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Comprehensive use of cardiopulmonary exercise testing in pediatrics

Wszechstronne zastosowanie testu spiroergometrycznego w pediatrii

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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 spoczynkowymi.
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

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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 can not 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 VO_{2max}, than international athletes, which practiced endurance type of sport, however they had significantly higher VO_{2max} 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 O_2 and CO_2 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 O_2 and CO_2 concentrations require the use of fast gas analysers, usually with a response time of less than 120 ms. In addition, synchronization of the flow, O_2 and CO_2 concentrations is required due to delays in the sample drain and in the gas sensor itself. Measurements of temporary O_2 and CO_2 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 O_2 and CO_2 is measured both during the inspiration and exhalation phases [27]. The major results are schedule in the following order: maximal oxygen uptake ($VO_{2max/peak}$), carbon dioxide emission (VCO_2), ventilatory threshold (VT), minute ventilation (VE), ventilatory equivalents for oxygen (VE/VO_2) and carbon dioxide (VE/VCO_2), respiratory exchange ratio (RER/R, VCO_2/VO_2), heart rate (HR), saturation ($SatO_2$), ECG, blood pressure (BP) [28, 29] The most important parameter examined in the assessment of physical fitness is VO_{2max}, which we describe as the maximum integrated capacity of the pulmonary system, cardiovascular system and muscular system to uptake, transport and utilize O_2 [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]. VO_{2peak} 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 CO_2 by a examined patient is an act of the substrate and metabolic rate utilized in oxidative metabolism. The sum of exhaled CO_2 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_{2max}. 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 operations. In the case of intense effort, the VE value enhance constantly, the steady state phase does not occur. During low intensity exercise, VE increases proportionally to VO_2 until it reaches 50–75% VO_{2max} [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 savouireship

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/1 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), $VO_{2max/peak}$ 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. FitnesGram is usually use 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.

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