Lecture notes

Exercise Physiology

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Physiology
Physiology can be defined as one of the branches of natural science, which deals with; functional aspect of living organism.

Exercise:
Exercise represents a subset of physical activity that is planed with a goal of improving or maintaining fitness. Series of muscular work or movement that is carried out in a sequential manner are called exercise .This is economical, skillful, coordinated and graceful manner in order to fulfill a particular task.

Exercise physiology:
Study of how exercise alerts the structure and function of the human body. Exercise physiology is the study, which deals with how the human body responds and adjusts to exercise.
Exercise physiology is an applied science that deals with various interaction and adjustment physiologically before, after and during exercise.

Clinical exercise physiology:
Study of exercise use in the treatment or rehabilitation of clinical disorders.

Importance of exercise physiology:

Exercise physiology is an aspect of sports medicine that involves the study of how the body, forms a functional standpoint,responds,adjust and adapts to exercise.

Now a day’s sports training purely based on science.Exercise physiology is one of the important subject of that science.

Exercise physiology provides the physiological basis of physical education fitness and athlete programme.

Exercise physiology provides the physiological basis of therapeutic exercise which is mostly important for physiotherapy.

Exercise physiology gives us the knowledge about structure and function of various types of muscle of human body.

It give us knowledge about Bio-energetic system.

It provide information about nervous control of muscular movement.

It is helpful for understanding of the functional aspect of respiratory and cardiovascular system.

Exercise physiology is informative for sports and nutritional effect on sports performance.

It gives the knowledge about work and environment such as summer, winter humid and high altitude.

Physical fitness and its development-Exercise physiology gives the knowledge how to improve strength,speed,endurance,flexibility and coordinative abilities.

Exercise physiology is helpful for scientific basis of training schedule and its evaluation.

It gives the knowledge about the effect of doping and alcohol on sports performance.

It is helpful to know the immediate and long term effect of physical training.

Exercise physiology is important for understanding body adaptation.

Exercise physiology is also important for right selection of activity for individual.

Benefits of Exercise

Exercise has enormous beneficial effects in our body. Physiologically, it benefits virtually every system and cell of the body.Some of those are given below:

1.It increases the size of the muscle fibres,consequently increasing the muscle mass and muscular activity in the body.
2.It increases bone calcium, thus helps in maintenance of bone mass, particularly in the later age and post-menopausal women.
3.It increases cardiac output, increasing the stroke volume of the heart.It produces electric stability of the heart muscles reducing the risk of cardiac arrhythmia.
4.It increases venous return.
5.It increases hemoglobin concentration in the blood, providing better oxygen carrying capacity.
6. It increases vascular resistance in the inactive muscles.
7.It inhibits the blood clotting processes and stickiness of the blood. contributing reduction in heart attacks.
8.It increases oxygen pick up in the lungs.
9.It increases oxygen supply in the heart muscles and increases greater extraction of oxygen at the peripheral level.
10.It strengthens the tendons,ligaments,muscles and other tissues around the joints,lubricating the joint cartilages and capsules,maintaining proper flexibility of joints.Greater the flexibility of joints,lesser will be the chances of injury.
11.It decreases resting heart rate.
12.It avoids senility-increases oxygen delivery of brain.
13.It activates the sympathetic nervous system and put the whole body on the alert.
14.It increases gastrointestinal tone.
15.It lowers the blood cholesterol,which is a majo risk factor in coronary heart disease,improving blood high-density cholesterol (HDL), which is cardioprotetive.
16.It decreases blood triglycerides.
17.Blood pressure increases during exercise, but in the long run,it decreases the blood pressure.
18.It decreases insulin requirement,increases insulin Sensitivity thus ameliorates diabetes mellitus.
19.It increases glycogen storage.
20.It burns carbohydrate(suger)
21.It helps better control of hunger,increasing the level of leptin in the circulation.
22.It decreases body fat .It benefits the cardiovascular system by reducing body weight.
23.It enhances metabolic functions i.e.controling the body weight,thus preventing obesity.
24.It increases aerobic threshold.
25.It decreases stress(attitude).
26.It increases ability to handle stress(biochemical).
27.It improves resistance to cold.
28.It increases basal metabolic rate(BMR).
29.It decreases load on the heart.
30.It decreases muscle dependence on suger.
31.It increases emotional lift.
32.It helps in increased production of endorphins by the brain,which are nature’s own opiates.
33.The physical exercise has positive influence on the psychological functioning also. It reduces anxiety and depression,thus elevates the mood.
34.It enhances the psychomotor development and capacity to face impediments.
35.It improves memory and increases self-esteem.

Energy:
Energy is regarded as the capacity to do work.

Forms of energy:
There are five forms of energy that are relevant to exercise physiology. These are:

1. **Chemical energy:** It is stored or released during the making or breaking of molecular bonds.

2. **Thermal energy:** It is absorbed or released in the form of heat.

3. **Mechanical energy:** It is expanded in the performances of physical activities.

4. **Electrical energy:** It reflects the work needed to move electrically charged particles against the forces produced by electric fields.

5. **Radiant energy:** It is transmitted in the form of electromagnetic waves.

Energy currency

Energy is used by the body for its various physiological purposes. The rate at which energy is use varies greatly with different physical activities. Exercise increases this rate. In fact it is the function of metabolism to provide this energy. Energy sources are stored metabolized and utilized by the body. Food particles are ingested absorbed and finally metabolized and transfer their chemical energy into high-energy phosphate bonds in adenosine tri-phosphate (ATP) which can be regarded as the energy currency of our body. During physical activities the enzyme ATPase breaks the high-energy bond in ATP and makes the energy available for muscular contraction.

Energy used in physical Activities

Activity	Cal/Kg/hr
Sitting and standing	1.7
Sedentary occupations (overall rate)	1.7
Light industrial work (overall rate)	2.5
Personal necessities, e.g. dressing undressing shaving, bathing etc.	3.0
Walking (5km per hour)	4.0
Active recreation (e.g. cricket)	4.0
Heavy work (overall rate)	5.0

Sources of energy

The major sources of energy in our body are carbohydrates, fats and proteins. They are provided by nutrients that must be digested and absorbed into the body.

Carbohydrates:
They are composed of carbon, hydrogen and oxygen molecules. They may be divided into:

1. **Monosaccharides:** It is the simplest form of Carbohydrates that is not further digested. The main Monosaccharides in the diet are glucose, fructose and galactose.

2. **Disaccharides:** They are formed when pairs of monosaccharides are linked together. The main Disaccharides in the diet are sucrose, lactose and maltose. Sucrose is comprised of glucose plus fructose. Lactose is comprised of glucose plus galactose. And maltose is comprised of glucose plus glucose.

3. **Polysaccharides:** They are large complex molecules that consist of many units of monosaccharides linked together. Starch is a Polysaccharides made by plant cell from units of glucose and glycogen is a Polysaccharides made by animal cells from units of glucose.

Fats:
Fat is a major source of energy in the resting state and during prolonged low- intensity exercise. It is obtained mainly from the diet, but can also be synthesized in the body from carbohydrate. If excess fat is supplied in the diet, this may be stored as fat reserves in the body.

Proteins:
During exercise, quantitatively, protein is a less important fuel than either carbohydrate or fat Protein generally accounts for less than 2% of the fuel metabolism during exercise of less than one hour's duration; during prolonged exercise, protein can account for as much as 10% of the total energy usage.

Immediate source of energy for muscle contraction

The immediate source of energy for muscular contraction is the high-energy phosphate ATP.

ATP is degraded via the enzyme ATPase as follows

$$\text{ATP} \xrightarrow[\text{ATPase}]{} \text{ADP} + \text{Pi} + \text{energy}$$

Formation of ATP without the use of O_2 is termed anaerobic metabolism in contrast production of ATP using O_2 as the final electron acceptor is referred to as aerobic metabolism

Muscle cell can produce ATP by any one or combination of three metabolic pathways:

(i) ATP – PC system
(ii) Glycolysis
(iii) Oxidative Phosphorylation

The ATP – PC system and glycolysis are two anaerobic metabolic pathways that are capable of producing ATP without O_2

The Biological energy Cycle

All energy in our solar system originates in the sun. Where does this energy is called Solar energy.

Actually this energy arises from nuclear energy. Some of this nuclear energy reaches the earth as sunlight or light energy.

