BLOCK 2

CARDIO-VASCULAR AND RESPIRATORY ENDURANCE

UNIT 4 PHYSICAL WORKING CAPACITY AND PHYSICAL FITNESS*

Contents

Learning Objectives

After going through this unit you will be able to comprehend:

- the definition, meaning and components of Physical Fitness;
- acute physiological adjustments from rest to sub-maximal exercise;
- acute physiological adjustments from rest to maximal exercise; and
- evaluation of response and assessment.

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4.0 INTRODUCTION

Since time immemorial humans have always attempted to get better and better in all their endeavors. We can observe these changes that have happened in the world around us from the past to the present. It will be so in the future as well though we cannot foretell what could actually happen. But we can be sure that there will be some changes, some for good and some could be for worse too. Important parts of such an endeavor is their zeal to have a better physical appearance, become stronger and look as perfect as possible. However, many of we humans have been forced to getting fitter, just to manage the widely prevalent life style diseases that have come to haunt us today. On one side there are people who are working hard physically to even make their ends meet such as a farmer or a construction laborer, on the other side there are people who are compelled to lead a sedentary life style but have no options to engage themselves in any form of physical activities or they are ignorant of the consequences of an inactive lifestyle or plainly very lazy to attempt any such activity. On yet another side there are people who are dedicated fitness freaks or sportspersons for whom physical fitness, perfection and performance in their respective fields have become a lifelong endeavor. But a significant number of people are on the side where they are engaged in their respective livelihood but take time out to work on their fitness just to stay healthy or manage any adverse health condition effectively. Examples of the former are people like Roger Federer the tennis ace or Mary Kom the ace Indian Boxer and examples of latter are the thousands of jogger and walkers, amateur gym goers and people engaged in regular exercises such as aerobics, yoga and Zumba, etc. Further, engaging in regular physical activities of any form will help in reducing the risks of many cardiovascular diseases such as high blood pressure, cardiac arrest etc. Regular exercise will make our heart stronger and more efficient. Hence, we can understand that whatever be our profession or livelihood we have to work to develop or maintain our fitness by engaging in regular physical activities of any form in order to lead a healthy and disease free life.

4.1 DEFINITION AND MEANING OF PHYSICAL FITNESS

Physical Fitness can be defined as our ability to carry out our everyday tasks smoothly and effectively and even after completion of the tasks we have energy in reserve to be cheerful and happy at home. Further, fitness can be either health related or performance related. Fitness related to health includes aerobic fitness, muscular fitness, flexibility and body composition whereas fitness related to performance consists of agility, coordination, balance, reaction time, power and speed. Therefore for you to be fit in terms of health or performance, you have to have a combination of parameters in which you have to be good.

4.2 HEALTH RELATED PHYSICAL FITNESS

Let us understand what is health related physical fitness. Cardio respiratory fitness is often referred as aerobic endurance or aerobic fitness. It refers to the functions of our heart, blood vessels and lungs in supplying vital oxygen to working muscles and tissues.

Muscular fitness refers to the ability of a muscle or a group of muscles to contract continuously without getting fatigued. Muscular fitness is slightly different from muscular endurance in the sense that the latter is the ability of the muscles to perform under conditions of fatigue (https://www.reference.com/health/definition-muscular-fitness-ce).

Flexibility is an ability to have maximum range of movement around a joint. In other words it can be said as the ability that allows the joint to function in its full range of movement. Flexibility will differ from person to person and will gradually reduce if not used appropriately.

Body Composition refers to the makeup of your body. The body is made up of lean tissue and fat tissue. Excessive amounts of body fats are related to poor health outcomes especially the fat around the abdominal area.

4.3 PERFORMANCE RELATED PHYSICAL FITNESS

Now what are the performances related physical fitness? Agility is the ability to change direction rapidly and accurately in response to outside stimuli. In most sports the athlete has to move from one position to another very quickly. Example: Quick moments executed by a rider in Kabaddi, a defender in kho-kho, a fielder in cricket, or a badminton player on the court to name a few.

Coordination is the ability to move the body in ways that requires complex inputs and carefully graded muscle contraction. In sports, complex movements cannot be performed without proper coordination. In other words we can say that coordination is the ability to combine different types or movements into specific meaningful patterns.

Balance can be defined as the ability to maintain the body in a defined position over changing centers of gravity. Maintaining neuromuscular system in a static condition for an efficient response or to control it in a specific efficient posture while it is moving, is the underlying principle of balance (UGC-NET Digest on Physical Education- Dr. M.L. Kamlesh).

Reaction time which is the sub component of timing is the ability of a person to initiate a movement in response to a stimulus. Reaction time can be of two types, namely simple reaction time (SRT) and choice reaction time (CRT). The former refers to the time the athlete takes to identify the presence of the stimulus and the later refers to the time taken to initiate a movement as per the choice of the athlete.

Power is the combination of speed and strength. In other words it is your ability to work against resistance in quickest possible time. Jump is the very common movement that is performed with power. A quick good throw is also possible with adequate generation of power.

Speed is the ability to rapidly contract your muscles in a sequenced manner to propel your body. It could also be termed as your capacity to execute successive movements of similar pattern in the quickest possible time such as the 100 meters dash or a quick run by the batsman in Cricket.

4.4 WHY DO I NEED TO BE FIT?

When we are fit, we manage all our everyday tasks in our work lives and our home lives with increased vitality and enthusiasm and reduced stress. We are much less likely to lose our temper under pressure if we are fit, or to make mistakes. We are more likely to enjoy our work and our family life and friendships.

YOU' RE UNFIT WHEN. . . .

- You get out of breath very quickly while climbing the stairs.
- You get breathless just as quickly while hurrying for your bus or train.
- You find it hard to pace up with little kids.
- You feel completely drained out after a tuff game of tennis or badminton.
- You are continuously adding on to your weight.
- You feel like taking a vehicle to all the places
- You get exhausted much quickly and easily than before.

PHYSICAL AND MENTAL ADVANTAGES OF GOOD GENERAL FITNESS

Being fit helps to prevent heart disease and osteoporosis, controls blood pressure and diabetes, develops body strength, alleviates arthritis, improves mobility, reduces breathlessness on exertion and keeps your weight in check. It also helps you to fight off depression and feelings of apathy, reduces the risk of a stroke - which could leave you completely incapacitated - and reduces general everyday stress.

4.5 HOW EXERCISE IMPACTS OUR BODY?

4.5.1 Acute Physiological Adjustments due to Exercise

The amazing human body that we have always responds to any form of work load on it. Consequently it also responds in equal measure to lack of exercises too. However, the distinguishing factor between the two measures is that change in our body can be felt quickly when work load is applied whereas the adjustments to our body systems due to lack of exercises will be gradual and can be noticed only after some period of time.

Let us understand the effect of such workload when our body is shifting from homeostasis to exercises. Any kind of activity performed by our muscles requires energy. This energy is supplied by energised phosphate bonds present in our body. The cells in our body store a small quantity of adenosine tri-phosphate (ATP) in the local muscle itself. This energy source can be utilised by the muscle without depending on the supply of oxygen. Hence, this energy can be utilised by the working muscle almost immediately or as soon as it needs it. However, if you exercise for more than two minutes the cells in the muscles must synthesise ATP by utilising any of the two energy pathways present in our body namely anaerobic (glycolytic) or aerobic (oxidative). During constant exercise routines or any activity that involves continuous repetition of the same actions, the energy systems used is aerobic in nature. But in most sports scenarios there is a use of both the pathways. However either of the two energy pathways tend to dominate the other. This domination depends on the nature and characteristics of each sport. In "stop and go", games refers to sports like tennis and cricket. Close to sixty or seventy percent of the energy is generated from stored ATP-creatine phosphate and anaerobic glycolysis and oxidative process generates the balance of thirty percent.

Activities, sports or work that principally relies on glycolytic or the ATP-phosphocreatine system is otherwise known as the anaerobic glycolysis. Such type of activities are said to be of anaerobic nature. Examples of such type of activities are 100 meter dash, bowling a fast ball in cricket, giving football a hard kick, executing a golf swing, executing a forehand drive in tennis, giving a boxing punch or lifting up a barbell with weight plates.

All the activities that continue for more than two to three minutes principally rely on oxidative metabolism as their energy source. These types of activities are known as aerobic type of activities. Examples of such activities are Marathon running, long distance swimming, cross country running, aerobic dance sessions, triathlon and so on.

Further, exercise also increases the production of heat significantly due to the increased metabolic rate resting level. The released heat requires to be transpired out of our body so as to regulate the temperature and protecting our health status. To regulate body temperature we possess a mechanism that helps in the regulation of body temperature. Our body comprises of two sets of dedicated control systems for this purpose namely, behavioral and physiological regulation. We will learn the effect of physiological regulation; the physiological heat regulation systems are

i) metabolic heat release control;

ii) regulation of flow of the heat through the blood to skin from core; and

iii) sweating control.

When heat stress is significant, cardiovascular help is required during exercise in order to support metabolism. Combined with exercise, the cardiovascular system may be pushed to its limit to support the competing metabolic and thermoregulatory effect or demands. The combination of exercise and heat stress could push the CV system to the extremes (Sawka & Wenger, 1988).

4.5.2 Acute Responses during Exercise on Our Circulatory System

The circulation of blood in the body is quickened due to quicker heart rate. This is the immediate effect of exercise. Cardiac output, which is the amount of blood pumped by our heart in one minute, is also increased. Cardiac output (CO) is the product of stroke volume and heart rate. The intensity of exercise has a direct impact on your heart rate. The cardiac output at rest will approximately be 5 L/min which could increase to 20-40 L/min, depending on the intensity level of exercise and conditioning. Approximately ninety five percent of your blood at the time of exercise is redistributed to the muscles that are active and to our heart. In people, who are healthy, their VO_2 max, stroke volume increases due to greater output of power and levels off in later stages of exercise. The increase could be approximately 40%-60% of their VO_2 max. Other increase in CO with increasing exercise intensity is primarily caused by increasing heart rate. Stroke volume could rise from 50ml at rest to120ml during exercise of maximal intensity in upright position. On the contrary, blood does not get accumulated in the lower extremity which improves venous return while exercising in the supine position. Therefore in supine position the resting stroke volume is greater. Hence, during activities such as swimming roughly around 20%-40 % increase is seen in stroke volume when compared to the resting value.

Hypertrophy of the heart muscles will be the result of all the above activities. The chambers of the heart will also get enlarged and gain in strength. However, many research studies have proved that training cannot have much effect on the maximum heart rate. But the efficiency of heart's functioning is improved due to its increased strength and size. Few other studies have proved that the supply of oxygen to the active muscles is better with a trained heart.

Check Your Progress 1

1) Write the acute changes that occur in the circulatory system due to exercise.

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4.5.3 Difference in Arterial and Venous Blood (CAO2 – CVO2)

The difference in arterial and venous blood **(**a-vO2) shows how effective the active muscles are in extracting oxygen from arterial blood. While resting the amount of oxygen content that can be extracted from the blood that flows in the arteries, is roughly 20% to 30% at the tissue level. The arterial flow of blood is always constant when the person does not suffer from any lung disease both during rest and during exercise. Hence, with the progressive increase in the intensity of exercise, the difference between the arterial and venous blood flow also increases.

4.5.4 Blood Pressure

In a healthy person the mean blood pressure (BP) and the systolic blood pressure increases correspondingly with the rise in the exercise intensity. However, the diastolic blood pressure more or less remains the same. Smaller muscle mass and vasculature creates higher resistance to blood flow. For example, there is an approximate raise of 10% in blood pressure when exercises are performed only by the arms in comparison with exercise for our legs because legs have larger muscles and vasculature. Therefore, caution must be exercised by people who are exerting themselves with exercise of their arms. The blood flow is restricted due to localised vasoconstriction during exercises involving static contraction, which also results in moderate increase in the cardiac output. However, during dynamic exercise there is a combined rise in systolic, diastolic and the mean blood pressures. When the intensity and duration of exercises are similar for both the types of exercises namely static and dynamic, the systolic and diastolic blood pressure could exceed 220 and 150 mm Hg respectively. This occurs when maximal static muscular contraction of the arm occurs (Rivera-Brown & Frontera, 2012).

4.5.5 Core Temperature Responses to Exercise

There is a significant increase in the core temperature during the initial phase of the exercise and as the exercise is continued the rate of increase is reduced so as to achieve a value that is essentially steady. The heat generated due to the metabolic process raises the core temperature. This released heat is actually the by-product of the contraction that occurs in your skeletal muscle. The metabolic rate increases quickly with the beginning of the exercises, but the bodies' thermoregulatory mechanisms response is not as quick for dissipation of heat. The heat so generated is lost by our body through radiation, convection, conduction and evaporation. The heat balance achieved by the thermoregulatory mechanisms and the metabolic rate and magnitude of core temperature elevation at the steady state is not influenced much by the environmental temperature. Nielson was the first person to present these ideas. He had engaged three participants who performed the exercises in varying intensities. The energy used for muscular contraction and storage of heat is represented by the value derived from the difference between the metabolic rate and the total heat loss. He concluded that the value of heat storage and the elevation of core temperature were constant in different environments. However, he also expressed that heat loss due to relative contribution of radiation, convection, conduction and evaporation means varied as per the environmental condition. Large skin to ambient temperature range helped radiative, conductive and convective exchange of heat in extremely high temperature environment of 100^{o} celsius, which accounted for about 70% of the heat loss. The body relied on evaporative exchange and decreased its dependence on other modes when the ambient temperature increased. Further, the body switched to radiative, convective and conductive mechanism, when the ambient temperature was higher than the skin temperature (Sawka and Wenger, 1988).

4.5.6 Cardiovascular Consequences of Thermoregulatory Increases in Skin Blood Flow

Even when the skin temperature is higher in areas of hot environment, the blood flowing through the thermoregulatory process in the skin does not respond to stress and heat generated through exercises. Since, core temperature is relatively lower, skin blood flow increases in response to the high skin temperature.

During exercise, metabolic rate and heat production may be ten or more times than their levels at rest. Even though core temperature rises during exercise and thus gradually widens the core-to-skin temperature gradient, its effect on core-to-skin heat transfer is far too little to match the increase in metabolic heat production. Besides widening the core-to-skin temperature gradient, the rising core temperature elicits reflex increases in skin blood flow which eventually produce a rate of core-to-skin heat transfer sufficient to re-establish heat balance.

4.5.7 Heat Stress Induced Circulatory Strain during Exercise

It is not been well established yet that there could be substantial thermoregulatory skin blood flow at the time of exercising. In general, the greater cardiac output causes the richer skin blood flow. As expected the most important reason for the increased cardiovascular strain associated with heat stress could be the higher heart rate and the resultant pumping of more blood. This additional work load of the heart is a major factor which results in a lot of cardiac strain on people suffering from heart related diseases. But in people who are healthy a reduced cardiac filling and stroke volume induces the cardiovascular strain connected with heat stress. This is because higher heart rate is needed to maintain the higher cardiac output. This is caused due to the compliant nature of larger surface area of veins of the skin. Further, the dilation of the blood vessels also occurs due to the effect of the heat stress. Hence, the blood vessels of the skin get enlarged due to greater quantity of blood pool in the skin whenever there is an increase in the skin blood flow. This also results in reduction of blood from the thorax, reduced volume of core blood and cardiac filling. Therefore the effect of blood pooling is the greater for a person standing upright because 70% of the blood volume is below the level of his heart. Therefore in an upright posture the stroke volume is bound to be lower than in supine position (Sawka & Wenger, 1988).

Check Your Progress 2

2) What are the two major adjustments in blood flow to meet the increased demands of the muscle during exercise?

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3) List the components of health related fitness.

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4) What is meant by athletic heart?

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4.6 ACUTE RESPONSES DURING EXERCISE ON RESPIRATORY SYSTEM

Although respiratory system is less adaptable than circulatory system, the muscles of the respiratory system will adapt to regular exercises and training. The adaptations will happen in the alveoli due to the increased ventilation. The muscles involved in respiration span the thorax and abdomen, the diaphragm, which is the body's important breathing muscle along with the intercostals muscles which are primarily used during passive breathing. Apart from the above, some muscles are engaged in inspiration and expiration which are sternocleidomastoid, serratus anterior, rectus abdominis and qudratus lumbrorum.

