CHAPTER 3

DESIGNING AND MONITORING AEROBIC EXERCISE

CHAPTER OVERVIEW

A MAJOR GOAL of a sound exercise program is to develop aerobic fitness. The energy consumed with aerobic exercise not only develops fitness, but also controls obesity, promotes health, and reduces the risk of cardiovascular disease. An aerobically active lifestyle not only lowers the risk of cardiovascular disease, but also adds years to your life. Improving aerobic fitness depends upon exercising at a suitable frequency, intensity, and duration, and using exercises that involve the large muscles of the body. This chapter gives concepts that will help you design a sound aerobic exercise program.

Total energy consumption integrates exercise intensity, frequency, and duration. The unit of energy consumption used is caloric expenditure expressed in kilocalories. To obtain health benefits and maintain a suitable body composition, your exercise program must consume an adequate number of calories. To maintain an adequate level of aerobic fitness you must not only consume calories, but also exercise at an adequate intensity for a sufficient period of time. This product of exercise intensity above a training threshold and time is known as aerobic minutes. Aerobic minutes and caloric expenditure [15] are two methods for monitoring aerobic exercise and they complement each other.

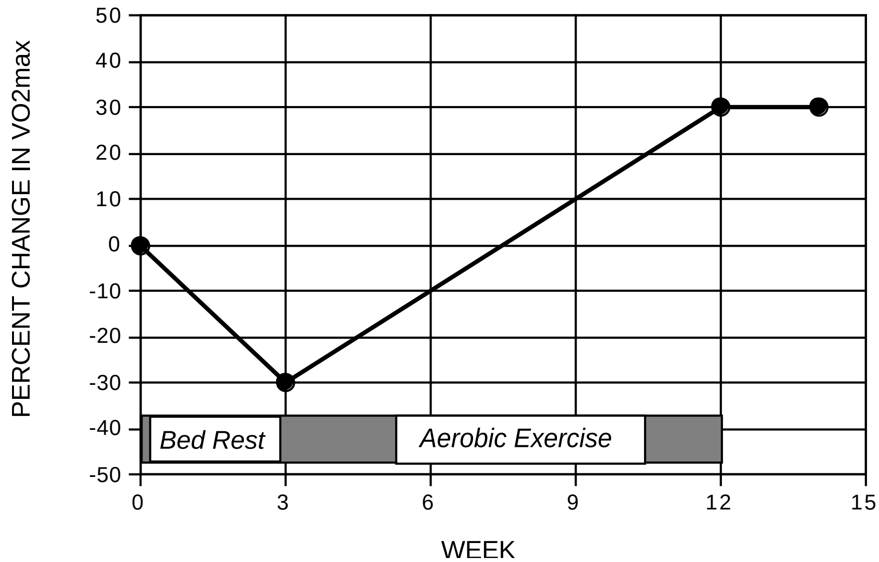
The general goals of Chapter 3 are to provide you with an understanding of the scientific basis of aerobic exercise and methods of monitoring and evaluating its quality. The major educational outcomes of Chapter 3 are to help you understand the following:

1. The link between sedentary lifestyle and health.
2. The physiological changes produced by aerobic exercise.
3. The quantity and quality of exercise needed to develop and maintain fitness and promote health.
4. The methods of regulating exercise intensity at a suitable level.
5. The methods used to quantify and evaluate aerobic exercise.
6. The methods used to compute caloric expenditure for:
    - Walking and jogging
    - Other exercise modes such as aerobic dance or tennis.

FIGURE 3-1.

Aerobic fitness decreases with physical inactivity and increases with proper aerobic training. Classic NASA bed rest studies showed that inactivity caused a rapid decline in VO2max. Appropriate aerobic exercise not only restores aerobic fitness, but also improves it.

Changes in aerobic fitness mirror exercise habits.



AEROBIC TRAINING AND FITNESS

This chapter defines the components of an exercise program designed to increase aerobic fitness and enhance health. The amount of improvement in your aerobic fitness depends largely upon how physically active you have been—the more sedentary, the more room for improvement. Obviously, if you have been very active, you will not experience as great an increase because you are already closer to your personal potential. For previously sedentary people aerobic fitness increases rapidly over a 2-3 month training period, and then minimally after that. With deconditioning (lack of exercise) there is a rapid drop in aerobic fitness in just a few weeks. Figure 3-1 illustrates these changes.

Aerobic exercise brings about several cardiovascular and body composition changes that causes your fitness to increase. Summarized next are these major changes.

- **Maximum cardiac output increases**. As you exercise aerobically your heart increases blood flow, or cardiac output to your exercising muscles. As your maximum exercise capacity increases, so does your maximum cardiac output.
- **Stroke volume increases**. Stroke volume is the amount of blood pumped from the heart with each heart beat. With training, the heart muscle strengthens and the stroke volume increases.
- **Submaximal exercise heart rate is lowe**red. If two people exercise at the same submaximal intensity, the oxygen requirements (VO2) will be similar. Since cardiac output is directly proportional to the oxygen uptake (VO2), their cardiac outputs also will be similar. Cardiac output is the product of the amount of blood pumped per beat (stroke volume) and the number of beats per minute (heart rate). Since the

stroke volume increases with fitness and the cardiac output at any submaximal exercise level stays the same, the heart rate for that level of exercise will be lower. For example, as you become more fit, you will notice that your heart rate gradually decreases when running at the same speed. The increase in stroke volume makes this happen.

Resting heart rate is lower. A typical resting heart rate is about 65-80 beats/min. In comparison, a highly trained endurance athlete may have a resting heart rate in the 40s. This decrease in resting heart rate is due to a combination of factors including an increased stroke volume.

Working muscles become more efficient. Exercise not only strengthens the bones, ligaments, and muscles, but also improves the delivery and transfer of oxygen from the blood to the working muscles. This improved oxygen delivery and utilization is due to increasing the blood flow to the exercising muscles and increasing the elements in the muscles that extract and metabolize oxygen.

Body composition improves. Aerobic exercise is an excellent way to burn calories. A sufficient amount of aerobic exercise reduces fat weight and increases fat-free weight, which consists mainly of muscle mass. This lowers percent body fat. It also has an additional benefit of improving VO2max on a per weight basis because you are no longer hauling the “extra baggage” consisting of body fat.

SEDENTARY LIFESTYLE AND HEALTH

The belief that exercise is good for your health has been the topic of scientific debate for many years. Serious scientific research started in the 1950s examined the role of exercise on health. This research confirmed that suitable amounts of aerobic exercise not only reduce the risk of coronary heart disease, but also increase life expectancy. These data come from two general sources: 1) physical activity required to perform work; and 2) physical activity habits exhibited by college alumni.

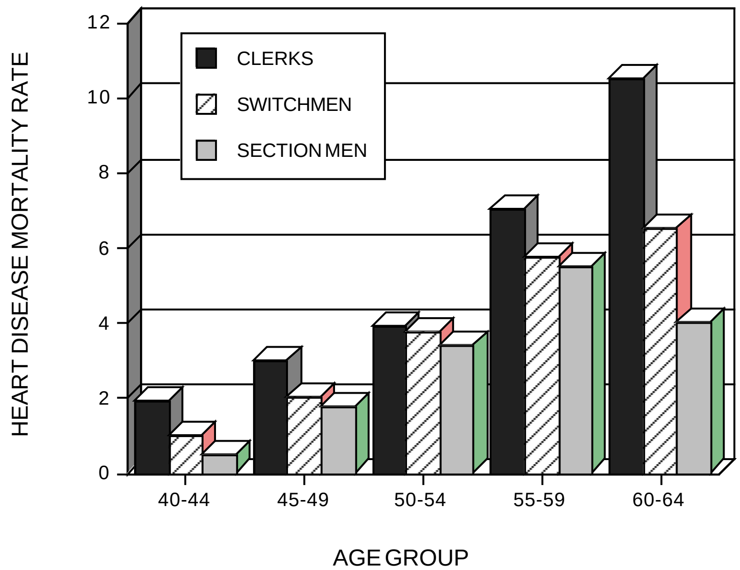
EXERCISE AND HEALTH

The initial data linking exercise and heart disease came from studying occupations. These studies found that people who had the most physically demanding jobs suffered fewer fatal heart attacks than their more sedentary counterparts. For example, conductors who walked up and down the stairs of double-decker buses in London had fewer heart attacks than the more sedentary bus drivers. In the United States, postal workers who walked and delivered mail had a lower incidence of heart disease than those who just stood and sorted it. American railroad workers (Figure 3-2) who did the heavy construction work (section men) were less likely to die of heart disease than those who worked in jobs requiring little (clerks) or moderate levels (switchmen) of physical activity [16].

A general research hypothesis developed from the research on occupational groups was that caloric expenditure was related to heart disease. This hypothesis was supported by some rather startling research that showed individuals who consumed the highest number of calories had the lowest heart disease rates [8]. This was an unexpected finding. Caloric consumption was measured by analyzing thousands of diets of men from three different populations. Further analysis showed that dietary caloric intake was an important marker of physical activity. Quite simply, those who expend more calories through exercise, consume more calories. The relationship between occupational caloric expenditure and heart disease was further supported with research with San Francisco stevedores [9]. They discovered that those workers who had jobs requiring a high caloric expenditure (5 to 7.5 kilocalories per minute) suffered fewer cardiac deaths than stevedores who performed the easy jobs (≤ 2 kilocalories per minute).

