Archives of Cardiovascular Disease (2014) 107, 319—327

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

REVIEW

The role of exercise testing in pediatric cardiology

Intérêt du test d'effort en cardiologie pédiatrique

Martial M. Massin

Division of Pediatric Cardiology, Queen Fabiola Children's University Hospital, Free University of Brussels (ULB), 15, avenue J.J.-Crocq, 1020 Brussels, Belgium

Received 21 January 2014; received in revised form 11 April 2014; accepted 15 April 2014
Available online 17 May 2014

KEYWORDS
Pediatric cardiology;
Exercise testing;
Congenital heart disease;
Arrhythmia;
Child

Summary Exercise testing for cardiac disease in children differs in many aspects from the tests performed in adults; their cardiovascular response to exercise presents different characteristics, which are essential for the interpretation of hemodynamic data. Moreover, diseases that are associated with myocardial ischemia are very rare in young patients, and the main indications for exercise testing are evaluation of exercise capacity and identification of exercise-induced arrhythmias. This article describes the specificity of exercise testing in pediatric cardiology, in terms of techniques, indications and interpretation of data.

MOTS CLÉS
Cardiologie pédiatrique ;
Test d'effort ;
Cardiopathies congénitales ;
Arythmies ;
Enfant

Résumé Le test d'effort chez les enfants cardiaques diffère par de nombreux aspects de celui réalisé chez l'adulte ; leur réponse cardiovasculaire à l'effort présente des caractéristiques dont la connaissance est essentielle à l'interprétation des données hémodynamiques. De plus, les maladies ischémiques sont exceptionnelles chez les jeunes patients et les principales indications du test d'effort sont une évaluation de la capacité physique et l'identification d'arythmies induites par l'exercice physique. Cet article décrit les spécificités techniques, les indications et l'interprétation des données en cardiologie pédiatrique.

Abbreviations: ECG, electrocardiogram; LQTS, long QT syndrome; PCO_2, partial pressure of carbon dioxide; PO_2, partial pressure of oxygen; SVT, supraventricular tachycardia; VAT, ventilatory anaerobic threshold; VE, minute ventilation; VCO_2, carbon dioxide production; VO_2, oxygen consumption; VT, ventricular tachycardia.

E-mail address: martial.massin@huderf.be

http://dx.doi.org/10.1016/j.acvd.2014.04.004

Background

Standardized exercise testing has almost become a routine procedure in the care of children with cardiac disease [1]. Impairment of functional capacity is usual in this population and may be the result of the primary cardiac problem, its treatment or hypoactivity. The test is often conducted to provide objective information about exercise capacity, to identify abnormal responses to exercise, to make management decisions, to assess the efficacy of medical and surgical interventions, to evaluate exercise-related adverse events, to define individual safety limits, to instill confidence in child and family, and to motivate patients to engage in physical activity, resulting in improved patient outcomes.

Procedure

An analysis of the possible gain in information expected from the test versus the potential harm induced is mandatory before a test is performed, even if adverse reactions are rare [2]. An exercise test should not be carried out if the patient has an acute infection, acute exacerbation of a chronic disease, or any other unstable health condition that may pose an additional transient risk. Severe obstructive diseases, pulmonary hypertension, severe heart failure or certain arrhythmias warrant special consideration. An experienced physician and emergency equipment should always be present during the test.

According to international recommendations [1], the test should be terminated when diagnostic findings have been established and further testing will not yield any additional information, when monitoring equipment fails, when signs or symptoms indicate that further testing may compromise the patient's well-being, and when extreme fatigue or other symptoms of insufficient cardiac output are associated with decrease or failure of heart rate to increase with increasing workload. Other criteria are progressive fall in systolic blood pressure with increasing workload, systolic hypertension > 250 mmHg, diastolic hypertension > 125 mmHg, intolerable dyspnoea or tachycardia, progressive fall in oxygen saturation < 90% or a 10-point drop from resting saturation in a symptomatic patient, 3 mm flat or downward sloping ST-segment depression, triggering of atrioventricular block or QTc lengthening > 500 ms and increasing ventricular ectopy with increasing workload, including a triplet.

