***Chapter 3***

*Principles of Stress and Adaptations to Exercise*

*by Scott Flynn*

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eveloping aerobic fitness can be an exciting and invigorating task. If not done properly, however, it can also become very discouraging as your perceived results seemingly don’t justify the effort. To really understand if your training plan is working or not, you need to understand what to look for in terms of changes. In other words, you should be able to answer the simple question: How will my body change if I consistently perform a walking/jogging routine?

When referring to change, exercise scientists generally use the term “adaptation.” The human body has an amazing capacity to physically adapt when exposed to challenging or stressful activities such as exercise. **Adaptation to stress** can occur as short or long-term changes (acute or chronic adaptation, respectively). Most importantly, fitness is the result of chronic adaptations. In this chapter, we will discuss the physical changes that occur as a result of exposure to exercise, specifically walking and jogging, and how to use that knowledge to your advantage when creating a personal fitness plan.

**Acute Adaptation**

At rest, the human body functions at a minimal level to maintain the necessary functions required to sustain life. When you are exposed to a stressful situation, such as walking at a brisk pace or jogging, your body must respond to meet the increased demands of the activity. Your heart must speed up to circulate more oxygen-rich blood, your lungs must work harder to bring in more oxygen and get rid of carbon dioxide, the endocrine system must release additional hormones and much more. This is easily detected by the sensation of increased heart rate, faster breathing and maybe even sweating. These physiological changes, in response to exercise, illustrate the concept of acute, or brief, adaptations.

A brief summary of specific acute adaptations as a result of walking and jogging are:

* Increased heart rate
* Increased breathing rate and depth of breathing
* Release of norepinephrine (noradrenaline), epinephrine (adrenaline), cortisol, endorphins, and inhibition of insulin.
* Body temperature increase followed with temperature regulation.
* Blood pressure increase
* Increase in cellular metabolism
* Increase in nervous system and skeletal muscle activity

From the short list above, it’s evident that walking and jogging requires significant physiological changes, when compared to the resting state of the body, to manage the energy requirements of an activity. For many, especially those unfamiliar with exercise, this experience can be quite uncomfortable at the onset of an exercise session and in the early stages of an exercise program. The resulting fatigue and occasional soreness can last for hours to days.

However, it is important to understand that this response is normal. While the acute adaptations occur during every exercise session, your body will adapt over time, altering the degree of these acute effects. For example, for individuals who haven’t participated in vigorous exercise for several months but begin a new routine, they may experience significant soreness after the first few exercise sessions. But, beyond the first few sessions the body will adapt. So long as they remain consistent in their efforts, they will likely not have to deal with soreness again. These adaptations, labeled **chronic adaptation**, don’t simply go away when the exercise session ends. They are long-term changes, though not permanent.

**Chronic Adaptations**

Before digging into specific adaptions, it is important to understand the physical demands of exercise. By understanding what needs to change, it will be easier to understand what actual changes occur and how to change those areas when you create a training routine.

First, let’s take a look at the working parts of the body specific to walking and jogging. The **cardiorespiratory system** consists primarily of the heart and lungs. The purpose of the heart is to pump nutrients and oxygen rich blood to the body’s cells and deliver waste product, such as carbon dioxide (CO2), to the lungs. The lungs work in tandem with the heart to bring oxygen into the blood so it can then be pumped by the heart, and to get rid of waste such as CO2 by exhaling into the external environment.

Of course, the arteries, veins, and capillaries along with the heart, are collectively part of the cardiovascular system. They serve as the highways for delivering blood to the body’s cells. As another important part of this puzzle, the muscle cells serve as the endpoint for the oxygen and nutrients in the blood. They also produce waste products as a result of cellular metabolism which then enters the blood circulation (see figure 3.2).

At this point, a series of questions must be answered to make this discussion relevant.

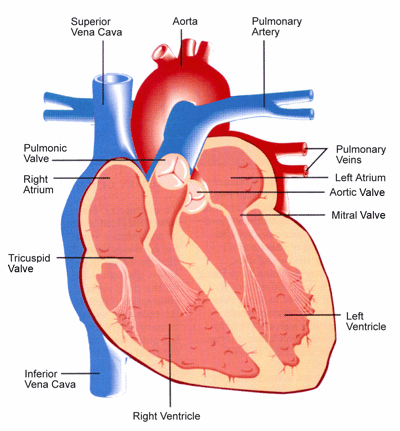
* What is accomplished by the cardio-respiratory system?
* Why do the cells need the oxygen and nutrients delivered in the blood?

