The Muscular System

E103 – Unit 2 Diploma Course
Pre-requisites to understand this module

If you already haven’t, you are requested to finish below modules first.

• Module 1 – E 101 – Introduction To Exercise Science
• Module 2 – E102 – Introduction To Resistance Training
Learning objectives

• To know the functions and properties of muscle fibers
• To understand the types of muscle tissue and the anatomy of the skeletal muscles
• To identify the major muscles in the human body
• To know the anatomy of muscle growth
• To understand the attachments of major muscle groups
• To know the different types of muscle fibers and the gender implications
• To understand the Henneman’s Size principle
• To know what happens to muscles with age

Learning outcome

• Describe the anatomy of skeletal muscles and muscle fibers
• Name and identify the major muscle groups in the body
• Explain the origin, insertion and action of major muscles
• Explain the impact of aging on the musculoskeletal system
Course Outline

- Functions of Muscle Tissue
- Properties of Muscle Tissue
- Types of Muscle Tissues
- Anatomy of Skeletal Muscles
- Major Muscles in the Body
- Skeletal Muscle Attachments
- Anatomy of Muscle Growth
- Types Of Muscle Fibers
- Muscle Fiber Recruitment
  ▪ Henneman’s Size Principle
- Ageing and its Effect on the Muscular System
Introduction

• A muscle is a group of muscle tissue that contracts together to produce force at the expense of energy

• They allow movement and help in maintaining posture and producing heat

• A large amount of body heat is produced by metabolism and muscle contraction
Functions of Muscle Fiber
Functions of Muscle Tissue

Body movement: Movement is the main function of the muscular system.

Body Posture: Muscles contract and allow the body to maintain posture while sitting or standing.

Heat Generation: Muscle contraction generates heat which helps maintain the body temperature.

Contraction of muscles allows not just movement across different planes of motion but also movement of internal organs to digest food as well as movements of bodily fluids.

The muscles responsible for posture have great endurance as they can hold the body upright without tiring for long durations.
Properties of Muscle Fiber
Properties of Muscle Tissue

- Excitability
- Contractability
- Extensibility
- Elasticity
Properties of Muscle Tissue

Excitability – Ability to respond to a stimulus. Delivered by either a motor neuron or even a hormone.

Contractility – Ability to forcefully shorten

Extensibility – Ability to be stretched

Elasticity – Ability to revert to its original length, after being stretched
Types of Muscle Tissue
Types of Muscle Tissue

**Smooth Muscle**
- Involuntary in nature, cannot be controlled
- Location – Inside organs like stomach, intestines, and blood vessels
- Appearance – Very smooth, uniform when viewed under a light microscope

**Cardiac Muscle**
- Involuntary in nature, cannot be controlled
- Location – Heart Muscle
- Appearance – Light and dark stripes when viewed under a microscope, (called striations) which is due to the arrangement of protein fibers inside of the cells that also indicates their strength

**Skeletal Muscle**
- Voluntary in nature, can be controlled
- Location – Across the body
- Appearance – Striped or Striated
Anatomy of Muscle Tissue
Skeletal Muscle

Skeletal muscles

• Have an origin and insertion point.

• The fleshy part in the middle is called the belly of the muscle which does the actual contraction.
Anatomy of Muscle Tissue

- Muscle
- Fascicle
- Endomysium
- Perimysium
- Epimysium
- Muscle fiber (cell)
  - Motor end plate (neuromuscular junction)
  - Muscle cell nuclei
  - Capillary
- Nerve axon
- Nerve axon branch
- Transverse tubule
- Sarcoplasmic reticulum
- Myofilaments
  - Actin
  - Myosin
- Myofibril
- Sarcomere

Figure 1-1 Muscle structure
Anatomy of Muscle Tissue

• Myofilaments – This structure contains contractile proteins
  ▪ Actin
  ▪ Myosin

• Myofibrils – Myofilaments

• Muscle Fiber – Myofibrils
  ▪ CT – Endomysium
Anatomy of Muscle Tissue

• Fascicle/Fasciculus – Muscle Fibers
  ▪ CT - Perimysium

• Muscle Belly – Muscle Fibers
  ▪ The fleshy part in the middle is called the belly
  ▪ CT - Epimysium
Connective Tissues
Connective Tissue – Fascia

