

Cardiorespiratory Fitness Evaluation In Obese Youth

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Cardiorespiratory fitness in obese children and adolescents

Obese children and adolescents usually have lower overall physical abilities and especially lower cardiorespiratory fitness (CRF) when compared to their normal-weight peers. This is mainly because of the increased effort required to move their larger body mass and carry an excessive amount of body fat ¹. It is only among extremely obese children that the lower CRF can partly result from impaired lung function, with decreased expiratory reserve volume and functional residual capacities due to their lower chest wall and lung compliance ²⁻⁵. He and al. did not observe any difference of pulmonary functions between lean and obese children, despite a higher prevalence of respiratory symptoms that may occasionally impair cardiorespiratory fitness in obese youth ⁶. Although lower cardiorespiratory performances are observed in obese children and adolescents compared to those of lean children and adolescents when adjusted to body mass, absolute performances are similar or higher, and these differences disappear when performances are adjusted to fat free mass, suggesting that muscle maximal oxidative ability is not impaired with obesity in youth ^{7, 8}. As an example, Lazzer et al. reported a maximal oxygen uptake (VO_{2max}) approximately 27% higher in 12-16 years old obese youth when expressed in absolute terms ($L \cdot min^{-1}$), but when VO_{2max} was adjusted to Fat-Free Mass there was no difference between the obese adolescents and their normal weight controls as illustrated by the Figure 1 ⁹. Using an incremental treadmill test conducted to exhaustion and the measurement of VO_{2max} , Watanabe et al. observed an inverse and significant relation between 12-15 years old obese adolescents' CRF and their body fat mass ⁷. CRF results are similar when VO_{2max} cannot be directly assessed and indirect methods are used to assess CRF (Queen's college step test) ¹⁰. Excessive body fat is also thought to contribute to the exercise intolerance and low CRF in obese youth ⁷. Some studies suggest different effects of obesity in girls and boys, as Mota et al. did not observe any CRF difference between lean, overweight or obese 8 years old boys, whereas overweight and obese girls were more likely to be unfit compared to lean girls ¹¹. This is in accordance with previous findings from a longitudinal study showing that CRF among girls but not boys was significantly associated with the incidence of overweight and obesity ¹².