Though the evidence of significant influence of training on respiratory system is minimal, the trained respiratory muscles are known to be stronger and fatigue resistant. This also allows for greater ventilation for longer periods of time than what existed prior to training. Tidal Volume will also show an increase due to the effect of increased ventilation. Exercise results in the delivery of increased amount of oxygen to the alveoli and reduces the amount of air trapped in the bronchial tubes during high breathing frequencies which makes breathing more efficient.

During exercise and recovery, more oxygen must be delivered from the lungs to the working muscles and excess carbon dioxide must be removed from the working muscles. Some key Points in our body's acute respiratory responses to exercise are given below:

- Higher Respiratory Rate
- Higher Tidal Volume
- Higher Ventilation
- Higher Lung Diffusion
- Higher Oxygen uptake
- Higher volume of Oxygen consumption (https://images.app.goo.gl/6pRWfvw8pxwqBLiZA).

4.7 PHYSIOLOGICAL RESPONSE TO SUB-MAXIMAL EXERCISE

Metabolic stress influences the hormonal response to exercises more than the intensity of absolute workout (Mazzeo and Marshall, 1989; Belman and Gaesser, 1991). The researchers had chosen GXT which is the abbreviation of Graded Exercise Testing and also known as the sub maximal test to represent lesser load of absolute work for older subjects when compared with younger ones. GXT is the most widely used test to measure the dynamic relationship between exercise and our physiological systems. They also applied the same strategy to compare sedentary and trained participants. Trained participants showed significantly higher levels of plasma hormone across all age groups when they performed sub maximal exercises for 45 minutes as compared to people who were sedentary. Another critical finding of their study was that the age related decline in hormonal responses was eliminated during the GXT measurement when the exercise duration was kept identical for all the participants of various age groups.

In other words plasma growth hormone concentration values increased during sub maximal exercise bout for all the trained participants when compared with their resting values than their sedentary counterparts. However, the values had not come down with age for both sedentary and trained participants. This result suggests that the growth hormone in older participants also responds similarly during sub maximal work load, if the duration and intensity of the exercise is also kept equal. When hormones were tested between the sedentary and the trained groups; generally no plasma hormone level decline was observed as per their age except for the catecholamine level in the sedentary participants.

The adrenalin gland of our body secretes the hormones such as epinephrine, norepinephrine, catecholamine which responds to physical and emotional stress. They are also responsible for our bodies fight or flight response. In a study, much higher values of plasma epinephrine was reported in both the middle aged and old sedentary participants during the 45 minutes sub maximal exercise routine when compared with younger participants. Many studies support the view that adrenergic receptor responsiveness decline with age (Sonntag, 1987; Lakatta, 1993).This fact could cause the compensatory rise in the catecholamine release during the stress periods for them. This could be the reason for higher norepinephrine values among the older participants. Lehmann et al. 1986, gave some exercise at a given intensity for the older participants in their study and reported higher catecholamine levels. He also concluded that age related difference could be due to the rates of catecholamine clearance in addition to adrenergic receptor desensitization. Fleg et al. (1985) in his investigation had propounded that older men showed higher catecholamine level at more or less the same intensity. This means that the adrenaline rush for older participants was more when compared to their younger counterparts.

When 45 minutes sub maximal exercise was administered, the blood lactate level was significantly low. This was contrary to many findings which had concluded that the plasma hormone levels in the trained subjects were high across all the age groups. Studies have also shown that pulsatile hormone response could be altered in younger populations due to endurance training (Bunt et al., 1986; Weltman et al, 1992).

Studies do conclude that in response to similar metabolic stress, growth hormone response can be improved by training in older individuals as well. This will infact allow them to maintain similar levels to their younger counterparts who underwent training. Many studies support the fact that plasma growth hormone can be increased in older people when administered with sub maximal exercise (Shephard and Sidney, 1975; Hagberg et al., 1988). Though growth hormone synthesis and release is known to diminish with age, a series of physiological benefits can be seen due to the effect of training. There are reports that administration of growth hormone in older people increases their cardiac output, increases their exercise performance, increases their lean body mass and also decreases their body fat (Rudman et al., 1990; Cuneo et al., 1991a, 1991b).

Across all the age groups, training resulted in helping the release of plasma catecholamine which is a hormone released by our adrenal gland during sub maximal exercise. This hormone is important because it prepares our body for the physical and psychological load of training or competition. Kjaer et al. (1985 and 1986) had demonstrated that higher levels of catecholamine levels were reported in trained young male participants in comparison with the untrained ones. The trained participants were probably training at higher relative and absolute workloads, higher medulla responsiveness and secretion capacity due to endurance training. It could well be concluded that a lifelong training for endurance permits maintenance of catecholamine response to a given metabolic exercise stress that is similar to the type administered on younger trained players. This could be substantially significant when compared to their counterparts of similar age.

Last but not the least, plasma cortisol response for training load on sub maximal exercise on young and middle aged people were studied. Some studies concluded that there was no change in the plasma cortisol level due to endurance training (Hartley et al., 1972; Kraemer et al., 1989). However, many researchers have also reported that for a given work intensity, higher level of plasma cortisol response was observed in the trained participants (Severson et al., 1977). There was no conclusive evidence as to why the older group people did not report any training effect as was seen in their younger counter parts. But possible factors that could have had an impact in the lack of training effect are as follows: the plasma cortisol levels could have been much higher in the young and middle aged subjects prior to the exercise bout itself and there could also have been some effect of altering the age and training patterns on the participant's normal bio rhythm or even reasons yet to be identified by science.

Finally, the study concluded that hormonal response could be very much enhanced due to a lifetime of endurance training with a similar load of acute exercises in the elder participants. Hormone levels similar to their younger counterparts could be maintained by them. Further, even with a single bout of intense exercise, the older trained individuals could considerably improve their hormonal response than sedentary young and middle aged participants (Silverman and Mazzeo, 1995).

4.8 PHYSIOLOGICAL RESPONSE TO MAXIMAL EXERCISE

VO_2 max peaks significantly during maximal exercise have been repeatedly proved (Astrand et al., 1973; Hagberg et al., 1988). Across all the age groups VO_2 max improved considerably due to endurance training. Maximal lactate and hormone concentration reported during GXT were lesser for elder participants in comparison to their younger counterparts. These results were prominent in growth hormone and cortisol response. This reduction could have resulted from a reduced capacity to synthesise and secrete the hormone from their reproductive glands or a decreased capacity to remove and clear the hormones from plasma, though the researcher were still in doubt about the latter as a cause.

However, many studies have shown that there is a reduction in capacity to produce growth hormones and cortisol (Serio et al., 1969; Romanoff and Baxter, 1975) among older people both during rest and also after different types of treatment including exercising and fasting. Amplitude and frequency of growth hormone pulses showed a marked decline in the secreting capacity with age when being monitored for 24 hours (Finkelstein et al., 1972; Ho et al., 1987;).

In addition, increase in somatostatin levels (Casad and Adelman, 1992;), alteration in the growth hormone messenger Ribonucleic acid or RNA releasing hormone and variations in the indicators of growth hormone and circadian rhythm patterns have been consistently reported. Somatostatin is a cyclic peptide well known for its strong regulatory effects throughout the body. Also known by the name of growth hormone inhibiting hormone, it is produced in many locations, which include the gastrointestinal (GI) tract, pancreas, hypothalamus, and central nervous system (CNS).

In order to attain the maximal work capacity of the older participants, duration of the exercise is vital because their growth hormone levels are low. During graded exercise testing or GXT, the peak hormone level achieved by these participants was the lowest, but they could also reach the peak they needed in the shortest exercise duration. A shorter exercise time could be the cause for lower hormonal response in the older participants as it depended much on the intensity and duration of the exercise. In this case a shorter exercise time could be the trigger. This could be the fact that growth hormone and cortisol responses are generally recognised as having longer response time to a given bout of exercise (Shephard and Sidney, 1975;).

Check Your Progress 3

5) What are the hormonal changes that occur due to maximal and sub-maximal exercises?

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4.9 ASSESSMENT OF SELECTED PHYSIOLOGICAL PARAMETERS

4.9.1 Heart Rate

Heart rate is one of the physiological parameter that can be easily measured. It is measured by the number of times the heart beats each minute. The heart rate is at its lowest when we have just woken up from a good night’s rest. It is higher during the normal course of your day and it is at its highest when you exercise. Your heart rate can be measured from just about any artery. In theory it can be accessed from any place where the pulse of the blood flow can be felt. But in practice, radial, carotid and temporal are the three points most common and widely used.

The ideal time for us to measure the resting pulse rate is to check it the first thing in the morning before getting out of bed. A stop watch that can show the lapsed time in seconds should be kept handy. For the purpose of locating the arteries either of the two common points namely carotid or radial pulse points have to be located. The former is situated slightly at the side of your wrists and the latter is situated at the junction point of your neck and jaws. The first two fingers of your hand should be used to palpate and find the pulse. Once the pulse is identified, it must be counted for one minute using the stop watch. The total number of pulses felt by your finger is your heart rate.

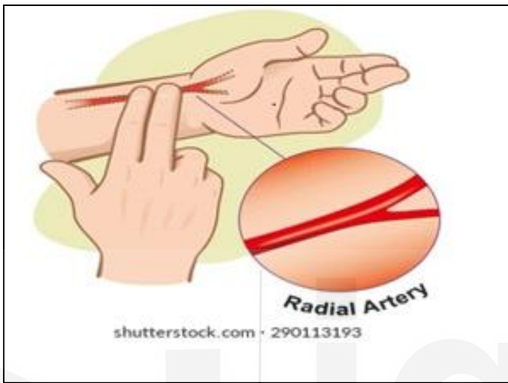

Figure 1: Location of Radial Pulse
Source: **https://www.shutterstock.com/image-vector/**

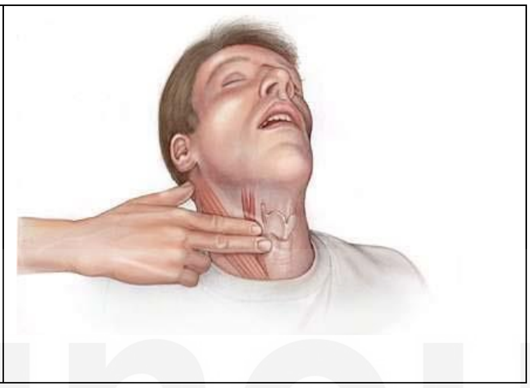

Figure 2: Location of Carotid Pulse
Source: **https:/medlineplus.gov/ency/imagepages/9800.htm**

4.9.2 Body Composition

Body composition can be assessed by many techniques such as skin folds; underwater weighing and so on but they require special equipment, space and training. Though these types of measurements give an accurate data, there are few simpler and easy to use methods that give a rough idea on the composition of our body. They are Body Mass Index (BMI) and waist circumference.

4.9.3 Body Mass Index (BMI)

This test is a very simple and can be done by ourselves. Though there are many studies that do not approve of this method, it could give some idea on the body composition. It can at its best be a kind of monitoring system. BMI gives you a weight range in relation to your height. The unit of measurement is in kilogram per square meter. BMI is calculated by measuring a person’s height and weight in meters and kilograms respectively. The data is applied to the formula:

BMI= weight in kilogram divided by height in square meters.

The resultant score is compared with the BMI norms given in table I. The norms will suggest in which category you will fall and give you an idea if you are underweight, Normal, Overweight, Pre Obese or Obese.

WHO CLASSIFICATION OF WEIGHT STATUS	
WEIGHT STATUS	BODY MASS INDEX (BMI), kg/m^2
Underweight	<18.5
Normal range	18.5 – 24.9
Overweight	25.0 – 29.9
Obese	≥ 30
Obese class I	30.0 – 34.9
Obese class II	35.0 – 39.9
Obese class III	≥ 40

Table 1: BMI Norms classification as per WHO

***Source*:** https://www.ncbi.nlm.nih.gov/books/NBK535456/

4.9.4 Waist Circumference

The varying patterns of distribution of fat in the body correlates with risk factors associated with various diseases. Accumulation of body fat on a specific location indicates high risk factors on health. People accumulated with more body fat around their trunk and abdominal areas are more at risk than people with accumulated body fat around hips and thighs.

Measuring tape is used as a tool to measure the waist circumference. It can also be done by using a thread to measure the waist and then by measuring it using a measuring scale. The circumference of the waist can also be measured by yourself or by using a partner to assist.

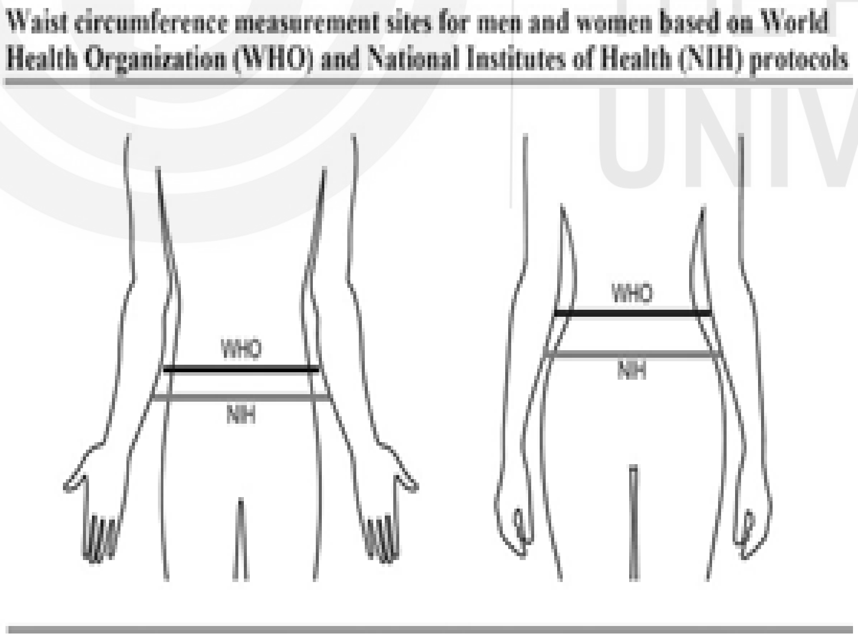

Figure 3: Measurement of Waist Circumference
Source: https://www.opportunityfitness.com.au/waist_girth

The following table shows the norms for classifying the circumference of the waist.

Health risk	WOMEN	MEN
Low Risk	below **31.5** inches	below **37** inches
Moderate Risk	**31.5 to 35*** inches	**37 to 40** inches
High Risk	**35*** inches or more	**40.2** inches or more

Table 2: Norms for Waist Circumference

***Source*:** https://www.whyiexercise.com/waistcircumference.html

4.9.5 Aerobic Fitness

The maximal oxygen consumption ability, which is also known as VO_2 max, is used to measure your aerobic fitness level. VO_2 max indicates the ability of our body to utilize the consumed oxygen in a given time. Higher value of VO_2 max indicates a better aerobic fitness and vice versa.

4.9.5.1 Rockport One-Mile Walking Test

This test is recommended only for people with sedentary lifestyle, to determine their VO_2 Max level. To complete this test you have to walk continuously for a mile. It is easy to measure the distance walked precisely when the test is performed on a standard track, if not any flat and even surface which is measured well in advance is good enough too. A proper pair of walking shoes and a stopwatch is mandatory to begin the test. Before the beginning of the test body weight in kilograms and pulse in beats/per minutes should be noted. The time taken to complete the course distance should be recorded. By applying the data collected to the formula in the table you can calculate the aerobic fitness level.

MALE	FEMALE
139.150 Minus (0.1692 multiplied by weight in kilograms) minus (0.3877 multiplied by age in years) minus (3.2649 multiplied by time in minutes) minus (0.1565 multiplied by heart beats per minute) = AEROBIC CAPACITY	132.835 Minus (0.1692 multiplied by weight in kilograms) minus (0.3877 multiplied by age in years) minus (3.2649 multiplied by time in minutes) minus (0.1565 multiplied by heart beats per minute) = AEROBIC CAPACITY

Table 3: Calculation of Aerobic Fitness for Male and Female

***Source*:** ACE Personal Trainer Manual, the Ultimate Resource for Fitness Professionals

The final score obtained after completing the necessary calculations as suggested separately for male and female. The final score represents the amount of oxygen required every minute per unit of your body weight. The higher the amount of oxygen consumed the better the aerobic fitness level. The following table shows the norms for classifying the aerobic fitness level.