• Connective tissue outside the epimysium, surrounds and separates the muscles

• These connective tissue layers may extend beyond muscle fibers to form tendons, which attaches the muscles to the bones

• It also has an abundant supply of nerve fibers and blood vessels

• Nerve fibers ensure that the signal to contract (as a response to stimuli) reaches the muscle, which then contracts the muscle.
Connective Tissues – Skeletal Muscle (in & around)

- **Outer layer**
  - Epimysium
- **Middle layer consisting of fasciculus**
  - Perimysium
- **Inner layer, which covers the individual muscle fiber**
  - Endomysium
Connective Tissue – Tendon

- Dense connective tissue that firmly attach muscles to bones
- The skeletal muscles attach to bones through tendons
- Muscle movement happens when the fibers shorten their length, which pulls on the tendons enabling movement.
Skeletal Muscle Names

Location – Many muscle names are based on which anatomical region they are located in.

No. of origins – A muscle can connect to more than one bone or multiple places to a bone.

Shape – Muscles can also be named after their shapes.

Size & Direction – For some muscles found in the same region, their size can be used to differentiate between them.

Naming of skeletal muscles
Muscle Name – Examples

• Location
  Many muscle names are based on which anatomical region they are located in. For example, the rectus abdominis and transverse abdominis are found in the abdominal region.

• Number of Origins
  A muscle can connect to more than one bone or multiple places to a bone. Consider that the bicep muscle has two origins, while triceps have three origins. Can you guess how many origins are there for the quadriceps muscles? Yes, four!

• Shape
  Muscles can also be named after their shapes, for examples the deltoids have a triangular or delta shape. Similarly, rhomboid major muscle group is a diamond or rhombus shape.
Muscle Name – Examples

• **Size**
  - For some muscles found in the same region, their size can be used to differentiate between them. Consider the gluteal region which contains three different sized muscles —the gluteus maximus (large size), Gluteus Medius (medium size), and Gluteus Minimus (smallest size).

• **Direction**
  - Finally, the direction along which the muscle fibers are laid out can also reflect in their names. In the abdominal region, the muscles that are straight up and down are the rectus abdominis, while those that run from left to right or transversely are the transverse abdominis, and which are at an angle are the obliques.
Action and Attachments
Skeletal Muscle Attachments

Muscle Origin
- Attachment site which is more stable and doesn’t move

Muscle Insertion
- Attachment of a muscle that moves during the contraction

Muscle Action
- The action of the muscle describes what happens when the insertion is brought closer to the origin
Group Action in Skeletal Muscle

- **Agonists** – Muscles that are the primary movers of a joint in one direction

- **Synergists** – Muscles that assist in that movement

- **Antagonists** – Muscles that oppose the movement

- For example, during a bicep curl the biceps brachii and the brachialis are the agonists, the brachioradialis is a synergist, and the triceps brachii is an antagonist to the movement
Major Muscles in the Body
Upper Body Anatomy

Upper Arm
Upper Body Anatomy

- Humerus
- Clavicle
- Sternum
- Scapula
- Ulna
- Radius
- Carpals (8)
- Metacarpals (5)
- Phalanges (14)
Upper Body Anatomy

**Clavicle (collar bone)**

**Right Scapula Bone**

Superior view

Inferior view
Biceps Brachii

• Biceps Brachii is one of the main muscles of the upper arm which acts on both the shoulder joint and the elbow joint.

• It derives its name from the fact that it consists of two (biceps) parts (heads): long-head and short-head.

• Both the heads are Bi-articulate muscle which means cross and perform actions at two different joints.
Biceps Brachii

Right Scapula Bone

- Acromion
- Coracoid Process
- Glenoid Cavity
- Subscapular Fossa
- Lateral Border
- Inferior Angle
- Superior Border
- Superior Angle
- Supraspinous Fossa
- Infraspinous Fossa
- Lateral Angle
- Spinale
- Medial Border

Anterior view

Posterior view
Biceps Brachii

• Origin
  ▪ Long head: supraglenoid tubercle of scapula
  ▪ Short head: coracoid process

• Insertion
  ▪ Radius

• Function
  ▪ Flexes and supinates forearms at elbow
    ▪ DB Bicep curls
    ▪ Preacher curls
  ▪ Long head weakly flexes the shoulder
    ▪ Exercise – DB Front Raises
The triceps brachii is a three-headed muscle of the arm, spanning almost the entire length of the humerus.