The millions of green plant that populate our earth store a portion of this energy from the sunlight in still another form-chemical energy.

In turn this chemical energy is utilized by green plants to build food molecules such as glucose cellulose. Proteins and lipids from carbon dioxide (CO_2) and water (H_2O). This process whereby green plants manufacture their won food is called photosynthesis.

We on the other hand are not capable of doing this. We must eat plant and other animals for our food supplies. We are therefore directly dependent on plant life and ultimately on the sun for our energy.

Food in the presence of O_2 is broken down to CO_2 and H_2O with the liberation of chemical energy by a metabolic process called respiration.

The sole purpose of metabolic respiration is to supply the energy we need to carry out such biological processes as the chemical work of growth and the mechanical work of growth and mechanical work of muscular contraction.

This entire process is called the biological energy cycle.

Adenosine triphospate (ATP)

1. Definition: ATP (Addeosine triphosphate) is a high energy phosphate compound which is the strong form of energy in the body.
2. Composition:
   a) Adenine
   b) Ribose
   c) Phosphates.
3. Source:
   a) Oxidative phosphory lation
   b) Glycolysis
   c) TCA cycle.
4. Functions It helps in
   a) Synthetic process
   b) Muscular contraction
   c) Nerve conduction
   d) Active transport
   e) Secretion by the gland.

In the living cell, the principal high-energy intermediate or carrier compound is adenosine triphosphate (ATP)

Catabolic process: Synthesized ATP
Anabolic process: Used ATP

ATP: is a nucleotide triphosphate containing adenine, ribose and three phosphate groups.

ATP: plays a central role in the transference of free energy from the exergonic to the endergonic process.

Exergonic: ATP $\longrightarrow$ ADP+P_1
Endergonic: glucose + Pi $\longrightarrow$ Glucose 6p+$H^2$0

ATP: The turnover over rate of ATP is very high. In humans, an amount of ATP approximately equal to the body weight is formed and broken down every 24 hours.

ATP: The rapidity of ATP turnover precludes its use as a storage from of energy.

Muscle metabolic system during exercise:

The same basic metabolic systems are present in muscle as all other parts of the body. These important metabolic systems are-

(i) The phosphagen system
(ii) Glycogen lactic acid system
(iii) The Aerobic system.

The Phosphagen system

The combined amount of cell ATP and cell phosphocreatinine are called phosphagen energy system.

This energy system can provide maximum muscle power for 8-10 seconds, Almost energy for the 100-meter dash.

ATP: The basic source of energy for muscle contraction is Adenosine tri phosphate (ATP) which contain the following formula-

Adenosine – $po_3 \sim po_3 \sim po_3$-

The bonds attaching the last two phosphate radicals to the molecule, designated by the symbol (~) are high-energy phosphate bond.

Each of this bond stores 7300 calories of energy per mole of ATP under standard conditions when one phosphate radical is removed from the molecule. 7300 calories of energy is released and that can be used to energize the muscle contractile process and same for the second phosphate molecule.

Removal of phosphate radical converts the ATP into ADP (Adenosine di- phosphate) and removal of the second, converts this ADP into Adenosine mono phosphate (AMP).

Release of energy from PC (Phosphocreatinine):

Phosphocreatinine also called creatinine phosphate (CP) it is another chemical compound that has a high-energy phosphate bond. That has following formula-

Creatinine ~ po_3-_

This can decompose to creatinine and phosphate ion and in doing so release large amount of energy. In fact the high energy phosphate bond of phosphocreatinine has more energy than the bond of ATP (10,300 calories permole**)**
Special characteristics of energy transfer from phosphocreatinine to ATP within a small fraction of a second. Therefore, all the energy stored in the muscle phosphocreatinine instantaneously available for muscle contraction, just as the energy stored at ATP.

Glycogen lactic acid sysytem:

The stored glycogen in muscle can be split into glucose then used for energy. The initial stage of this process is called glycolysis. This occurs without use of oxygen and therefore is said to be anaerobic metabolism.

During glycolysis, each glucose molecule is split into pyruvic acid molecules and energy is released to form ATP molecule. Ordinarily the pyruvic acid enters into the mitocondria of the muscle cells and reacts with oxygen to form still many more ATP molecules. How ever when there is insufficient oxygen for this second stage (the oxidative stage) of glucose metabolism most of the pyruvic acid converted into lactic acid.
(Lactic acid defuse from blood & interstitial fluid)

Therefore in effect much of the muscle glycogen becomes tactic acid and considerable amounts of ATP are formed entirely without the consumption.

Under optimal conditions, this anaerobic glycolysis mechanism (i.e. – glycogen lactic acid system) can provide energy for short to mrdium periods of muscle contraction. The period of muscle contraction is 1.3 to 1.6 min.

The Aerobic System

The aerobic system means the oxidation of good staffs in the mitochondria to provide energy. Glucose, fatty acid and anino acids from the food after some intermediate processing combined with 0_2 to release tremendous amount of energy. This energy are used to convert AMP and ADP into ATP. This system is used for prolonged athletic activity.

The brief overview of important metabolic system that supply energy for muscle contraction-

(i) Phosphocreatinine	Creatinine $+PO_3$	ATP		Energy
(ii) Glycogen	Lactic acid		ADP	for
(iii) Glucose		muscular		
Fatty acid				
Amino acid	$CO_2 + H_2O$		AMP	contraction

Energy Balance:

Energy is another word for "Calories"

Skeletal Muscle

Role of skeletal muscles in determining sports performance, a thorough understanding of muscle structure and function is important to the exercise scientists physical educator, physical therapist and coach. It is the purpose of this chapter to discuss the structure and function of skeletal muscle.

Human body contains over four hundred skeletal muscle, which constitute 40-50% of the total body weight.

Major functions of skeletal muscles:

i) Force production for locomotion and breathing
ii) Force production for postural support
iii) Heat produ8ction during cold stress.

- Skeletal muscles are attached to bones by tough connective tissue called tendon.
- One end of the muscle is attached to a bone4 that does not more (origin), while the opposite end is fixed to a bone (insertion) that is moved during muscular contraction.
- Flexors: Muscles that decrease joint angles are called flexors.
- Extensors: Muscle that increase joint angles are called extensors

Organization of skeletal muscle:

Skeletal muscle is made up of individual muscle fibres that are the "building block" of the muscular system in the same sense that the neurons are the building blocks of the nervous system.

Most skeletal muscles begin and end in tendons, and the muscle fibres are arranged in parallel between the tedious ends.

- Each muscle fibre is a single cell
- Muscle fibres are made up of myofibrils, which are divisible into individual filaments.
- The filaments are made up of the contractile proteins

Muscles fascia

Individual muscles are separated from each other and held in a position by connective tissue called fascia.

Muscle fibres:

Muscle fibre is a single cell that is multinucleated, long, cylindric and surrounded by a cell membrane (sarcolemma).

Muscle fascicle:

Individual bundle of muscle fibres are called muscle fascicle.

- Skeletal muscle in composed of muscle fascicle.
- Muscle fascicles are composed of muscle fibres or cells.
- Each fibre is composed of myofibrils

Composition of skeletal muscle

Muscle cells themselves
Nerve tissue
Blood
Various types of connective tissue

Layers of skeletal muscle:

- Epimysium: The outmost layer that surrounds the entire muscle in called epimysium
- Perimysium: Connective tissue inward from the epimysium is called perimysium. It surrounds individual bundles of muscle fibers.
- Endomysium: Each mucle fibers within the fasciculus is surrounded by connective tissue is called the endomysium.

Properties of skeletal muscle:

Excitability: the ability to respond to a stimulus (e.g., a neurotransmitter or hormone) by the generation and conduction of a reversal in membrane potential (action potential).

Contractility: the ability of muscle to contract and generate tension, at the expense of metabolic energy, when an adequate stimulus is received.

Extensibility: The ability of muscle to be stretched.

Elasticity: The ability of muscle to resume its resting length after being either stretched or contract

Structural Characteristics of skeletal muscle:

-Voluntary muscle having well developed cross – striations.

- Individual muscle fibers are separated (i.e. single cell)
- Muscle cell is multinucleated long and cylindrical
- Contains alternate light and dark band.
- There is no syncytial bridges between muscle cells.
- Does not normally contract in the absence of nervous stimuli.