VO2 Max Norms Chart

VO2 Max Norms for Men						
Age	**18-25**	**26-35**	**36-45**	**46-55**	**56-65**	**65+**
Rating	> 60	>56	> 51	> 45	> 41	>37
Excellent	52-60	49-56	43-51	39-45	36-41	33-37
Good	47-51	43-48	39-42	36-38	32-35	29-32
Above Average	42-46	40-42	35-38	32-35	30-31	26-28
Below Average	37-41	35-39	31-34	29-31	26-39	22-25
Poor	30-36	30-34	26-30	25-28	22-25	20-21
Very Poor	> 30	>30	> 26	> 25	> 22	>20

VO2 Max Norms for Women						
Age	**18-25**	**26-35**	**36-45**	**56-65**	**56-65**	**65+**
Rating	> 56	>52	> 45	> 40	> 37	>32
Excellent	47-56	45-52	38-45	34-40	32-37	28-32
Good	42-46	39-44	34-37	31-33	28-31	25-27
Above Average	38-41	35-38	31-33	28-30	25-27	22-24
Below Average	33-37	31-34	27-30	25-27	22-24	19-21
Poor	28-32	26-30	22-26	20-24	18-21	17-18
Very Poor	> 28	>26	> 22	> 20	> 18	>17

Table 4: Rockport One Mile Test Norms

Source: https://www.makeoverfitness.com/images/fitness-assessment-forms/vo$_2$-max-norms-chart.pdf

Check Your Progress 4

6) How will you administer Rockport One-Mile Walking Test?

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7) How will you measure heart rate? Discuss.

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4.10 SUMMARY

Human body is amazing indeed if we can keep it functioning like a well oiled machine. Since the time immemorial man has been fascinated by a perfect body and a strong physique. Man has also understood that the body can attain perfection if so desired by engaging in regular physical activities and training towards that goal. In this endeavor man began challenging his own fitness levels and performance. As technology and sedentary life style brought about three classes of people namely the ones getting fitter for better performance, people who were managing their fitness to stay healthy and the third who could not do anything to improve their fitness. When people are unable or ignorant about being fit and healthy they invite many diseases associated with heart and bones. Most people who exercise to manage their health have to be aware of what they are doing and what their aim should be to sustain a healthy lifestyle. We have to work towards pushing more and more people to start exercising to develop and keep up a healthy lifestyle.

Fitness can be of two types health and performance oriented. Most people have to be good in health related fitness components. When we do start exercising regularly changes begin to happen. The changes may be acute or chronic. When we exercise regularly acute changes occur in the circulatory system. Blood flow increases and there is also an impact on the blood pressure. The core temperature and blood flow of the skin increases significantly. Our body faces a lot of heat stress till it reaches the balance between the core and outer temperature.

Acute responses in the respiratory system include strengthening of the muscles engaged in breathing though direct impact on the respiratory system is minimal if any. The efficiency of our breathing enhances and the body is able to use up more oxygen. Further, certain type of hormones such as plasma growth hormones are positively impacted during sub-maximal exercises and hormones such as cortisol is impacted during maximal exercise. Finally, some selected and simple assessment tests for heart rate, body composition-BMI, waist circumference, and aerobic fitness give us an insight.

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4.11 HINTS/ANSWERS TO CHECK YOUR PROGRESS

1) The acute changes that occur in the circulatory system due to exercise are - increased heart rate increased cardiac output, increased stroke volume, stroke volume is higher while exercising in a supine position, increased blood pressure, the differences between arterial and venous blood flow is increased, vasodilation occurs and blood supply to the working muscles is increased

2) The two major adjustments in blood flow to meet the increased demands of the muscle during exercise are:

   - Increased Venous blood flow

- Increased Systolic Blood Pressure

3) Cardio respiratory fitness, muscular fitness, flexibility and body composition constitute as components of health related fitness.

4) Athletic heart reflects

- Hypertrophy of the Heart muscles
- The chambers of the Heart gets enlarged
- Efficient functioning of the Heart is increased
- Better supply of Oxygen to the muscles
- Decrease in the resting pulse rate

5) The hormonal changes that occur due to maximal and sub-maximal exercises are:

i) (Submaximal)

- Significant increase in the Plasma hormone
- Higher levels of Catecholamine in older adults
- Alteration in the Pulsatile in younger population
- Overall improvement in the Growth hormone
- Enhanced hormone response

ii) (Maximal)

- Decline in the amplitude and frequency of Growth hormone with age
- Increase in the Somatostatin levels
- Alteration in the Growth hormone messenger
- Duration of exercise positively impacts older participants
- Longer response time recorded for Growth hormone and Cortisol

6) Rockport One-Mile Walking Test the continues one mile walk time to determine their VO2 Max. Preferably use a standard track for the test; measure and record the pulse rate before the start. Measure and record the time taken to complete the course and apply the readings to the formula. Calculate the result. Scores are calculated separately for men and women

7) Heart rate

- To measure the number of times heart beats per minute
- Commonly measured spots are Radial, Carotid and Temporal arteries
- Palpate to find the exact spot in any of the above mentioned locations
- Count the beats for a minute using a stopwatch
- Record the count

UNIT 5 CHRONIC PHYSIOLOGICAL ADAPTATIONS TO EXERCISE TRAINING*

Contents

Learning Objectives

After reading this unit, you will be able to:

- comprehend the benefits of exercise and training on various body systems;
- understand the long term impact of exercises based on physiological characteristics such as age, sex and population; and
- understand the beneficial adaptions of regular exercise on the general population.

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5.0 INTRODUCTION

In as little as two weeks, an athlete who trains regularly can feel the long term cardiovascular effects in his or her body. It may take about four weeks for people who may have just begun to exercise to observe the changes. It has become an accepted fact in the scientific community that the effects of physical activity are by and large beneficial for the human body. A lot of them advocate that exercise, recommended diet, and a non-smoking lifestyle, are critical factors in preventing premature death. However, it should also be mentioned that the impact of nutrition combined with physical activities have prompted continuous arguments among scientists, experts, and laymen alike. Long-term influence of engaging in physical exercises on many of the major systems of the body based on age, gender and population will be looked into in this unit.

Intensity, duration and frequency determine the type and degree of physiological response to exercise. Environmental conditions too have their influence on such responses. The oxygen substrate requirements, while engaging in regular physical exercises is increased in the skeletal muscles. This also hastens the metabolites and carbon dioxide removal from the body. For meeting the increased demands, chemical, mechanical and thermal stimuli prompts changes in the metabolic, cardiovascular and ventilator functions in the body. The body responds as a whole to the demand placed on it continuously over a period of time.

Now let us start by looking into the chronic effect of exercise on our body systems:

5.1 LONG TERM EFFECTS OF EXERCISE AND TRAINING ON THE BODY SYSTEMS

Engaging in training regularly at least three times per week for six weeks could be enough to observe the adaptive changes in the systems of the body that were engaged or used. The results would be an increased performance in that specific training or its related sport. This could mostly improve the daily lifestyle and general health.

5.1.1 Impact and Adaptations in the Cardio Vascular System due to Exercise

The cardiovascular system responds to the effect of long-term physical activities by increasing the resting and exercising stroke volume of the left ventricle. Therefore, it reduces the resting heart rate even though resting cardiac output continues to be the same. As the chambers of the heart increase in size the maximal cardiac output is also increased though the maximum heart rate is constant. Further, the long term effects on cardiovascular system include:

- Cardiac hypertrophy; stroke volume (SV) shows improvement; resting heart rate (HR) reduces noticeably;

- the maximum cardiac output (q) also shows marked increase;
- significant number of capillaries get opened up in the muscles and lungs of our body; and
- the count in the number of red blood cells in our body also goes higher.

These types of changes occurs in the cardiovascular system due to continuous and regular bouts of physical exercises.

5.1.2 Impact and Adaptations in Respiratory System due to Exercise

The respiratory system responds to long term exercises by increasing the number and diameter of functioning alveoli and its capillaries; respiratory muscles in the intercostal and diaphragm regions gain more strengthas respiration gets powered by the muscles, their response is much similar to that of the skeletal muscles. As they grow stronger it enables them to raise the rib cage higher which allows for more air to flow into the lungs. This process also enables the lungs to contract more forcefully increasing the pressure differences. Energy generation through the aerobic energy system is improved and also the lactic acid tolerance.

5.1.3 Impact and Adaptations in the Muscular System due to Exercise

Muscle hypertrophy, improved tendon strength and improved ligament strength are some of the long term impact of exercises on Muscular system. Hypertrophy refers to an increase in size; hence, muscular hypertrophy refers to the size of the muscle getting larger. For example: Regularly training your biceps with bicep curls will result in bicep muscle hypertrophy.

5.1.3.1 Cardiac Hypertrophy

Due to the effect of exercises in the long term, the ventricle wall gets larger or thickens which is called as cardiac hypertrophy. Left ventricle is able to pump more blood due to increase in size of its muscle wall. Therefore with each contraction it pumps more blood. This results in the increase in stroke volume. An increased stroke volume (SV) results in a decreased resting heart rate. However, the cardiac output (Q) does not change as SV × HR = Q.

5.1.3.2 Capillarisation

This refers to a process in which new capillaries are formed. Chronic effect of exercise ensures that new capillaries are generated at the alveoli which are present in the lungs and also in the muscles that were exercised. This development causes the amount of oxygen that can be transferred to the muscles that are working to increase. Capillarisation in the alveoli ensures that removal of carbon dioxide is also increased.

5.1.4 Impact and Adaptations in the Circulatory System due to Exercise

Due to increased training of the cardiovascular system, the efficiency of the heart and lungs gets enhanced. The decrease in the resting heart rate indicates that the heart is able to circulate the blood in lesser number of contractions. The enhanced capacity of the person to draw breaths that are deeper and longer results in the need to take fewer breaths. This turn reduces the risk of heart diseases.

Therefore, as a long-term impact, the person's heart rate actually goes down. Reports of cyclists who compete in the *Tour de France* (a gruelling and strenuous bicycle rally conducted in France) are said to have the resting heart beats of only 40 each minute. However an average untrained adult could have a resting heart rate of about 72 beats per minute or a little less. Another important long-term benefit a trained or regularly exercising person will adapt to is that their blood pressure will be normalised. High blood pressure often seen in obese or sedentary people bears its links to many health hazards, including strokes.

Regular exercise provides many benefits to the trained person such as protecting from heart attack, stroke or diabetes. American Diabetes Association recommended exercising for a minimum of thirty minutes for five days in a week. This recommendation is considered crucial to protect the heart and blood vessels. Though heart attacks can occur in a world class athlete too, the association reported that far more Americans died each year of a sedentary lifestyle than they did from a fit lifestyle.

5.1.5 Impact and Adaptations in the Digestive System due to Exercise

The digestive system's proper functioning is ensured by exercising on a regular basis. It also aids the elimination of waste. Furthermore, an interesting research was conducted on forty Irish Rugby players versus another group of non-athletes identified that, the gut of the rugby players had more microbiota in their intestines (Clarke et al., 2014). This is said to have a beneficial effect on our body's immune system.

5.1.6 Impact and Adaptations in the Endocrine System due to Exercise

The long-term effect of physical activity on endocrine system is said to have a considerable role in strengthening the ticker which is an organ in our body that moves blood around by regular contractions, lowering blood sugar, and improving insulin levels. Yet there are reports of increase in the weight of the pancreas due to exercise. However, clinical evidence (Lawrence, 1926), showed that reduced insulin was required for a moderate diabetic person who exercised regularly. Another study by Gerl and Hofmann (1928) reported that exercise stimulated the islet tissues to greater activity, that due to regular training, the pancreas of a healthy adult responds with insulin secretion more promptly. This ceases the appearance of initial hyperglycemia of exercise. However, more studies may be needed in this area to arrive at strong conclusions.

5.1.7 Impact and Adaptations in the Muscular System due to Exercise

The impact of regular and repeated exercising over long periods is usually positive. Muscles and human bodies like being at rest but are forced to adapt to the stress placed on them by exercising regularly. When exercising is stopped, the beneficial adaptations could also be lost over time. One of the most noticeable long term effect of exercise especially weight training, is muscle hypertrophy, which in other words mean an increase in muscle mass due to exercise. A phenomenon called cross education occurs when a specific muscle is exercised but also results in the hypertrophy of the opposite muscle.

The approaches to gain significant and specific muscle growth have divergent views from the experts and professionals, than in their approaches which were focused on improvement of strength, power, or endurance. Consistent anaerobic strength training resulted in hypertrophy over the long term was generally accepted besides having an impact on muscular strength and endurance.

5.1.8 Impact and Adaptations in the Skeletal System due to Exercise

Physical exercises can increase bone density in the long term. It also enhances the ligament strength of the joints to which they are connected. The risk of osteoporosis is reduced with the increase in the bone density. However, when repetitive physical activity with too much load is practiced over long periods of time, it can cause stress fractures in bones and sometimes it can lead to severe back pain if the activity involves lifting of heavy weights.

5.1.9 Impact and Adaptations in the Immune System due to Exercise

The immune cells are made in the blood vessels which are assisted by the lymph vessels and nodes. The toxins in the blood are also removed and purified by the lymphatic system. Lymph flow is boosted by regular exercise. Thus a healthy immune system is promoted by exercises which protect our body from infections and diseases.

Exercise promotes production of more cells, and gut microbiota is a general theory. Microbiota is microorganisms that live in our digestive tract. They perform beneficial function and help in breaking down hard to digest foods. They also help in fighting infections and diseases. An enriched immune system when a person exercises regularly could last for several hours. However, there are studies that provide evidence that when exercise is carried out for more than two hours; it can cause weakening of the immune system for a short while.

But, on the other hand, thirty minutes of intense physical exercises may not weaken the immune system. Thus, the immune systems can suffer if anyone carries on doing the exercises for too long without proper rest and recovery.

Hence, it is recommended that one should always strive to maintain a healthy balance between exercise and rest.

Certain components of the human immune system are enhanced by performing moderate exercises over a period of time. The cells that kill by nature such as cells of the monocyte-macrophage system, B-lymphocytes and circulating T cells are found in the immune cells. It is also responsible for decreased occurrence of some infections and also perhaps cancer too (Keast, et al., 1988; Pedersen and Ullum, 1994; Shephard and Shek, 1995).

When higher intensity exercises are carried on for a longer period of time, it could have an adverse effect on the human subjects. This indicates that over loading could have adverse effects on the functioning of our immune systems. In addition, decrease in the response of T-lymphocytes to mutagenic stimulation, antibody synthesis reduction and plasma level of immunoglobins, and decreased functioning of macrophage phagocytosis is also possible due to excessive training or overload. The adverse effect on the immune system due to excessive high intensity training or overload causes reduction in the plasma glutamine levels (Newsholme and Parry-Billings 1994). However, a study on forty Irish Rugby players and a group of non-athletes concluded that the Rugby group which trained on a regular basis had more gut microbiota in their intestines, which was beneficial to the body's immune system *(Orla o'Sullivan 2015*).

Check Your Progress 1

1) What are the benefits of having strong inter-costal muscles and diaphragm due to regular exercise?

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2) Explain the meaning of Capillarisation. What are its benefits?

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3) Discuss the adaptations in our immune system due to long term regular exercising.

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5.2 IMPACT OF LONG TERM EXERCISE ON PHYSIOLOGICAL CHARACTERISTICS BASED ON AGE

Significant number of distinctions in physiological function between children and adults tend to fizzle out when they are scaled to the absolute values in order to accommodate the differences in body size. However, there are some notable exceptions such as the rate of identical absolute work performed on a bicycle ergometer; children and the adults reported more or less the same metabolic cost, or VO_2 demands. However, such demands were met differently by them. The stroke volume in children was lower due to the smaller size of their hearts though the rate of work was same as adults. As a compensatory response, their heart rate increased though it may also have been inadequate to raise the cardiac output (Bar-Or 1983). Hence, to achieve the same VO_2, the a-VO_2 difference gets higher to adjust for the reduced cardiac output. a-VO_2 known as the 'arteriovenous oxygen difference' is the difference in the oxygen content in the arterial and venous blood.