The answer to both questions is simple: energy.

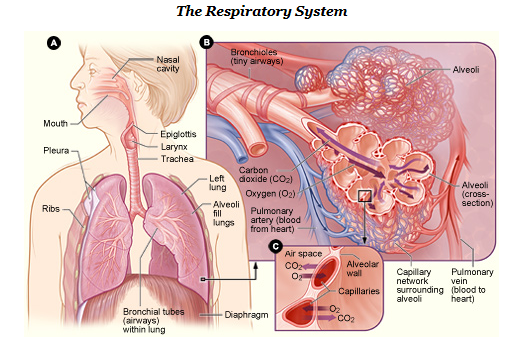
The cardiorespiratory system must work effectively in order to create an environment in the cell in which energy can be produced. Energy, in its basic form of **adenosine triphosphate (ATP)**, is created in the cells and must be available for the body to function. In other words, when you begin walking or jogging, you must increase the production of energy, or ATP, to meet the demands of the activity. Every activity, from rest to jogging a marathon, requires a certain amount of energy. In order to improve your fitness, you must increase your capacity to generate more energy, i.e. adapt. This, of course, is driven by the chronic adaptations which come as a result of consistent training not a result of one singular exercise bout.

As stated previously, in order to produce more energy, you must become more fit. For example, if you would like to increase your mile jogging time from 10 minutes to 9 minutes, you will need to alter your body’s capacity to produce energy. Figures 3.1, 3.2 and 3.3 illustrate a simplified version of the working components of the cardio-respiratory system.

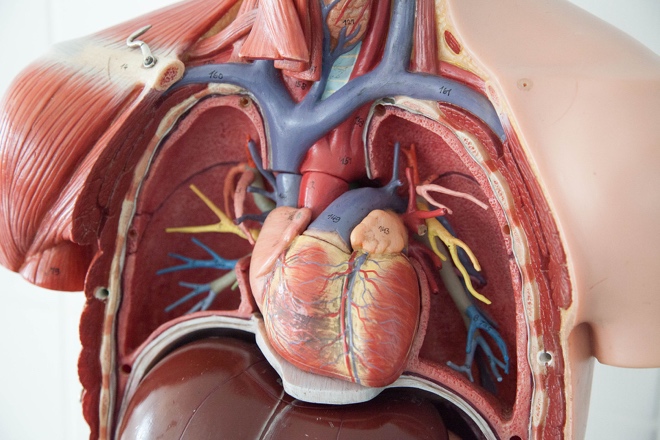
*Figure 3.1*



*Figure 3.2*



*Figure 3.3*



By Hikmet Gümüş - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=28813430

As you look at the illustration, think about how these working components could be altered to enable more ATP production.

**Pulmonary Adaptations**

The lungs function to bring oxygen into the cardiorespiratory system. As you inhale, your lungs (right and left sides) fill with oxygen. As a result, the increased pressure inside your lungs drives oxygen into the poorly oxygenated blood circulating past the lungs. While oxygen moves into the blood, CO2 simultaneously moves out of the blood into the lungs and is removed when you exhale.

In terms of adaptations, oxygen is key. Much like a manufacturer’s supply chain which requires more raw material to produce more product, the lungs must be able to handle more oxygen if more energy is to be produced. Interestingly enough, this is what happens with improved fitness.

As a result of consistent training, two very important adaptations to respiration occur. First, the **pulmonary ventilation** capacity increases. This means the amount of air inhaled increases from about 100-120 L/min to about 130-150 L/min in previously untrained athletes. In large, well trained endurance athletes, this number can exceed 200 L/min!

Secondly, the air inhaled and its ability to diffuse from the lungs to the bloodstream also changes (called **pulmonary diffusion**). Although your lungs may fill up with oxygen after a good breath, the total amount of oxygen in your lungs does not go into the blood stream. There is a “residual” amount left over which may linger in the lungs or be exhaled. However, in trained individuals, a greater percentage of oxygen which initially fills the lungs moves into the blood stream.1

Both of these adaptations are important because they enable more oxygen to move into the blood, which can then be delivered to cells for ATP production.