Muscle cell proteins:

1. Thick filaments:

-Thick filament (MW: 480000); they are filamentous protein.

-Each filament contains 200 myosin molecules.
-Each myosin molecule contains six polypeptide chains
-Two heaving chains arranged in helical structure and from tail body and portion of myosin head.
-Four short chains is the part of myosin head.
-Each molecole of myosin contains myosin head.
-The myosin heads have binding sites for:
The Actin molecules in the thin filaments and
ATP and contains AT Pase enzyme .
-Interaction of myosin head with actin filament cause muscle contraction.

2. Thin filaments:

These are filamentous protein. It is thin filament. Actin filament is composed of
Fibrous actin (globular protein)
Tnopomyosin
Troponin (T, C, I)

Fibrous actin: Contains active sites that bind with myosin head and cause muscle contraction.

Tropomyosin: Fibre like protein which wraps helically around thin filament.

Troponin: Globular protein complex, which binds Ca^{++} and initiates contraction cycle, is a complex of 3 proteins.

Troponin T: It binds troponin to tropomyosin and form troponin tropomyosin complex.

Troponin C: It binds with calcium (ca^{++}) that initiates muscle contraction.

Note – Each molecule of Troponin C can bind up to 4 calcium ions.

Troponin I: It inhibits the interaction of myosin with actin.

Question: What are the characteristics of slow Twitch & Fast Twitch Fibre?

Or ,write down the differences between Slow & Fast Fibre?

Characteristics	Slow Fibre/Type- I	Fast Fibre/Type-II	
		IIa	IIb
Morphology	Dark/Red	White/Red	White
❑ Colour			
❑ Capillery	High	Intermittent	Low Capillery
❑ Fibre Diametre	Small	Intermediate	Large Diameter
Bio-Chemistry			
❑ Oxidative/glycolytic	So(Slow Oxidative)	FOG(FastOxidative Glycolytic)	FG(Fast Glycolytic)
❑ Mysin ATPase Activity	Low	High	High
❑ Calcium Capacity	Low	Intermediate	High
❑ Glycolytic Capacity	Low	High	High
❑ Oxidative Capacity	High	Medium/High	Low
Function &Contractility			
❑ Speed of action	Slow	Fast	Fast
❑ Fatiguability	Low	Mderate	High
❑ Force Capacity	Low	Intermediate	High

Muscle twitch:

A single action potential causing a brief contraction followed by relaxation is called muscle twitch.

Parts of muscle twitch (contraction cycle)

1. Latent period 5 m sec	Time between application of AP and initiation of contraction
2. Contraction 40 m sec	Muscle shortens and does its work
3. Relaxation 50 m sec	Muscle elongates and returns to original position
4. Refractory period m sec	Time of recovery between stimulations of muscle

Duration of muscle twitch

Fast muscle fiber: 7.5 ms (millisecond)
Slow muscle fiber: 100 ms (millisecond)

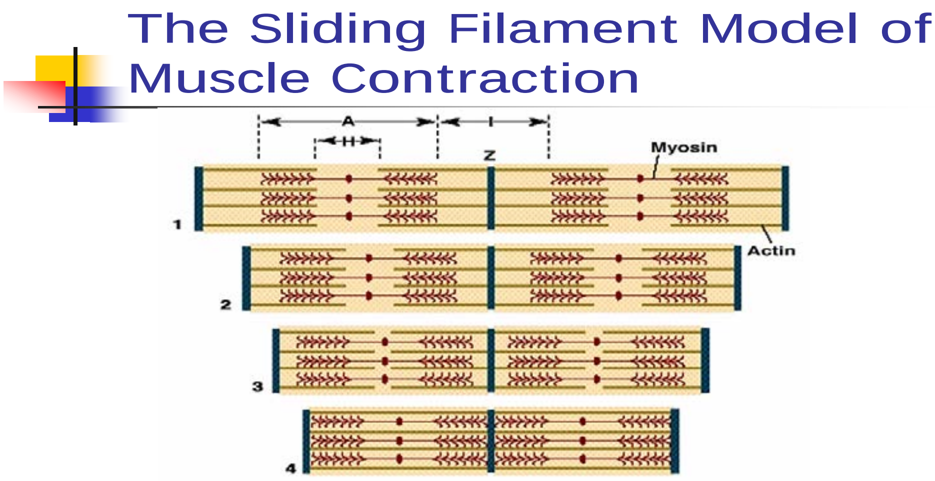
Sliding filament theory of muscle contraction:

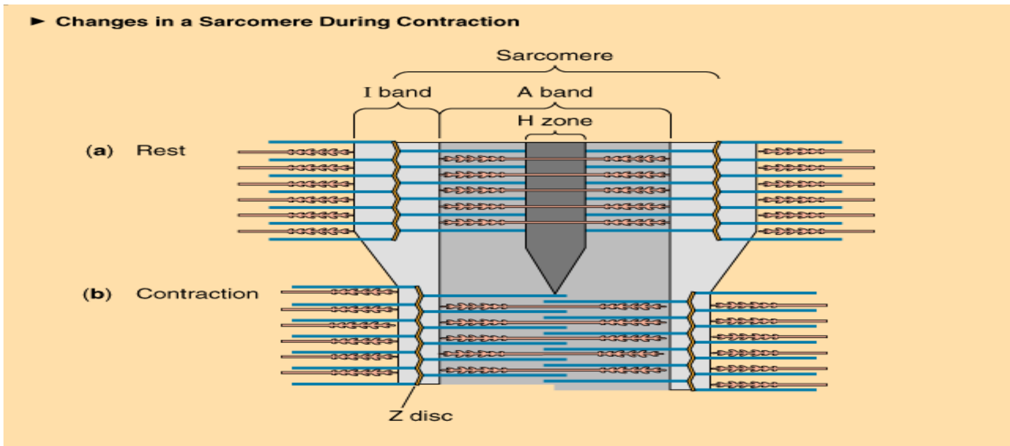
During muscular contraction the actin filaments slide over the myosin filaments forming the actomyosin complex. There is no shortening, thickening or folding of the individual filaments.

A band remains constant in size
H Zone becomes denser
I band varies in length becoming shorter

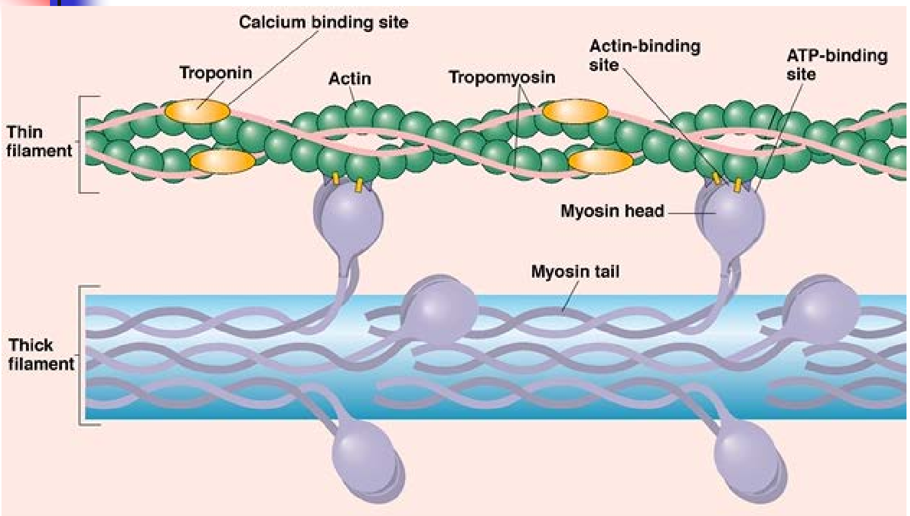
As a muscle contracts,
The Z lines come closer together
The width of the I band varies in length
The width of the H zones decreases but
There is no change in the width of the A band.

Conversely, as muscle stretched
The width of the I band increases
The width of the H zones increases but
There is still no change in the width of the A band.





Cross-Bridge Formation in Muscle Contraction



Aging:

The process of growing old involving the inability to reverse the gradual deterioration of cells important to the life process.

Aging should not be viewed as a sickness but as a natural process that involves the gradual alteration of body appearance function and tolerance to stress.

