Test spiroergometryczny (CPET) jest rodzajem metody, która umożliwia zintegrowaną odpowiedź na wysiłek fizyczny różnych systemów w organizmie dzieci i młodzieży. Zastosowanie w badaniach klinicznych u dzieci i młodzieży jest poszerzane w celu obiektywnej oceny upośledzenia zdolności organizmu do wysiłku fizycznego wraz z określeniem zdolności funkcjonalnej. Większa świadomość jest bardzo istotna w poznaniu współzależności między tolerancją wysiłkową a stanem zdrowia, porównując ją z wartościami społeczno

Słowa kluczowe: test spiroergometryczny, pediatria, ćwiczenie, wysiłek.

Introduction
The cardiopulmonary exercise test (CPET) allows the possibility to appoint the pathophysiological limitations of exercise and also the significance of functional impairment. It began to be use as a “gold standard” to evaluate the result of surgical, medical and rehabilitative treatment on cardiopulmonary function and to investigate the integrated physiological reactions to exercise in paediatric medicine. It is widely use in paediatric patients and adults and significantly improved the understanding of cardiopulmonary development in children and adolescents [1–3]. A large number of research tools are used in clinical practice to assess physical fitness. These tools have a lot of advantages and disadvantages [4]. Cardiopulmonary exercise test has become an chief clinical non-invasive tool to assess and predict the capacity of exercise in patients with heart failure and in different cardiac conditions. It supplies estimation of the exercise responses, affecting the cardiovascular, pulmonary, skeletal muscle, metabolism and the cellular system, which are not well reflected in individual organ systems by measuring function [5, 6]. Cardiopulmonary exercise test carry physiological parameters at rest and during progressive exercise. It determines the ability to produce energy at metabolically relevant time points as anaerobic threshold and the body’s cardiorespiratory fitness [7]. Resting pulmonary and cardiac function cannot reliably estimate physical performance and functional capacity [8]. Energetic human capacity is the most significant factor that sets the limits of physical capacity [9]. The cardiopulmonary exercise test allows to assess body’s response during sub and maximal exercise. Mainly measurements include gas exchange parameters such as: oxygen consumption, carbon dioxide production, minute ventilation, ECG monitoring, blood pressure and pulse oximetry [10]. In the latest years of CPET exploitation, the test has been appreciably identified by medical interest and as a physiological bases of different variables, which were before unknown and by accentuation proof for a multivariable approach. Most of problems with ventilation and its control were...
taken into consideration [11, 12]. An obstacle in performing the CPET test was mostly described as the financial barrier. Hospitals and institutions trying to initiate the action mentioned lack of funding as the most common reason for not being able to test [13, 14].

Material and methods

We performed a literature search at Google Scholar, PubMed, Science Direct, available literature from the book from 2006 to 2019 and internet sources. The bibliography search was reviewed and performed using selected keywords. This study is based on analysis of literature about cardiopulmonary exercise test and cardiorespiratory fitness.

Physiological bases to conduct cardiopulmonary exercise test

Physical effort requires coordinated actions of physiological mechanisms related to the functioning of the nervous system, circulatory system, respiratory system and internal function to cover the escalated energy demand of working muscles [10]. Features which condition physical performance are: efficiency of aerobic muscle supply and activation of biochemical processes determining the use of oxygen energy sources, removal of catabolite, efficiency of thermoregulation and size and efficiency of energy substrates use. Considering on the subject about efficiency, we cannot forget about the tolerance of fatigue changes during CPET test, which it can affect: aversion to effort or fear of effort. It can also occur pain, dyspnoea, palpitation, or excessive sweating [15]. In the study of children and adolescents, we must also consider the race of subjects. Studies conducted on Caucasian race in the United Kingdom have shown that, English children have higher cardiovascular fitness than Indian children [16]. Social, religious, linguistic and cultural traditions exclude involvement in physical activity, therefore their ability and approach to sport or recreation may be different from other children [17]. The surveys on male and female have shown that in swimmers of age from 9 to 20 years from West Bengal, had importantly lower than norm value of VO2max, than international athletes, which practiced endurance type of sport, however they had significantly higher VO2max parameter than sedentary girls of West Bengal [18, 19].