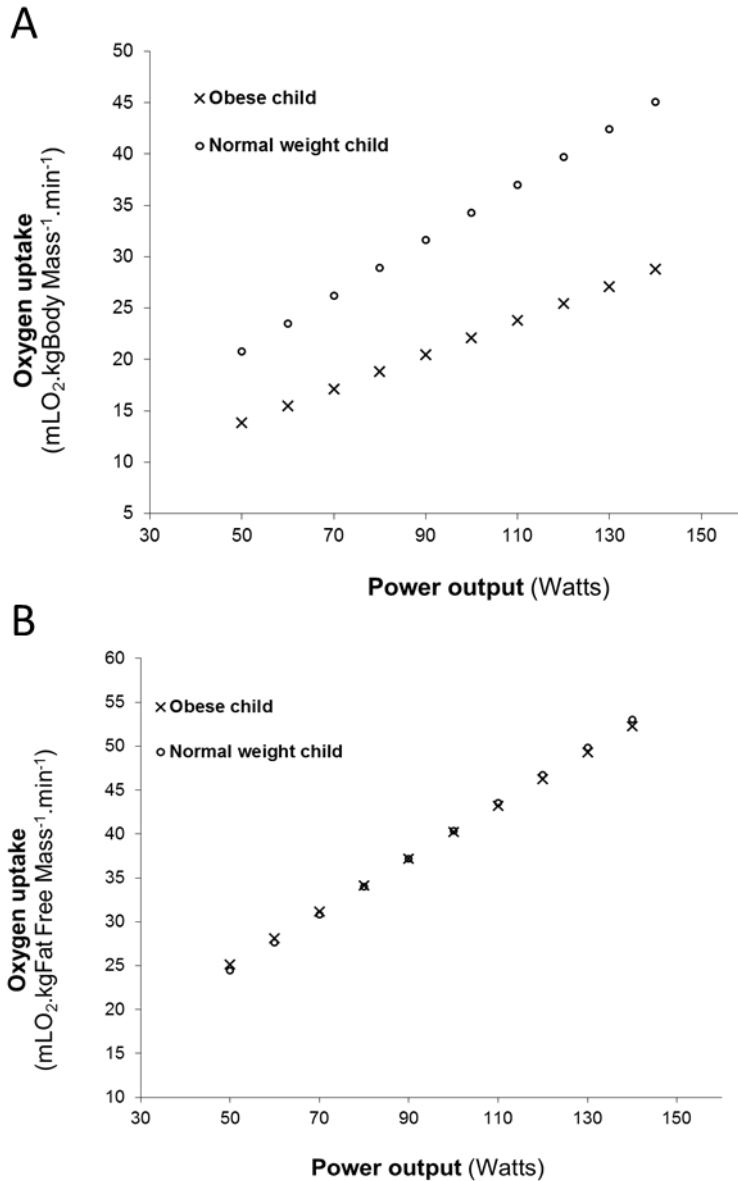


Figure 1. Illustration of the VO₂ differences between lean and obese youth depending on its expression during an incremental exercise test (relative to Body Mass (A) or Fat Free Mass (B)).

Although exercise training represent the best method to improve CRF in obese youth, their initial low fitness level is a barrier to their engagement in regular physical activity, contributing to the poor compliance usually observed in physical activity interventions¹³. An important clinical challenge to track the changes in physical fitness with these interventions is to properly assess CRF in obese youth by using validated and accurate tests.

How to measure CRF in pediatric obesity?

Maximal oxygen uptake (VO_{2max}): the “Gold Standard”

Laboratory tests to assess cardiorespiratory fitness either measure or predict oxygen uptake (VO_{2max}) and are accepted as reference methods¹⁴⁻¹⁷. Basically, VO_{2max} is assessed during a cycling or running graded exhaustive test with increasing workload (in Watt) when performed on a cycle ergometer or speed and/or slope when performed on a treadmill. Whether it is on a cycle ergometer or a treadmill, the stage duration at each workload or speed ranges between 1 to 3 minutes of duration. In children and adolescents, the criteria for achievement of VO_{2max} are subjective exhaustion, heart rate above 195 beats.min⁻¹ and/or Respiratory Exchange Ratio (RER, VCO_2/VO_2) above 1.02 and/or a plateau of VO_2 ¹⁸. Although this method is widely used the completion of maximal test requires strong encouragement from the investigation or medical team and remains difficult to perform in obese subjects. Obese children and adolescents specifically have been shown to express a significantly higher rate of perceived exertion during incremental test compared to their normal-weight peers¹⁹, with pain and fatigue considered as the main causes. Children who rarely engage in physical activity of high intensity, often fail to reach the required VO_{2max} criteria during a maximal CRF test, and if the aforementioned criteria are not met, the maximal oxygen uptake measured is termed VO_{2peak} rather than VO_{2max} ²⁰. VO_{2peak} represents the highest value of oxygen consumed by participants in a maximal protocol but with less stringent criteria than VO_{2max} . As an example, Breithaupt et al. reported that only 18 out of 62 obese children who performed a maximal CRF test were able to achieve VO_{2max} based on the criteria presented above²¹.

In addition to the measurement of VO_{2max} , two ventilatory thresholds (VT1 and VT2) can be determined during incremental test and are each characterized by a disproportionate increase in minute ventilation (VE) relative to the increase in VO_2 . Also VT1 and VT2 are considered as good physiological indicators of cardiorespiratory endurance, they are difficult to determine accurately in obese children and adolescents due to frequently erratic breathing. Some authors indicate that the thresholds are almost undetectable in up to 20% of children and adolescents^{22,23}. Despite these limitations, VT determination can be used for exercise prescription. For example, training below VT1 will represent a moderate intensity of exercise that will favor fat oxidation²⁴, training alternating moderate and high intensities (between VT1 and VT2) has been shown to reduce cardiovascular risk factors²⁵ and exercising at the VT2 can reduce post-exercise energy consumption²⁶.

Maximal laboratory tests with gas exchange measurement may represent the most accurate method to assess CRF, but these tests are often expensive and not accessible to all obese youth. Submaximal tests have been therefore been developed²⁷ for and validated in the general pediatric population, and are now applied to obese youth.

