Exercise & Sports Biomechanics
Prof. Viswanath Sundar
Department of Physical Education & Sport Science
Visva-Bharati University, Shantiniketan (WB)
Week 01
Lecture 05

Skeletal System Oestokinematics & Arthrokinematics

Hello everyone, welcome back to this course. Today, we will learn about the skeletal system. It gives our body shape, protects important organs like the heart, lungs, and stomach, and even helps us to move from one place to another. Without it, our body would look like jelly, right? So, what is the skeletal system?

Skeletal system:

The skeletal system is made up of bones, joints, and some special tissues like cartilages and ligaments. The bones give the body strength and structure. Joints connect the bones and allow movement. Imagine if there were no joints in my elbow, I could not even have a cup of coffee, right?

The next one is the cartilage

Cartilage:

Cartilage protects the bones and joints so that they do not rub against each other.

The next one is the ligament

Ligament:

The ligament helps the bones to hold together and makes the joint more stable. The human body has 206 bones and It is divided into two groups, which are the axial skeleton and the appendicular skeleton. The axial skeleton includes the skull, spine, and rib cage, and these bones protect organs like our brain, heart, and lungs.

The next one is the appendicular skeleton

Appendicular skeleton:

This includes the arms, legs, shoulders, and hips. These bones help us to move and carry weight. Do you know that babies are born with more than 270 to 300 bones, but as they grow, some bones join together?

Our skeletal system performs five important functions in day-to-day activities:

- The first one is support. The skeletal system provides support for our entire body. It gives us shape, and without bones, we would not be able to stand, sit, or maintain our posture. For example, the spine or backbone supports the upper body and helps us stand or sit straight.
- Next, it provides protection. Bones act like shields to keep our organs safe. For instance, the ribcage protects our heart and lungs, and the skull protects our brain. Without this protection, even small injuries could cause severe damage to our organs.
- Next is movement. Bones are the site of attachment for ligaments and tendons. That is why bones and muscles must work together to enable movement. When we move, the bones act as levers, and joints act as pivot points, allowing the bones to bend or rotate.
- The next important function is the production of blood cells. The red bone marrow produces red blood cells, which carry oxygen to every part of your body. White blood cells help protect you from infections. This is why bones are so important for our health, not just for strength but also for keeping our body functioning.
- Finally, mineral storage and calcium regulation. The skeletal system acts as a storage unit for important minerals like calcium and phosphorus. These minerals make our bones strong and healthy. In addition, they also help in nerve conduction and muscle contraction. When our body needs calcium, our bones release it into the blood to keep calcium levels balanced. And this process is essential for our muscles to move and our nerves to work properly.

Now, let us understand what a bone is

Bone:

Bone is a connective tissue made mostly of collagen and calcium phosphate. So, what is collagen? Collagen is the main fibrous protein which acts as a soft framework that gives the bone flexibility. The structure of collagen is very special.

It has a triple helix shape. It is like three twisted ropes. which make it very strong. The main mineral in bone is called hydroxyapatite. The chemical formula is calcium 10, phosphorus 6, and hydrogen 2, which means it is made up of calcium, phosphate, and a little bit of water. These minerals stick to the collagen framework and harden it, making bones strong enough to support our body.

Bones are composed of two types of tissue:

- One is cortical bone and cancellous bone. The cortical bone is also known as compact bone, which is hard and dense. It is found outside of bones, especially the shaft of long bones.
- The next one is the cancellous bone. It is also known as spongy bone. It is a lightweight and porous tissue which is found at the ends of the long bones.

Let us understand the structure of the bone

Structure of the bone:

The long bone has two main regions. One is the diaphysis and the second one is the epiphysis.

Diaphysis:

This is the long hollow shaft in the middle of the long bone. Inside the diaphysis, there is a space called the medullary cavity which is a hollow tube. In adults, the cavity is filled with yellow bone marrow which stores fat. The wall of the diaphysis is made up of compact bone which is very hard. This gives the bone strength so that it can support the body and handle the weight.

Epiphysis:

These are the wider sections at the end of the bone. Inside the epiphysis, you will find spongy bone which is lighter and less dense than the compact bone.The spaces in the spongy bone are filled with red bone marrow which makes blood cells.

There are three types of blood cells:

- One is red blood cells which carry oxygen to the body and remove carbon dioxide.
- The second one is the white blood cell, which helps us fight infection and maintain the immune system.
- The last one is the platelets, which help to stop bleeding by forming clots at injury sites.

In these epiphyses, the ends of the bones are covered with articular cartilage. It is a thin layer of hyaline cartilage that reduces friction and acts as a shock absorber when the bone moves.

During bone growth, the epiphysis and the diaphysis are separated by a thin plate of cartilage known as the epiphyseal plate. It is commonly referred to as the growth plate.