Cardiorespiratory fitness, is a solid parameter to estimate the capacity of the cardiovascular system to overcome extended physical work. It has been depicted to be the most dominant predictor of death rate and morbidity, besides of classical cardiovascular disease, risk factors such as cholesterol, smoking cigarettes, hypertension, and diabetes mellitus type 1 (T1DM) and diabetes mellitus type 2 (T2DM) [20]. In recent years, studies have documented the health benefits of regular physical activity. Nowadays it is highly appreciated that higher cardiorespiratory fitness and physical activity standards are beneficial for the diseases prophylaxis and prevention [21]. Physical activity is essential for human health in every period of life, and it gains special value during the time of the fastest and most intense development, i.e. childhood [22]. It has a positive effect on dealing with civilization diseases such as diabetes type 2 (T2DM), improves bone health, reduces the incidence of cancer, reduces signs of disability and extends life [23, 24].

Cardiopulmonary exercise test variables

The aim of spirometry is the continuous survey of respiration (spirography) and respiratory gas metabolism [25]. The tests are performed on a treadmill, cycle-ergometer or outdoor. Portable Ergospirometers are very often used to study physiological ventilation variables in field tests [26]. There are 2 basic types of ergospirometers. The first one is an ergospirometer with a mixing chamber. The principle of its operation, is that during breathing, samples of exhaled gas are taken and collected in a reservoir (chamber), where they are mixed. The size of a single sample is proportional to the current tidal volume (VT). In every constant period of time, measurements are made of the gas composition in the chamber, which is a mixture of taken samples. Measurements of average O2 and CO2 concentrations are obtained, e.g. another set of measurement data every 10 seconds. The action of the second one is based on continuous sampling of breathing air with a constant gas sample volume. In this method, measurements of O2 and CO2 concentrations require the use of fast gas analysers, usually with a response time of less than 120 ms. In addition, synchronization of the flow, O2 and CO2 concentrations is required due to delays in the sample drain and in the gas sensor itself. Measurements of temporary O2 and CO2 concentrations, are obtained after each breath. The advantage of the "breath-by-breath" type ergospirometers compared to devices with a mixing chamber is the high accuracy of the measurement regardless of changing environmental conditions, because the concentration of O2 and CO2 is measured both during the inspiration and expiration phases [27]. The major results are schedule in the following order: maximal oxygen uptake (VO2peak), carbon dioxide emission (VCO2), ventilatory threshold (VT), minute ventilation (VE), ventilatory equivalents for oxygen (VE/VO2) and carbon dioxide (VE/VCO2), respiratory exchange ratio (RER/R), heart rate (HR), saturation (SatO2), ECG, blood pressure (BP) [28, 29]. The most important parameter examined in the assessment of physical fitness is VO2max, which we describe as the maximum integrated capacity of the pulmonary system, cardiovascular system and muscular system to uptake, transport and utilize O2 [30, 31]. Through the value of the oxygen uptake kinetic reaction its survey is complex by the large "inter-breath" change in oxygen uptake in children during the test. It cuts the reliance in which kinetic variables can be asses and necessitates the measurement of variety identic transitions [32]. VO2peak is highest speed attained at the end of the test [33]. Ventilatory threshold is described as a the level at which, sudden growth in blood lactate is noticed. Output of lactic acid in the muscle rise curvilinear with increasing work load [34]. We also pay attention to the carbon dioxide that it is the sum of exhaled CO2 by a examined patient is an act of the substrate and metabolic rate utilized in oxidative metabolism. The amount of exhaled CO2 by a examined patient is an act of the substrate and metabolic rate utilized in oxidative metabolism. The amount of carbo-dioxide exhaled in oxidative metabolism for each litre of oxygen consumed is named (RER/R) the respiratory exchange ratio [35]. This parameter nearing to 0.7 if the dominant
fuel is fat to 1.0 if the prevalent fuel is carbohydrate. During dynamic exercise, the heart rate (HR) increases in order to respond to higher oxygen demand. It is accompanied by an increase in the stroke volume of the heart, which reaches its maximum value already at 30–50% VO$_{2\text{max}}$. Enhanced work of the heart causes an augmentation in blood flow mainly in working skeletal muscles, heart and skin at the expense of a decrease in flow through the kidneys, liver and visceral organs. During physical effort, the body increases its oxygen demand, so the lung ventilation process potentiates. After beginning of training, there is an increase in VE (minute ventilation), the breathing cycle speeds up and gets deeper. The rapid increase in VE lasts a few seconds after initiation of activity, then this trend slows down until it reaches a level of stabilization. The transition phase occurs when you stop exercising. In the case of intense effort, the VE value enhances constantly, the steady state phase does not occur. During low intensity exercise, VE increases proportionally to VO$_2$ until it reaches 50–75% VO$_{2\text{max}}$ [36]. Parameters related to cardiopulmonary exercise test were divided into this, which characterize circulatory system, lung ventilation, metabolic changes and those which are enters into gas exchange in the lungs [27].