It derives its name from the fact that it consists of three (triceps) parts (heads): Long-head, lateral-head, and medial head.

The long head is a Bi-articulate muscle which means cross and perform actions at two different joints.
Triceps Brachii

Right Scapula Bone

- Acromion
- Coracoid Process
- Glenoid Cavity
- Subscapular Fossa
- Supraspinous Fossa
- Lateral Border
- Medial Border
- Infraspinous Fossa
- Superior Border
- Superior Angle
- Spine
- Infraspinous Fossa

Anterior view

Posterior view
Triceps Brachii

Origin
▪ Long Head: Scapula
▪ Lateral head: Humerus
▪ Medial head: Humerus

Insertion
▪ Ulna

Function
▪ Extension of forearm
  ▪ Exercises - Overhead DB Extension, Cable triceps extension, triceps cable pushdown

▪ Long head is also responsible for extension and adduction of the shoulder
  ▪ Exercises – Parallel bar dips
Upper Body Anatomy

Chest
Pectorals (pectoralis major)
Pectorals (pectoralis major)

• The name pectorals is derived from the word pectus which means chest in the Latin language. It is a fan shaped muscle, also known as the body’s natural armour.

• It consists of two parts, one originating from the sternum bone and the other from the clavicle bone.
BICEPS
TRICEPS
PECTORALIS
TENSOR FASCIAE LATAE
SARTORIUS
RECTUS FEMORIS
VASTUS LATERALIS
VASTUS MEDIALIS
TIBIALIS ANTERIOR
GASTROCNEMIUS
SOLEUS
DELTOIDS
TRAPEZIUS
SERRATUS
LATISSIMUS
OBLIQUES
ADDUCTORS
Pectorals (pectoralis major)

Origin
▪ Clavicular Head: Medial end of the clavicle
▪ Sternocostal head: Sternum and upper 6 costal cartilages

Insertion
▪ Humerus

Function
▪ Shoulder adduction
  ▪ Exercise – Lateral raises
▪ Shoulder medial rotation
▪ Shoulder flexion
  ▪ Exercise – Front raises
▪ Shoulder horizontal adduction
  ▪ Exercises - Dumbbell fly and Bench press
Upper Body Anatomy

Deltoid
Deltoids

Humerus

Clavicle

Sternum

Scapula

Right Scapula Bone

Acromion
Coracoid Process
Glenoid Cavity
Subscapular Fossa
Lateral Border
Inferior Angle
Supraspinous Fossa
Modial Border

Anterior view

Posterior view

Superior Border
Superior Angle
Suprascapanular Notch

Acromion
Lateral Angle
Spine
Infraspinous Fossa
Deltoids

• The deltoid is a thick and triangular shoulder muscle that defines the round contour (shape) of the shoulder. The name deltoid originates from the Greek letter delta (Δ)

• It consists of three heads: Anterior head, Lateral head, & Posterior head.

• Uni-articulate muscle
Deltoids

• Origin
  - Anterior head: Clavicle
  - Lateral head: Acromion of scapula
  - Posterior head: Spine of scapula

• Insertion
  - Humerus

• Action
  - Anterior Head: Shoulder flexion and internal rotation
  - Lateral head: Abduction
  - Posterior head: Shoulder extension and external rotation
Upper Body Anatomy

Latissimus Dorsi & Trapezius
Latissimus Dorsi

• It originates from the lower back part of the body, and it covers a wide area. It extends, adducts and medially rotates the upper limb and is one of the main stabilizers of the spine during its various movements.

• The name literally means ‘broadest muscle of the back’.
Latissimus Dorsi

Origin
- Thoracic spine, thoracolumbar fascia, sacrum, ileum, 9-12th ribs

Insertion
- Humerus

Action
- Shoulder adduction
  - Lat pulldown, Pull ups (prone)
- Shoulder extension
- Seated row -
- Shoulder horizontal extension
- Shoulder internal rotation
- Weak – Lumbar extension, Lateral flexion and Thoracic extension (weak)
Trapezius

• The trapezius muscle is located on the posterior aspect of the neck and thorax.