Submaximal tests: from the laboratory to the field setting

When using validated tests, submaximal exercise testing offers a valuable and reliable alternative to estimate VO_{2max} . Submaximal measures do not require the participants to exercise until exhaustion and may thus overcome some of the limitations of maximal testing and are better tolerated by patients

experiencing physical limitation, important fatigue and pain while exercising¹⁷. Basically, extrapolations of VO_{2max} or maximal power output are performed from the theoretical maximal heart rate (HR), and the linear relationship between power output (or VO_2) and heart rate measured during at least two bouts of exercise performed at two different submaximal intensities of exercise²⁸. Estimation of CRF can also be done using other predictive variables such as HR recovery during step tests^{29,30} or validated predictive equations with parameters such as age, gender, body weight or rest heart rate among others³¹⁻³³.

Recently, Breithaupt et al. proposed a new submaximal protocol adapted to obese youth (The HALO protocol: Healthy Active Living and Obesity research group Protocol) that they compared with a direct progressive maximal test to exhaustion in 21 obese adolescents³⁴. The test consists in a walking test at constant speed (brisk but comfortable) during 4-min stages to ensure that steady state of VO_2 and HR is reached. After a 4-min warm-up, the incline of the treadmill is increased by 3% over each subsequent stage. The test ends when: i) the participant reaches 85% of his maximal estimated HR; ii) he completes 20 minutes of exercise; iii) he indicates that he can no longer continue. Then VO_{2peak} is predicted by extrapolating the HR- VO_2 linear relationship to age-predicted HRmax. While only 29% of their sample reaches a VO_2 plateau during the maximal test, all the participants ended the HALO protocol and expressed lower RPE. According to their results, the HALO submaximal protocol provides an accurate and valid method to estimate VO_{2peak} compared with a classical maximal test. Furthermore, this test results in better estimates of VO_{2peak} compared with previously validated submaximal estimations in obese youth³⁴.

A shorter submaximal protocol has also been validated in obese adolescents against a laboratory-based maximal VO_{2max} measure. Nemeth et al. asked 113 obese 12 years old boys and girls to complete a 4-minute treadmill exercise³³. After a 4-minute warm-up at a self-selected comfortable walking speed (treadmill grade = 0%); the participants were asked to maintain this speed for 4 minutes while the treadmill grade increased to 5%. Heart rate was recorded at rest and at the end of the 4 minutes as well as the self-selected speed. Based on these two variables, the authors proposed an equation that also included sex, weight (kg) and height (cm) to estimate VO_{2max} . These simple methods requiring only HR measurement accurately predict VO_{2max} in overweight and obese children and adolescents³³ and offers then practitioners feasible and simple methods to assess cardiorespiratory fitness.

Several inexpensive, easy to implement and reproducible field-methods initially validated in non-obese youth are commonly used obese youth^{17, 35-37}. The two main field tests used among pediatric obese populations are the Six-Minute Walk Test (6MWT) and the 20-Meter Shuttle Run Test (20MST).

The 6-minute walk test is an accurate and convenient method to assess CRF at submaximal intensity in children³⁸ and has been shown to better reflect daily living activities than any other functional walk test³⁹. The recently established reference values have facilitated the use of the 6MWT and allow determining whether a child has a good or a poor CRF⁴⁰⁻⁴⁴. Not surprisingly, several studies have shown lower distances completed during the 6MWT in obese compared to lean children and adolescents^{45,46}. Elloumi et al. confirmed the validity of the 6MWT in obese adolescents by comparison with a validated incremental submaximal protocol with gas exchange measurements⁴⁷. The 6MWT has also been shown to be sensitive to changes in physical fitness of obese adolescents following a 2-month physical activity^{47,48}. The 6MWT has also been used to estimate the maximal fat oxidation point (Fatmax or lipoxmax), when gas exchange measurement - with the VO_2 and VCO_2 data used to calculate the rate of fat oxidation - is not available (using the distance performed during the test as a central values in a predictive equation)⁴⁹.