**Cardiovascular Adaptations**

More oxygen in the arteries would be meaningless unless this oxygen can then be delivered to the cells. The heart serves as a pump, to generate pressure in the arteries so blood can flow efficiently to the areas of the body in need of what is found in the blood.

As a result of training, the heart’s capacity to circulate blood increases. One example of how this might occur can be seen in the size of the heart. Like other muscles of the body, the heart muscle increases with training. Specifically, the left ventricle, one of the four chambers of the heart, increases in mass and thickness, a condition known as **cardiac hypertrophy**. With a larger heart muscle, the heart contracts more forcefully pumping more blood per beat compared to the untrained state.

Another example, which may be related to cardiac hypertrophy, can be seen in the heart’s beating frequency, i.e. the heart rate. It’s not uncommon to see resting heart rate decrease as a result of endurance training. On average, the rate of the heart at rest or **resting heart rate** is around 70-75 beats per minute. While the cause is not entirely known, some estimate declines of 1 beat per minute, per week of training. Highly trained endurance athletes may see their resting heart rate between 30 and 40 beats per minute! Not only does this occur at rest, but also at a given submaximal work load. For example, if an untrained individual were to measure his/her heart rate while jogging at 11 minutes per mile in an initial assessment and found their heart rate to be 150 beats per minute, with 6 weeks of training that same individual might find that at the same pace, the heart rate is now at 144 beats per minute. This means the heart doesn’t have to work as hard to do the same amount of work.

As resting heart rate decreases, the resting time between heart beats is extended. During this resting time is when the four chambers of the heart fill with blood. With more time between beats, more blood can enter the heart’s chambers in preparation for the next beat. In combination with the more forceful contractions, the increased filling time contributes to an increase in **stroke volume**, or the amount of blood being ejected from the heart per beat.

As you can see, both heart rate and stroke volume contribute to the efficiency and capacity of the heart to circulate larger amounts of blood. When combined into a formula, the product of stroke volume and heart rate determine **cardiac output** (often labeled Q)**,** a key indicator of cardiac health and fitness.

*Q=stroke volume* x *heart rate*

At rest, in both trained and untrained individuals, Q remains close to the same at about 5-6 L/min. The decreased resting heart rate essentially cancels out the increased stroke volume. However, during exercise, Q is significantly higher in trained individuals, reaching over 30 L/min as opposed to 20 L/min in untrained individuals. 2

**The Cells**

The endpoint for nutrition and oxygen found in the blood is the cells. Cells need oxygen and fuel to generate ATP. In order to produce more ATP, cells must increase their ability to process oxygen and other nutrients.

The beginning of this, at the level of the cell, is to remove the oxygen from the blood. Just because it’s available in the blood, doesn’t provide additional benefit unless we can extract it and use it. Scientists can measure the amount of oxygen in arteries/veins before and after it is taken in by the cells, a measurement called the **arteriole-venuole difference (a-vO2 diff).** The difference indicates the amount taken up by the cell. Trained individuals have a greater a-vO2 difference than their untrained counterparts, implying cell in trained individuals can remove more oxygen into the cell than those who are untrained.

In addition to the a-vO2 difference, the working components of the cell must adapt to promote increased ATP production. Using the previous analogy of a manufacturing supply chain, once the raw materials arrive to the manufacturing factory, the factory must then be able to process the new materials. So it is with energy production.

The work horse of aerobic metabolism, and ATP production, occurs in the mitochondria of the cell. In response to aerobic training, cells develop more and larger mitochondria. Clearly, this creates a “bigger factory” for ATP production which in turn equals the ability to do more work.

**VO2max**

So far, we have discussed specific adaptations of the heart, lungs and cells. Collectively, these adaptations can be measured by determining the VO2max. If you’ll recall, VO2max, or maximal oxygen consumption, is a measurement of the body’s maximum capacity to take in and utilize oxygen. When thought of in the context of specific adaptations, the heart, lungs and cells all play a significant part in this measurement. A large VO2max would indicate that the lungs are operating at high levels (taking in the O2), the heart is pumping efficiently, and the cells are processing the additional oxygen properly.