Aging has been defined as a progressive loss of physiologic capacities that culminates in death.

Life expectancy:

The average, statistically predicted length of life for an individual.

Chronological:

The age of a person expressed relative to time (usually years). Chronological age is best represented by a person's birth date.

Biological age:

The functional age of an individual based on physiologic conditioning. Biological age is assessed by such variables as maximum oxygen uptake, bone mineral content, muscles strength or flexibility.

e.g A person who is 65 years of age may have a biological age of 45 based on that person's fitness and health status.

Longevity:

The duration of a life beyond the norm.
longevity is deified in the random house dictionary as a long dunation of life.

Individual live depends on

- Heredity
- Environmental factor
- Availability of good health services

Changes during the aging process

Appearance:

- Graying of hair
- Balding
- Drying and winkling of skin

Nervous system:

- Impairment of near vision
- Some loss of hearing
- Reduced taste and smell
- Reduced touch sensitivity
- Slowed reaction (reflexes)
- Slowed mental function
- Mental confusion.

Cardiovascular system:

- Increased blood pressure
- Increased resting heart rate
- Decreased functional capacity

Decreased cardiac output.

Body coneosition/metabolosm:

Increased body fat
Raised blood cholesterol
Slowed energy metabolism (blood metabolic rate)

Other physical characteristics:

Meno pause (women)
Loss of fertility (men)
Joints (loss of flexibility)
Loss of teeth (gum disease)
Bone mineral density.

CARDIO VASCULAR SYSTEM

HEART: The human heart is true wonder of nature, its 100000 beats per day allows us to live and breath.

Heart is the central pumping organ it receives and pumps out blood to the whole body.

Shape – Conical or roughly heart shaped.

Size – 12 cm from base to apex,
6 cm from anterior to posterior.

Situation: On middle mediastinum in between two lungs.

Weight: 250 to 300 gm.

Nerve supply – Sympathetic
_ Parasympathetic

Heart muscle/ Cardiac muscle:

a. Atrial muscle
b. Ventricular muscle
c. Specialized excitatory and conductive muscle fibers

- The Sinus node (Sino-Atrial or SA rode)
- Inter-nodal pathway
- The AV node (Atrio-ventricular node)
- The A-V bundle.

Penetrating portions
Distal portions

- The left and right bundles of purkinjie fibers

Layers of the heart wall:

From out to inward
1. Epicardium
2. Myocardium
3. Endocardium

Chambers of the heart:
1. Receiving chambers -Rt atriums
-Lt atrium
2. Distributing chambers -Rt ventricle
-Lt ventricle

Valves of the heart:
1. Atrio – Ventricular (or cusepid) valves:
Rt - Tnicuspid (three cusps)
Lt – Bicuspid or mitral
2. Semilunar valves
- PUL, semilunars
- Aortic semilunars valve

Properties of Cardiac muscle:

1. Automaticity
2. Autorhythmicity
3. Conductivity
4. Excitability
5. All or none law
6. Frank starling law
7. Refractory period
8. Functional syncytium

Circulation: it is the process of blood and lymph flow through a close system of vessels, called circulation.

Types of circulation:

a. Systemic circulation or greater circulation
b. Pulmonary or lesser circulation
c. Portal circulation

Sequence of circulation through heart:

From body

↓

Superior and inferior venacava

↓

Rt atrium

↓ Tricuspid valve

Rt ventricle

↓ Pulmonary artery (Rt&Lt)

Lung (Rt & Lt)

↓ Pulmonary vein (Rt & Lt)

Lt atrium

↓ Bicuspid valve

Lt ventricle

↓

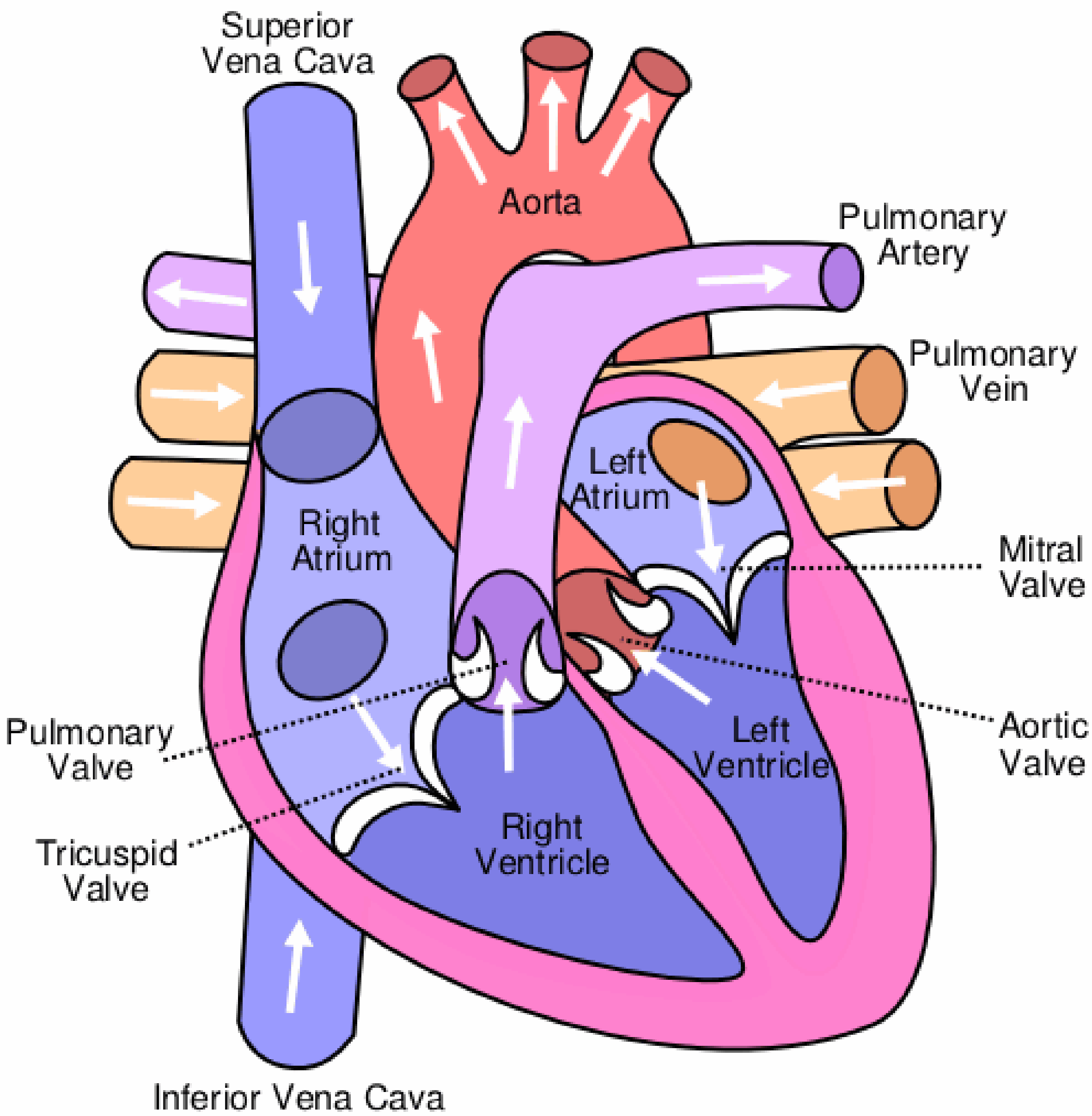
Arch of aorta

↓

Thoracic and abdominal aorta

↓

Body


Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Aortic Valve
Left Ventricle
Right Ventricle
Tricuspid Valve
Inferior Vena Cava

Venous Return:

It is the amount of blood that comes from periphery to right atria of heart in each minute. It is equal to cardiac out put.
It is about 5 liters/min.

Factors affecting venous return:

1. Muscular activity
2. Pumping action of heart
3. Pressure gradient in vessels
4. Respiratory pump
5. Gravity
6. Vasomotor tone

Cardiac reserve:

The maximum percentage that the cardiac output can increase about the normal level is called the cardiac reserve.

Normal value:

✱ Healthy young adult: 300 to 400 percent

✱ Athlete: It is occasionally 500 to 600 percent

✱ Whereas in heart failure there is no reserve.

