# **Cardiorespiratory Fitness**

Objectives:

* Define the cardiovascular and respiratory system
* Describe how the cardiorespiratory system works
* Identify the benefits of cardiorespiratory fitness
* What is the importance of this system?
* Identify methods for assessing and improving the CR system

## What is the cardiovascular and respiratory system?

Imagine for a moment climbing to the top of Mt. Everest, a challenging feat very few have accomplished. In the process, you gradually ascend from base camp, which sits at about 17,500 feet above sea level, to the peak at over 29,000 feet. At this elevation, the pressure of oxygen is so low, you struggle to take in a satisfying breath. Although you strive to breathe deeply, you are unable to get enough air. Your heart rate increases and you might even develop nausea and a headache. Unless your body has a chance to acclimate itself to higher elevations or you gain access to supplemental oxygen, your symptoms will persist or worsen.

These are the sensations many people with cardiovascular or respiratory illnesses, such as asthma, chronic bronchitis, or mild cardiovascular disease, experience on a daily basis. Climbing up a flight of steps may leave them gasping for air, as would walking briskly or even breathing in cold air. Regardless of the cause, being unable to take in sufficient air can create a sense of panic and cause serious physical discomfort.

From this simple example, hopefully, you feel an appreciation for the simple act of breathing and ensuing satisfaction that comes with each life-sustaining breath. For most people, unless they engage in strenuous physical activity sufficient to get them breathing hard, their **cardiovascular and respiratory system** (heart, blood vessels, and lungs) operates efficiently enough to go relatively unnoticed. However, does that mean their cardiorespiratory (CR) system is functioning at optimal capacity? Or, could it be operating at a minimum level and experiencing problems that go undetected? This chapter defines cardiorespiratory fitness, examines the benefits of a healthy CR system, and explores how to effectively assess and improve the CR system.

## The Benefits of Good Cardiorespiratory Health

The link below provides a list of specific benefits:

* [List of Benefits](http://www.livestrong.com/article/522212-a-list-of-the-benefits-of-cardiovascular-endurance/)

The article linked below describes how exercise protects against Cardiovascular Disease (CVD):

* [Preventing CVD](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2805367/)

## How the CR System Works

The cardiorespiratory system operates to obtain and circulate vital compounds throughout the body—specifically, oxygen and nutrients, such as food energy, vitamins, and minerals. Both oxygen and nutrients, which are imperative for cellular energy production, must be taken in from the lungs and digestive system. Because the heart and lungs are so interlocked in this process, the two systems are often labeled together as the cardiorespiratory system. Without a healthy respiratory system, the body would struggle to bring in enough oxygen, release carbon dioxide (the chemical waste product of cellular metabolism) and eliminate unwanted particles that enter the respiratory tract when inhaling. Without a healthy heart, transporting oxygen from the lungs and nutrients from the digestive system to the body’s cells would be impossible. If the health of the CR system were compromised enough, survival would be impossible. Additionally, both must be healthy or the function of one or the other will be compromised.

Below are several videos explaining how the cardiovascular and respiratory systems operate and function together:

* [The CR System and Exercise](https://www.youtube.com/watch?v=wzryR4PKGpk&feature=youtu.be)
* [How the Cardiovascular System Works](https://www.youtube.com/watch?v=_qmNCJxpsr0&feature=youtu.be)
* [Respiratory System Explained in Detail](https://www.youtube.com/watch?v=YJNoQdpFwnU&feature=youtu.be)

## The CR System and Energy Production

Clearly the cardiovascular and respiratory systems function as one, but why is the CR system so important? What makes the distribution of oxygen throughout the body so vital to existence? The answer is simple: ENERGY. While oxygen in and of itself does not contain any energy (**calories**), it does combine with fuel extracted from food once it has been introduced into the cell to help produce **adenosine triphosphate** (ATP). ATP is the basic form of cellular energy found in the body. Because the body stores very little ATP, it must constantly be regenerated. For this reason, people must continue eating and breathing to live.