**Contraindications and savourieship**

Each patient should receive instructions and basic information on how the laboratory equipment works and what the test procedure consists of. The patient should avoid eating meals, smoking cigarettes and drinking alcohol at least 2 hours before the test. Patient should wear comfortable clothing and footwear. It should also be also follow the history of medications and perform resting supine ECG to identify individual for whom the test could be contraindicated or should be performed with special safety features [37].

The basis that we can modify is the protocol with increasing linear load. It is able to choose Ramp or stepwise protocol. During the measurement process, the child should achieve a constant speed of 60 to 80 rpm. The load is gradually increased, depending on the chosen linear protocol. It is set to 1 W/kg of body weight as the basic load and increase the resistance every 10 seconds by 1 W. The load is heightened by increasing the resistance of the cycle-ergometer pedals. After reaching the desired parameters or when indicators to stop the examination appear, the doctor or paramedic decides to finish the survey. The test can also be interrupted at any time at the patient’s request or when disturbing symptoms appear. After the effort, a rest phase follows, then the patient is disconnected from the device and the electrodes are peeled off and discarded. The duration of the test lasts from 30 to 60 minutes [38].

We increase the effort load to: Obtain the maximum rhythm frequency (220-age), occurrence of symptoms indicating need to end the test (maximum stress test limited by symptoms), achieving 85% of the maximum frequency rhythm (submaximal exercise test) [39].

Absolute contraindications and exclusion criteria for children and adolescents are described in detail by American Heart Association (AHA). We can include among them: disagreement of person being examined/guardian, severe respiratory failure, congestive heart failure, active rheumatic fever with carditis, significant aortic stenosis, significant mitral valve stenosis, uncontrolled cardiac arrhythmias causing clinical symptoms or disadvantaging hemodynamics, severe arterial hypertension (systolic pressure & gt: 200 mm Hg and/or diastolic pressure & gt: 120 mm Hg), hypertrophic cardiomyopathy with former cases of collapse, diabetic children hypoglycaemia, hypoglycaemia above 250 mg/dl, severe disorders of other organs which may impact on the course of the effort or increase under their influence (e.g. infection, kidney failure, thyrotoxicosis), lower extremity phlebitis, physical disability which may prevent to perform safe and adequate test, mental disability preventing cooperation [40]. However, some children, adolescents and adults noticed discomfort with the mouthpiece, facemask, or with nose clip. Consequently, all these inconvenience, should be reported before starting the CPET test. They serve to show the need for versatile initial patient assessment, and precise monitoring during the survey [41]. Cardiopulmonary exercise test should be interpreted and controlled by a consultant with an experience in conducting the cardiopulmonary exercise testing. Furthermore, the individual performing the CPET test should be experienced in working on cardiopulmonary tests like also interpreting the outcomes [42]. However, despite their precision and reproducibility, cardiopulmonary exercise testing physicians (cardiologists, pulmonologists, and physiologists) must be well trained to avoid misinterpretation pitfalls and above all, highly experienced in clinical practice and pathological conditions [43].