Example: During severe exercise the cardiac output of the healthy young adult can rise to about five times normal; this is an increase above normal of 400 percent that is a cardiac reserve of 400 percent.

Factors affecting cardiac reserve:

Any factor that prevents the heart from pumping blood satisfactorily decreases the cardiac reserve.

This can result from –
a. Ischaemic heart disease
b. Primary myocardial disease
c. Vitamin deficiency
d. Dosage to the myocardiam
e. Valvular heart disease
f. Diphtheria etc.

Heart sound:

The vibratory motion of heart produced during the different events of cardiac cycle conducts through the structure surrounding the heart and produces special audible sound called heart sound.

Physiological basis that cause the heart sound:

a. Vibration of the taut values immediately after closure.
b. Vibration of the adjacent blood
c. Vibration of the walls of the heart and major vessels around the heart.

Clarification of heart sound:

1st heart sound 2nd heart sound	Audible by Stethoscope
3rd heart sound	detected by

4th heart sound phonocadiograph

Apex beat:

Definition: Apex beat is the lowest and outer most point of definite cardiac pulsation.

Location: In the 5th intercostal space 9cm from the midsternal line just medial to the left nipple.

Importance:

1. Measurement of heart rate
2. Position of heart whether dextro cardia or not
3. Different heart disease diagnosis
4. Displacement of mediustinum due to pneumo thorax, pleural, effusion left ventricular hypertrophy etc.

Heart rate:

The number of heart beat per minute is called heart rate.

Normal heart rate:

Adult (range)	: 60 – 90 / minute
Average	: 72 / minute
In fetus	: 140 – 150 / minute
In newborn	: 130 – 140/ minute
In children	: 80 – 120 / minute
In old age	: 75 – 80 / minute

Factors affecting/Regulating heart rate:

1. Higher centre: Stimulation of posterior group of hypothalamic nucleus increases heart rate, while middle group decreases heart rate stimulation of area 13 of frontal lobe, causes trachycardia.

2. Respiration: Heart rate increases during inspiration particularly in children and decreares during expiration.

3. Cardio varcular reflexes:
   a. Baroreceptor reflex: Stimulation of baroreceptor decreases the heart rate
   b. Brain bridge reflex: Stimulation of brain bridge increases heart rate

4. Temperature: Increase body temperatures increases heart rate by directly stimulating the S.A node

5. Intra cranial pressure: Increase intra cranial pressure stimulates cardio inhibitory centre and causes slowing heart rate.

6. Muscular exercise: it increases heart rate

7. Age: From infancy to old age heart rate progressively decreases

8. Sex: Females have slightly faster heart rate then male

9. Surface area: Heart rate is inversely proportional to surface area

10. Endocrine factors:
    a. Adrenaline: Accelerate
    b. Thyroxin: Accelerate
    c. Posterior pituitary hormone: depresses.

Athlete Heart

A non pathological enlarged heart often found in endurance athlete. It is the result of LVH (left ventricular hypertrophy) in response to training. This is common in athletes who exercise more than an hour almost every day and occasionally in heavy weight trainers.

Mechanism:

- Prolong endurance and weigh training

  Blood volume and left ventricular filling pressure

  Left ventricular volume (i.e. the walls stretch more when filled with blood)

- Natural physical Adaptation occurs in the athlete's heart due to regular exercise.

Thickness of the wall (Through the addition of sarcomeres) and increase
Chamber size.

- Endurance training improves heart performance by increasing left ventricular volume and cardiac contractility.

Changes in Athlete Heart

- Axis deviated to left more.
- Increase thickness of the wall
- Increases stroke volume (stroke volume 170ml. (Approx.) in elite endurance athlete)
- Increase cardiac out put.
- Brady cardia (Decreased resting and sub maximal exercise heart rate)
- Improved calcium release and transport.
- Altered ECG (Electro Cardiogram)

Distribution of blood flow

Hemodynamics:

Hemodynamic is the study of the factors that determine the blood flow and BP in the body.

Blood flows in the vascular system from a higher to the lower pressure.

The primary determinants of blood flow are -

(i) Pressure gradient
(ii) Resistance

The principles of rate of blood flow are –

(i)Rate of flow (F) & Pressure gradient

(ii) Rate of flow (F) $\propto \frac{1}{\text{resistance (R)}}$

Blood flow depends upon the flowing factors

(i) Pressure gradient
(ii) Velocity
(iii) Viscosity
(iv) Length of the vessel

Types of blood flow

(i) Laminar flow

(ii) Turbulent

Blood pressure:

The lateral pressure exerted by the blood per unit area of vessel wall while flowing through it is called BP.

BP= CO x TPR

Blood pressure = Cardiac output x Total peripheral resistance.

Components of blood pressure:

(i) Systolic blood pressure

(ii) Diastolic blood pressure.

Unit of BP

Unit is mm of Hg.

It is writhen systolic over diastolic pressure.

Blood pressure of a normal adult:

Systolic pressure: 100 – 140 mm of Hg

Average 120 mm of Hg

Diastolic pressure: 60 – 90 mm of Hg

Average 80 mm of Hg

Importance of blood pressure:

(i) It is essential for blood flow

(ii) It provides motive force for filtration at the capillery bed

(iii) It is essential for tissue nutrition

(iv) It is needed for urine formation

(v) It is needed for lymph formation

(vi) It is important for venous return

Normal values of blood pressure at different ages:

1. Infant : 60/30 mm of Hg
2. 1 year : 80/40 mm of Hg
3. 3 years : 100/60 mm of Hg
4. 20 years : 120/80 mm of Hg
5. 45 years : 145/90 mm of Hg

6. 70 years : 170/95 mm of Hg

Blood pressure measurement (method):

(i) Auscultatory method (both systolic and diastolic)

(ii) Palpatory method (only systolic

Systolic pressure:

It is maximum pressure during systole.

It is about 100 –140 mm of Hg

Average: 120 mm of Hg

Significance:

1. The extent of work done by heart
2. The force with which the heart is working
3. The degree of pressure which the arterial walls have to withstand
4. It increases during excitement, exercise, meals etc.
5. It decreases while sleep, rest etc.

Diastolic pressure:

It is the minimum pressure during diastole.

It is about 60 - 90 mm of Hg

Average: 80 mm of Hg

Significance:

1. It indicates the constant load against which the heart works.
2. Increased diastolic pressure indicates that heart is approaching to failure
3. It is the index of peripheral resistance

Factors that influence blood pressure:

a. Cardiac output
b. Peripheral resistance
c. Others:

1. Age: Increases with age
2. Sex: In female slightly lower (5mm of HG). After menopause it reaches male level.
3. Build: The systolic pressure is usually high in an obese person
4. Exercise: Systolic Pressure rises; diastolic pressure is usually a lower.
5. Posture: During standing diastolic pressure is slightly higher; systolic pressure lowers. In recumbent position this condition is reversed.

6. Diurnal Variation: During daytime pressure rises up to 2-0 clock and then there is a slight fall. In case of night workers the blood pressure rises during morning
7. During deep sleep there is fall of blood pressure by 15 – 20 mm of Hg
8. After weal: increased up to 20mm of Hg
9. Emotion and excitement: systolic pressure increase