• It is a large, triangular paired muscle which looks like a diamond when viewed together.

• The main function of the trapezius muscle is to stabilize the scapula in its anatomical place and control it during movements of the shoulder and upper limb.
Trapezius

• Origin
  ▪ Occipital bone, C1-C6 (through ligaments), C7 to T12

• Insertion
  ▪ Clavicle, Acromion, Scapula

• Function
  ▪ Elevation of scapula
  ▪ Depression of scapula
  ▪ Retraction of scapula
  ▪ Upward rotation of scapula
  ▪ Neck extension
Lower Body Anatomy

Quadricep group
Quadriceps

- Quadriceps, located at the anterior compartment of the thighs, are extremely powerful muscles that also assist in essential activities like walking, running, jumping, etc.

- Quadriceps muscle group
  1. Rectus Femoris
  2. Vastus Lateralis
  3. Vastus Medialis
  4. Vastus Intermedius
Quadriiceps

• Origin
  ▪ Rectus Femoris: Anterior inferior iliac spine and ridge of the Acetabulum
  ▪ Vastus Lateralis: Greater trochanter and Linea Aspera
  ▪ Vastus Medialis: Linea Aspera
  ▪ Vastus Intermedius: Linea Aspera

• Insertion
  ▪ Patella & Tibia

• Function
  ▪ Knee extension – Squat, Leg Press and Extension, Hack squat
  ▪ Hip flexion – Eccentric portion of squat
Lower Body Anatomy

Hamstring group
Hamstrings

- Hamstrings are a group of muscles located at the rear of the upper leg.

- They help in activities like walking, running, jumping; they flex the knee and extend the hip at the beginning of each step and many other physical activities.

- Hamstring muscle group
  1. Biceps femoris
  2. Semitendinosus
  3. Semimembranosus
Hamstrings

• Origin
  ▪ Bicep Femoris (short head): Linea Aspera
  ▪ Bicep Femoris (Long head): Ischial Tuberosity
  ▪ Semitendinosus: Ischial Tuberosity
  ▪ Semimembranosus: Ischial Tuberosity

• Insertion
  ▪ Bicep Femoris (short & long head): Head of Fibula
  ▪ Semitendinosus: Tibia
  ▪ Semimembranosus: Tibia

• Function
  ▪ Knee flexion – Seated/Prone Leg Curl, Nordic curl
  ▪ Hip extension – RDL, Good morning
  ▪ Hip medial and lateral rotation
Lower Body Anatomy

Gluteus group
The gluteal region is located posteriorly to the pelvic girdle, at the proximal end of the femur.

The muscles of the gluteal region help in moving the lower limbs at the hip joint.

This region includes the
1. Gluteus Maximus
2. Gluteus Medius
3. Gluteus Minimus
Glutes

- **Origin**
  - Gluteus Maximus: Ilium
  - Gluteus Medius: Ilium
  - Gluteus Minimus: Ilium

- **Insertion**
  - Greater Trochanter of Femur

- **Function**
  - Hip extension (Gluteus Maximus)
  - Exercises – Hip thrust, Good morning, Squat, RDL
  - Abduction of femur
  - Lateral band walks, Lateral leg swings with cable resistance
  - Medial/internal rotation of femur
  - Depression of pelvis
Lower Body Anatomy

Calves group
The calf muscle is located on the back side of the lower leg. During walking, running, or jumping, the calf muscle pulls the heel up to allow forward movement.

It is made up of two muscles. The gastrocnemius is the larger calf muscle. The gastrocnemius has two parts or "heads," (medial and lateral) which together create its diamond shape.

The soleus is a smaller, flat muscle that lies underneath the gastrocnemius muscle.
Calves

Origin
Gastrocnemius: Femur
Soleus: Tibia & Fibula

Insertion
Achilles Tendon

Function
Plantar flexes the feet
Flexes the knee
(Gastrocnemius only)
Anatomy of Muscle Growth
Hypertrophy

- Muscles can grow larger; also known as Hypertrophy. This generally occurs through increased use. Although to an extent hormonal or other influences can also play a role.