Two important layers that surround the bone:

Endosteum

It is a thin layer of bone cells next to the medullary cavity. This is the medullary cavity. And this is the endosteum. These cells help us to grow, repair, and remodel throughout our lives.

Periosteum

It is a double-layered structure that covers the outer part of the bone.This is the outer part of the bone, except at the joint level. The periosteum also helps in bone growth and repair, and in addition, all the blood vessels, nerves, tendons, and ligaments are attached to the bone at the periosteum. In simple terms, the blue area in this image is known as the diaphysis, which is the long shaft, and at both ends, it is known as the epiphysis. At the end of the epiphysis, you can find the articular cartilage to minimize shock absorption.

Inside the blue area is the medullary cavity, which is filled with yellow bone marrow. Red bone marrow is situated in the epiphysis. The outer part of the bone is surrounded by the periosteum. The inner part of the bone is covered by the endosteum.

The next one is the types of bones

Types of bones:

Long bones:

Long bones are composed of an elongated shaft with relatively wide and protruding ends. Examples like the femur, tibia, fibula, humerus, radius, and ulna are considered long bones. The next one is the short bones, which are small and cube-shaped. The length, width, and height are typically equal. For example, carpal and tarsal bones are considered short bones.

Flat bones:

Flat bones have a broad surface and provide protection to the soft tissues and organs beneath the bone. For example, the scapula, ribs, and sternum. The next one is the irregular bone, which usually varies in shape and size. Examples of irregular bones are the vertebrae and hip bones. Finally, the sesamoid bone is a small, flat bone shaped similarly to a sesame seed. An example of this sesamoid bone is the patella.

Next, we move on to joints

Joint:

The articulation of two or more bones is known as a joint. The joints are classified by their structure and function:

1. The structural classification explains how the joints are built. There are three types of structural classification: fibrous joint, cartilaginous joint, and synovial joint.
2. The functional classification, which explains how much they allow the bone to move. There are three types of functional classification: synarthrosis, amphiarthrosis, and diarthrosis.

Synarthrosis:

Synarthrosis is the fibrous joint or synarthrodial joint. These joints are made up of fibrous tissue that tightly connects the bones, and these joints are immovable, meaning that they do not allow any movement. For example, sutures in your skull.

Amphiarthrosis:

Amphiarthrosis is the cartilaginous joint, which is also known as amphiarthrodial joints. These joints are connected by cartilage. It can be either fibrocartilage or hyaline cartilage. They are slightly movable, allowing a small range of motion and aiding in shock absorption. For example, intervertebral joints of the spine.

Diarthrodial joints:

The synovial joint, also known as diarthrodial joints. These joints have a fluid-filled cavity called synovial fluid that reduces friction and allows smooth movement. They are freely movable joints, giving a wide range of motion. In these synovial joints, they allow for greater mobility, but they are less stable.

There are different classes of synovial joints in the body:

Hinge joints:

Hinge joints are uniaxial, which means they move in one direction, allowing flexion and extension movements. It is like opening and closing a door. For example, the elbow joint, which helps us to flex and extend the arm. These joints move in the sagittal plane around the frontal axis.

Saddle joint:

Saddle joints are multiaxial, which means they allow movements in all three directions. For example, the joint at the base of your thumb, which is the first carpometacarpal joint, allows the movements in the thumb to move in multiple directions, such as flexion and extension. Additionally, the opposition movement takes place in the thumb joint.

Pivot joint:

It is a uniaxial joint, allowing rotational movement around a single axis. Which means, this joint allows internal and external rotation. For example, the atlanto-axial joint in the neck helps you turn your head side to side, as if shaking your head to say no. This pivot joint moves in the transverse plane around the vertical axis.

Gliding joint:

These joints have a variable axis and allow sliding motion. This small gliding movement in multiple directions, for example, the intercarpal joints in the wrist, takes a very small gliding motion in the transverse plane.

Condyloid joint:

The condyloid joints are biaxial, which means they can move in two directions. They allow flexion and extension, abduction and adduction. For example, the wrist joint, the radiocarpal joint. The condyloid joints move in the sagittal and frontal planes around the frontal and sagittal axis.

Ball and Socket joint:

These joints are multi-axial, which means they allow movement in three directions. All the movements like flexion, extension, abduction, adduction, and rotation take place in these joints. For example, the shoulder joint, which is the glenohumeral joint, and the hip joint are examples. This ball-and-socket joint moves in all planes and axes. So far, we have explored the basics of the skeletal system.

[But why is it important to study this in sports biomechanics? And how can we translate this knowledge into sports and exercise? That is the key, right? We have also learned that bones have the ability to grow, adapt, and remodel throughout our lives.]

