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Heart Evaluation: Cardiopulmonary Exercise Testing (CPET)
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April 15, 2004
Your Life Your Health - *The Examiner*

The first time I saw a CPET result, I thought, "so many dots and so many curves, what can it all mean?" Terms like "VO2max" (spoken as "V dot O2 max" -- there should be a "dot" over the "V," but the computer will not make that mark) and "Anaerobic Threshold" were mysteries. After an introduction to CPET by Dr. Qamar Arfeen and participation in the Practicum on CPET at Harbor -- UCLA led by Dr. Karl Wasserman, who along with his colleagues and staff are the world leaders in this subject, those "dots and curves" have turned into an elegant display of vital information for assessing the health and wellness of our patients and for prescribing treatment and exercise for improving the health of our patients.

To benefit from the information obtained from the CPET, a clinician does not need to be able to do the primary interpretation, but does need to understand some of the terminology and normals of the result of testing. While there are seventeen "break points" -- points at which the interpretation of the CPET results branch into either normal or abnormal, which then leads the interpreter down a decision tree, which with experience and other clinical data, allows for a correct assessment of the patient -- there are only three such data points which I would like to discuss at this point.

They are:

- VO2 which represents the oxygen uptake and should be expressed with a "dot" over the "V". Along with VO2, the term "VO2max" will be used.
- Anaerobic Threshold
- Breathing Reserve

Science and Clinical Medicine

Perhaps, in no other area of medicine is the knowledge of the basic sciences of biochemistry and physiology more intimately related to clinical medicine than with the CPET. Oxygen is required for exercise because ultimately oxygen is required to produce the energy necessary to move muscles and bone. That energy is "packaged" in units called ATPs (adenosine triphosphate, high energy phosphate bonds), which provide the power for muscles to do their work. Limitations on work in the body, as evidenced by limitations on walking, running, jogging, lifting, etc., are dictated by oxygen utilization (symbolized as QO2, with a dot over the Q)

Oxygen utilization is determined by:

1. Maximal cardiac output the amount of blood your heart pumps with each beat multiplied by the number of times it beats in a minute.

2. Arterial oxygen content how much oxygen there is in the blood in your arteries.
3. Distribution of cardiac output to the exercising muscle how effectively blood is sent to the muscles by the arteries to and in your muscles.
4. Ability of the muscle to extract oxygen from the blood how much of the oxygen delivered to the muscle can be accepted by the muscles.

Effects of Training Let me digress for a moment and address what training does to each of the elements of oxygen utilization. The amount of oxygen taken up by the blood and therefore delivered to the body is dependent upon the lungs and on the blood flow. Blood flow is a function of "cardiac output," which is determined by the "stroke volume" -- how much blood is pumped by the heart with each beat -- and the heart rate -- how many times per minute the heart beats. Training will increase the cardiac output at maximum work because both the stroke volume and the heart rate are increased. At rest, and at specific work rates, the stroke volume is increased but the cardiac output is not because the heart rate is slower indicating that more oxygen is being delivered to the body by the slower heart rate. The fitter you are, the slower your heart rate will be, the slower it will increase as you exercise, and the higher it can go before you fatigue. All of this is demonstrated objectively by the CPET.

Muscles Extracting Oxygen from the Blood

Training also increases the ability of the muscle to extract oxygen from the blood, but how? With training a number of things happen to muscles which are stressed by the activity:

1. In the muscle fibers, the number and size of the mitochondria increase. The mitochondria are little power units in the muscle cells which produce the ATP mentioned above. Also, a number of enzymes in both the cytosol (the fluid in the cell) and the mitochondria increase. These changes enable the muscle cells to produce more ATP and therefore to function longer and with heavier loads before fatiguing. The changes also allow the muscles to extract more oxygen from the blood.
2. The ability to supply oxygen to the muscle increases with training. Myoglobin levels in the trained muscle are higher. Myoglobin is a protein in heart and skeletal muscles. When a muscle is exercised, it uses up available oxygen. Myoglobin has oxygen bound to it, thus providing an extra reserve of oxygen so that the muscle can maintain a high level of activity for a longer period of time.
3. Muscle capillaries proliferate out of proportion to the increase in muscle fiber size so that more capillaries surround a given muscle fiber. This decreases the diffusion distance form the oxygen source (hemoglobin in the muscle capillary) to the oxygen sink (the mitochondrion in the muscle cell.

These changes allow muscles to work longer and under a great load before fatiguing. This is the reason why a well-trained athlete can run over 26 miles at a pace of 5 minutes a mile without collapsing. It is also the reason why a poorly condition person cannot walk up one flight of stairs without huffing and puffing.