**Discussion**

Cardiopulmonary exercise test in clinical praxis is very useful and has potential indication for use in assessing the functional capacity of young people with moderate to severe valvular defects to evaluate for possible surgical intervention and to determine whether early fatigue is due to defect or deconditioning [44]. Cardiopulmonary exercise test contains estimation of tolerance and intolerance during exercise, rating of patients with cardiovascular like: (heart failure, transplantation, cardiac rehabilitation, and exercise individualization) and respiratory diseases as: (chronic obstructive pulmonary disease (COPD), cystic fibrosis, interstitial lung diseases, pulmonary vascular disease and exercise-induced bronchospasm) and different clinical applicabilities like exercise rehabilitation, preoperative risk evaluation and exercise prescription to overall health improvement [45, 46]. The cardiopulmonary exercise test with survey of metabolic parameters, such as peak myocardial oxygen consumption and also exercise ventilation, may help in the clinical assessment of hypertrophic cardiomyopathy (HCM) patients in their functional capacity [47–49]. Measurements of gas exchange are taking place more and more often in sports medicine. [50, 51]. It is a useful tool for assessing limitations during daily activities, that have a physiological basis on individual with chronic organ failure [52, 53].

Cardiopulmonary exercise test is one of the most important diagnostic methods used in cardiology and sports medicine. Measurements, including gas exchange parameters during
exercise, are characterized by a high prognostic value in patients not only with heart failure, but also with respiratory diseases [54]. It would seems that it is impossible to perform a test on people with mucoviscoidosis. With the right approach and load dosing, Urquhart and Vendrusculo conducted a study on a group of 4 children from the age of 14 to 15. The measurement of performance and efficiency in cooperation with the musculoskeletal system and the cardiovascular system provided by CPET test adds more information to individualize exercise programmes for patients with highest risk suffering on cystic fibrosis [55]. Also in patients with chronic obstructive pulmonary disease (COPD), VO_{2\text{max} \text{peak}} is the best indicator of aerobic fitness, as long as patients are able to exercise more than their limits [56].

In studies conducted by Hunt et al. cardiorespiratory fitness on children was measured by FitnessGram assessment protocol. This is a good comparative method to the cardiopulmonary exercise test, because of the cost and the possibility of conducting it in the field. FitnessGram is usually used to estimate cardiorespiratory fitness and improve health and physical activity in children and adolescents [57, 58].

**Conclusions**

Measurement of expiratory gas exchange during the test, physical activity is a repeatable and objective method, which enables accurate measurement of functional capacity. In this way, it is possible to detect the causes of reduced tolerance of effort, to notice the severity of many diseases, to monitor the effects of treatment and rehabilitation, but also to confirm the complete health and ability to exercise intensively.