10 Respiration: Falls during most part of inspiration.

Factors that control blood pressure:

a. Cardiac output: Cardiac output depends upon -

(i) Blood volume

(ii)Venous return

(iii)Force of contraction of heart

(iv)Frequency of heartbeat

b. Peripheral resistance: peripheral resistance depends upon –

(i) Elasticity of arterial wall

(ii) Velocity of blood

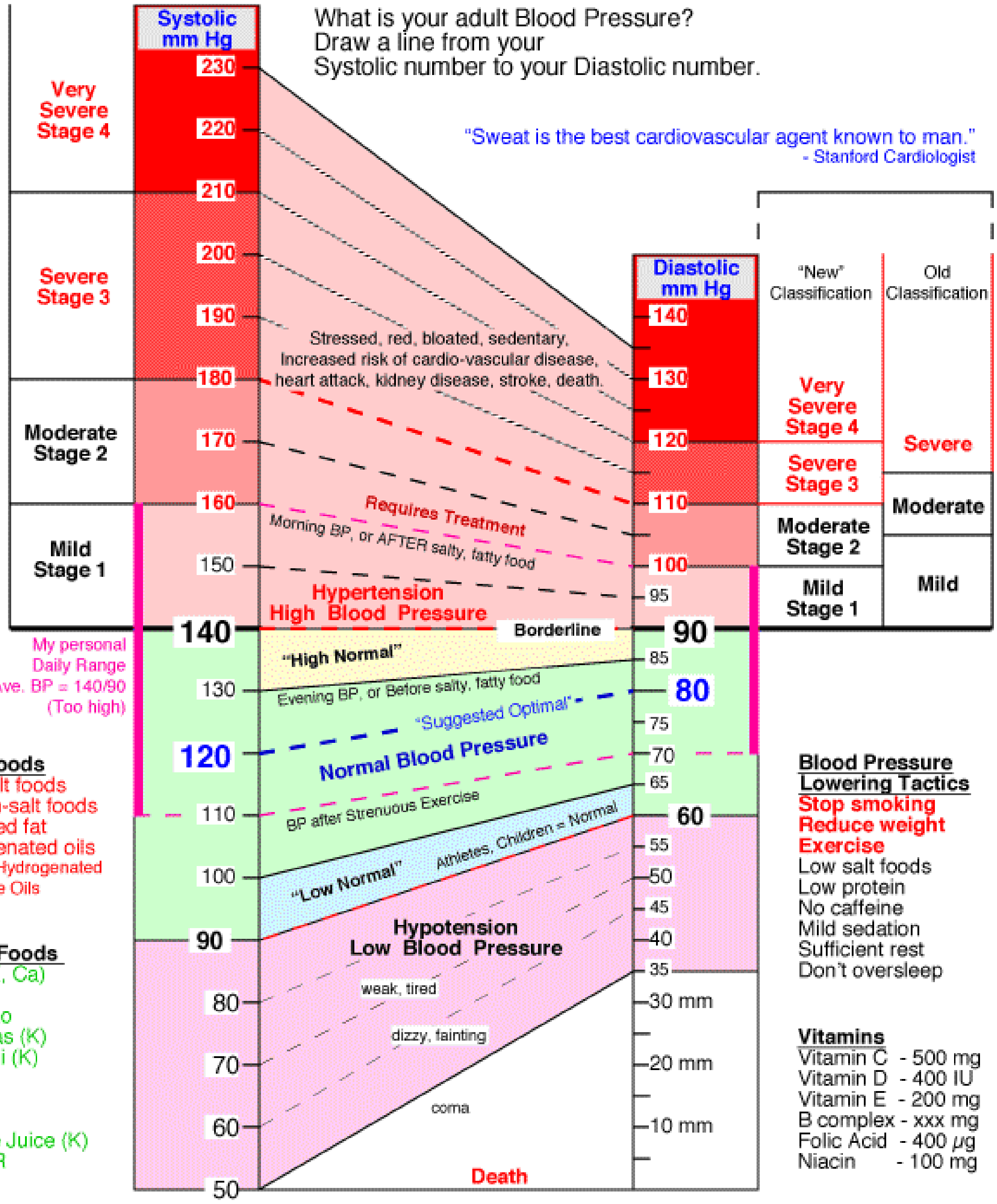
(iii) Viscosity of blood

(iv) State of lumen of blood vessels.

Blood Pressure Chart

What is your adult Blood Pressure?
Draw a line from your
Systolic number to your Diastolic number.

"Sweat is the best cardiovascular agent known to man."
- Stanford Cardiologist



"No" Foods
High-salt foods
Medium-salt foods
Saturated fat
Hydrogenated oils
Partially Hydrogenated Vegetable Oils

"Yes" Foods
(High K, Ca)
Apples
Avocado
Bananas (K)
Broccoli (K)
Fish
Grapes
Oats
Orange Juice (K)
WATER

Blood Pressure Lowering Tactics
Stop smoking
Reduce weight
Exercise
Low salt foods
Low protein
No caffeine
Mild sedation
Sufficient rest
Don't oversleep

Vitamins
Vitamin C - 500 mg
Vitamin D - 400 IU
Vitamin E - 200 mg
B complex - xxx mg
Folic Acid - 400 μg
Niacin - 100 mg

Amino Acids
Co-Q10 - 120 mg
l-carnitine - 1000 mg

Foods
Flax oil - 1 tbl
Fish oil- EPA 600 mg
- DHA 400 mg

Herbs
Hawthorne Berry - 1.5 g
Garlic - lots (selenium)

Minerals
calcium - 666 mg
magnesium- 266 mg
potassium- 2500 mg

These are the personal thoughts of the author - nothing is implied, promised or guaranteed - no advice is intended.

Structure of the Respiratory Tract:

1.Upper Respiratory Tract

a.Nose

b.Naso-pharynx

c.Larynx

2.Lower Respiratory Tract:

a.Trachea

b.Bronchi

c.Bronchioles &The Acinus.

Functions of the Respiratory Tract:

Nose:1.Warming of air during nasal breathing.

2.Humidification of air.

3.Filtration of inspired air.

Collectively those are called “conditioning of air”.

Pharynx: Air continues through the pharynx.

Larynx:1.Basic function is to keep blood and drink out of the airway.

2.Additional role to produce sound.

Trachea:1.Air enter into the body through trachea.

2.Provide a muco-ciliary escalator for removal of debris trapped of the mucus.

Bronchi: From the trachea air enters into the lungs through bronchi.

Acinus: The acinus is the gas exchange unit of the lungs.Each acinus comprises:

a.Respiratory bronchioles liading to.

b.Alveolar ducts,Alveolar sacs and

c.Alveoli.

Partial pressure of gases:

The amount of pressure exerted by the individual gas in a gas mixture,which is directly proportionate to the concentration(i.e. number) of gas molecule in that mixture.

Sites	PO2(mmHg)	PCO2(mmHg)
1.Atmospheric gas(inspired air)	158	0.3
2.Alveolar gas	100	40
3.End-Pul.capillery blood	100	40
4.Systemic arterial blood	95	40
5.Mixed venous blood	40	46
6.Expired gas	110	32

Gas exchange & transport:

Transport of O2 by blood:

1.From lung alveoli to arterial blood.

Partial pressure of oxygen in the lung alveoli is 104mmHg and in the arterial blood is 95mmHg.Due to this pressure gradient(104-95=9mm of Hg),O2 goes from alveoli to arterial blood.

2.From arterial blood to tissue fluid:

The partial pressure of O2 in arterial blood is 95mmHfg and in the tissue fluid level is 40mmHg.So,O2 enters into the tissue fluid at the pressure gradient of(95-40=55mm Hg)

3.From tissue fluid to cell:

The partial pressure of O_2 in the tissue fluid is 40mmHg and in the cell is 23mmHg.So,O_2 diffuses from tissue to cell at the pressure gradiant of(40-23=17mmHg).

Transport of Carbon-dioxide:

1.From body cell to tissue and arterial end of pulmonary capillary:

The pressure of CO_2 in cell is 46mmHg and in the tissue it is 45mmHg .So, CO_2 diffuse out of the cell and enters into tissue due to pressure gradiant (46-45)=1mmHg.

2.From arterial end of pulmonary capacity to alveoli:

The pressure of CO_2 in the arterial end pulmonary capacity is 45mm of Hg and in the alveoli is 40mmHg.So,CO_2 enters into the alveoli due to pressure gradiant of(45-40)=5mmHg.

Height and weight measurements

We measure the height and weight for assessing the body mass composition. Height and weight is important for using BMI scale.One of the most physiological characteristics of a sportsperson is height and weight. These are very important for a coach to evaluate the growth pattern and growth rate of adeloscent sportsman. Not only to identify talents for different games, physiological characteristics important factor. For example more height is required for basketball, swimming and throe etc. On the other hand soccer, boxing etc need long height as well as medium height. Other technical game also like shooting, table tennis needs height accordingly.So height and weight are one of the most important factors to a coach to identify sportsman for different games & sports.

We use standard anthropometrics rod for height measurement. (Nearest one mm was considered during the measurement), Weighting machine for weight measurement.

Usually the subject stands on a plain platform with Zygone parallel to the ground, landmarkas are selected and height is recorded between them. Minimum height at vertex point should not be considered for taking accurate measurement.