FIGURE 3-2. For all age groups studied, the lowest level of heart disease was for the railroad workers who had the most physically demanding jobs. The graph made from published data [16].

Physically active jobs reduce the risk of heart disease.



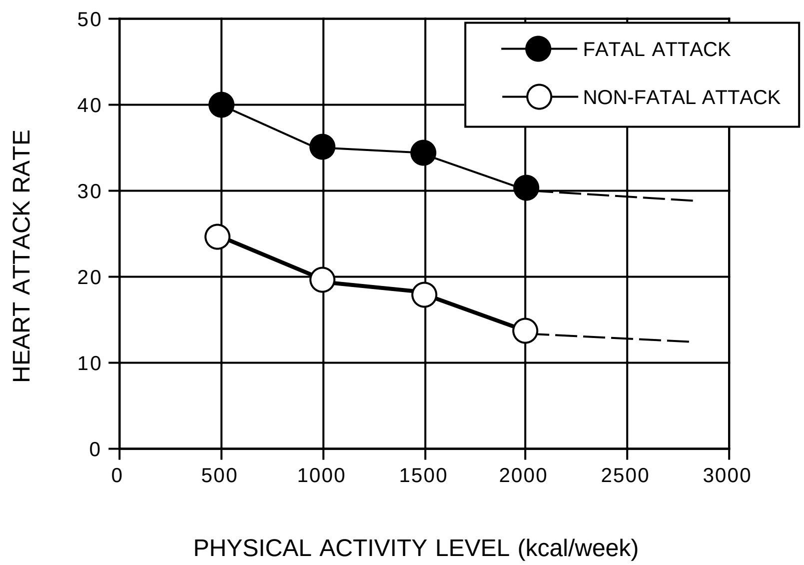
The link between caloric expenditure and heart disease has also been shown in college alumni. A survey measured the physical activity habits of nearly 17,000 Harvard alumni who entered college in the years 1916 to 1950 [10, 11]. The forms of physical activity included various types of sports, stair climbing, and walking. Those who expended the fewest calories had the most heart attacks. The most sedentary alumni (energy expenditure < 500 kilocalories/week) had the highest level of heart disease. The risk declined and leveled off when energy expenditure reached about 2,000 kilocalories/week (Figure 3-3). Continuous common forms of vigorous physical activity such as walking, climbing stairs, or playing strenuous sports regularly provided a degree of protection against a heart attack. Being a former college athlete did not reduce risk unless the person remained physically active. The alumni at highest risk of a heart attack were those former athletes who led a sedentary post-college life.

EXERCISE AND LONGEVITY

Data from the Harvard alumni study showed that physically active people have higher survival rates from heart attacks and live longer. Harvard alumni who consistently exercised during their lifetime had lower mortality rates than their sedentary classmates [12]. Walking, climbing stairs, and playing vigorous sports were the types of physical activity that increased longevity. The mortality rate of the alumni would be reduced by nearly 40% if they all were physically active non-smokers. Figure 3-4 includes a comparison of the alumni who expended ≥ 2,000 kilocalories per week with those who played vigorous sports. It shows that regular exercise extends life expectancy, but that moderate exercise, consuming at least 2,000 kilocalories per week, improved longevity more than just playing vigorous sports. At age 35, the physically active alumni could be expected to live about 2.5 years longer than their sedentary classmates. This may not sound that significant, but Paffenbarger, a leading epidemiologist, has made a startling comparison. If nobody died of cancer, the average increase in longevity would be *only 2 years*.[1] In this context, regular forms of suitable exercise are potentially equally beneficial to public health as cancer prevention.

FIGURE 3-3. The age-adjusted number of fatal and non-fatal heart attacks of Harvard male alumni for various levels of physical activity. The rates drop steadily to an activity level that consumes about 2,000 kilocalories/week and then level off. Graph developed from published data [10].

Expending calories reduces the risk of a heart attack.



POSITION STATEMENTS ON AEROBIC EXERCISE

Regular physical activity has long been regarded as an important component of a healthy lifestyle. The questions about exercise [1, 2, 13] frequently asked by both professionals and exercise participants are:

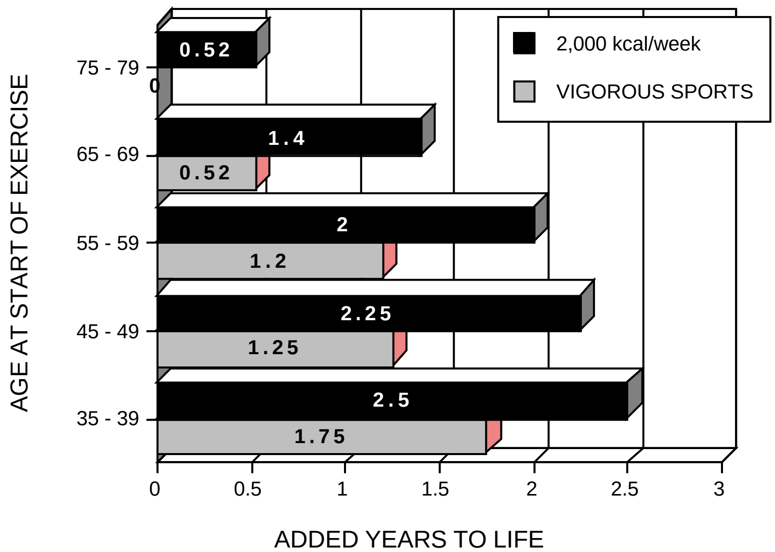
- How much exercise is enough?
- What type of exercise is best for developing and maintaining fitness?
- What type of exercise best maintains health and reduces the risk of degenerative diseases?

1. Communication with Dr. R. Paffenbarger at the Texas Chapter Meeting of the American College of Sports Medicine, Houston, Texas, December, 1985.

FIGURE 3-4.

The graph shows the years added to life to age 80 from an active lifestyle. It shows the value of starting an exercise program early in life and keeping with it. The values are adjusted for differences in blood pressure status, cigarette smoking, weight gain, and age of parental death. The graph made from published data (Paffenbarger, et. al., 1986).

Aerobic exercise extends life. Starting earlier in life extends life longer.



While competent professionals may differ somewhat on their answers to these questions, the development of position statements evolved through a consensus process by leading authorities and professionals. Provided in this section is a brief summary of two important position statements, one primarily focused on developing and maintaining aerobic fitness [2] and the second for public health [13].

PHYSICAL ACTIVITY AND PUBLIC HEALTH

Newly published scientific medical research links regular physical activity to a wide array of health benefits [7]. This scientific research motivated the Centers for Disease Control and Prevention and The American College of Sports Medicine (ACSM) to bring a group of experts together to review the pertinent scientific evidence and develop a clear, concise “public health message” on physical activity [13]. The public health statement is:

> “Every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week.”

In this statement physical activity is “any bodily movements produced by skeletal muscles that result in energy expenditure.” Moderate physical activity was defined as “...activity performed at an intensity of 3 to 6 METs, the equivalent of brisk walking at 3 to 4 mph for most healthy adults.” The public health statement was published in the *Journal of the American Medical Association* and as such, became a guideline for physicians to follow with their patients. The statement was fully endorsed by the American Heart Association.

DEVELOPING AND MAINTAINING AEROBIC FITNESS

The American College of Sports Medicine published the first position paper on exercise in 1978 [1] and then revised the statement in 1990 [2]. Using the existing scientific evidence, the statement defines the quality and quantity of exercise for developing and maintaining aerobic fitness, body composition and muscular strength of healthy adults. Provided next are the four recommendations.

- **Frequency of training.** Aerobic exercise should be engaged in from 3 to 5 days per week.
- **Intensity of training.** Aerobic exercise should be at an intensity of 50 to 85% of maximum oxygen uptake.
- **Duration of training.** Aerobic exercise should be continuous from 20 to 60 minutes per exercise session.
- **Mode of activity.** The aerobic exercise should be any activity that uses large muscle groups that are rhythmical and aerobic in nature. Examples are walking-hiking, running-jogging, cycling-bicycling, skiing, dancing, rope skipping, rowing, stair climbing, swimming, skating, and various endurance game activities.

KEY ELEMENTS OF AN AEROBIC EXERCISE PROGRAM

Sedentary lifestyle increases the risk of cardiovascular disease, and obesity. A physically active lifestyle not only lengthens life, but also enhances its quality. These benefits are for people of all ages. The components of an aerobic program are frequency, intensity, duration, progression, and mode. A sound aerobic exercise program has three phases:

- Warm-up exercises - 5 to 10 minutes.
- Individualized aerobic exercise - 20 to 60 minutes.
- Cool-down exercises - 5 to 10 minutes.