- The size of a muscle, in turn, is one of the main determinants of muscle strength, which may be measured by the amount of force a muscle can exert.

- For a muscle to get bigger, it must increase in size. Two primary mechanism have been proposed to explain how an increase in size of an intact muscle might occur.

- Hypertrophy is the increase in the size of each muscle fibers, whereas hyperplasia is an increase in the number of muscle fibers.
Hypertrophy & Hyperplasia
Hyperplasia

• When the size of the tissue increases because of an increase in the number of cells in that tissue. So far it seems that hyperplasia does not play a major role in overall muscle growth. As per research, it might account for about 5% of total size gains.

• Adopting specific training strategies to induce hyperplasia, then, should account only for about 5% of total training.

• Hyperplasia is also the method by which the liver restores itself from a partial resection.

• Normal training for a short term is not likely to cause hyperplasia. One needs to train for a very long time, utilize exercises that provide a huge load at a maximally stretched position for the specific muscle, to lead to hyperplasia of that specific muscle.
Types of Hypertrophy
Sarcoplasmic v/s Myofibrillar Hypertrophy

Untrained Muscle Fibre

Sarcoplasmic Hypertrophy

More Sarcoplasm

More Myofibrils

Myofibrillar Hypertrophy
Sarcoplasmic v/s Myofibrillar Hypertrophy

Myofibrillar H.  
This is when the myofibrils inside our muscle fibers grow bigger, allowing our muscles to produce more force, allowing us to lift more weight for a single repetition.

Sarcoplasmic Hypertrophy  
This is when the sarcoplasm surrounding the myofibrils expands, giving us more fuel and growth potential, and allowing us to do more repetitions.
Tom Platz squatted 500 lbs for 23 reps
Atrophy

• Atrophy: Muscles can also reduce in size and it can occur through lack of physical activity or from starvation.

• People who are immobilized for a length of time. With hypertrophy, the individual fibers become wider, while with atrophy, the fibers become narrower.

• In either hypertrophy and atrophy, the number of muscle fibers remains the same.
Muscle Protein Synthesis

• The nuclei within a muscle fiber increases production of the contractile protein
  ▪ Actin and Myosin, within the existing sarcomere.

• In the long run muscle hypertrophy is the result of an overall increase in muscle protein synthesis

• And a decrease in protein breakdown (catabolism), or a combination of both

• However, it is important for you to know that without a bout of exercise leading to higher protein breakdown, an individual might not be generating muscle protein synthesis for muscle growth.
Types of Muscle Fibers
Muscle Fiber Types

Slow Twitch
- Also known as Type 1 fibers
- Efficient at utilizing oxygen for energy and can function for a long period before they experience fatigue
- Highly resistant to fatigue and are stimulated in endurance exercise or high reps in resistance training

Fast Twitch
- Also known as Type II
- Better at generating short bursts of strength and will tire out faster than slow-twitch
- Most low-medium rep resistance training and/or power training stimulates this fiber type.
# Type II Classification

<table>
<thead>
<tr>
<th></th>
<th>Type I fibers</th>
<th>Type II a fibers</th>
<th>Type II x fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contraction time</strong></td>
<td>Slow</td>
<td>Moderately Fast</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Size of motor neuron</strong></td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Resistance to fatigue</strong></td>
<td>High</td>
<td>Fairly high</td>
<td>Intermediate</td>
</tr>
<tr>
<td><strong>Activity Used for</strong></td>
<td>Aerobic</td>
<td>Long-term anaerobic</td>
<td>Short-term anaerobic</td>
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<tr>
<td><strong>Maximum duration of use</strong></td>
<td>Hours</td>
<td>&lt;30 minutes</td>
<td>&lt;5 minutes</td>
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<tr>
<td><strong>Power produced</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Mitochondrial density</strong></td>
<td>High</td>
<td>High</td>
<td>Medium</td>
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<td>High</td>
<td>Intermediate</td>
<td>Low</td>
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<tr>
<td><strong>Oxidative capacity</strong></td>
<td>High</td>
<td>High</td>
<td>Intermediate</td>
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<tr>
<td><strong>Glycolytic capacity</strong></td>
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<td>High</td>
<td>High</td>
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<tr>
<td><strong>Major storage fuel</strong></td>
<td>Triglycerides</td>
<td>Creatine phosphate, glycogen</td>
<td>Creatine phosphate, glycogen</td>
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Muscle Fiber Fact

The distribution of Type I and II fibers varies in each person and in each muscle group.