**References**

1. Fahey J, Nemet D, Cooper DM. Clinical exercise testing in children. Clinical Exercise Testing. Progress in Respiratory Research Volume 32. Karger, Basel 2002; 32: 282–299.
2. Yu CCW, Mccmanus AM, Li AM. Cardiopulmonary Exercise Testing in Children. Hong Kong Journal of Paediatrics 2010; 15: 35–47.
3. Takken T, Bongers BC, van Brussel M, et al. Cardiopulmonary Exercise Testing in Pediatrics. Ann Am Thorac Soc 2017; 14 (Suppl 1): S123–S128. doi: 10.1513/AnnalsATS.201611-912FR
4. Valet M, Lejeune T, Hakizimana JC, Stoquart G. Quality of the tools used to assess aerobic capacity in people with multiple sclerosis. Eur J Phys Rehabil Med 2017; 53: 759–774. doi: 10.23736/S1973-9087.17.04218-6
5. Albouaini K, Egred M, Alahmar A, et al. Cardiopulmonary exercise testing and its application. Postgraduate Medical Journal 2007; 83: 675–682.
6. Kohazuki M, Cho C, Takahashi R, et al. Importance of Physical Activity and VO_{2\text{max} \text{peak}}. Asian Journal of Human Services Research 2018; 15: 85–92. doi: 10.14391/ajhs.15.85
7. Stevens S, Snell C, Stevens J, et al. Cardiopulmonary Exercise Test Methodology for Assessing Exertion Intolerance in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome. Front Pediatr 2018; 6: 242. doi: 10.3389/fped.2018.00242
8. Stavrou V, Bardaka F, Karetzi E, et al. Brief Review: Ergospirometry in Patients with Obstructive Sleep Apnea Syndrome. J Clin Med 2018; 7: 191. doi: 10.3390/jcm7080191
9. Rankovic G, Mutavdizic V, Toskic D, et al. Aerobic capacity as an indicator in different kinds of sports. Bosn J Basic Med Sci 2010; 10: 44–48. doi: 10.17305/bjbs.2010.2734
10. Straburzyńska-Migaj E. Testy spiroergometryczne w praktyce klinicznej. Wydawnictwo Lekarskie PZWL, Warszawa 2010; 49.
11. Guazzi M, Bandera F, Ozemek C, et al. Cardiopulmonary Exercise Testing: What Is Its Value?. J Am Coll Cardiol 2017; 70: 1618–1636. doi: 10.1016/j.jacc.2017.08.012
12. Guazzi, Marco, et al. EACPR/AHA Scientific Statement. Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. Circulation 2012; 126: 2261–2274. doi: 10.1161/CIR.0b013e31826f946
13. Huddart S, Young EL, Smith R, et al. Preoperative cardiopulmonary exercise testing in England – a national survey. Perioper Med 2013; 2: 4. https://doi.org/10.1186/2047-0525-2-4
14. Reeves T, Bates S, Sharp T, et al. Cardiopulmonary exercise testing (CPET) in the United Kingdom – a national survey of the structure, conduct, interpretation and funding. Perioper Med (Lond) 2018; 7: 2. doi: 10.1186/s13741-017-0082-3
15. Konturek S. Fizjologia Człowieka. Podręcznik dla Studentów Medycyny. Elsevier Urban & Partner, Wrocław 2013: 779–788.
16. Wills M. Physical Education in a Multicultural Society. Coventry, UK: Elm Bank Teachers’ Centre, 1980.
17. Mahoney C. 20-MST and PWCT0 validation in non-Caucasian children in the UK. Br J Sports Med 1992; 26: 45–47. doi: 10.1136/bjsm.26.1.45
18. Mandal A. Physical and motor fitness level of Indian (Bengalee) School going girls. Int J Appl Sports Sci 2006; 18: 50–64.
19. Mandal A, Sarkar N. Physique and fitness of swimmers from West Bengal: Centr Eur J Sport Sci Med 2018; 24: 77–90. doi: 10.18276/cje.2018.4-08
20. Després JP. Physical Activity, Sedentary Behaviours, and Cardiovascular Health: When Will Cardiorespiratory Fitness Become a Vital Sign? Can J Cardiol 2016; 32: 505–513. doi: 10.1016/j.cjca.2015.12.006
21. Myers J, McAuley P, Lavie CJ, et al. Physical activity and cardiopulmonary fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. Prog Cardiovasc Dis 2015; 57: 306–314. doi: 10.1016/j.pcd.2014.09.011