EXERCISE FREQUENCY

Exercise frequency refers to the number of times you should exercise per week. The desired frequency is from 3 to 5 times per week. If you exercise less than 3 times per week, aerobic fitness will not increase appreciably and may not be maintained. Exercising vigorously more than 5 times per week can cause injuries, especially leg and back problems. The public health recommendation of exercising on most, preferably all, days of the week is at a *moderate intensity.*

EXERCISE DURATION

Exercise duration refers to the number of minutes of continuous aerobic exercise during each session. Duration of training depends upon a suitable intensity. Exercising at an intensity that is too high causes fatigue, decreasing duration. Exercising at too low of an intensity does not provide an aerobic training benefit. An intensity between 50 and 85% of VO2max is suitable for reaching a duration of at least 20 minutes per session while still obtaining an aerobic training benefit. It may be difficult to reach this level initially, but after several weeks you will be surprised at your progress. The desired goal is to increase duration from 20 to 60 minutes if maximum fitness improvement is desired. Otherwise 20 minutes should be adequate to meet normal health and fitness goals.

EXERCISE INTENSITY

Exercise intensity defines how vigorously you exercise. This can be expressed in either absolute or relative terms. Absolute intensity is the amount of energy a task requires. In contrast, relative intensity defines aerobic exercise as a percentage of your maximum aerobic capacity (%VO2max).

Absolute Exercise Intensity

The amount of energy expended depends somewhat on exercise mode. For example, walking requires less energy than jogging. Walking up stairs is a higher absolute intensity than walking on the level. The unit of measurement that quantifies absolute exercise intensity is kilocalories typically determined from oxygen consumption and often expressed in METs. A MET is based upon the average amount of oxygen used at rest. It is a VO2 of 3.5 ml/kg/min. The equation that converts VO2 to METs is:

MET - AVERAGE VO2 AT REST **(EQ 3-1)**

$$\text{MET} = \left(\frac{\text{VO2 (ml/kg/min)}}{3.5}\right)$$

Expressing exercise in METs quantifies absolute intensity in multiples of resting energy expenditure. For example, the MET intensity of jogging at an 8-minute mile pace (i.e., 7.5 mph) is about 12.5 METs. That is, a person jogging at this pace uses 12.5 times more energy than when at rest. This MET intensity is the same for virtually anyone who is able to jog at this speed.

Relative Exercise Intensity

Relative intensity expresses aerobic exercise as a percentage of your maximum aerobic fitness (%VO2max). Jogging at 7.5 mph is an absolute intensity of 12.5 METs for everyone, but the relative intensity of this pace will be different for people who vary in aerobic fitness. This can be easily shown by example.

Calculation Example - Expressing VO2max in METS. Assume two people who weigh the same jog together at a pace of 7.5 mph (12.5 METs), and that the VO2max of one is 63 ml/kg/min and 49 ml/kg/min for the other. Since a MET equals a VO2 of 3.5 ml/kg/min, the VO2max of each person also can be expressed in METs (EQ 3-1). The maximum aerobic capacity of the joggers expressed in METs is:

$$\text{Very Fit Jogger} = \left(\frac{63}{3.5}\right) = 18\ \text{METs}$$

$$\text{Less Fit Jogger} = \left(\frac{49}{3.5}\right) = 14\ \text{METs}$$

If VO2max is known and expressed in METs (MET-max) relative intensity is determined by:

RELATIVE EXERCISE INTENSITY **(EQ 3-2)**

$$\%\text{VO2max} = \left(\frac{\text{MET-I}}{\text{MET-max}}\right) \times 100$$

Calculation Example - Determining Relative Intensity. As we will show later in this chapter, jogging at 7.5 mph represents an absolute intensity of 12.5 METs. Using EQ 3-2, the relative intensity for each jogger is:

$$\text{Fit Jogger} = \left(\frac{12.5}{18}\right) \times 100 = 69.4\% \text{ of VO2max}$$

$$\text{Less Fit Jogger} = \left(\frac{12.5}{14}\right) \times 100 = 89.3\% \text{ of VO2max}$$

Jogging at the 7.5 mph pace has the same absolute MET intensity and burns the same number of calories, but it is much more difficult for the less fit person. Jogging at 69% of VO2max is a suitable, comfortable intensity for the more fit person, while jogging at 89% of VO2max is too rigorous for either. The less fit person would have to slow his pace or quickly tire.

Determining Relative Exercise Intensity

The exercise intensity recommended in the 1990 American College of Sports Medicine position paper is 50-85% of VO2max. It is our experience that a practical level is about 70% of your VO2max. There are several methods that can help you find the appropriate intensity of aerobic exercise to allow you to exercise at 70% of your VO2max. These are:

- Direct calculation of percentage of VO2max from exercise intensity.
- Using exercise heart rate to estimate the relative intensity of exercise (%VO2max).
- Using rating of perceived exertion (RPE) to estimate the relative intensity of exercise (%VO2max).

Direct calculation of percentage of VO2max from exercise intensity. The most accurate method of determining relative exercise intensity is by directly calculating percentage of VO2max from exercise intensity. VO2max and the MET intensity of the desired exercise are used to compute percentage of VO2max. This method is suitable for exercise modes where energy consumption can be defined. The absolute intensity of cycling, rowing, cross-county skiing, walking, and jogging can be accurately determined from the rate of movement. The method is especially suitable for the popular exercise modes of walking and jogging. The equations for computing the MET intensity (MET-I) of walking and jogging [6, 14, 15] are:

MET INTENSITY (MET-I) FOR WALKING **(EQ 3-3)**

$$\text{Walking: MET-I} = \left[75 \times \left(\frac{\text{Distance in Miles}}{\text{Time in Minutes}}\right)\right]$$

MET INTENSITY (MET-I) FOR JOGGING **(EQ 3-4)**

$$\text{Jogging: MET-I} = \left[100 \times \left(\frac{\text{Distance in Miles}}{\text{Time in Minutes}}\right)\right]$$

Calculation example - MET-I of Walking and Jogging. Assume one person walks 2.8 miles in 45 minutes while another jogs 3.2 miles in 30 minutes. Further, assume the VO2max of the walker is 38 ml/kg/min (10.86 METs) as compared to

48 ml/kg/min (13.71 METs) for the jogger. The walking and jogging MET intensity (MET-I) calculations are:

$$\text{Walker: MET-I} = \left[75 \times \left(\frac{2.8}{45}\right)\right] = 4.7\text{ METs}$$

$$\text{Jogger: MET-I} = \left[100 \times \left(\frac{3.2}{30}\right)\right] = 10.7\text{ METs}$$

The relative exercise intensities (EQ 3-2 %VO2max) for the walker and jogger are:

$$\text{Walker: \%VO2max} = \left(\frac{4.7}{10.86}\right) \times 100 = 43.3\%$$

$$\text{Jogger: \%VO2max} = \left(\frac{10.7}{13.71}\right) \times 100 = 78.0\%$$

Our recommended guideline is to exercise between 60 and 80% of your VO2max. An intensity of 70% of VO2max is suitable for most. The example shows that the walker is exercising at a very low relative intensity. If the goal is to increase aerobic fitness, the walker should increase exercise intensity by walking at a faster pace or even starting to jog. The jogger is near the top of the desired relative intensity. He may want to consider a slower pace that is more comfortable so that he can exercise for longer periods of time.

Exercise heart rate to estimate percentage of VO2max. Since heart rate increases at a relatively linear rate with exercise intensity, it provides a good index of relative exercise intensity. This has led to the development of standard equations [15] for estimating exercise heart rates at various percentages of maximum capacity. Exercise heart rate estimates of exercise intensity provide a general guide, because although there is a linear relationship between heart rate and percentage of VO2max, the actual heart rate at a specific percentage of VO2max varies appreciably. This variation is due to many factors including emotion, stress, environmental conditions (heat, cold, and humidity), and unique ways that people deliver and use oxygen in their working muscles. Because of this variation, the heart rate at 70% of VO2max gives the best single value for prescribing exercise because it is in the middle of the recommended relative intensity, but the training heart rate zone (THRZ) provides a more realistic range. The THRZ is computed by adding and subtracting 5 beats to the 70% value. The general equations for estimating exercise heart rate (ExHR) at 70% of VO2max (%max) for men and women of different ages are:

70% EXERCISE HEART RATE - WOMEN **(EQ 3-5)**

$$\text{ExHR} = [(0.70) \times (220 - \text{Age} - 73)] + 73$$

70% EXERCISE HEART RATE - MEN **(EQ 3-6)**

$$ExHR = [(0.70) \times (220 - Age - 63)] + 63$$

Consider the following when using the equations.

- Maximum heart rate decreases with age. The term 220 - Age estimates maximum heart rate.
- These equations should not be used for anyone who is taking medication that affects heart rate because the 220 - Age estimate will be in error.
- The heart rate response to exercise differs somewhat for men and women. The values of 63 and 73 correct this difference.
- The value of 0.70 can be replaced to define an exercise heart rate at other levels, e.g., 0.65 for 65% of maximum capacity.

The use of the exercise heart rate equations for estimating exercise heart rate at 70% of maximum capacity is illustrated next for a 20-year-old woman and 25-year-old man.

