Self Assessment of Cardiovascular Fitness
Cardiovascular Formulas

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Subject undergoing treadmill exercise testing to directly measure to VO\textsubscript{2} MAX by measuring the O\textsubscript{2} consumption by subtracting the %O\textsubscript{2} from the inhaled air from the %O\textsubscript{2} for the exhaled air. That data combined with a precise knowledge of how much energy she is expending on the treadmill is used to calculate the value.
Physical Fitness formulas

A lot of information is generated on people during the typical Treadmill Fitness Exam. Physicians, trainers, or you can enter this data into a spreadsheet using these formulas and calculate a variety of measures of athletic fitness. In the following sections, the formulas used to calculate these various measures of fitness are provided along with a discussion for how I interpret them together with an explanation of each. As you will see, having an echocardiogram, which is a non-invasive imaging test of the heart can really provide you with what is needed to calculate these formulas a lot more accurately but that test is not needed unless you have specific medical indications. It is a harmless test though, without any risk, just costs money. Even without the echo, using simple at home or in the gym measurements you can do a good job of evaluating your cardiovascular fitness using these simple formulas.

Peak Exercise

Peak exercise is the highest level of work effort the person is capable of accomplishing while exercising on the treadmill.

METS

Metabolic Equivalents: is a measure of work expenditure during exercise that can be used to compare the work done by various forms of exercise or physical exertion. On the treadmill, an increase of 1 MPH in the speed or 2.5% in the grade elevation is equal to a 1 MET increase in work effort. The MET is a multiple of a person’s resting metabolic rate estimated from the treadmill grade and speed obtained at peak exercise. For every 1 MET increase in exercise work achieved during the treadmill test, the risk for cardiovascular disease is reduced by 12%. The risk of having cardiovascular disease is very low for persons who can reach the 13 MET level during the treadmill test. Excellent exercise capacity is defined as the ability to maintain exercise at above 13 METs for a sustained period of at least 10 minutes.

VO₂ Max

**VO₂ Max** is the abbreviation for the maximum O₂ consumption: the VO₂ Max is a measure of the O₂ consumption by the body at Peak Exercise.

\[ \text{VO₂ Max} = \text{MET} \times 3.5 \text{ml/min} \]

Where: METs are Metabolic Equivalents

Interpretation: Training and Fitness is associated with a higher O₂ consumption

Explanation: At rest, bodily oxygen consumption (VO₂) at rest is about 4 mg/kg/min. Most of the oxygen consumed by the body is used by the skeletal muscle and heart. In the unfit, exercise results in to 10x increase in O₂
consumption and in the fit O$_2$ consumption can increase up to 20x the resting value.

**Ventilatory Equivalent = VE**

VE is a measure of the efficiency of O$_2$ extraction during exercise.

\[
RR \div VO_2
\]

Where:
- RR = the respiratory rate
- VO$_2$ = the VO$_2$ Max

Interpretation: A lower value indicates enhanced O$_2$ extraction from arterial blood by fit muscles.

\[
\text{Change in VE} = \Delta VE
\]

\[
\Delta VE = (RRa - RRb) \div (VO_2 a - VO_2 b) \times -1
\]

Where:
- RRa = the respiratory rate at baseline
- RRb = the respiratory rate after training
- VO$_2$ a = the VO$_2$ Max at baseline
- VO$_2$ b = the VO$_2$ Max after training

Interpretation: The change in VE is a simply the VE before minus the VE after training. It is a simple way to calculate the affect of fitness on the efficiency of the CV system. The difference in the VE between the baseline measurement and the follow-up value is due to the training effect on muscle and cardiovascular microanatomy and physiology.

Explanation: In response to training, muscle cells increase the number and vigor of their mitochondria. These organelles are the energy factories for all cells. They metabolize glucose and fats into ATP, the body’s primary fuel. When ATP is combined with oxygen, energy is released. As training increases the concentration (number) and capacity (individual effectiveness) of the mitochondria, they are able to make more fuel (ATP) from a given blood flow. As the availability of ATP increases, more oxygen is consumed from each milliliter of blood passing by the muscle cell. The increase in efficiency of energy production means that for any level of exercise (work) performed by the fit, the respiratory rate (RR) is lower than for the less fit at the same level of exercise.