Measurement of height and weight according to the subjects name and age are recorded for calculating BMI.

$$\text{BMI} = \frac{\text{weight in Kg}}{(\text{Height in M})2}$$

And compare it with the norm

The International Classification of adult underweight, overweight and obesity according to BMI

Underweight	<18.50
Normal range	18.50 - 24.99
Overweight	≥25.00- 29.99
Obese	≥30.00≥30.00

Source: WHO .

Measurement of the Skin fold Thickness

Beneath the skin is a layer of subcutaneous fat and the percentage of total body fat can be measured by taking the skin fold at selected sites on the body. Only equipment needed is a pair of calipers.

- All the skin fold measurements were taken on the dominant side at the body and were recorded in millimeters.
- The skin fold was picked up between the thumb and the index finger so as to include two thicknesses of skin and subcutaneous fat.
- The calipers were applied about 1 cm from the fingers and at a depth about equal to the thickness to the fold.
- The procedure was repeated three times and the average was recorded.

Durnin and Rahaman have suggested the following sites for taking the skin fold measurements. While taking measurements the subjects was standing in anatomical position.

- Triceps: The skin fold was taken midway between the top of the shoulder and the tip of the elbow.
- Biceps: The skin fold was taken at a point midway between the elbow and the armpit.
- Subscapular: The skin fold was taken just below the tip of the shoulder blade at an angle of 45^0 to the inferior angle of scapula.
- Suprailiac: The skin fold was taken just above the crest at the hip.

All the four measurements were recorded in millimeters and summed up. With the help of a ready reckoner, the body composition was estimated.

VO2max

Fitness can be measured by the volume of oxygen you can consume while exercising at your maximum capacity.

VO2max is the maximum amount of oxygen in millilitres, one can use in one minute per kilogram of body weight.

Those who are fit have higher VO2max values and can exercise more intensely than those who are not as well conditioned.

Numerous studies show that you can increase your VO2max by working out at an intensity that raises your heart rate to between 65 and 85% of its maximum for at least 20 minutes three to five times a week.

A mean value of VO2max for male athletes is about 3.5 litres/minute and for female athletes it is about 2.7 litres/minute.

Normative data for VO2max

Normative data (Heywood 1998) for Female (values in ml/kg/min)

Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<25.0	25.0 - 30.9	31.0 - 34.9	35.0 - 38.9	39.0 - 41.9	>41.9
20-29	<23.6	23.6 - 28.9	29.0 - 32.9	33.0 - 36.9	37.0 - 41.0	>41.0
30-39	<22.8	22.8 - 26.9	27.0 - 31.4	31.5 - 35.6	35.7 - 40.0	>40.0
40-49	<21.0	21.0 - 24.4	24.5 - 28.9	29.0 - 32.8	32.9 - 36.9	>36.9
50-59	<20.2	20.2 - 22.7	22.8 - 26.9	27.0 - 31.4	31.5 - 35.7	>35.7
60+	<17.5	17.5 - 20.1	20.2 - 24.4	24.5 - 30.2	30.3 - 31.4	>31.4

Normative data (Heywood 1998) for Male (values in ml/kg/min)

Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<35.0	35.0 - 38.3	38.4 - 45.1	45.2 - 50.9	51.0 - 55.9	>55.9
20-29	<33.0	33.0 - 36.4	36.5 - 42.4	42.5 - 46.4	46.5 - 52.4	>52.4
30-39	<31.5	31.5 - 35.4	35.5 - 40.9	41.0 - 44.9	45.0 - 49.4	>49.4
40-49	<30.2	30.2 - 33.5	33.6 - 38.9	39.0 - 43.7	43.8 - 48.0	>48.0
50-59	<26.1	26.1 - 30.9	31.0 - 35.7	35.8 - 40.9	41.0 - 45.3	>45.3
60+	<20.5	20.5 - 26.0	26.1 - 32.2	32.3 - 36.4	36.5 - 44.2	>44.2

The Rockport Fitness Walking Test:

The Rockport Walking Test is a simple self-paced test to predict aerobic power (VO_2max). The test is ideal for use with large groups of subjects but can also be used for individuals.

The Test

The test consists of individual walking 1mile(1609 Meters) as fast as safely possible, without jogging or running.

Test procedure

-The test can be administered outdoors on a track or indoors on a Treadmill and will gives similar results .

-The subject's weight is recorded in Kg or Pounds.

-The subject is instructed for Walking one mile (1609meters) as fast as safely possible.

-Time is recorded after completion of one mile walk.

-Post exercise (Immediately on finishing the walk) heart rate (beats per minute) is recorded.

-Predicted VO_2 max (ml/Kg/min) is calculated by using the formula.

$VO_2max= 132.853-(0.0769 \times \text{Weight}) - (0.3877\times \text{Age}) + (6.315\times \text{Gender}) - (3.2649 \times \text{Time}) - t(0.1565\times \text{Heart rate})$

Or VO_2max (ml/Kg/min) is calculated by using the online calculator.

Where,

Weight is in Kg or pounds (lbs).

Gender Male = 1 and Female = 0

Time is expressed in minutes and 100ths of minutes.

Post Exercise Heart rate is in beats /minute.

Age is in Years.

The result is compared with the norm.

Improving your VO2max

The following are samples of Astrands (a work physiologists) workouts for improving oxygen uptake:

- (1) - Run at maximum speed for 5 minutes. Note the distance covered in that time. Let us assume that the distance achieved is 1900 metres. Rest for five minutes, and then run the distance (1900 metres) 20% slower, in other words in six minutes, with 30 seconds rest, repeated many times. This is equal to your 10 Km pace
- (2) - Run at maximum speed for four minutes. Note the distance covered in that time. Rest for four minutes. In this case, we will assume you run a distance of 1500 metres. Now run the same distance 15% slower, in other words in 4 minutes 36 seconds, with 45 seconds rest, repeated several times. This approximates to a time between the athlete's 5 Km and 10 Km time
- (3) - Run at maximum effort for three minute. Note the distance covered in that time. The distance covered is, say 1000 metres. Successive runs at that distance are taken 10% slower or at 3 minutes 18 seconds, with 60 seconds rest, repeated several times. This approximates to your 5 Km time

- (4) **-** Run at maximum effort for five minutes. Note the distance covered in that time. The distance covered is 1900 metres. Rest five minutes. The distance is now covered 5% slower with one and a half minutes rest. This is approximately 3K pace for you, i.e., five minutes 15 seconds/1900 metres
- (5) **-** Run at maximum effort for three minutes. The distance covered is 1100 metres. When recovered, the athlete then runs the same distance 5% slower, i.e., three minutes nine seconds/1100 metres, with one minute rest, repeated several times. This is at 3 Km pace

When and how often

It is suggested that in the winter sessions (1) and (2) are done weekly, and in the track season sessions (3), (4) and (5) are done weekly by runners from 800 metres to the half-marathon. Although it would be convenient to use the original distance marks made by the duration efforts, this does not take into account the athlete's condition before each session, so the maximum effort runs must be done on each occasion when they may be either more or less than the previous distance run. The maximum duration efforts are in themselves quality sessions. If the pulse rate has not recovered to 120 beats per minute in the rest times given, the recovery period should be extended before the repetitions are started. The recovery times between the repetitions should be strictly adhered to. These workouts make a refreshing change from repetition running. When all five sessions are completed within a month, experience shows substantial improvements in performance.

Cooper VO2max Test

The Cooper Test (Cooper 1968) is used to monitor the development of the athlete's aerobic endurance and to obtain an estimate of their VO2max.

Required Resources

To undertake this test you will require:

- 400 metre track
- Stopwatch
- Whistle
- Assistant

How to conduct the test

This test requires the athlete to run as far as possible in 12 minutes.

- The athlete warms up for 10 minutes
- The assistant gives the command “GO”, starts the stopwatch and the athlete commences the test
- The assistant keeps the athlete informed of the remaining time at the end of each lap (400m)
- The assistant blows the whistle when the 12 minutes has elapsed and records the distance the athlete covered to the nearest 10 metres

Assessment

For an evaluation of the athlete's performance select the age group and gender, enter the total distance covered and then select the 'Calculate' button in online calculator.