Exercise Heart Rate at 70% VO2max for a woman, age 20

$$ExHR = [(0.70) \times (220 - 20 - 73)] + 73 = 162$$

Exercise Heart Rate at 70% VO2max for a man, age 25

$$ExHR = [(0.70) \times (220 - 25 - 63)] + 63 = 155$$

The THRZ (± 5 beats/min of 70% value) for each would be:

- Woman: 157 - 167 beats/min
- Man: 150 - 160 beats/min

Exercise heart rate and THRZ provide an estimate of the intensity that you would like to exercise. While it is desirable to stay within the THRZ, this is not always possible. Equations 3-5 and 3-6 can be rearranged to estimate relative exercise intensity for the exercise heart rate achieved during an exercise session. This information can be used to decide if you need to increase or decrease exercise intensity. These equations for estimating the percentage of maximum capacity (percentage of VO2max) reached during exercise are:

HEART RATE PERCENTAGE OF MAXIMUM CAPACITY - WOMEN **(EQ 3-7)**

$$\%VO2max = \left(\frac{ExHR - 73}{220 - Age - 73}\right) \times 100$$

HEART RATE PERCENTAGE OF MAXIMUM CAPACITY - MEN **(EQ 3-8)**

$$\%VO2max = \left(\frac{ExHR - 63}{220 - Age - 63}\right) \times 100$$

Calculation example - Heart Rate Estimate of %VO2max. Assume the 20-year-old woman and 25-year-old-year-old man jogged together and achieved exercise heart rates of 175 and 180 respectively. Using equations 3-7 and 3-8, the exercise intensities were as follows:

Exercise Intensity 20-year-old woman

$$\%VO2max = \left(\frac{175 - 73}{220 - 20 - 73}\right) \times 100 = \left(\frac{102}{127}\right) \times 100 = 80\%$$

Exercise Intensity 25-year-old man

$$\%VO2max = \left(\frac{180 - 63}{220 - 25 - 63}\right) \times 100 = \left(\frac{117}{132}\right) \times 100 = 89\%$$

Rating of perceived exertion (RPE). There are times when heart rate is not a good indicator of relative exercise intensity. Environmental conditions such as heat and dehydration and various drugs affect the relationship between heart rate and VO2. Psychophysical scales [3, 4] provide another method of estimating relative exercise intensity. Figure 3-5 gives the RPE scale. The instructions for using the RPE Scale are:

INSTRUCTIONS FOR BORG'S RATIO RPE SCALE

We would like you to estimate the exertion you feel by using this scale. The scale starts with 0. “Nothing at All” and goes on to 10, “Extremely strong” - that is “Almost Max.” For most people 10 corresponds to the hardest physical exercise they have ever done; as hard as for example, the exertion you feel when you run as fast as you can for several minutes till you are completely exhausted, or when you are lifting or carrying something that is so heavy that you almost can’t make it. Maybe it is possible to imagine exertion or pain that is even stronger, and that is why the maximum value can be somewhat over 10. If you feel the exertion or pain to be stronger than “Extremely Strong”, you can use a number that is over 10, for example 11, 13, or an even higher number.

If the exertion is “Very weak” you should answer with the number 1. If it is only “Moderate,” you say 3 and so on. Feel free to use any number you wish on the scale, as well as half values (1.5)or decimals as (0.8, 1.7, 2.3). It is important that you give the answer that you yourself feel to be right and not what you think you should give. Answer as honestly as possible and try neither to overestimate nor underestimate the degree of exertion that you feel.

FIGURE 3-5. Borg's rating of perceived exertion (RPE) scale and instructions for using the scale. The shaded area represents 60% to 80% of VO2max. Source: Dr. G Borg, Department of Psychology, University of Stockholm, Sweden.

RPE	DESCRIPTION	
0	Nothing at All	just noticeable
0.5	Extremely Light	
1	Very Light	
2	Light	*weak*
3	Moderate	
4	**Somewhat Heavy**	
5	**Heavy**	***strong***
6		
7	**Very Heavy**	
8		
9		
10	Extremely Heavy	*almost max*
●	***MAXIMAL***	

The RPE scale is a simple method to regulate exercise. You can perceive and rate exercise strain or exertion. Many believe that RPE is the single best indicator of the degree of physical strain. The general RPE rating integrates data from the peripheral working muscles and joints, central cardiovascular and respiratory functions, and the central nervous system. These signals, perceptions, and experiences combine into a global, perceived exertion. The method involves rating feelings of the whole body as opposed to a specific body part. For example, while riding a bike, the legs tire before the arms. To use the RPE scale correctly, rate the sensations of the entire body, not just the legs.

The prime feature of the RPE scale is that the numbers and anchor expressions are simple and understandable. The RPE scale ranges from 0 to 10. The recommendation is to keep the intensity level between an RPE of #4 (Somewhat Heavy) and #7 (Very Heavy). If the rating is less than #4, your workout needs to be more demanding. When ratings exceed #7, you are most likely exercising too vigorously. Ratings between 4 and 7 represent a relative intensity range from 60% to 80% of VO2max. It is difficult to rate exercise intensity at low levels below #4, but easy to decide when exercise intensity is too difficult, i.e., a RPE rating ≥7. The RPE method is also an excellent way to estimate percentage of VO2max.

PROGRESSION

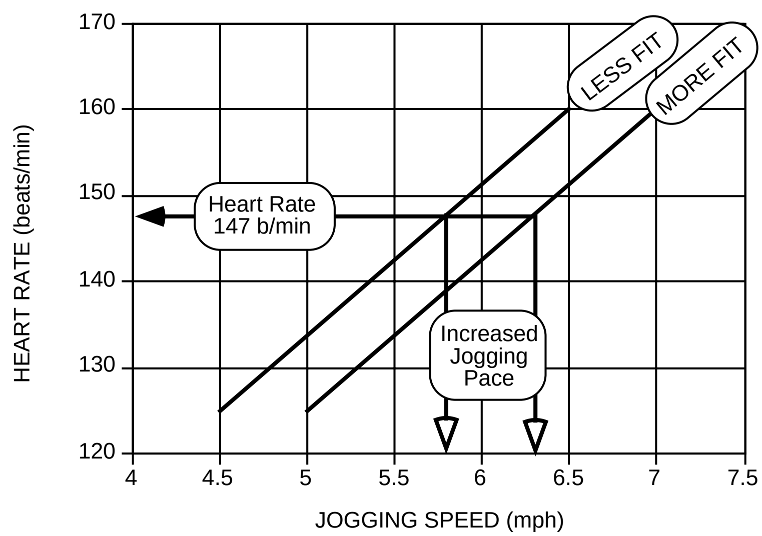
Progression refers to a systematic increase of exercise intensity, duration, or frequency over time. To continue to improve aerobic fitness, the aerobic exercise requirements must be steadily increased. How fast to make changes depends upon your initial level of fitness, health, injury problems, amount of training, genetic potential, and fitness goals. There are several methods you can use to regulate your progression.

Using Heart Rate and RPE to Regulate Progression

Exercise heart rate is an excellent method of regulating progress. As aerobic fitness improves, exercise heart rate decreases for a given absolute MET intensity. To exercise at the same percentage of VO2max, the MET intensity must be increased, e.g., jog at a faster pace. Exercise heart rate then becomes an "internal biological intensity meter," automatically adjusting intensity for an optimal exercise program. Figure 3- 6 illustrates how exercise heart rate regulates progression. RPE provides an adjunct to exercise heart rate. If the new intensity level feels too difficult, slow the progression. You also may progress at a slightly faster rate if the new level feels too easy.

FIGURE 3-6. As fitness improves, you need to exercise at a higher intensity to maintain your heart rate at a specific level. If we assume this is a 36-year-old man, 70% of VO2max represents a heart rate of about 147 beats/min. When unfit, jogging at 5.5 mph elicits a heart rate of 147 beats/min, but as fitness improves, the person must jog at a faster pace to maintain the same heart rate. Increasing MET intensity while maintaining the same heart rate (training heart rate) is an easy way to adjust progression.

As fitness increases, you must increase exercise intensity to maintain the same heart rate.



1.5 Mile Walk/Jog Goal to Aid in Progression

Exercise heart rate and RPE are excellent methods to regulate progression. Yet, some find it useful to have a goal. Using data from students enrolled in adult fitness courses at the University of Houston, we developed a method of defining a realistic final 1.5 mile walk/run goal. Table 3-1 provides low, average, and high goals based upon the student's starting VO2max. The exercise mode was walking and jogging. Use heart rate and RPE as guides to monitor progress and help you reach your goal. The steps for establishing your individualized 1.5 mile run/walk goal:

1. Find your VO2max at the start of your walk/jog aerobics program. The U of H non-exercise test is one test that can provide this information.
2. Once you know your VO2max, consult Table 3-1 and establish your progression goals. The standards are:

TABLE 3-1. Low, average, and high 1.5-mile run goals for a VO2max (ml/kg/min) at the start of an aerobics program.

INITIAL VO2MAX **	ESTIMATED 1.5-MILE TIME* GOALS		
	LOW	AVERAGE	HIGH
20 - 22	18.14	17.11	16.08
23 - 25	17.47	16.44	15.41
26 - 28	16.79	15.76	14.73
29 - 31	16.12	15.09	14.06
32 - 34	15.45	14.42	13.39
35 - 37	14.78	13.75	12.72
38 - 40	14.11	13.08	12.04
41 - 43	13.43	12.41	11.37
44 - 46	12.76	11.73	10.71
47 - 49	12.09	11.06	10.03
50 - 52	11.42	10.39	9.36
53 - 55	10.75	9.72	8.68
56 - 58	10.07	9.04	8.01
59 - 61	9.41	8.37	7.34
62 - 64	8.73	7.71	6.67

*Times expressed in 1/100th of a minute. **Initial VO2 max from U of H non-exercise test.