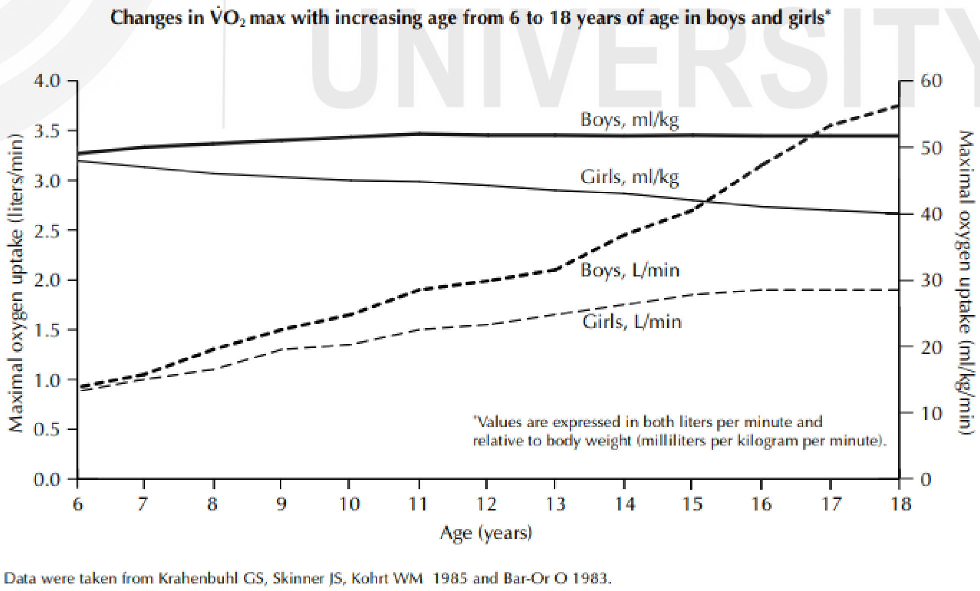

Figure 1: Developmental aspects of maximal aerobic power in children.

Source: Exercise and Sport Sciences Reviews 1985; 13:503–538.

VO_2 max is denoted in litres per minute. It increases for the boys in the age range of 6 to 18 years and for girls in the age range of 6–14 years, (Figure 1) after which it reaches a plateau (Krahenbuhl, Skinner, Kohrt, 1985). It generally remains stable for boys but steadily decreases for girls in the respective age range mentioned above, when expressed relative to body weight i.e., millilitres perkilogram per minute, (Krahenbuhl, Skinner, Kohrt 1985). The most likely cause for this variation is varying patterns of physical activities because in a study conducted among elite male and female endurance runners, the difference in their aerobic capacity was significantly less when compared with boys and girls in general (Wilmore and Costill 1994).

General inactivity is closely linked to deteriorating physiological functioning related to aging. In older adults, there is a gradual decline in maximal heart rate and maximal stroke volume as they age. VO_2 max tends to be lower in aged adults than in young adults due to reduced maximal cardiac output (Raven and Mitchell, 1980). A cross sectional study had reported that VO_2 max reduces approximately at the rate of 0.40 to 0.50 millilitres per kilogram per minute in a year for men. However, this rate of reduction is less in case of women (Buskirk and Hodgson, 1987). Increase in VO_2 max values is possible for both aged men and women through regular training or exercise to nearly that of values reported in young adults (Kohrt et al., 1991). When active and sedentary people were compared for the loss of VO_2 max based on age and training status, their inter-relationships were brought to light (Figure 2).

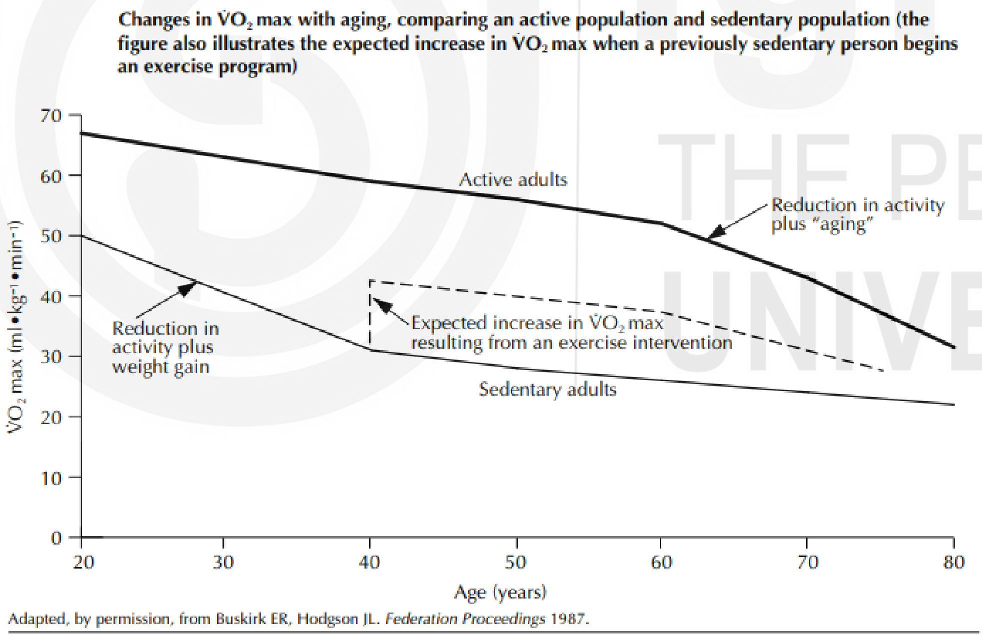

Figure 2: Developmental aspects of maximal aerobic power in children.

***Source*: Exercise and Sport Sciences Reviews 1985; 13:503–538.**

In a comparative study between aged adults and middle aged adults on cardiorespiratory responses, the results showed that the stroke volume of the older adult was generally lower than their counterparts. The heart rate of aged adults was higher than the middle aged adult in order to maintain the cardiac output. Both the groups were tested at the same absolute submaximal rate of work. Though the increase in heart rate is generally insufficient, the a-VO2 difference needs to be raised for providing the same uptake of submaximal oxygen (Raven and Mitchell, 1980; Thompson and Dorsey, 1986). However, higher stroke volume was reported in aged adults at both submaximal and maximal rates of work in some studies (Rodeheffer et al., 1984).

Reduced physical activity along with the aging process itself is the cause for worsening physiological function which is usually connected with aging. Good levels of cardiovascular, metabolic and VO2max functions can be maintained by even a previously sedentary older adult by adopting an active lifestyle or by increased physical exercise (Kohrt et al., 1991). Similar positive results were also elicited in the function of the skeletal muscle (Rogers and Evans 1993). For instance, Fiatarone (1994) and his fellow scientists conducted a ten week training program of progressive resistance exercise which resulted in 113 percent increase in the strength of men and women who had a mean age of 87.1 years. The study also reported that the cross-sectional thigh muscle area of the participants had also improved along with their capacity to climb stairs, gait velocity, and spontaneous activity levels. The ability of the elderly people to live an independent life could be enhanced by increasing their endurance and strength.

5.3 IMPACT OF LONG TERM EXERCISE ON PHYSIOLOGICAL CHARACTERISTICS BASED ON SEX

Provided that the duration and exercise level are normalised, both men and women who exercised regularly reported similar responses in respiratory, cardiovascular and metabolic functions in majority of the cases. They recorded similar increase in relative VO_2 max (Kohrt et al., 1991; Mitchell et al. 1992). Few studies reported that women who are older managed this increase inVO_2 max predominantly with a greater a-VO_2 difference. Younger women and men however, managed the activity with significantly high stroke volume that resulted in the maximising the cardiac output substantially (Spina et al., 1993). Equivalent development in strength was observed in both men and women when they were put through a bout of resistance training. Women, however, gained lesser fat free mass because of decreased muscle hypertrophy (Rogers and Evans, 1993; Holloway and Baechle, 1990). To conclude, physiological adaptations to long term physical activities are certainly beneficial to people of all ages, both male and female.

5.4 IMPACT OF LONG TERM EXERCISE ON PHYSIOLOGICAL CHARACTERISTICS BASED ON POPULATION

Studies have revealed that the children (Godin, 1913), youth (Matthias, 1916): Hcrxheimer, 1921), college students (Kohlrausch, 1924), and adults (Hcrxheimer, 1922) did not show a proportionate increase in their muscle girth in relation to the corresponding work done by them. Matthias and Herxheimer through their study brought to light that when the body length is in the process of rapid growth, exercise did not have the desired effect on the muscle growth when compared to the stage which was predominated by the tendency towards the growth. Kohlrausch initiated a study of physical education among college students and concluded that the least improvement in muscle girth was associated with the thinnest “asthenic type of individuals. The greatest response was recorded with the middle sized students. Herxheimer directed his research on policemen in training and concluded that the underweight group had improved the most. Hence, it can be understood that different types of body types in our population may respond differently to regular and continues training or exercise. However, it must be noted that the positive adaption was always seen in all the people, but the degree of improvement varied according to their body types.

Greatest strength was observed in the muscle groups that an Olympic athlete employed vigorously according to the needs of their specific sport. (Ethe and Fischer 1929) The study conducted by Abramson (1929) concluded that the strength gained through long term training adaptation was still present, even after one year but at significantly reduced levels. In an long-term experiment by Holck (1929) which was under careful control, revealed that the endurance of his forearm flexors, assessed using a Mosso type ergo graph, increased continuously in noticeable spasmodic fashion for many years. Data showed that with continuous training for four and half years, five hundred percent of his original endurance level was reached as his high point. Similarly, Hedvall (1915) achieved an improvement of eight-hundred and nineteen percent after training his arms for fifty days using a Johansson ergo graph. The study also concluded that in less than two months after stopping his daily training, the work capacity of his legs reduced to one-third of his peak training performance. Further, Kohlrausch found reduction in muscle girths after a summer season training in track and field. The track and field training followed a season of strenuous gymnastic training during the winter months. This proved that the adaptations that occur in our body are not permanent. The training and exercise should be continuous and lifelong activity. The adaptations gained due to training however long it may be, will start declining if not continued over a period of time.

Check Your Progress 2

4) Analyse the deteriorating physiological functioning in our body due to aging.

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5) Present the various beneficial adaptations due to long term regular exercises on the population in general.

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5.5 SUMMARY

The beneficial adaptations due to long term regular exercise or physical activity on the general population are many. Exercises need not necessarily be strenuous every time you do it, but it should be for reasonable duration of time providing an enjoyable experience. Exercise and diet plays a vital role in appropriate management of weight. It also helps in prevention and management of obesity. Energy intake should balance with energy output for maintenance of weight and output should be more than intake for reduction in weight and vice versa.

Your heart gets strengthened by regular and long term training along with improved circulation. This results in significant improvement in the oxygen levels in the body. The risks of cardiovascular diseases are also mitigated considerably. Engaging in long term regular training and exercise will normalize blood pressure and triglyceride levels. Regular long term training and exercise promotes insulin function by reducing the levels of blood sugar. This will bring down the risk of metabolic syndrome and type 2 diabetes. If not prevent, it will certainly help in the management of the disorder.

Human body releases certain chemicals when we exercise. They could improve the relaxation and mood of that person. This will, in turn help in better management of stress and depression. It aids in keeping the mental skill such as thinking and judgment sharp as we grow older. Exercises help keep your thinking, learning, and judgment skills sharp as you age. Regular exercise and training stimulates the release of proteins and other useful chemicals. This results in the development of the structure and function of our brain. Further, regular strengthening exercise aid in development and maintenance of muscle mass and strength. In young children it will build strong bones and ensures slower loss bone density as we grow older.

Engaging in training and exercises regularly promotes good and deep sleep for longer duration. This helps the body to recover and refresh faster. Exercising regularly over a period of time, can also make it easier to quit smoking by reducing the cravings and withdrawal symptoms.

In case of older adults the risk of going off balance and falling can be reduced by regularly engaging in balance and strengthening exercises of light to moderate intensity. Research has indicated that engaging in regular and long term physical activities or training will increase the life span. It also promotes good health and positivity throughout the life.

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5.7 HINTS/ANSWERS TO CHECK YOUR PROGRESS

1) The benefits of having a strong inter-costal muscles and diaphragm due to regular exercise are ability to raise the rib cage higher, enhanced flow

of air in the lungs, lungs can contract more forcefully, improved energy generation and increased lactic acid tolerance.

2) Capillarisation is new capillary formation in alveoli and the muscles and its benefits include increased oxygen supply to the working muscles and removal of carbon dioxide is faster.

3) The adaptations in our immune system due to long term regular exercising results in: enhanced lymph flow, protection from infection and diseases, enhanced cell production, extended life for the immune cells, raised count of gut microbial, prolonged high intensity exercises may cause adverse effect and decreased response of immune cells when high intensity exercises are carried on for a long time without proper rest and recovery

4) Deteriorating physiological functioning in our body due to aging are

Gradual decline in the Maximal Heart Rate

Gradual decrease in the Stroke Volume

Lower VO_2 max

Reduced Cardiac Output

5) Various beneficial adaptations due to long term regular exercises on the population in general are:

Effective weight management

Reduced risk of heart diseases

Better sugar and insulin management

Improved mental health

Stronger bones and muscles

Improved sleep quality

Enhanced life expectancy

UNIT 6 EXERCISE AND AGE*

Contents

Learning Objectives

After going through this unit, you will be able to:

- edify the various mechanisms that work simultaneously while exercising;
- understand the two major forms of exercise- aerobic and anaerobic;
- recognise the role of activeness and physical fitness for people belonging to any age-group; and
- obtain reasonable knowledge about the relationship existing among exercise, health and age.

6.0 INTRODUCTION

Oxygen that plays a crucial role in generation of a high energy compound- *adenosine triphosphate* (ATP) is vital for maintenance of cellular activity. Reserves of oxygen and ATP in human body are very limited, that are then taken care of by various physiological mechanisms making both oxygen and ATP available to body all the time without a delay/shortage. Molecular oxygen is supplied to the body via three steps.

- exchange of oxygen and carbon dioxide takes place between body and environment;
- both these gases are then transported to/from the bodily tissues in the blood; and
- finally the oxygen is utilized at the cellular level for accomplishing various essential functions (McArdle.et.al. 2010a).

Here, one must realise that oxygen demands are fairly small when body is at rest. Based upon size and composition of the body, it needs about one fourth of a litre of oxygen every minute. However, during exercise the amount of oxygen essential for maintaining adequate levels of ATP rise manifolds- up to around twenty-folds (Bassest and Howley, 2000). When energy demands of cells and tissues are fulfilled by the breakdown of creatinine-phosphate, without the involvement of oxygen, it is referred to as anaerobic metabolism.

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It occurs during extensive physical activity or exercise, where muscle cells and tissues are utilised to the maximum. Also, when ATP is produced in body by the breakdown of glucose, releasing a restricted amount of ATP giving off lactic acid, such oxygen-independent mechanism is termed as anaerobic metabolism. Lastly, the metabolic state known as aerobic metabolism, that uses oxygen for energy production, includes all the daily activities such as working, eating, playing, etc; involves the breakdown of carbohydrates and fats into carbon dioxide and water. (McArdle et al., 2010 a).

To oxygenate the increased blood flow that is required during physical work or exercise, the person starts taking deeper breaths and breathes faster, up to 40–60 breaths per minute. Breathing patterns during physical activity or exercise, advance in a highly economical and effective manner. Consumption of oxygen and release of carbon dioxide are influenced by physical activity the most than any other physiologic pressure. An increased gaseous exchange between the alveoli and blood maintains gas concentrations. Every minute on an average 8-10 litre of air moves in and out of lungs, at rest that ensures an uninterrupted gaseous exchange; but in case of maximal oxygen uptake this volume rises up to about 100-200 litres per minute (Basset and Howley, 2000). Volume of air increases to such an extent as the sole aim of physiological mechanisms for then is to flush carbon dioxide out and make maximum amount of oxygen available to cells and tissues. A limited proportion of lungs' capacities are used at rest, while during exercising or doing any other physical activity substantial reserves, stored for every physiological mechanism, are utilised then. During light to moderate intensity exercises, ventilation increases linearly with carbon dioxide production and oxygen consumption. In moderate exercise, ventilation process increases with increased consumption of oxygen and release of carbon dioxide. In case of severe/strenuous exercise, an uneven increase in ventilation takes place whereby rate of breathing increases to the highest with increased oxygen concentration and fall in carbon dioxide proportions. This, is significant to provide good aeration of body tissues and blood (McArdle et al., 2010 a).