Within the context of fitness, the purpose of the cardiorespiratory system is not only to produce energy but to also adapt in a way so that energy production can be optimized. For example, a high school cross country runner wants to be fit enough to compete in the state cross country meet. Unfortunately, this athlete’s current mile times are 6 minutes per mile. In other words, that is the maximum work rate possible for this athlete. However, the goal is to improve to 5 minutes per mile, or improve the maximum work rate. To do so, more energy must be produced. According to the principles of adaptation, it is possible for this athlete to become more efficient at producing energy, enabling him to run a mile in less time. An example of this adaptation comes from the world record mile time of 3 minutes and 43 seconds. The world record marathon time (26.2 miles) is 2 hours, 2 minutes, and 52 seconds. That equates to 4 minutes and 41 seconds per mile over the 26-mile course. That is some serious ATP production!

## Oxidative Energy System (Aerobic)

As oxygen and nutrients are delivered to the cells, they are utilized to produce ATP. The workhorses of the cell for oxidative metabolism are the **mitochondria**. This form of energy production is contingent on the ability of the CR system to deliver oxygen and nutrients and the cell’s ability to process that oxygen. Because of the importance of oxygen in this particular energy-producing pathway, it is called the oxidative energy system, or **aerobic system**.

Oxidative energy production is the primary means of ATP production during rest and for activities that last for 2 minutes or longer. Although other forms of energy production assist in ATP production at any given time, long duration exercise sessions rely on this aerobic pathway. Also, in contrast to other forms of ATP production, the oxidative energy system uses both carbohydrates and fats for fuel sources.

**To consider:** What activities would emphasize development of this energy pathway?

## Immediate/Explosive Energy System

While the oxidative system is the primary source of ATP production, it does require a few minutes for the system to begin operating at full capacity during exercise. How then could the body immediately produce enough energy to perform a strenuous activity, such as sprinting 50 meters? Clearly, another energy system must drive ATP production. The immediate or explosive energy system utilizes the storage of **creatine phosphate** (CP) and the storage of **adenosine diphosphate**, which is stored in very small amounts, to generate ATP. When needed, this energy system provides enough ATP to sustain a short-duration, explosive activity, approximately 10–20 seconds or less. Once CP is depleted, other energy systems must assist in the ATP generating process.

## Non-Oxidative or Anaerobic Energy System

As the name implies, the **non-oxidative energy system** does not require oxygen to generate ATP. Instead, the cells where the ATP is produced require **glucose** (carbohydrates that have been broken down) as the fuel source. Like the immediate energy system, this system is associated with high intensity and short duration movements. While it is possible for some elite athletes to maintain exercise at “anaerobic” levels for several minutes, even they will eventually fatigue as a result of the non-oxidative system’s ability to sustain ATP production for events lasting longer than approximately 2 minutes.

As glucose is processed to produce ATP, the natural byproduct of this process, lactic acid, also begins to accumulate. The result of excessive lactic acid accumulation contributes to muscle fatigue, making it impossible to continue exercise at a high intensity.

## Energy Systems Combine

It is important to understand that energy systems do not operate in a compartmental fashion, but rather operate simultaneously, each carrying some of the burden of ATP production. For example, a professional soccer player would spend most of the match “cruising” at a light/moderate intensity level, thus primarily utilizing the oxidative energy system. However, during the match, he or she may sprint for several hundred meters, utilizing the explosive and non-oxidative system, or he or she may jump, requiring use of the explosive system. Thus, both energy systems are utilized simultaneously throughout the match. To improve performance, this player would need to develop the energy system which is utilized the most during the match.

## Changes in the CR System

An improvement in CR functioning, or fitness level, requires adaptation of the system. Remember, the point is to more effectively generate ATP so more work can be accomplished. In order to process more oxygen and deliver more oxygenated blood to the cells, the overall system must undergo changes to make this possible. Here is a list of adaptations that occur to the CR system as a result of consistent aerobic exercise:

* Resting heart rate may decrease. The average resting heart rate hovers around 70–75 beats per minute. Elite athletes may have resting heart rates in the high 30s. Generally, resting heart rate may decrease by approximately 10 beats per minute with chronic exercise.
* Pulmonary adaptations, such as increased **tidal volume** (the amount of oxygen entering the lungs with each breath) and increased **diffusion capacity** (the amount of oxygen that enters the blood stream from the lungs). This allows for more oxygen to enter the pulmonary circulation en route to the left side of the heart.
* The heart muscles, specifically the left side of the heart, increase in size making it possible to contract more forcefully. As a result, more blood can be pumped with each beat meaning more oxygen can be routed to the systemic circulation.
* More oxygen is delivered and transported into the cells where ATP production can occur. This is called the **arterial-vein difference** (a-VO2diff)

These changes in the system are not permanent because of a process known as the **principle of reversibility**. Following a period of inactivity, the benefits from chronic aerobic exercise will be reversed.