- **HIGH** (75th percentile)—only 25% of the students exceeded this level.
- **AVERAGE** (50th percentile)—A realistic goal for most, 50% of the students exceeded the average time.
- **LOW** (25th percentile)—75% of the students exceeded this time.

3. During your exercise program, periodically take the 1.5 mile walk/run test. Compare your achieved time with the time given in Table 3-1.
4. You may need to increase intensity, duration, and frequency to reach your goal.

EXERCISE MODE

Exercise mode is the type of aerobic exercise. Playing sports, aerobics, walking, jogging, bike riding, rowing, and swimming are some popular forms of aerobic exercise. A suitable exercise mode involves rhythmical exercise using the body's large muscle groups. Is there a best aerobic exercise mode? Not really, but some are better than others. It is important to find an exercise mode that is enjoyable.You are more likely to exercise regularly if you enjoy the activity. Provided next is a general evaluation of common, suitable aerobic exercise modes.

Walking and Jogging

Walking and jogging are excellent, popular exercise forms of exercise. They involve the body's largest muscle groups located in the legs. It is easy to regulate the intensity of walking and jogging because speed can be determined, and MET intensity accurately computed. Walking and jogging do not require specialized equipment nor do you need to belong to a fitness club. A limitation of walking and jogging is the lack of upper body muscular training, but many runners lift weights to build their upper body. Excessive running and walking can lead to orthopedic problems caused by the "steady pounding."

Swimming

Swimming is not only an excellent form of exercise for health and fitness, but also provides a level of safety for those who enjoy water sports. This mode is especially useful for people with orthopedic problems because the buoyancy enhances movement and reduces the stress on the body. Unlike walking and jogging, most of the power used to propel yourself comes from the upper body. The legs tend to stabilize your position. Of course, you must have access to a pool. Many fitness centers not only have a pool, but also aerobic conditioning programs using swimming.

Cycling

This exercise mode is growing in popularity. Like walking and jogging, cycling primarily involves the lower body. Standard equations are available to compute the MET intensity of cycling at various rates, which helps regulate training intensity. Outdoor cycling requires suitable weather and equipment. Many fitness facilities have stationary cycles for indoor training. Many of these provide computerized estimates of the number of calories expended. Cyclists have fewer orthopedic injuries because cycling does not involve the steady pounding on the ground found with jogging. Yet, there is risk of serious injury when cycling on busy streets. Some cities in the United States and Europe have special bike trails.

Cross-country skiing

This is an excellent mode of exercise that involves both the arms and legs. World class cross-country skiers have the highest recorded VO2max values, well in the 80s. Just because very fit people choose this type of exercise does not mean that it has any extraordinary fitness benefits above other types of suitable aerobic exercise.The obvious limitation of this form of exercise is the need for special equipment and a suitable environment. Competitive skiers now train in the summer with the use of "roller-skate type" equipment that duplicates the skiing action.

Rowing

This sport is growing in popularity. Like cross-country skiing, rowing involves not only the large muscles of the legs, but also the arms and back. Rowing's obvious limitation is the need for a suitable body of water and a rowing scull. There are rowing clubs that share sculls among members. Many fitness centers have rowing machines for indoor training. Rowers have fewer orthopedic injuries compared to joggers because the rowing action does not involve the steady pounding on the ground. Astronauts use rowing and cycling exercise in space to battle the effects of the micro gravity environment.

Aerobics

This has become a very popular exercise mode. Aerobic facilities are generally available so finding somewhere to exercise is usually not a problem. Videos and television programs are also available for home use. Exercising too forcefully can cause orthopedic problems, which can be minimized with low-impact aerobics. It is difficult to quantify the absolute MET intensity of aerobics. Two individuals may "follow" the same routine, but exercise at different MET intensities. You can gauge your individual exercise intensity by using exercise heart rate or RPE.

TABLE 3-2. Average and range (R) of the MET intensity of common sports and exercise modes.

LIGHT INTENSITY			MODERATE INTENSITY			HEAVY INTENSITY		
MODE	**AVG**	**R**	**MODE**	**AVG**	**R**	**MODE**	**AVG**	**R**
Archery	3.9	3-4	Cycling for Plea-sure	5.1	3-8	Badminton	5.8	4-9
Billiards	2.5	2-3	Dancing (social)	5.1	4-7	Basketball (game play)	8.3	7-12
Bowling	3.1	2-4	Golf (walking)	5.1	4-7	Dancing (aerobic)	7.5	6-9
Fishing	3.7	2-4	Hiking	5.1	3-7	Handball	9.1	8-12
Horseshoe Pitch-ing	2.5	2-3	Hunting Small Game	5.1	3-7	Racquetball	9.1	8-12
Sailing	2.9	2-3	Scuba Diving	5.1	2-9	Soccer	9.1	8-12
Shuffleboard	2.5	2-3	Volleyball	4.5	3-6	Tennis	7.1	5-9

Sports

Many play sports for enjoyment and competition. If the MET intensity is high enough, sports also can develop aerobic fitness. Games such as tennis, racquetball, and basketball develop aerobic fitness because they are intense enough and they use the body's large muscle groups. In contrast, bowling is a popular, enjoyable sport, but due to its low absolute exercise intensity, it is a poor form of aerobic exercise. Table 3-2 presents general ranges and average MET intensities of many popular sports. The average represents a "typical" intensity level, while the range represents the usual variation. Those listed under "Heavy Intensity" are the best sports for developing aerobic fitness.Understand that your intensity will not necessarily be the same as shown in the table. It will depend upon the intensity with which you play the sport (%VO2max) and your personal aerobic fitness level (VO2max).

Sports may not be the best forms of aerobic exercise to use early in a training program. Many games require stopping and starting, causing intensity to vary. The excitement and periodic need for peak performance can cause you to "push" too hard. This may cause you to exceed your "safe" training intensity, and increase the risk of injury. The best way to minimize injury is to engage in a conditioning program and not overextend yourself during play.

MONITORING AEROBIC EXERCISE

Improving your aerobic fitness is important because the higher fitness level allows you to exercise harder and longer. This increases your capacity to expend energy. The reason for this is that you can exercise at a higher absolute intensity (MET intensity) while at the same percentage of VO2max. Exercising at a higher absolute intensity increases the energy expended per minute. Additionally, a higher level of aerobic fitness allows you to exercise longer without fatigue because any absolute level of activity will be a lower percentage of your VO2max. Figure 3-7 illustrates these important ideas.

Monitoring exercise involves combining exercise intensity, duration, frequency, and mode into a single term. This can be done by computing total caloric expenditure or aerobic minutes. The aerobic minute method is a simple method of gaging exercise for improving aerobic fitness. The method does not provide an estimate of the amount of energy expended. The caloric expenditure method does.

MONITORING EXERCISE BY AEROBIC MINUTES

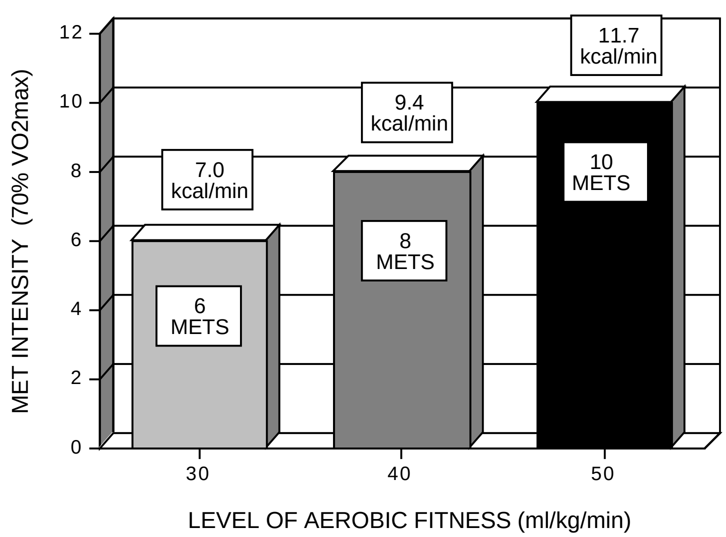
Aerobic minutes, developed by one of the authors (R.M.R), is the duration of exercise at a suitable intensity, is a simple method for the quantification of aerobic exercise to improve fitness. At rest you use energy, but this does not increase your aerobic fitness. Exercise intensity is the stress required to increase fitness. It must be above a threshold level before aerobic fitness increases significantly. Aerobic minutes are the number of minutes you exercise at an intensity adequate to obtain an aerobic training benefit, i.e., increase your VO2max. That is, aerobic minutes are the number of minutes you exercise within a relative intensity of 60-80% of your VO2max.

The simplest way of determining aerobic minutes is to monitor relative exercise intensity. This chapter shows that exercise heart rate and RPE are excellent methods for determining relative intensity. Measuring heart rate during jogging and walking is easy, but much more difficult with forms of exercise such as playing tennis where heart rate varies continuously. For these more variable exercise modes, the RPE method is more suitable. The appropriate RPE range is from 4 to 7. Remember, as you become more fit, you will need to increase your absolute intensity (e.g., jog faster) to maintain the same relative intensity, e.g., 70% of your VO2max. This important idea of progression has been discussed fully.