Red blood cells are now laden with oxygen and require a distribution network that connects the lungs with other parts of body and a means of delivery around the body. Heart, the main organ in-charge of systolic blood pressure and diastolic blood pressure, acts as the basic driving force for transporting oxygen through arteries and veins that directs blood to move to respective target regions. During exercise, demand for oxygen by working muscles increase that is met with an increase in blood flow through the pulmonary circulation (Basset and Howley, 2000). At work or while exercising typical blood pressure may go as high as 175/65 and heart that beats at a rate of about 50–90 beats per minute normally in the absence of any considerable amount of strain, begins pumping more blood out to all parts of body especially to the working muscles. The increased oxygen demand of muscles during exercise is fulfilled by increased cardiac output resulting from a faster heart rate and larger stroke volume. The volume of blood pumped out of the left ventricle of the heart during each systolic cardiac contraction is known as stroke volume (SV). The difference between *the left ventricular end-diastolic volume (ESV) and the left ventricular end-systolic volume can be used to compute the SV volume.*

Blood flow through the pulmonary circulation increases while exercising or doing any activity. Adrenaline that is also released into the blood during this state, acts as a vasodilator that leads to arteriolar dilation that further increases blood supply to lungs. It means that the heart rate increases and reaches up to 170–210 beats per minute during intense exercise, while heart pumps out more blood with each beat when the stroke volume becomes higher (McArdle et al., 2010 a).

During steady state physical activity, systolic blood pressure and heart rate both increase, while afterwards the systolic pressure plateaus. In this case, diastolic blood pressure hardly changes or may even fall. At rest, most of the total blood volume moves to the viscera-gut, liver, spleen, kidneys and skin. While working or exercising, most of the blood is provided to the working skeletal muscles. There is also increase in the flow of blood to the skin needed for dissipation of heat (McArdle et al., 2010 a). As the extent of any physical activity increases, oxygen demand also rises, until a point is reached when it fails to boost further in spite of additional increment in work load. This is termed as maximal oxygen consumption also known as VO_2 max. After VO_2 max has been achieved an increased workload can be sustained only for a very short period, and by using the anaerobic metabolism in the working muscles. A person's VO_2 max level is not fixed at a given value. It could be altered by the level of physical activity done habitually. All of these changes and mechanisms are coordinated and controlled by special centers in the brain. It uses the nervous system and chemical messengers to control all of these processes. The strength and endurance of ventilatory muscles could be further developed through specific exercise training that also improves both inspiratory muscle function and maximal voluntary ventilation. Ventilatory training enhances exercise capacity and reduces physiologic exertion. Cardiac output may increase from 5 L/min to the maximum of 35 L/min in trained athletes or those involved in high physical activity on a regular basis (Bouchard et al., 1979).

6.1 EXERCISE AND TRAINING

Physical exercises depend upon the overall effect they have on the human body. Aerobic exercise entails any physical activity that uses large muscle groups and causes body to use more oxygen than it would do while resting. Movements from aerobic exercise cause heart rate to increase contributing towards improvement in body's oxygen consumption mechanism. Aerobic exercises also help increase body's stamina and improve cardio-respiratory fitness (McArdle et al., 2010a). It is for this reason that such exercises form an important part of all types of training regimes ranging from professional athletes to those for everyday person. VO_2 max is a convincing indicator of aerobic capacity and fitness. It is also a relatively good predictor of endurance performance; however it is not the only predictor of physical performance. VO_2 max tends to be higher among males than the counterpart. Young adult males have an average VO_2 max of 45 ml/kg.min and that among similar sample of females reaches as high as 35ml/kg.min. However, it can be increased with continual training (Bouchard et al., 1979).

Jogging/running gently at a steady pace is recognised as a great option for maintaining weight. Without imposing excessive stress on joints elliptical training, where a stationary exercise machine is used, can aid to perform walking or running. For people with hips, knees and ankles pain such an exercise could be a perfect alternative for maintaining physical activeness even in such state. Walking is another type of aerobic activity that involves moving about at a quite regular pace over short, medium or longer distances. Training with treadmill could provide numerous workout plans through multiple program set ups. Switching between running and walking could be an effective cardiovascular aerobic activity. This could be achieved by warming up first through walking and then taking a switch-off from walking for three minutes to running for another three minutes, each. Swimming can be another option for carrying out oxygen-rich energy consumption mechanism to further improve upon. It demands using both arms and legs to keep oneself afloat and move either forwards or backward. Swimming is a good full body exercise for those looking forward towards strengthening their core while improving cardiovascular endurance, simultaneously. Cycling is another low-stress exercise for the joints being equally great for improving leg strength. It typically involves pedaling longer distances than walking and/or jogging, both (Kylasov and Gavrov, 2011).

Anaerobic exercise that firm, strengthen and tone muscles as well as improve bone strength, balance and coordination includes strength and resistance training. Lactic acid is one of the products of anaerobic-carbohydrate metabolism taking place in cells. It is a very strong acid that is usually found in body in the form of lactate, on getting dissociated from its hydrogen ions. The amount of lactic acid in blood at the end of a maximal exercise/test reflects-

- intensity of that exercise for participant, for whether the participant gave maximal effort for the exercise,
- extent to which the participant need to refurnish the aerobic energy production system with anaerobic energy production, and
- and finally, the participant's lactic acid tolerance (Coggon and Coyle, 1991).

It should be noted here that the amount of lactic acid present in blood at any given point of time depends upon two factors as

- to the concentration of lactic acid being produced, entering the circulatory mechanism, and
- the concentration that is being flushed from the circulatory system.

Generally, endurance trained subjects tend to have lower blood lactate values at any given running speed or intensity, than the untrained counterparts. This happens because the trained participants have a better ability to use aerobic metabolism and a further better ability to clear lactate from circulation (Coggon and Coyle, 1991).

Production of lactate in cells is related with the release of hydrogen ions that are yet again known to cause muscle fatigue via different mechanisms. Athletes who could perform at high intensity work outs with minimal lactate accumulation in blood stream are able to avoid fatigue, better. The ability to use anaerobic energy systems is very important during high intensity exercise for which it is not uncommon to find very high maximal blood lactate values in athletes competing in high intensity events. Marathon running is greatly dependent upon anaerobic metabolism (Coggon and Coyle, 1991).

Check Your Progress 1

1) Name the two major forms of exercises based on cardio-respiratory metabolic functioning.

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2) What is the main byproduct of anaerobic metabolism?

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3) What is the key difference between aerobic and anaerobic metabolism?

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6.2 EFFECTS OF EXERCISE AND TRAINING ON HEALTH

As you are aware, one is capable of achieving immense flexibility through exercise and physical fitness activities, they also promote a vast and complex range of health-related benefits. Individuals keeping up the required physical fitness levels could indeed regulate the distribution of fat in their body and consequently prevent getting obese. Abdominal fat deposition, specifically higher ratio of visceral fat in body is noted to be cut-down directly by engaging in exercises employing aerobic metabolism. Trainings aimed at building strength have been known to increase the amount of muscle mass in body. However it could also reduce body fat, at the same time, so related precautions must be taken accordingly (Pedersen and Febbraio, 2012). Retaining physical fitness and exercising regularly have been proven to confer positive effects over body with blood pressure as staying active by building up a stronger heart, thereby regulating the blood pressure. Physical activity is capable of influencing factors that directly correlate to cardiovascular health. It can ensue one's blood pressure, cholesterol levels, blood lipid levels, blood clotting factors and strength of blood vessels. Sufficiently high activity level also improves body's metabolic activity relative of insulin. Physical activity tends to boost the immune system (Vander et al., 1994). However, it is significant to know that the health-related quality of life is dependent on the concentration of endogenous factors such as sex hormones, metabolic hormones, growth hormones, body temperature, blood flow, hydration status and body position, all of them are enhanced by considerable amount of exercise and active state. Moderate to high intensity physical activity has been shown to increase the count of natural killer cells, natural killer T cells, macrophages, neutrophils, eosinophils; complementing cytokines, antibodies and T cytotoxic cells. However, mechanism linking the interaction between physical activity and immune system has not yet been understood completely (Hale, 2003).

Cancer Prevention Centers for Disease Control and Prevention has proposed lifestyle-relating guidelines to maintain a balanced diet and engaging in suitable physical activity programmes to cut down the risk of appearance of several majorly prevalent lifestyle diseases. The World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) have provided a list of recommendations, with which they have found that consistency in physical fitness, activity and dietary factors relate directly with prevention of cancer, reflected by the evidence. The WCRF/AICR recommendations include the following:

- Body weight should be regulated carefully and strictly; by achieving leanness as much as possible, without becoming underweight all through;
- It is ideal for adults to engage in moderate intensity physical activity for 150 minutes of or vigorous intensity physical activity for 75 minutes, at least once in a week;
- Children should engage in moderate or vigorous physical activity, each week for at least 60 minutes;
- Daily-based physical activity for at least thirty minutes should be practiced by everyone;
- Avoiding sugar and limiting overconsumption of energy packed foods and eatables could solve numerous purposes associated by physical fitness;
- An ideal diet is a balanced diet with a variety of vegetables, grains, fruits, legumes, etc;

- Sodium intake along with the consumption of red meat and processed meat must be put on a strict limit; and
- Limiting alcoholic-drinks as two for men and one for women, a day (Malina et al, 2004).

These recommendations are widely supported by the American Cancer Society and the American Heart Association, too. Individuals with strict adherence to such guidelines could substantially reduce risk for development of cancerous state and afford prevention towards a multitude of chronic-health problems. Regular physical activity helps managing ideal blood pressure and makes possible achieving just right cholesterol levels - two key components that closely correlate with heart diseases and development of diabetic state, also. The American Cancer Society encourages public to adopt and maintain a lifestyle consisting of adequate physical activity by suggesting to meet the criteria through engaging into a variety of sports and activities such as hiking, swimming, circuit training, resistance training, weight lifting, etc. As discussed in the context of cancer it has been understood that cancer is not a disease that can be cured by physical fitness alone. Rather it is a multifactorial disease, for which physical fitness is one of the many controllable prevention factors (Malina et al., 2004).

Among females, prior to and during menopausal phase as do the female body changes there are several physical, physiological or internal changes taking place within their bodies. These changes could be manipulated in a way that would affect least to the mental and physical well-being by maintaining a healthy fitness level with regular exercise (Duong and Lee, 2015). With the onset of menopause, women tend to experience a reduction in muscle mass and an increased level in fat content of body. Even slight increase in exercise stretches could help to prevent appearance these changes, or slow down the processes along with least weight gain (Pedersen and Febbraio, 2012). With weight loss through regular exercise, reduces the vulnerability for different forms of cancers. Physical activity also slows the pace of bone loss closely associated with menopause, thus reducing the chance of bone fractures and osteoporosis. Excess weight increases vulnerability of heart diseases and hampers proper functioning of glucose metabolism, while regular physical activity counters both of these effects. Being involved in regular activities improves psychological health, not only for times during or after menopause but throughout till when life progresses. Physically active women undergo less bothersome hot flushes. Exercise enhances mood and reduces depressive feeling and anxiety releasing dopamine, neurotransmitters, endorphins and endo-cannabinoids. A short workout session or walk causes body to release them which then makes individual feel better (Duong and Lee, 2015).

6.3 EXERCISE, HEALTH AND AGEING

Exercise and physical activity, especially in relation to the older adults, is in the forefront of health since the last many decades due to its contribution into the overall health of an individual and also the community health, in general. Involvement in high intensity activities decreases with progressing age among adults while the prevalence of inactivity increases considerably with age. Physical fitness is a way to prevent ill health and get rid of diseases especially for senior citizens (Fried et al., 2001). When ageing as a biological phenomenon of growing older brings changes in the physical, psychological and social aspects of a person; healthy ageing is referred to as the physical, social, psychological and economical capacity of working with advancing age. Aging becomes healthy with sufficient intensity and frequency of physical activeness and resultant fitness. With physical fitness individuals can survive independently in their old ages without any health issues. Growing old healthier and enjoying the well-being need investment in promotion of health so as to avoid dysfunctioning and suffering from diseases through prolonged engagement in regular physical activity. However, the maintenance of regular physical activity depends on intrinsic motivation of the elderly (Singh, 2002). An optimum level of physical activeness increases mobility, prevents vulnerability for cardiovascular diseases, diabetes and reduced bone-mineral density. It also improves body balance thereby preventing falls, mental health, and cognitive functioning and enhances social relationships (Rosenbaum et al., 2014).

Physical activity has a fundamental role in prevention and treatment of chronic diseases. Precise measurement of physical activity is instrumental for investigating trends and associations of work out state with diseases carried out in many surveillance and epidemiological studies. Almost all public health initiatives aimed at increasing physical activity rely on measuring physical activity so as to monitor their effectiveness (Cavanagh et al., 1998). Human body composition, reflecting the physique pattern of a person changes with increasing age. Muscle strength, highest between ages 20 and 40, declines rapidly after middle age. Rate of decline in muscular power with age is similar among males and females. Accelerated strength loss with ageing coincides with weight loss and increase in vulnerability for chronic disorders such as diabetes, cardiovascular diseases and other lifestyle-associated disorders (Davis and Fox, 2007). Age-related performance decrement is visible to a greater extent among women than their counterpart. Exercise training for healthy elderly enhances heart’s systolic and diastolic properties and increases aerobic power. Endurance training done from 9 to 12 months tends to improve maximum oxygen uptake by 19% in men and 22% in women. Resistance training stimulates protein synthesis, slowing down loss of muscle strength with advancing age. Regular strengthening and balance exercises aid in reducing orthopedic injury in older men and women (Cavanagh et al., 1998). In post-menopausal women, regular exercise augments hormone replacement therapy to increase total bone mineral density (Duong and Lee, 2015). So, regular exercise in both men and women of older age groups help ensuring longevity of a person.

Keeping an eye over each phase of life is vital that needs to be viewed from a life-course perspective, as ageing is a lifelong process. Therefore, regular physical activity starting from early childhood through adulthood is an essential element for promoting overall health over an individual as well as the community level, as a whole. No amount of physical activity could cease the biological ageing process completely. However, it is well-proven that regular exercise could actually minimise the physiological effects of an otherwise sedentary lifestyle. Also, enough activity levels achieved on a daily basis tend to increase active life-expectancy by limiting the development and progression of chronic disease and disabling conditions. Physical activeness among elderly is critically important for preventing numerous diseases, maintenance of independence and improvement of quality of life (Wen et al., 2011). There is also emerging evidence for significant psychological and cognitive benefits emerging from regular physical activity-participation by the older adults. Ideally, the recommended exercise for older adults includes aerobic exercises, muscle strengthening exercises and flexibility exercises (Singh, 2002).

It is instrumental for the older adults to avoid inactive living style rather adopt regular physical activity regimen. They must realise that the need for physical activity does not end in later life as regular physical activity brings significant health benefits to people of all ages. With evidences increasingly indicating that enough amount of physical activity can extend the stretch of active and independent living, reducing disability and bringing about improvement in the quality of life of older people is an undeniable fact. A large-scale longitudinal (8-years) study carried out by Wen et al. (2011) found that every additional 15-minutes of daily exercise upto 100-minutes per day resulted in a further 4% decrease in mortality from any cause. There are researches, as those done by Cavanagh et al. (1998), and Davis and Fox (2007), proving that increasing physical activeness help minimising the burden on health and social-care through healthy ageing.

Check Your Progress 2

4) Briefly explain the role of exercise and training in enhancing ageing process.