## Assessing CR Fitness

To adequately prepare for starting a personal fitness program, it is important to first assess your current level of fitness. There are multiple methods for assessing a person’s level of fitness. Each of the walking/jogging assessments discussed here attempts to estimate a key physiological marker of the heart’s and lungs’ functioning capacity and maximal oxygen consumption. M**aximal oxygen consumption**, or VO2 max, measures the body’s maximum ability to take in and utilize oxygen, which directly correlates to overall health and fitness. A good estimate of VO2 max provides a one-time glance at a person’s health and fitness level and a baseline measurement for reassessment at future dates to gauge improvements.

Some of the most common walking/jogging assessments used to estimate VO2 max include the 12-Minute Walk, 1.5-Mile Run/Walk Test, 3-Minute Step Test, and 1-Mile Walk Test. Unfortunately, these field assessments, although practical and inexpensive, only provide estimations. More accurate assessments require a lab-based VO2max test using equipment that measures the volume of oxygen and carbon dioxide being moved in and out of the air passages during exercise. Although this test is more accurate, the expense and availability make it impractical for most. Unlike the lab test, the field assessments are relatively cost free, user-friendly and require very little expertise to conduct or perform. In addition, the key point of the assessment is measuring differences rather than absolute values, and the field tests accurately meet that objective.

Information on how to safely perform these assessments will be provided at the end of this chapter.

## Measuring Heart Rate

Those starting the VO2max assessments must first measure their heart rate, an important component used in the calculations.

Here is a video describing how to determine heart rate:

* [How to check your pulse](https://youtu.be/W5K_HR6hxMY)

## Creating a Plan to Develop CR Fitness

Once the assessments have been completed, the next step is to develop a plan for maintaining or improving your current level of fitness. This fitness plan should include activities that are safe and adapted to meet your personal goals. Once these fitness goals have been identified, the principles of adaptation to change can be utilized to achieve those goals. These principles include **specificity**, targeting specific areas in a workout, and **overload,** the practice of increasing exertion as the body adapts to ensure continued gains in fitness levels. Specifically, you need to apply the FITT principle (**F**itness, **I**ntensity, **T**ime, and **T**ype) described in detail in the previous chapter, “Fitness Principles”:

* **Frequency**: 3–5 days per week for healthy adults.
* **Intensity**: moderate to vigorous intensity, which equals 40–85% of heart rate reserve, or 55–90% of percentage of max heart rate. (More information about intensity will be provided later.)
* **Time/duration**: 20­­–60 minutes per session or accumulation of 150 minutes per week. Sessions must be continuous for 10 minutes or more.
* **Type/mode**: Use large muscle groups and exercises specific to cardiorespiratory exercise.

Click on the link below for ACSM’s latest recommendations on the quantity and quality of exercise for adults:

* [ACSM's Official News Release](http://www.acsm.org/about-acsm/media-room/news-releases/2011/08/01/acsm-issues-new-recommendations-on-quantity-and-quality-of-exercise)

## Measuring Intensity

Intensity may be the most important aspect of the FITT principle. Engaging in a “cardio” program that does not stress the CR system to the recommended levels will be ineffective. Engaging in a program that overstresses the system can lead to injury and pose unnecessary risks. So how do you know if you are in the right range?

Heart rate is one of the best ways to measure effort level. Walking and jogging increase a person’s heart rate. Based on the function of the heart, this is no surprise. The heart rate directly correlates with the amount of oxygen being taken in by the lungs. As activity increases in intensity, oxygen demands increase and so does heart rate.

Because of this relationship, heart rate can be used in the design of an effective walking and jogging program by creating target heart rate zones. Heart rate zones represent an intensity range—a low end heart rate and a high end rate—within which a person’s heart rate would fall during a walking or jogging session.

The first step in determining your **target heart rate (THR)**, is to determine your **maximum heart rate (MHR),** bothmeasured in beats per minute (bpm). Generally, MHR is estimated to be your age subtracted from 220 beats per minute. In other words, your heart rate should theoretically stop increasing once it reaches the calculated maximum. While helpful, it is not uncommon to see variances in the laboratory tested maximum heart rate versus the calculated method.