However, the training effect is "specific" to the muscles being stressed, which means that when you are walking, jogging or running, your arm and shoulder muscles are not being trained.

Likewise when you are lifting weights, the muscles of locomotion in the legs are not being trained.

The Heart Is a Muscle

One last comment about the effects of training is in order. The increased stroke volume is due to the fact that the heart, which is a muscle, responses to exercise as any other muscle. The heart gets larger -- hypertrophies -- with increases in both ventricular wall thickness and chamber size. This enables the heart to delivery more oxygen per stroke to the body.

Walking at a pace of fifteen-minutes-per mile requires a sixteen to twenty fold increase in oxygen consumption of the muscles of locomotion. While a person may not be able to walk at this pace at present; if they begin walking where they can, and gradually increase their distance and rate, they will be able to walk at a fifteen-minute- per mile pace and faster because:

1. Their stroke volume will increase.
2. Their mitochondria will increase in their leg muscles.
3. They will develop more Myoglobin.
4. Enzymes required for production of energy will increase.
5. Their heart muscle will get stronger.
6. More capillaries will form in their muscles.

The active person will be healthier, will live longer, and every disease known to man, including cancer prevention and/or survival will improve.

Back to CPET Definitions

The three most important data points in the CPET are "VO2max" or "peak VO2" if the maximum is not achieved, the "anaerobic threshold" and the "breathing reserve."

VO2max (oxygen uptake) -- This is the volume of oxygen extracted from inspired air in a given period of time expressed in milliliters per minute or liters per minute. This can differ from oxygen consumption. Oxygen consumption is the amount of oxygen utilized by the body's metabolic processes in a given time and is expressed in units of liters per minute. In the steady state, oxygen uptake and oxygen consumption are equal. Traditionally, the VO2max is the highest attainable oxygen uptake for a given subject. If the maximum is not achieved, then the highest level is termed the peak VO2.

O2 consumption (designated as QO2) is the amount of oxygen utilized by the body's metabolic processes in a given time and is expressed in units of liters per minute. As the VO2 (oxygen uptake) increases with increasing external work, some of the determinants of oxygen uptake -- stroke volume, heart rate or tissue extraction -- may begin to level off. The main determinants of VO2max or peak VO2 are genetic factors and the quantity of exercising muscle. These values are also determined by age, sex, body size, obesity, and training.

Anaerobic Threshold is considered as an estimator of the onset of metabolic acidosis caused predominantly by the increased rate of rise in arterial lactate during exercise. The anaerobic threshold is referenced to the VO2 (oxygen uptake) and is expressed as a percentage of the VO2max predicted value. Ultimately, the limitation on the work load of a muscle is determined by oxygen uptake and the anaerobic threshold. As both the VO2 and AT go up, the person is able to go farther, faster and longer.

Breathing Reserve is the amount of breathing capacity expressed as a percent of the Maximum Voluntary Ventilation (MVV) which remains when a person stops their CPET evaluation due to fatigue, dypsnea or pain. The MVV is conventionally measured at rest from maximal volitional effort for short periods of time, e.g., twelve seconds, and expressed in units of liters per minute. If the breathing reserve is normal, then any abnormality of the CPET is probably related to the heart and/or muscles as opposed to the lungs.

Assessment

If the VO2max is 85% or above of predicted; if the anaerobic threshold is 40-60% of the "VO2max" and if the breathing reserve is 10-40% of the MVV, then the patient for all intents and purposes is normal. If one of these is abnormal, the CPET can lead to the making of an accurate and specific diagnoses ranging from COPD to ischemic heart disease to Congestive Heart Failure, to primary pulmonary hypertension, to deconditioning due, to a sedentary life style. There are unique patterns which can tell you if the patient has a right to left cardiac shunt due to a patent foramen ovale or a number of other cardiac, pulmonary, and muscle diseases.

Getting a CPET

Currently, SETMA is the only clinic in Southeast Texas which performs CPET. This gives us the ability to provide our patients with superior care and diagnostic capabilities. It also provides us the opportunity to encourage other clinicians to begin performing this very excellent test.

If you are a patient of SETMA and have shortness of breath or other cardiovascular symptoms, ask your healthcare provider to order a CPET. If you want to know what your aerobic power or critical power is (see The Examiner, April 8, 2004) so that you can be given an effective exercise prescription, ask your health care provider for a referral for a CPET. If your insurance company will not pay for the test either because you are not a patient of SETMA, or because you are not ill, the cost of the test is not great and the information is incredibly valuable to you. It will be worth paying for the test yourself in order to benefit from the knowledge.

You can be healthy but you must "take charge" of the care of your own health. A CPET is a good place to start.