Computing aerobic minutes is very simple. Just count the number of minutes of exercise which you perform at an intensity of 60-80% of your VO2max. The aerobic minute recommendations for young adults are:

FIGURE 3-7. Increasing aerobic fitness enhances your capacity to expend calories. Shown is the MET intensity at 70% of VO2max for a 154-pound person for different levels of aerobic fitness. The figure shows that the number of kilocalories expended increases as aerobic fitness increases.

Increasing aerobic fitness increases your ability to expend calories and exercise longer at any absolute intensity.



- **STARTER MAINTENANCE PROGRAM**
  - 20 Aerobic Minutes per Session
  - 60 Aerobic Minutes per Week
- **PROGRAM TO INCREASE FITNESS**
  - 30 Aerobic Minutes per Session
  - 90 Aerobic Minutes per Week

MONITORING EXERCISE BY CALORIC EXPENDITURE

Scientists have developed methods for determining energy expenditure of humans. The most accurate, but impractical method is by direct calorimetry. A slightly less accurate but useful method is by indirect calorimetry. These methods provide the theoretical basis for the energy expenditure equations provided in this chapter.

Total energy output is the sum of energy lost as heat plus energy transferred through mechanical work, water vapor, urine, and feces. Physiologically, the most accurate way to assess energy expenditure is through the measurement of the total heat energy liberated (calories) during an activity and for a while afterward. In the laboratory, a calorimeter measures the heat energy released by assessing the temperature rise of a known volume of water. A calorie is the heat energy required to raise the temperature of 1 gram of water 1° centigrade. A calorie is a very small quantity so the measurement unit used more typically for evaluating exercise and diets is the kilocalorie, which represents 1,000 calories. In this text, whenever calories are used, the unit is actually kilocalories.

The direct calorimetry system requires specially developed chambers and very accurate scientific equipment to measure temperature changes. This method is expensive and rarely used. Direct calorimetry is the “gold standard” for the evaluation of energy expenditure during rest and physical activity.

Indirect calorimetry circumvents many technical problems associated with direct calorimetry. Indirect calorimetry involves measuring the volume of air breathed during exercise and the amount of oxygen and carbon dioxide in the expired air during rest or exercise. Brooks and Fahey [5] describe the basis of oxygen utilization on metabolism.

> Metabolism can be defined as the total of processes occurring in a living organism. Because heat is produced by those processes, the metabolic rate is shown by the rate of heat production. All processes of metabolism ultimately depend on biological oxidation, so measuring the rate of oxygen consumption yields a good estimate of the rate of heat production, or metabolic rate. The maximum capability of an individual to consume oxygen (VO2max) is highly related to that individual’s ability to do hard work over prolonged periods. A high capacity to consume and use oxygen shows a high metabolic capacity. (p. 35)

The assumption of indirect calorimetry is that the required energy will be produced from the metabolism of foodstuffs with oxygen. Depending upon the food source, the energy equivalent of oxygen ranges from 4.7 kilocalories per liter of oxygen for 100% carbohydrate metabolism to 5.1 kilocalories per liter of oxygen for fats. Since metabolism is rarely 100% of either, the caloric expenditure of aerobic exercise ranges between these extremes.

The most common method of estimating energy expenditure during work and exercise is with energy cost equations. These equations are obtained by comparing the actual energy cost of an activity, usually by indirect calorimetry, to the external energy cost, such as the speed and grade, or other measurements of intensity. The assumption of these equations is an energy equivalent of oxygen is about 4.8 kilocalories per liter. The equations are less accurate, but a more practical method of estimating caloric expenditure compared to direct or indirect calorimetry. Based on these studies the relationship between VO2 and calories burned during aerobic exercise has been defined. One liter of oxygen burned yields 4.8 kilocalories. For a 60 kilogram person then, exercising at one MET yields 1 kilocalorie per minute. Therefore, for a 60 kilogram person, total kilocalories equals the product of MET-I and minutes of exercise, i.e., duration of exercise.Total caloric expenditure varies according to the person's body weight. The next section of this chapter presents and illustrates these equations.

Computing Caloric Expenditure - General Equation

The information required to calculate the number of calories expended through exercise is:

1. Exercise intensity expressed in METs (MET-I).
2. Duration of exercise in minutes.
3. A body weight factor, which is weight in kilograms divided by 60. The equation for converting weight in pounds to the weight factor is:

WEIGHT FACTOR **(EQ 3-9)**

$$\text{Weight Factor} = \left(\frac{\text{Weight in Pounds} \times 0.455}{60}\right)$$

The general equation for computing the total number of kilocalories expended during an exercise session is:

GENERAL CALORIC EXPENDITURE EQUATION **(EQ 3-10)**

$$\text{Kcals} = (\text{MET-I} \times \text{Duration in Minutes} \times \text{Weight Factor})$$

Calculation Example - Caloric Expenditure Walking and Jogging. Assume two individuals exercise together, both jogging four miles in 35 minutes, a MET-I of 11.4 METs. The body weights of the two joggers are 193 and 148 pounds. The weight factors (EQ 3-9) for these two weights are 1.46 and 1.12. The total caloric expenditure (EQ 3-10) for each is:

$$\text{Jogger 1} = (11.4 \times 35 \times 1.46) = 583 \text{ kcals}$$

$$\text{Jogger 2} = (11.4 \times 35 \times 1.12) = 447 \text{ kcals}$$

These computational examples show that caloric expenditure is not only dependent on MET-I and duration of exercise, but also body weight. For the same exercise program heavier people expend more energy than those who weigh less. The reason for this is that it takes more energy to move the larger mass.

You must know MET-I to use the general caloric expenditure equation (Eg. 3-10). Standard equations are available to compute the MET-I for exercise modes that involve movement, e.g., walking, jogging, and cycling. In contrast, sports such as tennis or basketball, and other forms of aerobics do not have suitable energy equations. This is because energy expenditure cannot be accurately measured, and the absolute intensity will vary from person to person. The MET intensity of these exercise modes depends upon: 1) how vigorously you exercise; and 2) your VO2max. How vigorously you exercise can be determined by using indicators of relative intensity—exercise heart rate and RPE. Provided next are these methods of calculating caloric expenditure.

Computing Caloric Expenditure - Sports and Other Common Exercise

It is common practice to list the intensity of sports and other activities. Table 3-2 gives the average and range MET intensities for common exercise modes. These MET-I values are typical absolute intensities for the general population. To illustrate, the table shows that the average MET-I for tennis is 7.1 METs, with a range from 5 to 9 METs. The reason for the MET-I range can be appreciated by observing people play tennis. The level of play of world-class players is extremely vigorous. In contrast, recreational players usually play at a much lower intensity. Running may be the exception, not the rule for most recreational players, while the opposite would be the case for world-class players. Obviously, the MET-I increases as the physical activity becomes more strenuous, e.g., running instead of walking. For these reasons, the absolute intensity values are just general guidelines; these MET-I estimates are not very accurate for determining your true caloric expenditure during exercise.

Your actual absolute exercise intensity (MET-I) depends upon how hard you exercise, that is your relative intensity (i.e., percentage of VO2max), and your maximum aerobic fitness, or VO2max. By knowing your VO2max and the relative intensity of exercise, MET-I can be determined in the following way.

1. **Find your VO2max.** Chapter 2 presents several acceptable methods. The U of H non-exercise method is especially valuable.
2. **Find the relative intensity of exercise.** This can be determined from your exercise heart rate or RPE.
3. **Find your MET-I.** Table 3-3 gives the absolute intensity (MET-I) for various levels of aerobic fitness, and RPE.
4. **Compute your caloric expenditure.** Use EQ 3-10 to compute caloric expenditure.

TABLE 3-3. MET intensity (MET-I) for levels of aerobic fitness at different levels of RPE determined exercise intensity.

VO2MAX	RPE 4	RPE 5 & 6	RPE 7
	60%VO2MAX	70%VO2MAX	80%VO2MAX
20 - 22	3.6	4.2	4.8
23 - 25	4.1	4.8	5.4
26 - 28	4.6	5.4	6.1
29 - 31	5.1	6.0	6.8
32 - 34	5.6	6.6	7.5
35 - 37	6.1	7.2	8.2
38 - 40	6.6	7.8	8.9
41 - 43	7.2	8.4	9.6
44 - 46	7.7	9.0	10.2
47 - 49	8.2	9.6	10.9
51 - 53	8.9	10.4	11.8
54 - 56	9.4	11.0	12.5
57 - 59	9.9	11.6	13.2
60 - 62	10.4	12.2	13.9

Calculation Example - Caloric Expenditure of Playing Tennis. Assume two people of different skill levels play tennis together. Assume the more skilled player has a higher aerobic capacity (40 ml/kg/min) than the other (35 ml/kg/min). Because of superior skill level, the more fit player can control the ball and force the less fit person to run all over the court. Because of this, the RPE rating of the less fit player is 7. In contrast, the RPE of the more fit player is only 4. Using Table 3-3, the MET intensities are: Less Fit Player, 8.2 METs; and Higher Fit Player, 6.6 METs. If the body weights of the two are the same, 165 pounds (weight factor 1.25), the computed caloric expenditure (EQ 3-10) for 55 minutes of tennis would be:

$$\text{Less Fit Player} = (8.2 \times 55 \times 1.25) = 564 \text{ kcals}$$

$$\text{More Fit Player} = (6.6 \times 55 \times 1.25) = 454 \text{ kcals}$$

This example shows why MET-I must be individually determined and not estimated from the table values. These two people played the same game of tennis for the same number of minutes, yet in this example, the less fit player expended over 100 kilocalories more than the higher fit player. Both fitness level and intensity of play must be considered.