The next step in calculating THR is to calculate a specific percentage of your MHR. This is done using two different methods. Keep in mind, finding the THR is the objective in both methods, even though slightly different numbers are used.

The first method, called Max Heart Rate Method, is more commonly used.

### Max Heart Rate Method

1. Calculate MHR;

MHR = 220 – age.

1. Calculate high and low THR by plugging in a percentage range. In this example, 60% and 80% are being used.

MHR x .60 = THRLow

MHR x .80 =THRHigh

1. The resulting low and high THR numbers represent the range, or target intensity.

The target intensity signifies an optimal training zone for that particular walking or jogging session. By keeping the heart rate within that range, you will drive adaptation specific to that intensity. By using real, but random numbers, and plugging them into the above equation this becomes apparent.

Female, aged 20:

1. MHR = 220 -20

MHR = 200 bpm;

1. THRlow = 200 x .60

THRlow = 120 bpm

THRhigh =200 x .80

THRhigh = 160 bpm

1. THR = 120 - 160 bpm

To achieve her self-established goals, the female in the example above will need to stay within the range of 120 and 160 bpm. If her efforts are intense enough that she begins to exceed 160 bpm during her session, or easy enough that her heart rate falls below 120 bpm, she would need to change her intensity mid-session to get the optimal results.

### The Karvonen Formula or Heart Rate Reserve Method

1. Calculate MHR; MHR = 220 – age.
2. Determine your **resting heart rate (RHR)**.
3. Find the **heart rate reserve (HRR)**; HRR = MHR – RHR
4. Calculate high and low THR by plugging in a percentage range and then adding in the RHR. In this example, 60% and 80% are being used.

THRlow = HRR x .60 + RHR

THRhigh = HRR x .80 + RHR

1. The resulting low and high THR numbers represent the range, or target intensity.

Clearly, the Karvonen formula requires a few more steps, specifically, the incorporation of the resting heart rate. Using the same female in the example above, along with a randomly selected RHR, the THR looks like this:

1. MHR = 220 – 20

MHR = 200

1. RHR = 72 bpm (randomly selected)
2. HRR = MHR – RHR

HRR = 200 – 72

HRR = 128

1. THRlow = HRR x .60 + RHR

THRlow = 128 x .60 + 72

THRlow = 149 bpm

THRhigh = HRR x .80 + RHR

THRhigh = 128 x .80 + 72

THRhigh = 174 bpm

1. THR = 149 – 174 bpm

A comparison of the two methods, reveals that the low and high end of the Karvonen formula is much higher than the Max Heart Rate method, even though the exact same percentages have been used. If the female in this example used the Karvonen Formula, she would find herself at a much higher intensity, especially at the low end of the range (120 vs. 149 bpm). How can this be? Aren’t these formulas supposed to have the same objective?

While it is true that both equations are used to estimate a target heart rate range, only the Karvonen Formula takes into account the RHR, the lowest possible heart rate that can be measured for that individual. The Max Heart Rate method assumes the lowest heart rate possible is “0,” a number to be avoided if at all possible! Because of the difference between 0 and the maximum heart rate, the calculated percentages result in a much lower number. In terms of accuracy, the Karvonen method is superior. It simply is a better representation of true target ranges.

### Other Ways to Determine Intensity

Since not everyone owns a heart rate monitor, other methods of determining exercise intensity have been developed. One particular method, called the **rating of perceived exertion (RPE)**, uses subjective measurement to determine intensity. The method is as simple as asking the question, Overall, how hard do I feel I am working? The answer is given based on a scale of 6 to 20 with 6 being almost no effort and 20 being maximum effort. Studies have indicated that when subjects are asked to exercise at a moderate or heavy intensity level, subjects can accurately do so, even without seeing their heart rate. As a result, using the RPE scale can be an effective way of managing intensity.

The original RPE scale or **Borg Scale**, designed by Dr. Gunnar Borg, was developed to mimic generalized heart rate patterns. The starting and ending point of the scale are less intuitive than a typical scale of 1-10. By design, the 6 represents a resting heart rate of 60 bpm and the 20 an exercise heart rate of 200 bpm, a beat count someone might experience at maximum effort. Over time, a modified Borg Scale was developed using a simple 1–10 scale, with 1 being resting effort and 10 being maximum effort. Even though the modified scale is more intuitive, the traditional scale is still used more frequently.