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6.4 SUMMARY

Metabolic requirements of human body at rest or during exercise are met by oxygen supply to tissues and carbon dioxide removal from the tissues. Capacity to breathe, transfer oxygen to the lungs, enhance lung volumes/capacities, increase cardiac output, transporting oxygenated blood to active muscles and to remove carbon dioxide from the tissues during stress condition such as exercise determines the physical working capacity of an individual. The ability to perform physical activity for a prolonged duration depends upon efficient delivery of oxygen to the working muscles. Sustaining this energy requirement for a longer duration is determined by the cardio-respiratory endurance of the individual. When this process completes in the presence of oxygen-rich cellular environment, it is termed as aerobic metabolism, while that taking place in absence of oxygen is referred to as anaerobic metabolism. He/she while exercising reaches a steady state at which the person is comfortable with the exertion put forth by throughout the exercise. For this, cardio-respiratory endurance forms a crucial component of physical fitness. As a consequence of enhanced cardio-respiratory response to exercise any individual could develop high endurance with adequate training, compared to a sedentary individual. Regular exercise and physical activity greatly improves the overall physical working capacity of person of any age. Since ageing is an inevitable phenomenon resulting into gradual yet continual decline in the functional capacity; exercise and physical activeness have an important role to play towards successful ageing. Regular physical activity becomes an effective mechanism to reduce the functional degeneration of the body due to ageing process and thereby improves the overall health of the elderly, and consequently the quality of their life.

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6.6 HINTS/ANSWERS TO CHECK YOUR PROGRESS

1) Aerobic exercise and anaerobic exercise.
2) Lactic acid/ lactase.
3) Aerobic metabolism uses oxygen as its chief source of energy production, while anaerobic metabolism produces energy in the absence of oxygen.
4) An optimum level of physical activeness increases mobility, prevents vulnerability for cardiovascular diseases, diabetes and reduced bone-mineral density. It also improves body balance thereby preventing falls, mental health, and cognitive functioning and enhances social relationships.

UNIT 7 ANTHROPOMETRY AND CVD AND RESPIRATORY FUNCTIONS*

Contents

Learning Objectives

After reading this unit, you will be able to:

- understand the cardio-vascular and respiratory functions;
- know how to measure them; and
- learn about anthropometric measurements which predict cardiovascular diseases and lung function abnormalities.

7.0 INTRODUCTION

The total work an individual can accomplish is restricted largely by the heart, for this organ pumps blood, which in turn carries oxygen and nutrients to the cells of the body and transports away the waste products such as carbon dioxide, lactic acid etc.

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In a microscopic view, the cells of cardiac muscles appear striated and the arrangement of actin and myosin protein filaments looks similar to that of skeletal muscle. The cardiac muscle is composed of three separate muscle fibres: the atrial and the ventricular muscles and the specialised excitatory and conductive structures. These fibers are joined by surface connections called intercalated discs which run transversely across the fibers. Because of this syncytial arrangement, an impulse originating at one point in the heart spreads throughout the muscle mass and the entire heart contracts with every beat. The muscle tissues of the heart possess auto rhythmicity which means that it does not need nerve impulses to start each contraction. The contraction of the heart is due to a wave of depolarisation originating from a small area of specialised tissue in the right atrium known as sino-atrial (S-A) node, or the pacemaker (Shavers, 1981).

The heart contains four chambers the right and the left auricles and the right and left ventricles, all weighing less than a pound (Figure 1). The right atrium receives blood from the superior and inferior vena cava veins and pumps it to the right ventricle, which in turn pumps it via the *pulmonary arteries* to the lungs. Here it flows through capillaries where oxygen is absorbed and carbon dioxide is removed. It then flows into the left ventricle which pumps it out through the aorta, and through the systemic arterial system to the capillary beds of the various tissues. The vessel carrying blood from the heart is referred to as an artery and one carrying blood to the heart is known as a vein (Shavers, 1981).

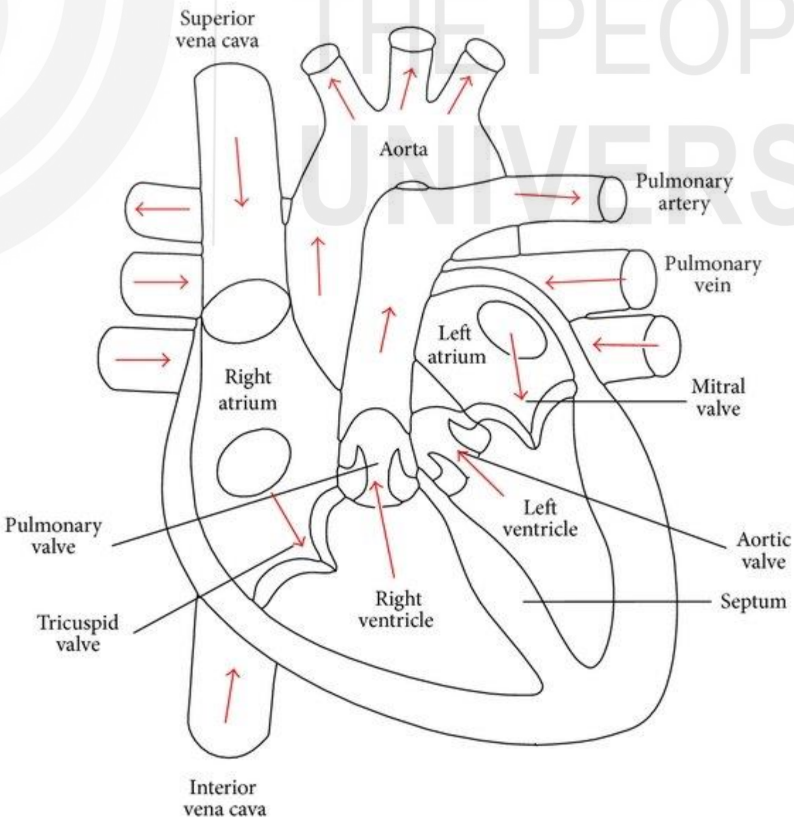

Figure 1: Structure of Human heart

Source: Sahu et al, 2015

The systemic arteries contain oxygenated blood which is bright red in color and often referred to as arterial blood, whereas venous blood is much darker in color and it contains deoxygenated blood. Thus we see that there are two parallel circulations, each with its own pump. The *pulmonary circulation* allows gas exchange in the lungs, and the *systemic circulation* is responsible for maintaining internal circulation (Shavers, 1981).

7.1 THE CARDIAC CYCLE

The *cardiac cycle* involves all the pressure changes, volume changes, and the valve actions that take place during one complete phase of contraction and relaxation of the heart. The contraction of the atrium and ventricle is known as systole and the relaxation as diastole. The period during which the entire heart is completely relaxed is termed as diastasis. Therefore, a typical cardiac cycle includes three phases:

- diastasis (resting period),
- systole (contraction period), and
- diastole (relaxation period).

The vibrations set up in the heart and vessels by the closure of these valves result in the heart sound. Since all the valves of the heart are closed and no blood is being pumped out during this period, the ventricles are in a state of isometric contractions. That is heart muscle cannot shorten during this phase. However, as the ventricular pressure continues to rise above the pressure in the pulmonary artery and the aorta, the valves at the entries of these vessels open and blood is immediately pumped out into the circulation. Since the heart (Ventricular chamber) muscle is able to shorten during the ejection period, this represents an *isotonic type contraction*. When ventricle systole is completed, this marks the beginning of ventricle diastole (relaxation).

During this period of relaxation, intra-ventricular pressure falls markedly. In fact, when it drops below the pressure in the pulmonary artery and the aorta, the valves guarding these vessels close, thus allowing the second heart sound to be heard. When the ventricles are completely relaxed and the intra-ventricular pressure continues to fall and thus drops below the intra-atrial pressure, the A-V valve open again. The *third heart sound* is caused by the vibrations of the chamber walls caused by movement of blood into the relaxed ventricles (Shavers, 1981).

7.1.1 Cardiac Output

Cardiac output is defined as the volume of blood pumped by the heart in one minute, and is generally expressed in liters per minute. Cardiac output is the product of heart rate times stroke volume (the amount of blood pumped with each beat of the heart). For example, if heart rate equals 72 beats per minute and stroke volume equals 70 ml of blood, then cardiac output is equal to 5,040 ml/min.

a) **Cardiac output during rest**: At rest in the supine position, the normal cardiac output in adults is approximately 5 liters per minute. This is generally achieved with the heart rate of 70 beats per minute for the untrained person and 45 beats per minute for endurance trained person.

b) **Cardiac output during exercise**: During exercise up to 40 to 60 percent of maximal capacity, cardiac output in trained athletes may be increased to 40 liters per minute, whereas untrained subjects may attain outputs of about 20 liters per minute. This increase in cardiac output is due to increase in both heart rate and stroke volume. Thus, the greater changes in cardiac output attained by trained athletes are due to their greater ability for increasing the stroke volume of the heart.

7.1.2 Heart Rate

The impulse that causes the heart to contract rhythmically originates within the heart muscle itself, in the right atrium known as the pacemaker or S-A node. Both nervous and chemical factors are involved in the regulation of heart rate during rest and exercise (Shavers, 1981).

Factors affecting Heart rate

There are several factors that affect the resting heart rate besides exercise and training. These include:

- **Posture:** Body position has a definite effect upon heart rate, although the extent of variation differs with each individual. It appears that the typical response from the sitting to the standing position is an increase of around 10 to 12 beats per minute. This is due to the influence of the gravity which lowers the volume of blood returning to the heart when one goes from a reclining position to a sitting or standing position. Individuals who are physically fit show a smaller increase between lying and standing than do sedentary individuals.

- **Sex:** The adult female's resting heart rate is some 5 to 10 beats per minute faster than that of the adult male under any given situation. The average resting heart rate is approximately 78 beats per minute for adult men and 84 beats per minute for adult females.

- **Age:** The resting heart rate drops progressively from birth (when it is approximately 130 beats per minute) to adolescence but in old age it again increases slightly. Also, maximum heart rate decreases at a rate of not quite one beat per year.

- **Emotion:** Emotional stress accelerates the resting as well as the exercise heart rate. Although an increased heart rate is most easily observed during rest in people as an anticipatory reaction, emotions may also result in an excessive cardiorespiratory adjustment during light exercise.

- **Environmental Factors:** The high temperature and altitude greatly increase the heart rate. In addition, for any standard temperature and workload, the increase in heart rate will be significantly greater if the air is still and the humidity is high.

Check Your Progress 1

1) List down the various factors which influence heart rate.

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7.2 STROKE VOLUME

Stroke volume is directly related to the diastolic volume up to a critical point. The increase in stroke volume is due to a greater emptying of the heart with each beat and not to a greater diastolic filling. This increased stroke volume implies a greater force of ventricular contraction during exercise. It is believed that the greater force of contraction is caused in part by an increased stimulation of the heart muscle from the sympathetic nervous system and by the increased amount of epinephrine hormones released from the adrenal glands. The stroke volume increases progressively from rest to moderate work and then it levels off at about 30-40 percent of the maximum aerobic power. The trained athletes have a greater capacity for extracting more oxygen from the blood into the muscle tissues than the sedentary subjects (Shavers, 1981). At rest and in the supine position the stroke volume of an adult man (non-athlete) is around 70 to 100 ml per beat depending upon the body size. For athletes, resting values are around 100 to 120 ml per beat. Thus a relatively slow resting heart rate, coupled with a relatively large stroke volume indicates efficient circulatory system. Because of the smaller size of heart in women, their stroke volume is usually 25 percent lower (Shavers, 1981).

Check Your Progress 2

2) Define Stroke volume.

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7.3 ANTHROPOMETRY AND CARDIOVASCULAR DISEASES (CVD)

Cardiovascular morbidity and mortality have been associated with different anthropometric measurements. BMI, Waist circumference, Hip circumference, Waist hip ratio have been found helpful in assessing the risk of CVD (DEEDI et al., 2017).

Anthropometric indices related to CVD risk factors in children and adolescents not only serves as a means of identifying overweight status but also the abdominal fat deposition that is found to be related to chronic diseases later in life (Janssen et al., 2005).

In adults, the waist circumference (WC) correlates well with intra-abdominal fat mass and has proved to be an independent risk for obesity-related diseases (Yusuf et al., 2005; Lemieux et al., 2000).

It is widely agreed that chronic diseases are escalating much more rapidly in developing than industrialised countries (Yusuf et al., 2001). Underlying genetic tendency or early-life adverse events may contribute to the metabolic syndrome and adverse body fat-patterning including abdominal adiposity and its related complications in non-European populations (Popkin, 2004).

Recent researches have shown that among men, a unit increase in BMI and WC are positively associated with an increased risk of CVD death (Luksiene et al., 2015).

In recent years, with regard to interrelationship of anthropometric indices with cardiovascular diseases, discussion has increased about which measure of overweight and obesity is the best indicator to identify those individuals who are at high CVD risk (Bastien et al., 2015; Huxley et al., 2010). The most popular measures are height and weight, expressed preferably as body mass index (BMI). However, recent research shows that BMI cannot make the distinction between an elevated body weight due to high levels of lean compared to fat body mass and an excess of body fat is more frequently associated with metabolic abnormalities than a high level of lean body mass (Bastien et al, 2015). The measurement of the waist circumference (WC) is used mostly for defining central obesity, but this measurement has been criticised for not taking into account differences in body height (Ashwell & Hsieh, 2005). It has been proven that an individual's percentage of body fat is higher in shorter people compared to taller people with an equivalent BMI (Han et al, 1997). It has been found that waist height ratio (WHtR) may be used as marker of body fat centralisation, which could be an efficient predictor of CVD risk (Ashwell & Hsieh, 2005; Kaess, 2010). Measures of WC, waist hip ratio (WHR) and WHtR, which more accurately describe the distribution of body fat compared with BMI, have been suggested to be more closely associated with clinical outcomes and mortality (Huxley et al., 2010; Petursson et al., 2011).

7.4 LUNG FUNCTIONS

In general, respiration refers to all of the processes that contribute to the exchange of gases between the body and the external environment.

Lungs provide the gas exchange surface separating blood from alveolar gases. Lungs have extremely large surface area for gas exchange. Pulmonary ventilation functions primarily to maintain a constant and favorable concentration of O_2 and CO_2 in the alveoli during rest and exercise.

Pulmonary Ventilation – It is the process by which ambient air is moved into and exchanges with air in the lungs.

O_2 is transferred from alveolus to capillary blood, CO_2 is transferred from capillary blood to alveolus. Each minute at rest 250 ml of O_2 and 200 ml of CO_2 diffuse in opposite directions.

During inspiration, the diaphragm descends, ribs are raised, volume increases, intra-pulmonic pressure decreases and the air rushes in, and as a consequence chest cavity size increases. Muscles responsible for this are: external intercostals, sternocleidomastoids and spinal extensors. Expiration is a passive process wherein diaphragm relaxes, ribs are lowered, volume decreases, intra-pulmonic pressure increases, air rushes out, as a result chest cavity size decreases.

Measuring Lung Volume:

Lung volume measurements can be done in two ways:

i) During forced expiration or inspiration which is called as Dynamic lung volumes.

ii) During normal or relaxed breathing which is called as Static lung volumes.

Lung volumes vary with

- age,
- gender,
- body size,
- body composition and
- stature

Static Lung Volume measurements are measured through spirometer by taking following measurements:

Tidal Volume (TV): It is the volume of air inspired or expired per breath.

Inspiratory Reserve Volume (IRV): It is the maximum amount of air inhaled after normal inspiration (at the end of tidal volume).

Expiratory Reserve Volume (ERV): It is the maximum amount of air exhaled after normal expiration (at the end of tidal volume).

Residual volume (RV): It is the volume of air left (residue) after full expiration.

Dynamic lung volumes are measured through spirometer by taking following measurements:

Forced vital capacity (FVC): It is the maximum volume of air exhaled from lungs during forced expiration after taking deep breath i.e. maximum inspiration. It is the sum of Tidal volume (TV), Inspiratory Reserve Volume (IRV) and Expiratory Reserve Volume (ERV).

FVC= TV+IRV+ERV

Forced expiratory volume in 1 second (FEV_1): It is the maximum volume of air exhaled from lungs in the first second of forced expiration after taking deep breath i.e. maximum inspiration.