For example, postural muscles such as the calves have a high percentage of Type I muscle fibers.

Genetics also play a role in determining the percentage of Type I or Type II fibers in a muscle.

Through training a person can improve specific characteristics of the muscle fiber (oxidative potential, fiber size, enzyme content) but not the muscle type itself.
Muscle Fiber Fact

Athletes who are naturally good in different sports generally are genetically suited.

But of course, years of practice also plays a role in why some excel while others with more genetic potential are not disciplined enough to leverage their advantages.
Muscle Fiber Fact

For example, elite level rowing athletes will have higher percentages of Type I muscle fibers in their upper-body.

While elite weightlifters may have higher percentages of Type II muscle fibers.
Muscle Fiber

Gender-based differences
Gender-based differences – Male

• Exhibit more muscle fibers as compared to women; this may be due to hormonal action.

• If androgen hormones, also known as male hormones, are very high during the prenatal period, then the individual will have more muscle fibers.
Gender-based differences – Women

- Women have relatively more slow-twitch fibers as compared to men. This leads them to handle more volume in their workouts. But they will not be able to generate as much power in short burst activities as men.

- It is still very unclear to what extent the difference in muscle fibers is due to physical activity, hormonal function, and or other factors.

- Sex differences in strength in adults are greater in the arms and shoulders than in the legs.

- On average, the female's upper body is 50 % to 60 % as strong as the male's upper body and the female's lower body is 70 % to 80 % as strong as the male's lower body.
Muscle Fiber Recruitment Pattern
Motor unit

• MU – A motor neuron along with the muscle fiber it controls is called a motor unit. The fibers connected to a single neuron are spread out and not necessarily adjacent to each other.

• Muscle fibers are activated when the nervous system recruits muscle tissue via the activation of motor units. This allows fibers across the muscle to get activated with a single motor neuron.
Henneman’s Size Principle

Henneman's Size Principle states that under load, motor units are recruited from smallest to largest.

- Type I Fibers: Slow-twitch, Fatigue resistant
- Type II Fibers: Fast-twitch, Fatigue prone

In what order do we recruit our muscle fibers?

Henneman’s Size Principle

Motor units are recruited from smallest to largest based on the force we need to exert.
All or None Principle

Motor unit
A motor unit comprises either all Type I (slow twitch) or all Type II (fast twitch) muscle fibers; no motor units contain mixed muscle fiber types.

When a motor unit is stimulated all fibers contract at the same time.

The total force generated depends on the number on number of activated motor units.

Muscle fiber
A muscle fiber either contracts completely or does not contract at all. Muscle fibers are recruited “All or None”, no signal is sent to activate partial muscles.
Effect of Ageing
On the Muscular System

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Ageing

• With increase in age, people tend to lose muscle mass and strength which is known as Sarcopenia.

• The possible explanation for sarcopenia to occur is that the motor neurons will get de-innervated or detached from the muscle fibers in the motor units with aging or inactivity.
Ageing

Factors contribute to loss in muscle mass with ageing.

• Decrease in Muscle Protein Synthesis (MPS),

• Increase in Insulin Resistance

• Decrease in BMR

• Higher percentage of body fat has also been found with ageing.
Ageing & Progressive Resistance Training

• Studies have shown that with age, type II fibers decrease in size. This leads to decrease in the strength of older people.

• Therefore, to overcome this problem, older people should get involved in physical activity.

• Research says that being sedentary causes loss in power, strength, and muscle mass.

• Studies have proven that muscle gain is possible even in older age if progressive resistance training is done with adequate nutrition.
Your feedback is valuable

Do click the link in the chat and provide your feedback!

Help us to care better.

Some important steps taken so far based on your feedback -

1. We have added practical points wherever possible (across all modules)
2. We have improved your dashboard
3. We have added prerequisites in all the modules in order to help you set a better learning flow
4. We have aligned our query solving strategies
5. To help part-time students to learn flexibly, we have arranged all N&E diploma modules in the weekdays and weekends

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