So, while measuring lung capacity, stroke volume and a-vO2 difference is important, a better predictor of performance can be seen by measuring the VO2max. Presumably, the greater the VO2max, the better an athlete can perform. Luckily, VO2max is a very adaptable component of aerobic fitness. By some accounts, it can increase by up to 50%, depending on the starting fitness level.

It can also be used as a strong predictor of health when trying to assess cardiorespiratory fitness. The ACSM suggests three important areas can be measured in maximal oxygen consumption measurements: an indication of cardiorespiratory health, an indication of activity levels, and a predictor of all-cause mortality. 3

VO2max is measured most accurately in a laboratory in which the subject exercises until complete exhaustion while using a special mouthpiece attached to a computer to analyze oxygen intake and CO2 output.

Other measurement techniques use prediction equations to estimate VO2max. While less accurate, these prediction equations provide a practical and simple way to assess cardiorespiratory fitness. For the purposes of the general public, the more important measurement is the change between beginning and ending fitness levels which, these models can do accurately enough.

The VO2max measurement can be expressed in multiple ways. Often, it is measured in liters per minute (L/min), indicating an absolute value of how much oxygen has been taken in. Because adult males generally have larger lungs than females, an absolute measurement could be interpreted as males being superior to females in aerobic capacity. However, the measurement more accurately compares men and women when expressed as milliliters per minute per kilogram of body weight (mL/kg/min). When expressed this way, size is incorporated into the measurement giving a much clearer picture of true aerobic capacity. A link of VO2max ratings can be found below.

[VO2max Ratings Explained](https://www.whyiexercise.com/VO2-Max.html)

**Lactate Threshold**

Another area that significantly relates to fitness is the body’s ability to buffer lactic acid build up in the blood. Lactic acid, often incorrectly associated with muscle soreness, results from cellular metabolism. As cells process fuel (carbohydrates) in order to produce ATP, lactic acid is produced and released into the blood stream. At low levels, the body’s natural buffering capacity prevents lactic acid from building up and negatively impacting performance. However, during high intensity endurance exercise, high levels of lactic acid is produced, overwhelming the buffering capacity and fatigue ensues. That tipping point, the point in which the buffering capacity is overwhelmed, is called the **lactate threshold (LT)**.

Considered by most to be the best predictor of performance, the goal in improving fitness is to improve the lactate threshold. For example, a runner may reach his/her LT when jogging a 7:30 min/mi pace, and when the heart rate is at 156 beats per minute. In order to improve fitness, this runner must adapt so that the new LT occurs at 7:00 min/mi pace and 163 beats per minute. In other words, the runner can now buffer more lactic acid delaying fatigue and improving mile time by 30 seconds per mile. Over the course of a marathon, that’s a 13-minute improvement!

This is, in fact, what happens with consistent aerobic training. When charted along with the heart rate, the LT shifts to the right (see figure 3.2) as fitness improves. Well trained athletes may see their LT at 90% or more of their max heart rate! This essentially means an athlete can exercise at near maximum effort without getting fatigued as a result of lactic acid build up.

**Section II**

**Principles of Adaptation to Stress**

For many readers, the actual adaptations that occur as a result of consistent aerobic training are uninteresting and seemingly irrelevant to learning how to create a walking and jogging plan. However, because these adaptations are key markers of fitness, knowing what adaptations occur should help guide you in how to target them in your plan. This section outlines the principles of adaptation to stress, or the “how” part of organizing an exercise plan.

**Overload Principle**

Consider the old saying, “No pain, no gain.” What does this really mean? Is it really saying that exercise must be painful to get anything from it? Absolutely not. If that were the case, it would make exercise a lot less enjoyable. Maybe a better way to relay the same message would be to say improvements are driven by stress. Physical stress, such as walking at a brisk pace or jogging, places increased stress on the regulatory systems that manage increased heart rate and blood pressure, increased energy production, increased breathing, and even sweating for temperature regulation. The subsequent adaptations that occur, make it so that the same stress previously experienced feels less stressful. As a result, more stress must be applied to the system in order to stimulate improvements, a principle known as the **overload principle**.