**O$_2$ Pulse**

The O$_2$ pulse is the relationship between the consumption of oxygen during exercise and the heart rate.

\[
O_2 \text{ Pulse} = VO_2 \div HR
\]

Where:
VO₂ = VO₂ Max
HR = highest pulse rate at max exercise achieved

Interpretation: Training leading to Fitness is associated with a higher O₂ Pulse. Explanation: The fit are able to extract more O₂ from the blood than and the unfit so their VO₂ is higher. The fit are able to perform more exercise (work) at a lower heart rate (HR) than the unfit. So an increase in VO₂ or a decrease in heart rate both result at any level of VO₂ are signs of improved fitness and lead to a higher O₂ Pulse.

Resting Heart Rate = RHR

In a person not on any medications that affects heart rate RHR is a simple bedside tool I find very useful for grossly estimating a patient’s cardiovascular fitness. To be accurate the RHR needs to be obtained when the subject is truly at rest and not emotionally excited or upset.

RHR > 80 BPM poor cardiovascular fitness
RHR > 70 < 80 fair cardiovascular fitness
RHR > 60 < 70 good cardiovascular fitness
RHR < 60 excellent cardiovascular fitness

Interpretation: Those with high RHR have low VO₂ and those with the lowest RHR have the corresponding highest VO₂. Why because their cardiovascular system is so efficient at delivering oxygen to the tissues, meaning the muscles and the brain and the mitochondria within the muscle is very efficient at turning that oxygen into fuel. The opposite is true for those with high RHR.

Stroke Volume = SV

SV ≈ 70 ml at rest in a healthy 70 kg adult male
SV ≈ 55 ml at rest in a health 54 kg adult female

In cardiovascular physiology, stroke volume (SV) is the volume of blood pumped from the left ventricle per beat. Stroke volume is calculated using measurements of ventricle volumes from an echocardiogram and subtracting the volume of the blood in the ventricle at the end one contraction called end-systolic volume the from the volume of blood just prior to the next contraction when the heart has filled with blood called the end-diastolic volume. The term stroke volume can apply to each of the two ventricles of the heart, although it usually refers to the left ventricle. The stroke volumes for each ventricle are generally equal, both being approximately 70 mL in a healthy 70-kg man. Since we don’t have an echocardiogram and SV is fairly uniform I suggest using this estimate. For women use a value of 55 ml to account for their smaller heart chamber size (≈23% smaller).
Cardiac Output = Q
Cardiac Output is abbreviated “Q” and defined as the volume of blood pumped from the heart in one minute. At any level of exercise, Q is the product of the heart rate (HR) x the stroke volume. Stroke volume (SV) is the quantity of blood ejected into the aorta by the heart with each contraction. In the healthy trained or untrained heart at rest, Q is about 5 liters per minute. During maximal exercise in the healthy but unfit, Q can increase 5 times to 25 liters/min. In the fit, Q can increase to 40 liters/min. The QMax is the highest Q measured at peak exercise.

\[ Q = HR \times SV \]

Where:
\[ HR = \text{heart rate} \]
\[ SV = \text{stroke volume} \]

### Echocardiogram Data on a Fit 70 kg Adult Male

<table>
<thead>
<tr>
<th>Measure</th>
<th>Left ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-systolic volume</td>
<td>52 mL</td>
</tr>
<tr>
<td>End-systolic volume / body surface area (mL/m²)</td>
<td>29 mL/m²</td>
</tr>
<tr>
<td>End-diastolic volume</td>
<td>153 mL</td>
</tr>
<tr>
<td>End-diastolic volume / body surface area (mL/m²)</td>
<td>83 mL/m²</td>
</tr>
<tr>
<td>Stroke volume</td>
<td>101 mL</td>
</tr>
<tr>
<td>Stroke volume / body surface area (mL/m²)</td>
<td>55 mL/m²</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>66%</td>
</tr>
<tr>
<td>Heart rate</td>
<td>60–100 bpm</td>
</tr>
<tr>
<td>Cardiac output</td>
<td>6.0–10.0 L/minute</td>
</tr>
</tbody>
</table>

The example in the table shows values measured by echocardiogram on a 70-kg man with good cardiovascular fitness whose resting pulse rate is 60 bpm. At the end each heart contraction at rest, his end-systolic volume was imaged with the echocardiogram. This device is able to measure the heart chambers in real-time using sonar-like sound wave technology. His chamber volume averaged over several heart cycles was 52 ml. The same image is taken when the left ventricle finishes filling with blood returning from being oxygenated from the lungs. This is known as the end-diastolic volume and in him was 153 ml. The measured stroke volume SV can be simply calculated from subtracting these two values 153 ml – 52 ml = 101 ml. This means under these conditions at rest with each heartbeat he ejects 101 ml of blood from his heart into his circulation.