Check Your Progress 3

3) Distinguish between static and dynamic lung volume?

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7.5 SPIROMETRY

With the advent of Spirometer in 1846 by Hutchinson, (Spriggs et al., 1976) vital capacity and lung function testing came to the forefront. At the time of World War II, Pulmonary Function Test (PFT) assumed a vast practical importance and a rapid progress ensured. The progress has then steadily occurred with constantly improving investigation techniques and equipment. During the last few decades, PFT has gained importance and the tests are routinely used. Spirometry is quick, noninvasive and painless. It is performed under various conditions with the subject breathing into a tube attached to the machine, which calculates the amount of air the lungs can hold and the rate that air can be inhaled and exhaled.

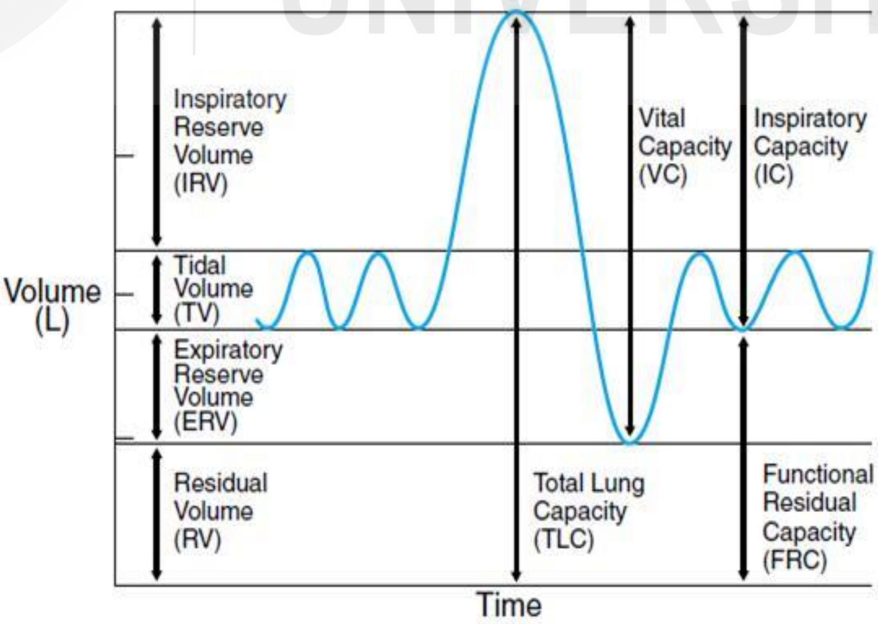

Figure 2: **Diagram showing Lung Volume and capacities**
Source:https://www.memorangapp.com/flashcards/162084/The+Respiratory+System%3A+Spirometry/)

7.6 FACTORS AFFECTING LUNG FUNCTIONS

Aging and lifestyle affect lung volumes and pulmonary function.The various lung parameters measured can be utilized for diagnosis of respiratory disorders and status of ventilatory function. Some of the reasons for the decrease in the lung functions with increase in age are:

- elastic recoil
- decrease in the strength of the respiratory muscles
- increase in the stiffness of thoracic cage
- decrease in the permeability of the cell membrane

The residual volume is most affected due to aging. Residual volume is 1.5 liter at the age of 25 years and 2.2 liter at the age of 60 years. The ratio of RV/TLC is also affected. It is 25% at the age of 25 years and increases up to 37% at 60 years of age.

In man the most convenient indices of body size are weight and stature but in the presence of stature, weight is only weakly correlated with indices of lung function; the size is better related to

- indices of linearity,
- the body fat which in large amounts has an adverse effect and
- the muscularity which, when it is increased, is usually associated with above average performance.

Stature is positively correlated with lung size as compared to any other measurement. The relationship between lung size and stature is almost linear in adults and for children exponential model is appropriate. It has long been recognized that gender-race differences in lung function exist, lung functions are better in males than in females.

Most studies focus on the relationship of lung function with age, particularly with normal growth and decline as the age increases. Studies are done on small number of subjects, and all but the most complex models for children or adults cannot account for the plateau in lung function which occurs at this time. In these investigations, height, which is strongly associated with lung function, was controlled for in order to better understand the pure relationship of lung function with age. The models which best describe lung function over a large age range will not necessarily be the best models for describing the height-lung function relationship at one extreme of the age distribution, particularly since nonlinear effects of age and interactions of age with height and other variables which may exist over a large age range are difficult to adjust for.

Ethnic group is an important determinant of lung size and ventilator capacity but does not influence the capacity of the lung to transfer oxygen into the blood.

Environmental factors which influence the respiratory functions of the lung are

- physical activity,
- the altitude,
- air pollution,
- smoking.

High altitude also affects the respiratory functions of the lung and causes

- hypoxemia,
- the density of the respired gas,
- selection of people whose genetic constitution have a competitive advantage,
- high level of physical activity and difficult terrain.

Pulmonary function at high altitudes is affected by a mechanism which is not well known yet. Some studies carried out on animals indicated that hypoxia in animal leads to respiration adjustment and increases lung capacity. Richard et al. (2000) argued that at high altitude where air pressure decreases gradually, expiration becomes easier. Moreover, due to the plasticity tissues of lungs, its capacity at high altitude also follows the Boyle-Marriot law inverse proportional relationship between the absolute pressure and volume of a gas (Hackett and Roach, 2001).

Respiratory muscle power and strength that play major role in respiration may be affected by high altitude.

In hypoxic conditions the chest size becomes larger; hence there is considerable increase in the lung functions among Peruvian and Himalayan populations. (Malik and Singh, 1979)

The high altitude hypoxic stress restricts the response and adaptation of the lung during rest as well as during exercise when oxygen and carbon dioxide fluidity is more.

7.6.1 Respiratory Functions, Age and Body Size

The functional residual capacity is small among infants. Respiratory rate is also high. The weight of the infant as well as age determines the consumption of oxygen. After stabilisation of functional residual capacity at birth, the ventilation minute volume and the alveolar ventilation are comparable to adults when, the difference in metabolic rate, is taken into consideration. Respiratory functions depend on body size and during childhood after allowing for the effects of body size is nearly independent of age. The size of the lung determines the respiratory functions such as total lung capacity, subdivisions, the indices which are dependent upon lung size, including the forced expiratory flow and the transfer factor. In children, till puberty these indices are related to stature in a curvilinear manner, a linear relationship on height raised to the power of about 2.6. Logarithms are used to analyse the relationship between lung size and respiratory functions.

After stature has been taken into account the indices are independent of age and usually independent of body weight and sitting height, but body muscle and fat respectively influence indices which include IC and ERV (Cotes, 2006). The rate of growth of the trunk and all its contents of which the lungs are also a part is greater during adolescent period and that is why, the sitting height is used as a reference variable.

7.6.2 Anthropological Dimensions

Pulmonary functions have been shown to correlate negatively with age, while a highly positive correlation has been recorded in relation to the height and sitting height in both sexes. In males, a positive correlation has been recorded in relation to the arm and leg length (Gomzi et al., 1983).The pulmonary functions of females negatively correlate with the body circumference (Gomzi et al., 1983, Pavlica, 1996), skin-fold and weight. The chest variables do not correlate with lung capacity to highest possible extent, which has already been detected among adults (Behuli, 1987; Pavlica, 1996). Studies correlating trunk and vital capacity of young males (Papovic et al.), proved that only shoulder width and sitting height positively correlate with vital capacity measures. All the indices other than $FEV_{1.0}$/FVC increase with standing height (Wasserman, 1999). There is linear relationship in the lung function with sitting height (Torres et al., 2003). Chest expansivity is defined as the value of maximum expiration minus value of maximum inspiration. More the value of chest expansivity, better is the lung function. Blair and Hickam (1995) found that FRC was lower in the seated position than in the standing position, and still in the supine position. In the supine position there is a lot of blood in the capillaries, Diaphragm shifts towards head, lung function reduces. Townsend (1984) found slightly higher $FEV_{1.0}$ and FVC values in standing subject than in sitting posture. (Makhsous et al., 2004), reported that slumped posture significantly reduced the lung capacity, compared with that of normal and WO-BPS postures (sitting upright with partially removed ischial support and lumbar support). Lin et al. (2006) concluded that slumped posture has significantly lower values of lung capacity and expiratory flow and in the standing were significantly superior to those in slumped, normal sitting postures. Lung functions are the function of thoracic size. Vital capacity has correlation with many anthropological dimensions and can be regarded as an indicator of body constitution type. Stepwise multiple regressions have found that BMI and biceps skinfold thickness contributed significantly to prediction of residual volume and TLC.

Check Your Progress 4

4) How Anthropological dimensions affect Lung function?

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7.6.3 Lung Functions and Circumferences

Canoy et al. (2004) compared the relations of WC, WHR, and BMI with FVC and $FEV_{1.0}$ and found that pulmonary function was negatively associated with increasing quintiles (group of population according to distribution of values) of WHR, WC, and BMI, and, after adjustment for height, WHR in men and WC in women were associated with a bigger reduction in respiratory function than was BMI. When subjects were divided according to waist (abdomen) - hip circumference ratio (WHR), VC and TLC were significantly less in those with larger WHR (Darryl, 1997). Compared with WHR, WC is a more convenient measure, is less likely to be influenced by sex or degree of obesity, and is a better correlate with visceral adipose tissue. However, although these measures are convenient and can easily be applied in large-scale epidemiologic studies, they cannot separate out contributions of increased abdominal mass, restricted outward movement of the muscular abdominal wall, and intra- thoracic factors. Magnetic Resonance Imaging (MRI) scanning, which can quantitate intra- abdominal fat, may validate these measures in future epidemiologic studies.

It was also found that if the value of hand grip strength is more, better is the pulmonary lung functions.

7.6.4 Obesity and Lung Functions

In obese people, the presence of adipose tissue around the rib cage and abdomen and in the visceral cavity loads the chest wall and reduces functional residual capacity (FRC) (Salome et al., 2010). Even a slight change in weight decreases the FRC and ERV values. This change in FRC values with an increase in weight has an impact on lung functions. This decrease in FRC values escalates the risk for both expiratory flow limitation and airway closure. These low ERV values give rise to abnormalities in ventilation distribution. Obesity may also have impact on broncho-constriction which leads to airway closure and thus affects ventilation distribution. Thus we can say that obesity has harmful impact on lung function even in the absence of any lung disorder.

Although obesity was found to be associated with severe impairment of ventilation, most of the study population has been morbidly obese adults. No correlation was observed between pulmonary function parameters and anthropometric measurements in the pediatric age group (Maiolo et al., 2003) Salome et al., 2010).

7.7 SUMMARY

The cardiovascular disease is widely considered the main cause of death and disability worldwide. A positive relation have been recognised between cardiovascular indicators and genetic, environmental and lifestyle factors. Various research studies have shown that, BMI, WC and WHR were the best indices for predicting CVD risk factors among populations. They can be used for clinical purposes to regularly measure WC and WHR in addition to BMI as a screening tool to identify high risk population.

Although the effects of sex, ageing, height and race on pulmonary function tests have been described, only non-significant associations have been observed between body weight and lung function among healthy persons after having accounted for the effects of age and height. However, few studies have considered the influence of body compartments (e. g. lean and fat masses and their distribution) on lung function and respiratory gas exchange.

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7.9 HINTS/ANSWERS TO CHECK YOUR PROGRESS

1) Factors which affect heart rate are exercise, strength training, body posture, age, emotional state, environmental factors, etc.

2) Stroke volume refers to amount of blood pumped by the left ventricle of the heart in one contraction. The stroke volume is not all the blood contained in the left ventricle; normally, only about two-thirds of the blood in the ventricle is expelled with each beat. Together with the heart rate, the stroke volume determines the output of blood by the heart per minute.

3) Static lung functions are not affected by the rate of air movement in and out of the lungs. It includes following lung volumes i.e. TV (tidal volume), IRV (inspiratory reserve volume), ERV (expiratory reserve volume), and Force Vital Capacity (FVC)) whereas dynamic lung functions depend upon the rate at which air flows out of the lungs. It includes stroke volume, breathing rate not air movement in single breath and minute ventilation (VE).

4) Standing height and sitting height in both sexes have positive impact on lung function (more the height lung function will be better). In females, body circumference, skinfold and weight negatively impact lung functions. In males more the arm and leg length higher will their lung volumes.

UNIT 8 GENDER AND ETHNICITY*

Contents

LEARNING OBJECTIVES

After going through this unit, you will be able to:

- understand the concept of physical fitness;
- describe the five areas of physical fitness;
- know the health benefits of physical activity and cardiorespiratory fitness; and
- recognise the gender and ethnic difference in cardiorespiratory fitness.

8.0 INTRODUCTION

Physical fitness is a state of health and well-being, and the ability to perform physical work and other activities all through the day. A minimal level of fitness is essential to carry out daily activities without being physically exhausted. Physical fitness is multidimensional and there are five key components that define the physical ability or fitness, which are muscular strength, cardiorespiratory endurance, flexibility, muscular endurance and composition of the body (Flynn et al., 2018). There are various advantages of physical fitness which include more years of life without disease, longer life expectancy, higher quality of life and psychosocial well-being that involves social, physical, and emotional aspects.

8.1 FITNESS RELATED HEALTH

Fitness and health are essential for a long, active and quality life. Without distinction of race, religion, political belief, economic or social condition, the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being. As defined by WHO, health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 2021).

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Physical health is vital to the complete health of an individual. Physical fitness and better health outcomes are correlated. Physical activity plays a key role in preventing various health issues. Regular exercise is the single most important thing that a person can do for maintenance of good health. It reduces the risk of various diseases such as stroke, heart disease, diabetes, depression, cancers etc.

To perform daily activities without exhaustion, it is necessary to maintain health in the five areas of physical fitness. Improvement in these areas of physical fitness will enhance quality of life, optimize health and well-being and decrease risk of chronic disease.

Below is a short description of each of the areas of physical fitness:

- ***Cardiorespiratory endurance:*** It is the ability to carry out prolonged, large muscle, dynamic movements at a moderate to high level of intensity. Cardiorespiratory endurance relates to the heart's capability to pump blood and lungs' capability to take in oxygen.
- ***Muscular strength:*** It is the capacity of the muscles or muscle group to exert force over a single or maximal effort.
- ***Muscular endurance:*** It is the capability of muscle to perform repetitive movements for extended periods.
- ***Flexibility:*** It is the ability to move joints (such as elbow or knee) through a full range of motion.
- ***Body Composition:*** It is the relative amount of fat to fat-free mass. Body composition influences quality of life and overall health and wellness. Improving cardiorespiratory endurance, muscular strength and muscular endurance will enhance body composition by decreasing body fat. Excessive body fat reduces physical and mental performance, appearance, and increases health risks.

Besides the five health-related dimensions, there are six skill-related components that help in improving optimal fitness, which are agility, coordination, speed, power, balance, and reaction time. These components do not directly affect a person's health, but they are important. Skill associated components are more often linked with skill development and sports performance.

When subjected to stress human body adapts appropriately. In the perspective of exercise, stress can be described as a physical exertion above the normal activity. There is individual variability in activities that result in stress and the differences depend on their level of fitness. Stress is relative to individuals; but there are guiding principles in exercise that can assist people to manage how much stress they experience to prevent injury as well as enhance their body's capacity to adapt. These principles give useful insights essential for managing an efficient fitness plan.

Physical activity is any movement carried out by skeletal muscle that involves energy. Health benefits of physical activity include improved blood-lipid profile, blood pressure and heart health. Physical activity is aimed at improving health and exercise is aimed at improving health and fitness. The extent of stress placed on the body during exercise can be controlled by Frequency, Intensity, Time and Type. These variables are known as FITT (Flynn et al., 2018).

Frequency and Time of Exercise

In order to enforce new stress and enhanced adaptation, variables can be managed in combination with other variables or independently. Frequency and time can be as such. Frequency correlates to how regularly exercises can be taken up over a period of time. The frequency of walking or cycling sessions would be determined weekly in most cases. To stimulate advancements, a beginner may ascertain that two to three exercise sessions a week are adequate. However, to a seasoned veteran two to three exercise sessions may not be sufficient to stress the system.