Age Gender Distance metres

Assessment -

Normative data for the Cooper Test

Male Athletes

Age	Excellent	Above Average	Average	Below Average	Poor
13-14	>2700m	2400-2700m	2200-2399m	2100-2199m	<2100m
15-16	>2800m	2500-2800m	2300-2499m	2200-2299m	<2200m
17-19	>3000m	2700-3000m	2500-2699m	2300-2499m	<2300m
20-29	>2800m	2400-2800m	2200-2399m	1600-2199m	<1600m
30-39	>2700m	2300-2700m	1900-2299m	1500-1999m	<1500m
40-49	>2500m	2100-2500m	1700-2099m	1400-1699m	<1400m
>50	>2400m	2000-2400m	1600-1999m	1300-1599m	<1300m

Female Athletes

Age	Excellent	Above Average	Average	Below Average	Poor
13-14	>2000m	1900-2000m	1600-1899m	1500-1599m	<1500m
15-16	>2100m	2000-2100m	1700-1999m	1600-1699m	<1600m
17-20	>2300m	2100-2300m	1800-2099m	1700-1799m	<1700m
20-29	>2700m	2200-2700m	1800-2199m	1500-1799m	<1500m
30-39	>2500m	2000-2500m	1700-1999m	1400-1699m	<1400m
40-49	>2300m	1900-2300m	1500-1899m	1200-1499m	<1200m
>50	>2200m	1700-2200m	1400-1699m	1100-1399m	<1100m

Heart Rate

Heart Rate: Heart rate, determined by the number of times heart beats in each minute, is an important measure of health.

Heart rate can vary as the body's need to absorb oxygen and excrete carbon dioxide changes, such as during exercise or sleep.

How hard your heart has to work during various activities can tell you a lot about your overall physical condition.

Resting Heart Rate: The resting heart rate (HR_{rest}) is a person's heart rate when they are at rest, that is lying down but awake, and not having recently exerted themselves.

Your resting heart rate measures the speed at which your heart beats during periods of little physical activity. The best time to measure your resting heart rate is in the morning before you get out of bed.

The typical resting heart rate in adults is 60-90 bpm,[with rates below 60 bpm referred to as bradycardia, and rates above 100 bpm referred to as tachycardia. Conditioned athletes often have resting heart rates below 60 bpm, with values of below 40 bpm not unheard of. For instance, cyclist Lance Armstrong has been known to have resting heart rates to as low as around 32 bpm, cyclist Miguel Indurain had a resting heart rate of 28 bpm. The low pulse in conditioned athletes is due to hypertrophy of the cardiac muscles, therefore enabling a higher volume of blood being pumped at each beat (i.e. higher stroke volume).

The normal heart rate **in children** is variable and depends on the child's age. Children exercising can have heart rates up to 200 bpm

Possible points for measuring the heart rate are:

1. The ventral aspect of the wrist on the side of the thumb (radial artery).
2. The ulnar artery.
3. The neck (carotid artery).
4. The inside of the elbow, or under the biceps muscle (brachial artery).
5. The groin (femoral artery).
6. Behind the medial malleolus on the feet (posterior tibial artery).
7. Middle of dorsum of the foot (dorsalis pedis).
8. Behind the knee (popliteal artery).
9. Over the abdomen (abdominal aorta).
10. The chest (apex of heart), which can be felt with one's hand or fingers. However, it is possible to auscultate the heart using a stethoscope.
11. The temple (superficial temporal artery).
12. The lateral edge of the mandible (facial artery).
13. The side of the head near the ear (basilar artery)

Counting the pulse at the carotid artery has proven to be the easiest place to locate the pulse. Press gently on one side of the neck with your index and middle finger until the pulse is felt. Count each beat you feel to determine your heart rate.

MAXIMUM HEART RATE

Before you can calculate your "target exercise heart rate," you first need to determine your "maximum heart rate".

The traditional formula for calculating maximum heart rate is:

- **Max HR = 220 - age**

However, several years ago, researchers in the department of kinesiology and applied physiology at the University of Colorado in Boulder noticed that this formula underestimated exercise heart rates in older subjects.

Hirofumi Tanaka, PhD, and his group conducted an exhaustive review of 351 studies involving nearly 19,000 subjects and derived a new formula. They then validated the new formula in 514 healthy subjects.

The formula they propose is:

- **Max HR = 208 - (age x 0.7)**

In 40-year-old subjects, both formulas yield the same result (ie., 180 beats per minute). However, the Tanaka equation produces slightly lower limits (than the old formula) in subjects younger than 40, and raises the limit slightly in subjects older than 40 years old.

Other formulas exist. What's important is that, for the elderly, and people who are not in shape, maximum heart rate should be determined by calculation since it would be too risky for these people to submit themselves to an all-out exercise test.

The formula deemed least objectionable was:

$HR_{max} = 205.8 - (0.685 \times age)$
This was found to have a standard deviation that, although large (6.4 bpm), was still considered to be acceptable for the use of prescribing exercise training HR ranges.

Other often cited formulae are:

- $HR_{max} = 206.3 - (0.711 \times age)$

  (Often attributed to "Londeree and Moeschberger from the University of Missouri")

- $HR_{max} = 217 - (0.85 \times age)$

  (Often attributed to "Miller et al. from Indiana University")

- $HR_{max} = 208 - (0.7 \times age)$

  (Another "tweak" to the traditional formula is known as the Tanaka method. Based on a study of thousands of individuals, a new formula was devised which is believed to be more accurate).

TRAINING HEART RATE

Now that you know your maximum heart rate, you can determine your training heart rate. Coaches and their athletes know that driving the heart rate up into a specific range is the key to improving performance in aerobic events like cycling, distance running, etc. For example, Ed Eyestone offers the following guidelines in the November 2004 issue of **Runner's World** magazine:

- **70-80% max HR:** aerobic training pace
- **80-90% max HR:** lactate threshold pace
- **90-97% max HR:** long-interval pace
- **95-100% max HR:** short-interval pace

Serious endurance athletes (triathletes, distance runners, etc.) will train mostly at the aerobic training pace. About 10% of their training will be at the lactate threshold pace. Extremely-intense

"intervals" make up only a small percentage of the overall training plan.

Training heart rate is also helpful for people who want to exercise for health benefits. Research shows that untrained individuals will begin to improve their aerobic fitness when they exercise regularly at 50% of their maximum heart rate (Pollock ML, et al. 1998).

For example, for a 60-year-old person, the maximum heart rate (using the Tanaka equation) is 166. Fifty percent of that is 83 beats per minute. Thus, exercise does not need to be exhausting to achieve a health benefit.

The Target Heart Rate or Training Heart Rate (THR) is a desired range of heart rate reached during aerobic exercise which enables one's heart and lungs to receive the most benefit from a workout. This theoretical range varies based mostly on age; however, a person's physical condition, gender, and previous training also are used in the calculation. Below are two ways to calculate one's THR. In each of these methods, there is an element called "intensity" which is expressed as a percentage. The THR can be calculated as a range of 65%–85% intensity. However, it is crucial to derive an accurate HR_{max} to ensure these calculations are meaningful (see above).

Example for someone with a HR_{max} of 180(age 40, estimating HR_{max} As 220 − age):

65% Intensity: (220 − (age = 40)) × 0.65 → 117 bpm
85% Intensity: (220 − (age = 17)) × 0.85 → 153 bpm

Karvonen method

The Karvonen method factors in resting heart rate (HR_{rest}) to calculate target heart rate (THR), using a range of 50–85% intensity:

$$THR = ((HR_{max} - HR_{rest}) \times \%\ intensity) + HR_{rest}$$

Example for someone with a HR_{max} of 180 and a HR_{rest} of 70:

50% Intensity: ((180 − 70) × 0.50) + 70 = 125 bpm
85% Intensity: ((180 − 70) × 0.85) + 70 = 163 bpm

Zoladz method

An alternative to the Karvonen method is the Zoladz method, which derives exercise zones by subtracting values from HR_{max}:

$THR = HR_{max} - Adjuster \pm 5$ bpm
Zone 1 Adjuster = 50 bpm

Zone 2 Adjuster = 40 bpm
Zone 3 Adjuster = 30 bpm
Zone 4 Adjuster = 20 bpm
Zone 5 Adjuster = 10 bpm

Example for someone with a HR_{max} of 180:

Zone 1(easy exercise): $180 - 50 \pm 5 \rightarrow 125 - 135$ bpm
Zone 4(tough exercise): $180 - 20 \pm 5 \rightarrow 155 - 165$ bpm