Walking and jogging not only benefit physical health, but many enjoy the social benefits realized by exercising with friends. When walking or jogging with friends, intensity can easily be measured by monitoring your ability to carry on a conversation. With the **Talk Test**, if you are only able to say short phrases or give one word responses when attempting to converse during an exercise session, this would suggest you are working at a high enough intensity that your breathing rate makes conversation difficult. Certainly, if you can speak in full sentences without getting winded, the intensity would be very light. Just like RPE, the Talk Test is yet another way to subjectively measure intensity, which can then be correlated with heart rates.

**Terminology Checklist**

**Cardiorespiratory system:** The term used to describe the relationship between the cardiovascular system (heart and blood vessels) and respiratory system (lungs).

**Calorie:** A term used to describe food energy. Scientifically, it is the amount of energy needed to raise one kilogram of water, 1 degree Celsius. More accurately, it is one kilocalorie.

**Adenosine Triphosphate (ATP):** The basic unit of energy used by the cells.

**Aerobic energy system:** The term used to describe the way cells produce ATP. In this case, the cells require oxygen to assist in ATP production.

**Mitochondria:** The area (organelle) of the cell where ATP is produced.

**Creatine phosphate:** a compound found in the cells and used by the immediate energy system that can be used to produce ATP.

**Non-oxidative energy system:** a term used to describe the way cells produce ATP. In this case, cells do not require oxygen to produce ATP.

**Glucose:** The simplest form of sugars found in the blood.

**Tidal volume:** The amount of air measured during inspiration or expiration.

**Diffusion capacity:** The amount of air that is transferred from the lungs to the blood.

**Areterial-vein difference (aVO2diff):** The difference between the oxygen found in arterial blood and venous blood.

**Principle of Reversibility:** The fitness principle describing how fitness is lost while detraining.

**Maximal oxygen consumption (VO2max):** The maximum amount of oxygen the body can take in and utilize.

**Specificity:** A fitness principle describing how fitness improvements or adaptations to exercise stress are specific to the type of training that is performed.

**Overload:** The fitness principle describing how adaption to exercise stress is driven by progressively increasing the workload during training.

**Target Heart Rate (THR):** A term describing heart rate zones that represent an intensity range—a low end heart rate and a high end rate—used as a guide for exercise intensity.

**Max heart rate (MHR):** The maximum number of beats per minute the heart can contract.

**Resting Heart Rate (RHR):** The minimum number of beats per minute the heart contracts.

**Heart Rate Reserve (HRR):** The difference between the maximum heart rate and the resting heart rate. This term is also used to describe a method for calculating target heart rate.

**Rating of Perceived Exertion (RPE):** A self-assessment used during exercise used to estimate the intensity of the work being performed. The scale used, called the Borg Scale, ranges from 6 to 20.

**Talk-test:** A self-assessment used during exercise to estimate the intensity of the work being performed. The assessment is based on the degree of breathlessness observed while attempting to talk during exercise.

Test Your Knowledge

1. Which of the following is one of the primary functions of the cardiorespiratory system?
   1. To transport oxygen
   2. To pick up waste products
   3. To transport nutrients
   4. All of the above are functions of the cardiorespiratory system.
2. Cardiorespiratory endurance is developed best by activities that:
   1. Involve continuous rhythmic movements of large muscle groups.
   2. Alternate between brief periods of maximal exertion and rest.
   3. Gently extend joints beyond their normal range of motion.
   4. Involve working with weights or resistance.
3. Maximal oxygen consumption (VO2max) is:
   1. The body’s maximum ability to take in and utilize oxygen
   2. The velocity of oxygen flowing through the blood
   3. Solely determined by genetics
   4. Very difficult to predict
4. The non-oxidative energy system could provide energy for up to:
   1. Maximum of 10 second or less
   2. Up to 2 minutes
   3. As long as needed
   4. Up to 5 minutes
5. Adenosine triphosphate (ATP) is defined as:
   1. The building block of proteins
   2. The stored form of sugar
   3. The simplest form of carbohydrate in the blood
   4. The basic form of energy used by the cells.

Answer key: 1:D 2: A 3: A 4: B 5: D