The 20-meter shuttle run test (20MST) developed by Leger et al. is among the most used field tests to assess cardiorespiratory fitness in youth⁵⁰. During this test, children are instructed to run for as long as possible between two lines drawn 20 meters apart at an increasing speed imposed by a recording emitting tones at appropriate intervals. The test starts at 8 km/h and increases by 0.5 km/h every minute. The test ends when the participant is not able anymore to complete a whole stage. Castro-Pineiro et al. showed that overweight and obese children performed less well than lean ones at this test⁵¹, and this is partly explained by the excessive start speed during the original test (8 km/h). This led to the development of an adapted version of the test, with the use of an incremental shuttle walk test with 15 levels from 1.8 to 10.3 km/h over a 10-meter distance³⁶. More recently, an adapted version of the 20MST has been developed in obese children and adolescents⁵². 10 stages have been added at the beginning of the original 20MSRT in order to reduce the starting speed and speed over the duration of the test⁵². Then, the participants are asked to start at 4 km/h (walk speed) with an increment of 0.5 km/h every minute. The original start speed of 8 km/h is reached after the first 10 minutes. The authors reported a strong correlation between the maximum speed obtained and laboratory-assessed peak VO_2 ($r=0.81$), which indicates the validity of this adapted version of the test in obese youth⁵².

Conclusion and Recommendations

Cardiorespiratory fitness is impaired in obese children and adolescents, and is among the main reasons for their low engagement into physical activities. There is a double interest in properly assessing CRF in this population. First, CRF is an important clinical parameter for the diagnosis and follow-up of the current and future functional and metabolic health of obese youth. A laboratory-based direct and maximal assessment should thus be encouraged.

Second, from a more practical point of view, CRF is necessary information to obtain when implementing interventions for the treatment of obesity, especially when it is based on physical activity-based programs. Disposing of CRF indicators will help the practitioners and/or educators to properly prescribe physical activities by determining the appropriate exercise intensities and controlling their progression through the intervention. When direct $\text{VO}_{2\text{max}}$ measurement is not available, submaximal and field testing are reliable alternatives. Thanks to their easy feasibility, these tests can be repeated many times during the program to and bring adaptation to the exercise prescription if necessary.

BOX 1

Cardiorespiratory fitness, or **aerobic capacity**, describes the ability of the body to perform high-intensity activity for a prolonged period without undue physical stress or fatigue. High level of cardiorespiratory fitness enables people to carry out their daily occupational tasks and leisure pursuits more easily and with greater efficiency ⁵³.

Cardiorespiratory endurance, or **aerobic fitness**, is the ability of the cardiorespiratory system to supply oxygen to active skeletal muscles during prolonged submaximal exercise and the ability of the skeletal muscles to perform aerobic metabolism ⁵⁴.

BOX 2

Limiting factors in the evaluation of CRF in obese youth

Pain. The excess body weight characterizing overweight and obesity is responsible for increase overall and lower limb musculoskeletal pain limiting their engagement in exercise ⁵⁵. In a recent review, Smith et al. pointed out the musculoskeletal and osteoarticular dysfunction and pain induced by obesity in youth ⁵⁶. Overweight and obese children and adolescents experience decreased joint health and increased dysfunction resulting in more ankle, foot and knee problems than their lean peers ⁵⁷. Such physical impairments are limiting factors leading to premature interruption during maximal and submaximal testing.

Respiratory limitations. Obesity is accompanied by numbers of respiratory complications that limits the adherence of overweight and obese youth to exercise testing and programs. Decreased thoracic compliance, increased airway resistance and breathing at low pulmonary volumes have been identified among others ⁵⁸⁻⁶⁰ and contribute to ventilator constraint ⁶¹, increased fatigue of respiratory muscles ⁶² leading then to dyspnea. Since ventilator response to exercise in youth is excessive relative to the metabolic demand, it increases ventilator constraint in obese children and adolescents ^{63, 64}. In addition, due to their reduced airways relative to lung size ⁶⁵ youth with obesity experience increased expiratory flow limitation that limits their compliance to maximal and submaximal exercises ⁶⁶.

Rate of Perceived Exertion (RPE). Although few data are available regarding the real perceived exertion of obese youth during incremental tests, it has been shown that obese children rate their perceived exertion during a CRF test significantly higher than their lean peers ¹⁹. Belanger et al. found that obese adolescents express higher absolute RPE during a maximal incremental test compared with a submaximal one ⁶⁷. According to Ward & Bar-Or, the excess body weight and lower physical abilities and capacities induced by obesity increase their perception of exercise difficulties and compose the main limitations to physical activity ⁶⁸. This excessive RPE during exercise may lead to premature interruption of the tests and then underestimation of their aerobic capacities.

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