For example, a beginning weight lifter performs squats with 10 repetitions at 150 lbs. After 2 weeks of lifting this weight, the lifter notices the 150 lbs. feels easier during the lift and afterward there is less fatigue. So, 20 lbs. are added and the lifter continues with the newly established stress of 170 lbs. The lifter will continue to get stronger until he reaches his maximum capacity or the stress stays the same at which point his strength will simply plateau. This same principle can not only be applied to gaining muscular strength, but also flexibility, muscular endurance and cardiorespiratory endurance.

**FITT**

In exercise, the amount of stress placed on the body can be controlled by four variables: Frequency, Intensity, time (duration), and type, better known as FITT.

**Frequency and Time**

Each variable can be used independently or in combination with other variables to impose new stress and stimulate adaptation. Such is the case for frequency and time.

Frequency relates to how often exercises are performed over a period of time. In most cases, the number of walking or jogging sessions would be determined over the course of a week. A beginner may determine that 2-3 exercise sessions a week are sufficient enough to stimulate improvements in VO2max. On the other hand, a seasoned veteran may find that 2-3 days aren’t enough to really stress the system. Per overload principle, as fitness improves so must the stress to continue to improve and avoid plateau. Expert recommendations suggest for optimal health and improvement you should plan to walk or jog “most” days of the week (4-5 days a week).

The duration of exercise, or time, also contributes to the amount of stress experienced during a workout. Certainly, a 30-minute brisk walk is less stressful on the body than a 4-hour marathon. Experts recommend 30-90 minutes per exercise session to adequately stimulate adaptation. In the beginning phases of developing a plan, you should aim for the lower range of the recommendations with the intent to gradually increase the duration of your sessions as your fitness progresses.

Although independent, frequency and time are often combined into the blanket term, volume. The idea is that volume more accurately reflects the amount of stress experienced. For example, when attempting to create a walking and jogging plan, you may organize 2 weeks like this:

* Week 1-three days a week at 30 minutes per session
* Week 2-four days a week at 45 minutes per session

At first glance, this might appear to be a good progression of frequency and time. However, when calculated in terms of volume, you see the aggressive nature of the progression. In week 1, three days at 30 minutes per session equals 90 minutes of total exercise. In week two, this amount was doubled with four days at 45 minutes equaling 180 minutes of total exercise. Doing too much, too soon, will almost certainly lead to burn out, severe fatigue, and injury.

Scientists, such as Hunter Allen, have developed many ways to monitor the proper amount of weekly volume by way of stress calculations. The concept takes in to account the time, the intensity of effort, and the distance and creates a training stress score (TSS). The TSS can then be used to estimate possibility of over stressing the body or fine tuning the amount of stress and rest so optimal fitness can be achieved.

**Type**

Simply put, the type of exercise you perform should reflect your goals. In walking and jogging, the objective of the exercise is to stimulate the cardiorespiratory system. Other activities that accomplish the same objective include swimming, biking, dancing, cross country skiing, aerobic classes, and much more. So, these activities can be used to build lung capacity and improve cellular and heart function.

However, the more specific the exercise the better. While vigorous ball room dancing will certainly help develop the cardiorespiratory system, it will unlikely improve your 10k time. To improve your performance in a 10k, you will need to spend most of your training time jogging, as you would do in the actual 10k. In other words, train the way you want to adapt. This concept, called the **principle of specificity**, should be taken in to consideration when creating a training plan.

In this discussion of type and the principle of specificity, a few additional items should be considered. Stress, as it relates to exercise, is very specific. There are multiple types of stress. The three main stressors are: metabolic stress, force stress, and environmental stress. Keep in mind, the body will adapt based on the type of stress being placed on it.

Metabolic stress results from exercise sessions when the energy systems of the body are taxed. For example, sprinting short distances requires near maximum intensity and requires energy (ATP) to be produced primarily through anaerobic pathways (pathways not requiring oxygen to produce ATP). Anaerobic energy production can only be supported for a very limited time (10 seconds to 2 minutes). However, distance running at steady paces require aerobic energy production, which can last for hours. As a result, the training strategy for the distance runner must be different than the training plan of a sprinter so the energy systems will adequately adapt.