Logging is a useful method of monitoring your exercise program and judging progress. Chapter 6 illustrates the use of the computer to log exercise and compute caloric expenditure. If computer facilities are not available, exercise logs can be kept manually with a few simple calculations. This is shown in the lab section (Appendix B, Lab 6).

Computing Caloric Expenditure for Walking and Jogging

Equations 3-2 and 3-3 can be used to estimate the MET intensity for various walking and jogging speeds. As you will see in this section, it is not necessary to compute the MET-I to estimate the caloric expenditure for walking and jogging. An important energy expenditure principle is that the amount of calories expended during exercise depends on the total amount of work completed [6, 14, 15].

Caloric expenditure is the product of MET-I and exercise duration. The total work idea applied to walking and jogging is that the total number of calories consumed is directly related to the total distance traveled. Although MET-I increases as your walk or jog faster, it takes less time (i.e., duration) to cover a given distance, while the total energy consumed over the distance covered is the same. Because of this, these equations can be simplified. The distance covered in miles replaces MET-I and duration. The simplified equations are:

CALORIC EXPENDITURE EQUATION FOR WALKING **(EQ 3-11)**

$$\text{Walking: kcal} = (75 \times \text{Distance Walked in Miles} \times \text{Weight Factor})$$

CALORIC EXPENDITURE EQUATION FOR JOGGING **(EQ 3-12)**

$$\text{Jogging: kcal} = (100 \times \text{Distance Jogged in Miles} \times \text{Weight Factor})$$

Calculation Example - Computing caloric expenditure of walking and jogging. Assume that the exercise program of a person who weighs 176 pounds is to walk 4 miles in 75 minutes on one day and to jog 3.2 miles in30 minutes on another. The weight factor for the 176-pound person is 1.33. The caloric expenditure for walking and jogging is:

$$\text{Kcal Walking} = (75 \times 4.0 \times 1.33) = 399 \text{ kcals}$$

$$\text{Kcal Jogging} = (100 \times 3.2 \times 1.33) = 399 \text{ kcals}$$

These computations show that the caloric expenditure for walking 4 miles was identical for jogging the shorter distance. In terms of caloric expenditure, the benefits of these two exercise programs are the same. But does the walk increase aerobic fitness? Remember, increases in VO2max depend upon a suitable exercise intensity, 60-80% of VO2max. In order to determine this, the relative intensity of the walk (4 miles in 75 minutes) and jog (3.2 miles in 30 minutes) must be determined. Equations 3-2 and 3-3 provide these calculations.

$$\text{Walk: MET-I} = \left[75 \times \left(\frac{4.0}{75}\right)\right] = 4.0 \text{ METs}$$

$$\text{Jog: MET-I} = \left[100 \times \left(\frac{3.2}{30}\right)\right] = 10.7 \text{ METs}$$

Equation 3-4 is then used to compute exercise intensity i.e., percentage of VO2max.Assuming the VO2max of the person is 50 ml/kg/min (14.29 METs), the walk and jog intensities are:

$$\text{Walk: \%VO2max} = \left(\frac{4.0}{14.29}\right) \times 100 = 28\%$$

$$\text{Jog: \%VO2max} = \left(\frac{10.7}{14.29}\right) \times 100 = 75\%$$

In terms of weight loss and possibly health factors, the programs have similar benefits, but the walking program would not increase aerobic fitness. The intensity is too low, and aerobic minutes would be zero. In contrast, the intensity of the jog is suitable for increasing VO2max.

The equations also show that for the same distance, jogging expends more calories than walking [6, 14, 15]. When a person jogs their arms swing, and movement comes from small leaps that lift the body. Both actions use more energy, and by that expend more calories. The walk and jog equations are only valid for traveling on level ground. Traveling up hills increases caloric expenditure because of an increase in absolute intensity. The MET-I of walking and jogging up a hill depends on both speed and the percent grade of the hill. Table 3-4 gives MET-I for walking and jogging up hills of various grades. These MET intensities provide accurate estimates of caloric expenditure if you know the grade of the hill. This may not be realistic because the grade for most outdoor courses is not constant. If you would rather walk than jog, Table 3-4 shows that the MET-I can be increased by walking up hills, or if a treadmill is available, raise the elevation. This would be similar to walking up a hill.

The total work equations mathematically illustrate an important aerobic exercise principle for walking and jogging—caloric expenditure depends upon the distance traveled, not the speed of movement. Many different duration-intensity combinations produce the same total caloric expenditure. Since high intensity exercise is not enjoyable and increases the risk of injury, it is usually better to exercise at a lower, more comfortable intensity for a longer duration. The common idea of “no pain, no gain” is not correct. This produces the same caloric expenditure. Remember, that to increase your aerobic fitness you must exercise strenuously enough to obtain adequate aerobic minutes.

TABLE 3-4. MET intensity (MET-I) for walking and jogging speeds (mph) on level at various grades (%).

SPEED (mph)	PERCENT ELEVATION OF GRADE					
	0%	3%	6%	9%	12%	15%
WALKING						
2.5	3.1	3.8	4.6	5.3	6.1	6.8
3.0	3.7	4.6	5.5	6.4	7.3	8.2
3.5	4.3	5.4	6.4	7.5	8.5	9.6
4.0	5.0	6.2	7.4	8.6	9.8	11.0
4.5	5.6	6.9	8.3	9.6	11.0	12.3
JOGGING						
4.5	7.5	8.8	10.2	11.5	12.9	14.2
5.0	8.3	9.8	11.3	12.8	14.3	15.8
5.5	9.1	10.8	12.4	14.1	15.7	17.4
6.0	10.0	11.8	13.6	15.4	17.2	19.0
6.5	10.8	12.7	14.7	16.6	18.6	•
7.0	11.6	13.7	15.8	17.9	•	•
7.5	12.5	14.7	17.0	19.2	•	•
8.0	13.3	15.7	18.1	•	•	•

*Unrealistic MET-I.

The total work equations make it easy to log exercise in terms of caloric expenditure. The final chapter illustrates the use of the computer to log exercise by this method. The exercise logging lab (Appendix B) provides a form that eases the calculation of caloric expenditure for walking and jogging

DESIRABLE ENERGY EXPENDITURE LEVELS

Caloric expenditure is important for weight control and health promotion. We have shown that the number of calories expended during exercise depends not only on exercise intensity and duration, but also body weight. If two people of different weights complete the same exercise program (e.g., jog 3.5 miles in 30 minutes), the person who weighs more expends more calories. To correct for this, caloric expenditure can be expressed per kilogram of weight. The recommended *minimum* caloric expenditure is 4 kilocalories per kilogram of body weights per aerobic exercise session [2]. The equation for computing the minimum number of total kilocalories per aerobic exercise session is:

MINIMUM CALORIC EXPEDITURE **(EQ 3-13)**

$$\text{Total kcal per Session} = \left(\frac{\text{Weight in Pounds}}{2.2}\right) \times 4$$

The minimum recommended caloric expenditure level of 4 kilocalories per kilogram of body weight per session is much lower than the 2,000 kilocalories per week shown by medical scientists to reduce the risk of cardiovascular diseases and promote health. The

2,000-kilocalorie per week criterion not only considers recreational exercise, but also the energy expended through daily living tasks (e.g., walking to work, climbing stairs, gardening, etc.). The 4-kilocalorie per kilogram of body weight guideline considers just the exercise program and not daily living tasks. Adding the caloric expenditure from daily living tasks to an energy expenditure of about 1,000 kilocalories (for a 154-pound person) from a structured aerobic exercise program per week is likely to translate into more than 2,000 kilocalories of total exercise per week. An assumption of the ACSM caloric guideline if the person's daily living habits are reasonably active—climbing stairs rather than using elevators, and walking rather than riding—have health promotion benefits.

SOME GENERAL EXERCISE CONSIDERATIONS

Aerobic exercise is generally safe and promotes good health, but it is important to follow some simple guidelines.

Overwork

Try to avoid overworking. Do not strain yourself. Exercise at an intensity that is comfortable. If it feels too difficult, slow down.

Environmental considerations

Beware of exercising in the extremes of weather. You should avoid vigorous exercise in hot, humid environments. This can lead to dehydration, heat exhaustion, and even heat stroke, which can be fatal. Discussed next are the symptoms of these heat disorders and first aid procedures.

- **Heat cramps** are painful spasms of the muscles used during exercise. Massage or mild exercise of the affected areas and taking in fluids often relieves the cramps.
- **Heat exhaustion** causes fatigue, hyperventilation, headache, loss of concentration, light headedness, nausea, and muscle cramps. Sweating and chills may be present. Go to a cool, dry environment, and drink plenty of fluids.
- **Heat stroke** is characterized by altered consciousness and a cessation of sweating. The alteration of consciousness may progress to coma, seizures, or collapse. The skin is flushed, hot, and dry. Heat stroke requires immediate medical treatment, and getting the person to a cool, dry environment. Give the person plenty of fluids.