In keeping with the principle of overload, as fitness progresses, stress must surge to ensure continuous benefits and prevent plateauing. The duration of exercise also adds to the extent of stress felt during a workout. Four-hour marathon is more stressful on the body than a thirty-minute brisk walk. Although time and frequency are autonomous, they are often merged together as volume. The level of stress experienced is more precisely indicated in volume. It is related to the progression principle which relates to an optimal overload of the body without compromising safety by way of finding an amount that will drive adaptation.

Nature of Exercise

The nature of exercise performed by individuals should reflect his/her goals. In cardiorespiratory fitness exercise, the intention is to stimulate the cardiorespiratory system. Other activities that can stimulate the cardiorespiratory system include aerobic classes, dancing, swimming, etc. These exercises can develop lung capacity and enhance heart function. To ensure fitness, it is better to be more particular in exercise. When creating a training plan, the principle of specificity should be taken into consideration.

Stress is very specific in relation to exercise and there are various types of stress. Metabolic stress, force stress and environmental stress are the three main stressors. Body adapts based on the kind of stress being laid on it. Force stress accounts for the extent of force essential during an activity. For instance, significant force production is necessary to lift heavy loads in weightlifting. Training strategies must be different to acquire the right kind of musculature since the force requirements differ.

Environmental stress, for instance exercising in the heat, places enormous extent of stress on the thermoregulatory systems. The only approach to adapt is through heat exposure and proper adaptation can take days to weeks. In brief, to enhance performance, training the way a person wants to adapt or being specific in training is vital.

Intensity

The most important variable of FITT is intensity of the activity which drives adaptation more than any other components. It is essential for beginners in fitness program to quantify intensity. Intensity can be measured by heart rate, which is one of the best techniques to appraise a person's effort level for cardiorespiratory fitness. Quantify in numeric value will provide a better understanding of the effort level during exercise sessions. It will also assist in designing sessions that adjust individual goals.

Rest, Recovery and Periodisation

Athletes have been challenged to balance their exercise efforts with performance enhancements and sufficient rest. Rest and recovery from the stress of exercise ought to be proportionate to prevent excessive stress. Progressive fitness training phases can be split into different sections to achieve optimal rest and recovery without overstressing. This training principle, periodisation, is particularly vital to serious athletes. The principle of periodisation suggests that training plans incorporate phases of stress followed by phases of rest.

To achieve healthier lifestyle, it's important to set goals using the SMART (Specific, Measurable, Achievable, Realistic, and Timely) guidelines after assessing one's current fitness levels and then create personalised fitness plan. Once these steps are taken up, significant progress has been made toward accomplishing a healthier lifestyle. After investing energy and time to develop a well-designed and thoughtful fitness program, it is time to gain the returns of good execution.

The evaluation, planning and preparation are certainly the toughest parts of achieving a healthier lifestyle. Once a person knows what to do and how to do it, accomplishment is just a matter of executing it. But the capability to stick with a program proves hard for most people. Identifying barriers that may prevent a person from steadily following through will prevent getting derailed from their set goals. Among the barriers, shortage of time has been mentioned as one of the most common challenges. Work schedules and daily living activities can leave a person with little time to pursue one's goals. Preparing a list of the things that prevent a person from consistently exercising and then evaluating schedule and finding a time for squeezing in exercise routine can help. Irrespective of when exercise is scheduled, it's important to exercise consistently.

For achieving consistency in daily fitness program, below are a few additional tips:

- Think long term and think lifestyle: The intention is to make exercise an enjoyable activity daily throughout life. Developing a passion for exercise will not happen instantly. Forming your ideal schedule will take time. Commence with this understanding in mind and be patient with yourself as you work through the challenges of including exercise as a regular part of your life.

- Take off slowly: There is no need to overdo exercise in the first week. You are in this journey for the long haul. Plan for low intensity activity, for initial two to three days per week, and for realistic periods of time, about twenty to thirty minutes per session.

- Start with low Intensity or low Volume: You can start with low intensity exercise and progressively improve your efforts in terms of quality and quantity as fitness progresses. This can be done with more time and frequency. You can also improve your intensity as you progress. Both should not be changed at the same time in starting a program.

- Keep track: Outcomes of exercise program usually appear in a very anticlimactic manner, slowly and subtly. Consequently, when immediate improvements are not evident, participants become disheartened. So, keeping track of one's steady efforts, body composition, and fitness test results will help. Observing those subtle improvements will encourage and motivate you to continue your fitness program.

- Seek support: Support is important in fitness program as it provides encouragement, accountability and inspiration. People who share a common interest will enhance your ability to continue in your fitness program. So, look for family members, friends, groups, or even virtual group using apps and other online forums for support.

- Change your activities periodically: Changing your physical activities sometimes will prevent boredom. Overall targets are to be consistent, build fitness, and reap the health benefits related with fitness program. Instead of engaging in the same activity such as walking, jogging, riding a bike or playing basketball always, sometimes change the activities. Also change the place of your workout by finding new walking paths, parks or hiking trails.

- Have fun: You are more likely to accomplish a long-term lifestyle change if you enjoy your activities. While you cannot presume to be excited about exercising daily, you should not be afraid of your daily exercise schedule. If it is dreadful, consider altering your activities more, or finding a new activity that's more enjoyable.

- Eat healthier: There is nothing more disappointing than being steady in your efforts to be fit without noticing the outcomes on the scale. Eating a balanced diet will quicken the results and enable you to feel more accomplished throughout your activities (Flynn et al., 2018).

Check Your Progress 1

1) Explain the five key components of physical fitness.

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2) What are the skill-related components that help in improving optimal fitness?

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3) Explain how stress placed on the body during exercise is controlled by Frequency, Intensity, Time and Type.

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8.2 HEALTH BENEFITS OF PHYSICAL ACTIVITY AND CARDIORESPIRATORY FITNESS

There are plentiful advantages of physical activity. Cardiorespiratory fitness and physical activity are associated to decrease all- cause and cardiovascular mortality. In addition to this, physical activity also lowers the development of chronic illness and boosts the healthy psycho-social and cognitive function. For optimal health, it is very important and necessary to encourage regular physical exercise. The advantages of physical activity demonstrate a dose-response association with health. Health benefits escalate with increase in physical activity level. Substantial attempts should be made to encourage this important agent of health, given the considerable health benefits provided by physical activity. Promoting physical activity should continue to be an essential health care policy objective (McKinney et al., 2016).

8.2.1 Cardiorespiratory Fitness

Cardiorespiratory fitness is a well- known and proven predictor of number of health outcomes. Understanding the pathways of improving the cardiorespiratory fitness is important for the development of proper interventions (Zeiher et al., 2019). One of the most dynamic aspects of the strategy to manage non-communicable diseases is the reduction of sedentary lifestyle and the advancement of physical activity (WHO, 2018; WHO, 2013).

Physical activity has always been related to positive health consequences and decline in all-cause mortality (Warburton and Bredin, 2017). Cardiorespiratory fitness is a characteristic of physical health that is associated to advantageous health outcomes. Physical activity is considered as behavioral and defined as any bodily movement which includes the exposure of energy. It is also described as the ability of the circulatory, muscular and respiratory system to supply oxygen during continued moderate-to-vigorous dynamic exercise (WHO, 2010a). Hence, cardiorespiratory fitness and physical activity are associated, but not the same. Cardiorespiratory fitness is often expressed as maximal oxygen consumption (VO_2 max) and it is usually evaluated using treadmill or ergometer exercise tests, while physical activity is often evaluated through self-report. Since cardiorespiratory fitness is important in non-communicable diseases prevention, it is essential to better comprehend the associates and determining factors of cardiorespiratory fitness in the general population (Zeiher et al., 2019).

Cardiorespiratory fitness describes the capacity of the body to deliver oxygen from the atmosphere to the skeletal muscles and to utilise it to produce energy to sustain muscle activity in the course of exercise. Internationally recognized gold standard measure of youth cardiorespiratory fitness is the peak oxygen uptake. Peak oxygen uptake is often expressed in relation to body mass or age. Peak oxygen uptake rises in accordance with physiological and morphological changes associated to growth and maturation. The tempo and timing of these physiological and morphological changes are specific to individuals. Fat-free mass is the most powerful morphological influence on peak oxygen uptake but not body mass (Armstrong and Mechelen, 2017; Armstrong and Welsman, 2019).

Sedentary persons are at greater risk for developing cardiovascular disease compared to active individuals. Physical inactivity is escalating globally causing remarkable health consequences and enormous burden to the healthcare systems. Physical factor is considered as the fourth leading risk parameter for mortality globally (WHO, 2010). Various researchers recommended that cardiorespiratory fitness is more closely related with cardiovascular disease risk parameters as compared to the physical activity (Mcmurray et al., 1998).

8.2.2 Determinants of Cardiorespiratory Fitness

The maximum rate at which oxygen can be used by the body during maximum physical exertion is expressed as VO2max.There are various factors affecting VO_2max and the values range from <20 ml/kg/min in inactive adults to 70-94 ml/kg/min in athletes (Kenney et al., 2015). As shown in comprehensive systematic review, there are a wide range of individual factors related to cardiorespiratory fitness (Zeiher et al., 2019). Some factors such as age, waist circumference and body mass index showed steady evidence of an association with cardiorespiratory fitness, while other factors appeared inconsistent or inadequate evidence of an association with cardiorespiratory fitness. There are few studies that have examined the association between cardiorespiratory fitness and behavioral factors other than physical activity and smoking, and the relationship between psychosocial factors and cardiorespiratory fitness. From the comprehensive systematic review, numerous implications for health promotion practice can be drawn. Socio demographic factors are correlated with cardiorespiratory fitness and this realization can be utilized in identifying subgroups of comparatively unfit persons who should be pursued for interventions. Strong relationship between cardiorespiratory fitness and aerobic leisure-time physical activity was evident from the review (Zeiher et al., 2019).

Cardiorespiratory fitness further depends on age, sex, genetics, body fat, smoking status and medical conditions (Zhang et al., 2004; Suminskiet al., 2009; Hirai et al., 2011). Obesity was also associated with lower maximal oxygen uptake and weaker cardiorespiratory fitness (Green et al., 2018). Longitudinal studies suggested that a low VO_2max is strong and independent prognosticator of several non-communicable diseases (Hooker et al., 2008; LaMonte et al., 2005). Conversely, VO_2max values higher than 30 ml/kg/min are associated with a lowered risk of mortality (Castillo-Garz´on et al., 2006).

Check Your Progress 2

4) Describe the determinants of cardiorespiratory fitness.

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5) What are the health benefits of physical activity and cardiorespiratory fitness?

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8.3 GENDER AND ETHNIC DIFFERENCE IN CARDIORESPIRATORY FITNESS

Gender and ethnic difference in cardiorespiratory fitness were manifested in various studies. Comprehensive systematic review showed that being male was independently associated with cardiorespiratory fitness. Moreover, ethnicity, education and socioeconomic status were also independently and consistently associated with cardiorespiratory fitness. But cardiorespiratory fitness showed inverse relationship with age, body mass index, body fat, waist circumference, and heart rate (Zeiher et al., 2019).

Gender disparity in cardiorespiratory fitness was also evident from other studies. A cross-sectional study conducted among healthy Swiss employees showed difference between men and women with mean VO_2max significantly higher among men than women. The study also showed that the fittest group among the participants were the younger ones and had a lower body mass index and waist circumference. The younger participants were more physically active and had higher difference of maximal to resting heart rate, and a lower double product, calculated as heart rate multiplied by systolic blood pressure at rest. Age, sex, waist circumference, smoking status and difference of maximal to resting heart rate are the most important determinant factors of cardiorespiratory fitness (Kind et al., 2019).

There are individual differences in response to stress though the principles of adaptation to stress of exercise can be applied to everybody. In HERITAGE Family study, families of five members which include mother, father and three children took part in a training program for twenty weeks. All the participants exercised three times in a week. By the end of fourteen weeks, they increased their exercise time to fifty minutes. There were wide-ranging individuals and families difference in responses to the same exercise. Such findings have led researchers to believe that individual differences in exercise response are genetic. Some professionals estimated that genes contribute to outcome of training up to 47% of outcome. Besides genes, there are also other factors such as gender, age and training status at the beginning of a program that can affect adaptation. Individuals with less training background experience rapid improvement (Flynn et al., 2018).

A cross-sectional study (Mungreiphy et al., 2012) carried out among young adults of three different ethnic groups of India from various geographical regions ranging in age from 20 to30 years showed ethnic differences in adiposity and cardiorespiratory fitness among the North-East Indians, South Indians and North Indians populations. General body fat deposition, evaluated by body mass index, grand mean thickness and the percentage of fat, was found to be the highest one in the Delhi region. But central adiposity evaluated from waist height ratio, waist hip ratio and conicity index was found to be suggestively higher among the subjects from Manipur, North-East India indicating a comparatively more androidal pattern of fat deposition in the population. Inter-population differences for most of the adiposity indices were significant. Respiratory efficiency differed significantly among the different ethnic groups.

Ethnicity, adiposity, and cardiorespiratory fitness were found to be associated. Lung functions as assessed from forced vital capacity, forced expiratory volume in 1s, forced expiratory ratio and peak expiratory flow rate were found to be more efficient among participants from North-East India than their counterparts from plains, suggesting an improved respiratory efficacy, and an adaptive role of higher physical activity level at hilly landscapes. Participants from Delhi, North India were more obese as compared to the participants from other regions and had relatively poor lung functions. This can be attributed to their sedentary city lifestyle, characterized by lower physical activity, irregular food habits and fast-food culture. Gender differences in the association of adiposity and hypertension was observed. The different ethnic groups demonstrated noticeable variations in body dimensions and cardiorespiratory health. There were gender and ethnic differences in adiposity measures and its associations with cardiorespiratory health indicators (Mungreiphy et al., 2012).

As evident from several studies, cardiorespiratory fitness is an essential health indicator and there are marked ethnic and gender variations. The results from various studies on cardiorespiratory fitness emphasize on the significance of encouraging physical fitness across gender, ages, and ethnicity to achieve good health and wellbeing.

Check Your Progress 3

6) Explain the gender and ethnic difference in cardiorespiratory fitness.

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8.4 SUMMARY

Physical fitness is the body's ability to function efficiently and effectively. It also helps in resisting diseases and enhancing healthy psychosocial and cognitive function. To improve the different aspects of health which include physical, mental and social well-being, it is vital to promote regular physical exercise and should continue to be an essential health care policy goal. Improvement in the different dimensions of physical fitness, muscular strength, cardiorespiratory endurance, flexibility, muscular endurance and composition of the body will enhance quality of life, optimize health and well-being. There are gender and ethnic difference in physical fitness and health outcomes. To achieve good health and wellbeing, various findings emphasize on the importance of promoting physical fitness across ages, gender and ethnicity.

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8.6 HINTS/ ANSWERS TO CHECK YOUR PROGRESS

1) The five key components of physical fitness are cardiorespiratory endurance, muscular strength, muscular endurance, flexibility and body composition.
2) The skill-related components that help in improving optimal fitness are agility, coordination, speed, power, balance, and reaction time.
3) Physical activity is any movement carried out by skeletal muscle that involves energy. The extent of stress placed on the body during exercise can be controlled by Frequency, Intensity, Time and Type. These variables are known as FITT.
4) There are a wide range of individual factors related to cardiorespiratory fitness. Some factors such as age, waist circumference and body mass index showed steady evidence of an association with cardiorespiratory fitness.
5) For optimal health, it is very important and necessary to encourage regular physical exercise. There are plentiful advantages of physical activity. Cardiorespiratory fitness and physical activity are associated to decrease all- cause and cardiovascular mortality. In addition to this, physical activity also lowers the development of chronic illness and boosts the healthy psycho-social and cognitive function.
6) Cardiorespiratory fitness is an essential health indicator and there are marked ethnic and gender variations. Being male was independently associated with cardiorespiratory fitness. Ethnicity, education and socioeconomic status were also independently and consistently associated with cardiorespiratory fitness. But cardiorespiratory fitness showed inverse relationship with age, body mass index, body fat, waist circumference, and heart rate