Likewise, force stress accounts for the amount of force required during an activity. In weight lifting, significant force production is required to lift heavy loads. The type of muscles being developed, fast-twitch muscle fibers, must be recruited to support the activity. In walking and jogging, the forces being absorbed come from the body weight combined with forward momentum. Slow twitch fibers which are unable to generate as much force as the fast-twitch fibers, are the type of muscle fibers primarily recruited in this activity. Because the force requirements differ, the training strategies must also vary to develop the right kind of musculature.

Environmental stress, such as exercising in the heat, places a tremendous amount of stress on the thermoregulatory to the heat, sweating increases as does plasma volume, making it much easier to keep the body at normal temperatures during exercise. The only way to adapt is through heat exposure which can take days to weeks to properly adapt.

In summary, being specific in your training, or training the way you want to adapt, is paramount. So, when you create your training plan, base your training on your goals.

**Intensity**

Intensity, the degree or difficulty at which the exercise is carried out, is the most important variable of FITT. More than any of the others, intensity drives adaptation. Because of its importance, it’s imperative to quantify your intensity as opposed to estimating it as hard, easy, etc. Not only will this help you understand your effort level during the exercise session, but it will also help you design your session to accommodate your goals.

How then can intensity be measured? Heart rate is one of the best ways to measure your effort level. As you’ve undoubtedly noticed, when you begin walking and jogging heart rate increases. Based on the function of the heart, this shouldn’t be a 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 to help in the design of your walking and jogging program. This is accomplished by creating heart rate zones. Heart rate zones represent an intensity range, a low-end heart rate and a high end, in which you could carry out your 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’s not uncommon to see variances in the laboratory tested maximum heart rate versus the calculated method (*see Max Heart Rate below*). Other studies have also determined that more accurate prediction equations exist that is consistently more accurate such as 207-.7 x age. 3 However, for the sake of what’s most commonly used, we will use 220-age.

The next step in calculating THR is to calculate a percentage of your max. 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.
2. 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, age 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

As you can see, 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.

As you can see, the Karvonen formula requires a few more steps, specifically, the incorporation of the resting heart rate. Using the same female in the previous example 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

At first glance, you will immediately see 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. Certainly, by using the Karvonen Formula you would find yourself 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 we would like to stay away from 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 should be used whenever possible. It simply is a better representation of true target ranges.

The optimum ranges to achieve the best results range from >40% to <90% of HRR. Once again, the target HR range selected should be established based on individual goals. For example, walking at a low percentage of HRR results in a greater percentage of calories being burned from fat whereas more intense exercise will result in a greater percentage of calories being burned from carbohydrate. This would be helpful if weight loss were the desired goal. A more in depth look at this phenomenon will be discussed in a later chapter.

**Measuring Heart Rate**

While exercising, heart rate can be tricky to measure. At rest, the index and middle finger on your wrist or neck can easily be used for an accurate reading. However, the bouncing from ground impact and the dexterity to hold fingers in place required while exercising make it very challenging to avoid over-counting beats, keep track of counting and time, and convert that into target heart rate. Most people have to stop to accomplish this seemingly simple task. To determine if you were in the proper zone, you would have to stop multiple times throughout the session. Of course, each time you stop, your heart rate will slow making the measurement inaccurate.

Technology over the last 25 years has developed in a way that products can now track heart rate and zones, keep track of the duration of the session, track your pace and distance, determine your stride rate and stride length, and even alert you if you go outside your preset parameters. For some devices, this data is recorded and available for download via software to analyze and scrutinize.

For most of these products, simply called heart rate monitors, the baseline purchase models include a chest strap that serves as a heart rate detection device and wrist watch that serves as a receiver and data collector. While exercising, your heart rate is detected by the chest strap sensors and displayed on the watch monitor or app screen. More sophisticated models may display additional information such as current heart rate zone, pace and distance.

Although generally more expensive, these types of devices prevent you from needing to stop to take your pulse and are able to average your heart rate during the session. As technology has advanced, you may even be able to pair up your device to an app used by your smartphone where you can view a live feed of your distance and heart rate on your phone. In other words, your smartphone becomes the receiver so no wrist watch is needed.