22. McKinney J, Lithwick DJ, Morrison BN, et al. The health benefits of physical activity and cardiorespiratory fitness. Br Columbia Med J 2016; 58: 131–137.
23. Shiroma EJ, Lee IM. Physical activity and cardiovascular health: lessons learned from epidemiological studies across age, gender, and race/ethnicity. Circulation 2010; 122: 743–752. doi: 10.1161/CIRCULATIONAHA.109.914721
24. Kokkinos P, Myers J. Exercise and physical activity: clinical outcomes and applications. Circulation 2010; 122: 1637–1648. doi: 10.1161/CIRCULATIONAHA.110.948349
25. Hollmann W, Prinz JP. Ergospirometry and its History. Sports Medicine 1997; 23: 93–105. doi: 10.2165/00007256-199723020-00003
26. Diaz V, Benito PJ, Peinado AB, et al. Validation of a new portable metabolic system during an incremental running test. J Sports Sci Med 2008; 7: 532–536. doi: 10.1519/JSC.0b013e31823a3c6b
27. https://www.vo2max.pl/page.ergospirometry_mobilne_. Accessed 17.09.2019
28. Bednarska D, Sinkiewicz W, Kubicz J, et al. Znaczenie badania ergospirometycznego w diagnostyce choroby wieńcowej. Folia Cardiologica Excerpta 2008; 3: 236–241.
29. Paroli G, Głownczyńska R. How to interpret cardiopulmonary exercise testing results in patients with heart failure in everyday clinical practice. Folia Cardiologica 2014; 9: 313–320.
30. Poole DC, Willkorn DP, Jones AM. Validity of criteria for establishing maximal O2 uptake during ramp exercise tests. Eur J Appl Physiol 2008; 102: 403–410. doi: 10.1007/s00421-007-0596-3
31. Smirnau BP, Bertucci DR, Teixeira IP. Is the VO2Max that we measure really maximal? Front Physiol 2013; 4: 203. doi: 10.3389/fphys.2013.00203
32. Fawcner SG, Armstrong N. Oxygen uptake kinetics. Paediatric Exercise Science and Medicine. Second Edition. Oxford University Press, Oxford, New York 2008; 297–307.
33. Cerezuela-Espejo V, Courel-Itañeñ J, Morán-Navarro R, et al. The Relationship Between Lactate and Ventilatory Thresholds in Runners: Validity and Reliability of Exercise Test Performance Parameters. Front Physiol 2018; 9: 1320. doi: 10.3389/fphys.2018.01320
34. Ghoshr AK. Anaerobic threshold: its concept and role in endurance sport. Malays J Med Sci 2004; 11: 24–36.
35. Walsh C, Jakeman P, Moles R, et al. A comparison of carbon dioxide emissions associated with motorised transport modes and cycling in Ireland. Transportation Research Part D: Transport and Environment 2008; 13: 392–399. doi: 10.1016/j.trd.2008.07.002
36. Wojtasik W, Szulc A, Kołodziejczyk M, Szulc A. Selected issues concerning the impact of physical exercise on the human organism. Journal of Education, Health and Sport 2015; 5: 350–372. doi: 10.5281/zenodo.44392
37. Gibbons RJ, Chatterjee K, Daley J, et al. ACC/AHA/ACP-ASIM guidelines for the management of patients with chronic stable angina: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients With Chronic Stable Angina). J Am Coll Cardiol 1999; 33: 2092–2197. doi: 10.1016/s0735-1097(99)00150-3
38. Wołoszyn F, Pańczyszyn-Trzewik P, Ziajor S, et al. Applicability of Cardiopulmonary Exercise Test. Eur J Clin Exp Med 2019; 17: 351–355. doi: 10.15584/ejcem.2019.4.11
39. http://kardiologia.biziel.pl/102f.pdf. Accessed 06.09.2019
40. Karila C, de Blic J, Wearessyckle S, et al. Cardiopulmonary Exercise Testing in Children. Chest 2001; 120: 81–87. doi: 10.1378/ chest.120.1.81
41. Rodriguez AP. Cardiopulmonary Exercise Testing. Cardiology Procedures 2017; 45–52. doi: 10.1007/978-1-4471-7290-1_5