If you have to exercise in the heat, do it during the coolest parts of the day, early in the morning, or in the evening. Be sure to drink plenty of water *during* and *after* exercise. It is not advisable to take salt tablets during exercise because this may cause further dehydration. After vigorous exercise, a mild amount of salt replacement is fine, and can often be obtained with a normal diet. Drinking orange juice after exercise is one way to replace needed fluids.

Exercising in very cold weather can put additional strain on your heart and muscles. An adequate warm-up is mandatory. The combined effect of wind and temperature, the wind-chill factor, should be considered. Table 3-5 gives the wind-chill factor, and exercise guidelines. Heavy air pollution aggravates respiratory problems such as asthma. In susceptible people, it can even lead to angina, a serious heart condition that requires medical care.

TABLE 3-5. *WIND CHILL DETERMINATION:* Both wind speed and temperature should be considered when judging the safety of exercise in cold weather. The numbers in the boxes indicate what temperature (without wind) the environment feels like. For example, if the temperature is 30° F and the wind is 25 mph, it feels as if the temperature is 0° F.

WIND (mph)	*TEMPERATURE in FARENHEIT* 40°	30°	20°	10°	0°	-10°	-20°	-30°
0	40	30	20	10	0	-10	-20	-30
5	35	25	15	5	-5	-15	-25	-35
10	30	15	5	-10	-20	-35	-45	-60
15	25	10	-5	-20	-30	-45	-60	-70
20	20	5	-10	-25	-35	-50	-65	-80
25	15	0	-15	-30	-45	-60	-75	-90
30	10	-5	-20	-35	-50	-65	-80	-95

LITTLE ***INCREASING*** ***GREAT***

DEGREE OF DANGER →

Clothing

It is important to dress appropriately. Your attire should consist of thin, loose fitting clothing. If you walk or jog, get a good pair of shoes. There are many acceptable and stylish brands available; concentrate on comfort and support. If ankle, knee or hip problems develop during your exercise program, it may be due to your shoes. Different shoes or a prosthesis may be needed.

Do not use rubber suits when exercising in hot humid weather. The body must breathe to cool properly. Rubber suits keep in the body heat and increase the risk of thermal injury.

Signs of Exercise Intolerance

The old “wives tale” that exercise must hurt to be beneficial is not true. Aerobic exercise programs should be comfortable, i.e., between 60% and 80% of your aerobic capacity (i.e., VO2max). Although exercise is generally safe, it can cause or unmask serious problems that require medical attention. If during exercise, any of the following symptoms develop, stop exercise and consult a physician.

- Chest discomfort, particularly a heavy, “squeezing” sensation in the chest, jaw, neck, shoulder or arm that comes on with exercise and subsides with rest.
- Shortness of breath out of proportion to your level of exercise.
- After exercise, irregular heartbeats or skipped beats that feel like a fluttering or bumping in the chest.
- Severe dizziness, nausea, or vomiting that usually comes on with exercise.
- Severe aches or pains aggravated by exercise.

SUMMARY

A sound aerobic exercise program is one that meets your needs, goals, and fitness level. A properly designed program expends sufficient calories and increases your VO2max. This reduces the risk of obesity and heart disease and allows you to work and play without fatigue. The essential elements of an aerobic exercise program are: intensity, duration, frequency, mode, and progression. A properly designed aerobic program integrates these elements. The desirable guidelines are:.

- **Intensity of training**—60 to 80% of your VO2max, which can be determined by exercise intensity, heart rate, or RPE.
- **Frequency and duration of training**—20 to 60 minutes of continuous aerobic activity, 3 to 5 times per week leads to aerobic improvement.
- **Progression**—As you become more fit, your capacity to exercise steadily improves. As fitness increases, you need to increase intensity and duration gain additional benefit.
- **Mode of exercise**—The recommended activities use the large muscle groups, in a continuous rhythmical nature. The large muscle groups of the body must be exercised to tax the body's oxygen delivery system, the heart, lungs, and circulation.

Aerobic minutes and *caloric expenditure* provide two complementary ways of evaluating the quality and quantity of an aerobic exercise program. Aerobic minutes method are the number of minutes you exercise aerobically at a relative intensity of 60-80% of your VO2max. The number of calories expended through aerobic exercise is the product of absolute exercise intensity (MET-I), duration of exercise in minutes, and body weight. The caloric expenditure for walking and jogging depends upon the total number of miles traveled. For a 60-kilogram person, the number of calories expended to travel one mile is 75 for walking and 100 for jogging. For many sports and other forms of aerobic exercise, people will vary the intensity of exercise. For these exercise modes, MET-I is computed from the person's VO2max and relative exercise intensity determined from exercise heart rate or RPE.

The recommended minimum level of exercise for a sound aerobic exercise program for young adults is:

AEROBIC MINUTES

- 20 Minutes per Session
- 60 Minutes per Week

KILOCALORIES PER KILOGRAM OF BODY WEIGHT

- 4 per Exercise Session
- 12-16 per Week
- ≈ 1,000 kilocalories per week for a structured exercise program

STUDY QUESTIONS

These study questions should help you figure out if you have mastered the content in this chapter.

1. What are the scientific recommendations for an aerobic exercise program that will develop physical fitness?

- Exercise frequency?
- Exercise duration?
- Exercise intensity?
- Exercise mode?
- Exercise progression?

2. If VO2max is 50 ml/kg/min, what will be the relative exercise intensity (i.e.%VO2max) for the following conditions?

- Walking at 3.5 mph
- Jogging at 7.3 mph

3. Define and relate the following terms.

- Percentage of VO2max
- Training heart rate zone

4. What are the training heart rate zones for men and women of the following ages? 25, 35 and 45 years.

5. What are aerobic minutes and how may they be used to evaluate an aerobic exercise program?

6. What terms are needed to calculate the number of kilocalories expended during exercise?

7. Why is it difficult to find the MET intensity of activities such as aerobic dance or tennis as compared to walking, jogging or pedaling a stationary bike?

8. What is the MET intensity for the following?

- Walking 3.6 miles in 55 minutes
- Jogging 5 miles in 50 minutes.

9. What is the MET-I for the following for a 25-year-old man with a VO2max of 45 ml/kg/min and a 25-year-old woman with a VO2max of 35 ml/kg/min?

- Playing basketball at a RPE of 6.
- Aerobics at a heart rate of 140 beats/min.

10. What is the caloric expenditure for a person who weighs 175 pounds for the following?

- Walking 4.3 miles.
- Jogging 6.1 miles.
- With a VO2max of 43 ml/kg/min, exercising for 35 minutes at 70% of VO2max.

REFERENCES

1. ACSM, Position statement on the recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. *Medicine and Science in Sports and Exercise*, 1978.10:vii-x.

2. ACSM, The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Medicine and Science in Sports and Exercise*, 1990. 22:265-274.

3. Borg, G., A category scale with ratio properties for intermodal and interindividual comparisons, in *Psychophysical Judgment and the Process of Perception*, H.G. Geissler and P.Petzold, Editors. 1982, VEB Deutscher Verlag der Wissenschaften: Berlin.

4. Borg, G. and D. Ottoson, *The perception of exertion and physical work*. 1986, Stockholm: The Wenner-Gren Center.

5. Brooks, G. and T. Fahey, *Exercise Physiology: Human Bioenergetics and its Applications*. 1984, New York.: John Wiley and Sons.

6. Cox, G.E., The Energy Cost of Horizontal Running, Master's Thesis in Health and Human Performance. 1996, University of Houston: Houston.

7. Fletcher, G.F., et al., Position statement: statement on exercise: benefits and recommendations for physical activity programs for all Americans. *Circulation*, 1992. 86:340-344.

8. Gordon, T., et al., Diet and Its Relation To Coronary Heart Disease and Death In Three Populations. *Circulation*, 1981. 63:500-515.

9. Paffenbarger, R.S., et al., Work-energy level, personal characteristics, and fatal heart attack: a birth cohort effect. *American Journal of Epidemiology,* 1977. 105:200-213.

10. Paffenbarger, R.S., A.L. Wing, and R.T. Hyde, Physical activity as an index of heart attack risk in college alumni. *American Journal of Epidemiology*, 1978. 108:161-175.

11. Paffenbarger, R.S., et al., A natural history of athleticism and cardiovascular health. *Journal of American Medical Association*., 1984. 252:491-495.

12. Paffenbarger, R.J., et al., Physical activity, all cause mortality, and longevity of college alumni. *New England Journal of Medicine*, 1986. 314:605-613.

13. Pate, R.R., et al., Physical activity and public health: A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association*, 1995. 273(5):402-407.

14. Ross, R.M. and A.S. Jackson, Development and validation of total-work equations for estimating the energy cost of walking. *Journal of Cardiac Rehabilitation*, 1986. 6:185-192.

15. Ross, R.M. and A.S. Jackson, *Exercise Concepts, Calculations, and Computer Applications*. 1990, Carmel, IN: Benchmark Press.

16. Taylor, H.L. et. al., Death Rates Among Physically Active and Sedentary Employees of the Railroad Industry. *American Journal of Public Health,* 1962. 52:1692-1707.