Less expensive models may help you determine heart rate but do so by placing your finger on a button and holding it in place. This method is generally less accurate, requires you to stop your exercise, and does not keep track of an average over the session. Some phone apps use the same concept to give you momentary readings of your heart rather than continuous measurements. One exception to this can be found in the Garmin fitness watches, FitBit devices, and smart watches which keep continuous measurements without a chest strap by using an infrared sensor.

**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 yourself the question: “overall, how hard do I feel like I’m 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 more intuitive, the traditional scale is still used more frequently.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Intensity Scales** | | | | | |
| General | Talk Test | Modified  Borg | Borg RPE | % HRR | %HR Max |
| Light | Easy  Conversation | 0 | 6 | 30 | 57 |
| 1 | 7 | 35 | 60 |
| 2 | 8 |
| 9 |
| 3 | 10 |
| 4 | 11 | 39 | 63 |
| Moderate | Brief Sentences | 5 | 12 | 40 | 64 |
|  | 13 |
|  | 6 | 14 | 59 | 75 |
| Vigorous | A few words | 7 | 15 | 60 | 76 |
| 16 |  |
| 8 | 17 | 89 | 95 |
| Anaerobic | Unable to  speak/one word phrases | 9 | 18 | 90 | 96 |
| 19 |
| 10 | 20 | 100 | 100 |

Data are from: American College of Sports Medicine, ACSM’s Guidelines for Exercise Testing and Prescription, 9th Edition

Walking and jogging not only benefits physical health, but many enjoy the social benefits 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’re working at a high enough intensity in which your breathing rate makes conversation difficult. Certainly, if you can speak in full sentences without getting winded, the intensity would be very light. So, just like RPE, the Talk Test is yet another way to subjectively measure your intensity which can then be correlated with heart rates (see figure 3.4).

**Periodization**

For hundreds of years, athletes have wondered how to balance their exercise efforts with performance improvements and adequate rest. Over this time frame, exercise scientists and athletes alike have determined that by dividing the training phases into blocks, or periods, optimal fitness can be achieved without overstressing the athlete. This training principle, called **periodization**, is especially important to serious athletes but can be applied to most walking and jogging plans as well.

Keep in mind, the overlying purpose of developing a walking and jogging program stems from creating a simple way to live an active lifestyle. Up to this point in the discussion, the principle of stressing the body to adapt has been emphasized to the point it could be misunderstood as a non-stop thing. The principle of periodization, however, suggests that training plans incorporate phases of stress followed by phases of rest. Without rest, the body becomes overstressed.

Training phases can be organized on daily, weekly, monthly, and even multi-annual cycles (called micro-, meso-, macrocycles, respectively). An example of this might be:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Week | Frequency | Intensity | Time | Type |
| 1 | 3 days | 40% HRR | 25 min | walk |
| 2 | 4 days | 40% HRR | 30 min | walk |
| 3 | 4 days | 50% HRR | 35 min | walk |
| 4 | 2 days | 30% HRR | 30 min | other |

As you can see, the volume and intensity changes from week 1 to week 3. But, in week 4, the volume and intensity drops significantly to accommodate a designated rest week. If the chart were continued, weeks 5-7 would be “stress” weeks and week 8 would be another rest week. This pattern could be followed for several months.

Without periodization, the stress from exercise would continue indefinitely eventually leading to fatigue, possible injury, and even a condition known as **overtraining syndrome**. Overtraining syndrome is not well understood but results from psychological and physiological factors which cause a decline in performance and cannot be fixed by a few days’ rest. Instead, weeks, months and even years are sometimes required to overcome the symptoms of overtraining syndrome. Symptoms included are:

* body weight loss
* loss of motivation
* inability to concentrate or stay focused
* feelings of depression
* lack of enjoyment in things that normally are enjoyable
* sleep disturbances
* change in appetite

**Reversibility**

Chronic Adaptations are not permanent. As the saying goes, “use it, or lose it.” The **principle of reversibility** suggests that activity must continue at the same level to keep the same level of adaptation. As activity declines, called **detraining**, adaptations will recede.