42. Smaż K, Jaxa-Chmielec T, Cwyczko T, et al. Cardiopulmonary exercise testing in adult cardiology: expert opinion of the Working Group of Cardiac Rehabilitation and Exercise Physiology of the Polish Cardiac Society. Kardiol Pol 2019; 77: 730–756. doi: 10.33963/kp.14889
43. Nedeljković I, Mazić S, Žugić I, et al. Clinical application of cardiopulmonary exercise testing in current cardiology practice and special patient subsets. Srce i Krvić Sudovi 2012; 31: 166–173.
44. Messika-Zeitoun D, Johnson BD, Nikomo V, et al. Cardiopulmonary exercise testing determination of functional capacity in mitral regurgitation: physiologic and outcome implications. J Am Coll Cardiol 2006; 47: 2521–2527. doi: 10.1016/j.jacc.2006.02.043
45. Stringer WW. Cardiopulmonary exercise testing: current applications. Stringer WW. Cardiopulmonary exercise testing; current applications. Expert Rev Respir Med 2010; 4: 179–188. doi: 10.1586/ers.10.8
46. ATS/ACCP Joint Statement on Cardiopulmonary Exercise Testing. ATS/ACCP Statement on Cardiopulmonary Exercise Testing. Am J Respir Crit Care Med 2003; 167: 211–277. doi: 10.1164/rccm.167.2.211
47. Sharma S, Elliott P, Whyte G, et al. Utility of cardiopulmonary exercise in the assessment of clinical determinants of functional capacity in hypertrophic cardiomyopathy. Am J Cardiol 2000; 86: 162–168. doi: 10.1016/s1000-9149(00)00854-7
48. Sharma S, Firozzi S, McKenna WJ. Value of exercise testing in assessing clinical state and prognosis in hypertrophic cardiomyopathy. Cardiol Rev 2001; 9: 70–76. doi: 10.1097/00045415-200103000-00005
49. Rigopoulos AG, Panou F, Sakadasikis E, et al. Cardiopulmonary Exercise Test Parameters at Three Months After Alcohol Septal Ablation in Hypertrophic Obstructive Cardiomyopathy Are Associated With Late Clinical Outcome. Heart Lung Circ 2059; 29: 202–210. doi: 10.1016/j.hlcc.2018.12.007
50. Salvati A, Ora J, Donatucci B, Rogliani P. Cardiopulmonary exercise test in athletes and coronary diseases. Medicina dello sport; rivista di fisiopatologia dello sport 2016; 69: 289–296.
51. Wołoszyn F. Cardiopulmonary exercise test performed on a football player: a case report. Eur J Clin Exp Med 2019; 17: 101–104.
52. Wouters MA, Eterman EF, Meijer RM, et al. Task-related oxygen uptake and symptoms during activities of daily life in CHF patients and healthy subjects. Eur J Appl Physiol 2011; 111: 1679–1686. doi: 10.1007/s00421-010-1794-y
53. Akkermans MA, Siljen MJ, Wouters EF, et al. Validation of the oxygen mobile metabolic system in healthy subjects. J Sports Sci Med 2012; 11: 182–183.
54. Kurpesa M, Jerka K, Bortkiewicz A. Cardiopulmonary exercise testing – Its application in cardiology and occupational medicine. Medicyna Pracy 2014; 65: 665–674. doi: 10.13075/mp.5893.00029
55. Urquhart DS, Vendrusculo FM. Clinical interpretation of cardiopulmonary exercise testing in cystic fibrosis and implications for exercise counselling. Paediatr Respir Rev 2017; 24: 72–78. doi: 10.1016/j.prrv.2015.09.009.
56. Herdy AH, Ritt LE, Stein R, et al. Cardiopulmonary Exercise Test: Background, Applicability and Interpretation. Arq Bras Cardiol 2016; 107: 467–481. doi: 10.5935/abc.20160171
57. Hunt ET, Whitfield ML, Brazendale K, et al. Examining the impact of a summer learning program on children’s weight status and cardiorespiratory fitness: A natural experiment. Eval Program Plann 2019; 74: 84–90. doi: 10.1016/j.evalprogplan.2019.02.009
58. Suminski RR, Blair RI, Lessard L, et al. Physical Education Teachers’ and Principals’ Perspectives on the Use of FitnessGram. SAGE Open Med 2019; 7: 2050312119831515. doi: 10.1177/2050312119831515

Woloszyn F, Mazur A.