Defining that an effort was maximal may sometimes be difficult, but is very important to determine maximal exercise data. A plateau of oxygen uptake (i.e. an increase during the final completed stage of an incremental exercise test of < 2 mL/kg/min for a 5—10% increase in exercise intensity or of < 2 standard deviations of the average increase in oxygen uptake during the preceding stages) occurs in half of the children [3]. In other cases, the investigators have to rely on their impression that a maximal effort has occurred and on indicators such as heart rate > 200/min on a treadmill or > 195/min on a bicycle, breathing reserve < 40% or a respiratory exchange ratio of ≥ 1 on a treadmill or 1.05 on a bicycle [4].

Exercise testing in children, especially sick young children, is more challenging than in adolescents and adults. Treadmill exercise testing is possible in children from the age of 3 years, but a harness with a rope and one extra-staff member may be necessary to safeguard the child during the test. Nevertheless, owing to the strong resemblance to daily activities, the larger muscle mass involved and the lower probability of leg muscle fatigue, a treadmill test may be especially advantageous in very small or very sick children, as well as increasing the likelihood of the cardiorespiratory system being the limiting factor. Because cycle ergometry requires that the subject maintains a cycle cadence with increasing workloads (especially with a mechanically braked cycle ergometer that cannot vary resistance to keep workload constant over a range of pedal speeds) and because the patient must be big enough to reach pedals, exercise testing on a bicycle is hardly possible before the age of 6 years. Bicycle testing is portable and less expensive than treadmill testing, and accurate determination of the workload is easy. Moreover, the upper body is more stable on a cycle ergometer than on a treadmill, so a bicycle is preferred when the underlying condition requires accurate blood pressure assessment or ischemia detection on an electrocardiogram (ECG). However, many subjects may not be accustomed to cycling and premature muscular fatigue during bicycle testing may prevent them from reaching maximal effort.

Numerous exercise protocols have been used in children. Most laboratories use continuous graded protocols requiring a maximal effort, even if important data can be obtained during submaximal exercise [4]. The choice of protocol depends on the age and body size of the child to be tested, the measurements planned and the equipment available. Hemodynamic and gas exchange responses are better, and determination of the ventilatory threshold is easier in protocols with shorter stage durations, the so-called ramp protocols, whereas a steady state for more physiological functions (heart rate and oxygen uptake) requires exercise stages of ≥ 3 minutes. In general, the total exercise duration should be kept to 6—12 minutes in children, to avoid premature muscle fatigue and lack of attention and motivation. For treadmill exercise testing, most laboratories use the Bruce treadmill protocol [5,6], in which increase in work rate is accomplished by increasing speed and grade every 3 minutes. Disadvantages of the Bruce protocol are large interstage increments in work that can make estimation of maximal values less accurate, and intermediate stages than can be either run or walked, resulting in different oxygen costs. Alternatives, with a slower increase in workload, are more appropriate for unfit patients; an example is the Balke protocol, in which the speed of the belt is held constant and the increase in work rate is accomplished only by increasing the slope. Different protocols are also used for cycle ergometry [7]. When an electronically braked cycle ergometer is available, a continuous ramp protocol is usually preferred. Increments in workload can be increased by 5 to 20 W/min, depending on height, weight or body surface area [8], or can be standardized by 0.25 W/kg/min [9]. Additional procedures are used to answer specific questions, such as the Wingate test protocol to determine anaerobic power, step-like increases of workload to assess oxygen uptake kinetics, or a 4—10-minute intense exercise bout to induce bronchoconstriction.

Exercise testing with ECG monitoring, but without gas analysis, is sufficient when only abnormal blood pressure