In cardiorespiratory endurance, key areas such as VO2max, stroke volume, and cardiac output all declined with detraining while submaximal heart rate increases. In one study, trained subjects were given bed rest for 20 days. At the end of the bed rest phase, VO2max had fallen by 27% and stroke volume and cardiac output had fallen by 25%. For the most well-trained subjects in the study, it took them nearly 40 days after bed rest to get back into pre-rest condition. In a study of collegiate swimmers, lactic acid in blood after a 2-minute swim more than doubled after 4 weeks of detraining, showing the ability to buffer lactic acid was dramatically affected. 5

Not only is endurance training affected, but muscular strength, muscular endurance and flexibility all show similar results.

**Individual Differences**

While the principles of adaptation to stress can be applied to everyone, not everyone responds to the stress in the same way. In the HERITAGE Family study, families of 5 (father, mother, and 3 children) participated in a training program for 20 weeks. They exercised 3 times per week, at 75% of their VO2max, for up to 50 minutes by the end of week 14. By the end of the study, a wide variation in responses to the same exercise regimen were seen by individuals and families. Those who saw the most improvements, saw similar percent improvements across the family and vice versa. Along with other studies, this has led researchers to believe individual differences in exercise response are genetic. Some experts estimate genes to contribute as much as 47% to the outcome of training.6

Besides genes, other things can affect the degree of adaptation such as the training status at the start of a program, age, and gender. As you might expect, those with less training background show rapid improvement whereas those who are well trained improve at a slower rate.

Regardless, it is important to understand as you establish your goals that you may not have the same response as your peers. Setting realistic goals and modifying them if necessary are important to avoid frustration and program cessation

**Key Terms**

**Principles of adaptations to stress:** guidelines related to managing the application of stress during physical activity/exercise.

**Acute adaptation:** a temporary change or modification to the operation of a system as a result of exposure to exercise.

**Chronic adaptation:** a semi-permanent change or modification to the operation of a system as a result of consistent exercise.

**Overload Principle:** a principle of adaptation to stress suggesting the amount of stress applied during exercise must exceed a threshold level to stimulate adaptation.

**Volume:** the term used to describe “how much” stress is being applied by combining the duration and frequency of exercise.

**Specificity:** the principle of stress suggesting activities should be closely centered around the primary outcome goal, i.e. train the way you want to adapt.

**Reversibility:** the principle that adaptations to stress can be lost over time if training is modified or stopped.

**Periodization:** a method of organizing workouts into blocks or periods. These cycles consist of work/stress periods and rest periods.

**Overtraining syndrome:** a condition of chronic stress from physical activity affecting the physical and psychological states of an individual or athlete.

**Detraining:** the act of no longer training at all or decreasing the amount of training.

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

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

**Pulmonary ventilation:** The amount of air measured during inspiration or expiration.

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

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

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

**Cardiac hypertrophy:** the enlargement of the heart muscle.

**Stroke volume:** the amount of blood pumped out of the heart after each heart beat.

**Cardiac output:** The combination of heart rate and stroke volume equals the total output of the cardiac muscle.

**FITT principle:** a principle related to overload; an acronym standing for frequency, intensity, time, and type which are the four variables that can be modified to manipulate the amount of stress experienced during exercise.

**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.

**Lactate Threshold:** the point at which lactic acid can no longer be buffered by the body leading to accumulation of lactic acid in the muscle.

**Borg Scale:** a subjective scale used to estimate exercise intensity.

**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. Increased heart rate is an example of an acute adaptation to exercise.

True or False

2. Resting Heart Rate (RHR) will \_\_\_\_\_\_\_\_\_\_\_ as a result of endurance training.

a) Increase

b) Decrease

c) Stay constant

d) Become inconsistent

3. The formula to measure Cardiac Output includes:

a) Stroke Volume and Pulmonary Ventilation

b) Heart Rate and Pulmonary Diffusion

c) Stroke Volume and Heart Rate

d) Arteriole-venuole Difference and Pulmonary Ventilation

4. The most important variable of FITT principle is:

a) Frequency

b) Intensity

c) Type

d) Time

5. The ***best*** method to use when estimating your Target Heart Rate is the:

a) Karvonen Formula

b) Max Heart Rate Method

c) Heart Rate Reserve Method

d) Resting Heart Rate Formula

6. The training principle that divides training phases into blocks to achieve optimal fitness without overstressing the body is called:

a) FITT principle

b) Overload principle

c) Principle of Reversibility

d) Periodization

Answer Key:

1. True
2. b.
3. c.
4. b.
5. d.

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