The ejection fraction EF can be calculated by dividing the quantity of blood ejected by the heart with each beat by the amount of blood that had filled the heart just prior to the contraction beginning. This is calculated by dividing the stroke volume by the end-diastolic volume or 101 ml ÷ 153 ml = 66%. At rest his heart rate was 60 bpm and during the treadmill test his heart rate increased to 100 bpm. We can use his heart rate HR and stroke volume SV to calculate his cardiac output CO at rest and during exercise using the equation HR x SV =
CO. At rest CO = 60 bpm x 101 ml = 6.06 L/min. With exercise CO = 100 bpm x 101 ml = 10.1 L/min. Prolonged aerobic exercise training over time results in better delivery and extraction of oxygen from the blood and a preference for metabolizing triglycerides rather than glucose. These are the two factors are responsible for the training effect observed in those who have achieved various degrees of cardiovascular fitness. The result is an increase in stroke volume that is due to a slower heart rate that prolongs ventricular filling during diastole. The enlarged end-diastolic volume results in an increased ejection fraction, which raises the cardiac output.

While these changes in performance are exponential enhancements with regard to optimal health and wellness, we need not travel to these airy heights to achieve our goals. OH&W is achieved at the “good” RHR for instance between 60 bpm 70 bpm. No need to get into the 50s. Frankly few rarely attain what the human body, spirit, mind, and hearts are capable of. From the Integral Medicine point of view our purpose is to develop ourselves in all these ways taking a balanced approach. Spending too much time and effort within one of our four quadrants such as the physical domain risks becoming “pointy headed” as my dear mother in law said about people who were stuck in on one thing to the exclusion of all else.

Rate Pressure Product = RPP
The rate pressure product is abbreviated RPP and defined as the product of the highest systolic blood pressure and the highest heart rate obtained during the treadmill test.

\[ RPP = HR_{\text{max}} \times SBP \]

Where:
- \(HR_{\text{max}}\) = the maximum heart rate recorded during a treadmill test.
- \(SBP\) = the highest systolic blood pressure recorded during treadmill test.

**Maximum Heart Rate = HR_{\text{max}}**
The measured HR_{\text{max}} is the highest HR measured during peak exercise.

**Estimated HR_{\text{max}} = 220 – age**

Interpretation: Like RPP, the heart rate is an indirect measure of the Cardiac Output (Q). While Cardiac Output (Q) is a function of stroke volume x heart rate the higher the HR the higher the Q. This fact coupled with the fact that SV changes little with training or with exercise means that we can get a good estimate of Q from the HR alone. A lower HR_{\text{max}} recorded at maximal exercise is characteristic of improved fitness.
Explanation: a slightly increased stroke volume and an improved efficiency of extraction of O₂ by the exercising muscle characterize a fit cardiovascular system. These features of fitness explain how a slower heart rate can support a higher work effort by the CV system.

**Training Heart Rate Zone = The Zone**
This is the heart rate of about 70% to 85% of your maximum heart rate.

The Zone = HRmax x 70% to HRmax x 85%
Where:
HRmax = the highest HR measured during peak exercise

One goal of fitness training is to raise your resting heart rate to your target heart rate zone for at least 20 minutes 4 days each week. This is best accomplished by participating in an aerobic exercise like brisk walking, using the elliptical trainer, or a bicycle. Consistently reaching this goal on a regular basis leads to improved fitness of the cardiovascular system and musculature. Getting into The Zone is the best way to develop cardiovascular fitness and once it is obtained, is the best way to keep it.

**Maximum Blood Pressure = MBPmax**
The MBPmax is defined as the highest blood pressure reached during exercise.
We are centrally located in North Atlanta in the Brookhaven community near the intersection of Dresden Dr. and Peachtree Rd. and the Brookhaven Marta Station. Our office is on the second floor of the multi-use Village Place building that has retail and restaurants on the first level, business and medical condos on the second level and residential condos on the third.

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**Brookhaven Marta Station**  
Located in Brookhaven At Village Place  

We are on the north side of Dresden Dr. Our address is 1418 Dresden Dr, Suite 225, Atlanta Georgia, 30319. The restaurant Kaleidoscope is at the west end of the building and Verde is at the east end. See the map below or for additional information call 404-574-2373.