There are two fundamental laws that are very crucial for all coaches, sports scientists, and sports medicine specialists to understand and apply across all levels of sports and life. These are Wolff's Law and Davis's Law.

Wolff's Law:

Wolff's Law focuses on bone. It was developed by Julius Wolff, a German anatomist, and it states that bone grows and remodels in response to the forces and stress placed upon it. This means that bones are not static structures. They are dynamic and constantly adapting to our activities. For example, if you regularly lift weights, the increased load on your bone signals the body and brain to deposit more bone tissue, which makes the bone stronger and denser. On the other hand, if you live a very sedentary lifestyle or if you are in a space where there is no gravity, your bones can become weaker. Because of that, you will not have enough strength. There is a saying, use it or lose it. When you put stress on your bones, like doing physical activity, it encourages bone growth. But if you do not, the bone density decreases, which increases the risk of fractures or conditions like osteoporosis.

Davis's law:

Davis's law applies to soft tissues like muscles, tendons, and ligaments. It is named after Henry Gasset Davis, an American orthopedic surgeon. It states that soft tissues adapt to stresses similar to Wolff's law. For instance, when you stretch regularly, your muscles and tendons lengthen over time, which increases flexibility. But, if you stop stretching or remain in a fixed posture for too long, these tissues can shorten and reduce your range of motion. That is why, The sports science and sports medicine community always emphasize proper rehabilitation exercises after an injury. If you do not move an injured joint or muscle enough, the tissues around it get stiffened, and there is a limitation of movement. On the other hand, if you are doing appropriate and consistent flexibility exercises and strengthening, it will help you to restore the complete function of the bone and muscle.

We have conducted research to explore the application of Wolff's law in designing orthotic shoes for correcting clubfoot. Using advanced imaging techniques, we have developed a detailed 3D model of the affected foot, which helped us to design the orthotic shoe, and we have analyzed it using finite element analysis. The key features of the shoe are that it was developed with a deep heel cup for stability and mechanical linkages that apply gradual and controlled corrective forces.

By applying a gentle and consistent pressure, these orthotic shoes promote the reshaping of bone and soft tissues over time, which helps us in offering an effective and non-invasive method to correct the deformity of the clubfoot. With this understanding, it is time to put these principles into practice. Encourage everyone to incorporate weight-bearing activities to support better bone health.

Next, we move on to Osteokinematics and arthrokinematics

Osteokinematics and Arthrokinematics:

The motion of the bones relative to the three planes, such as flexion, extension, abduction, and adduction, is referred to as osteokinematic motion. Here we have taken the knee as an example. The first one is flexion and extension, valgus and varus. And the last one is internal and external rotation, which occurs in the knee joint. These movements are considered osteokinematic motions.

In order to perform these osteokinematic motions, there must be movement between the articular surfaces of the joint. Motion between the articular surfaces is known as arthrokinematics. Here we have a femur and tibia. The distal part of the femur and the proximal part of the tibia interact at the articular surfaces to move the joint.

To understand this deeper, we need to explore the concept of Arthrokinematics. It includes three specific types of accessory motions, which are roll, glide, and spin. The first one is roll. It is also known as rock. It is a series of points on one articular surface contacting a series of points on another articular surface.

We will take the knee joint as an example again so that we can understand the role much deeper. So, I have said one articular surface contacts the series of points on the other articular surface. So, the femur is one articular surface, and the tibia is another articular surface. Imagine that we have one point here, which is known as 0.

Second, we have a second point, which is known as 1. We have a third point, which is known as 2, and so on. Now, you can see this animation as it moves: 0 will connect with 0, 1 will connect with 1, and 2 will connect with 2. Right? This means a series of points on one articular surface directly contacts a series of points on the other articular surface, which means roll.

So, whenever the roll occurs, 0 and 0 should contact each other, 1 and 1 will contact each other and 2 and 2 will contact each other. In the knee example, knee flexion will only take up to 20 degrees of flexion, not more than that. Why? Because the femur articular surface is much bigger than the tibia articular surface.

If it tries to roll, Beyond 20 degrees of flexion, what happens? It will come out of the tibia. There is no possibility of rolling without gliding movement. So, what is meant by gliding?

Glide:

Glide is also known as a sliding movement or a translation movement. It is when a specific point of one articulating surface comes in contact with a series of points on another surface. Similarly, we have an articulating joint. But this time, it is going to be only one articulating surface point. So, here in the tibia, we will take only one point as zero, and in the femur, we will take it as zero.

Now, what is going to happen? It is going to glide and is going to contact a series of points on the other surface. Here, I am going to make a series of points in the femur but not in the tibia. So, what is going to happen? When we roll on the right side, you have seen 0 is going to connect with 0, and 1 is going to connect with 1. But in the glide, The 0 will connect with 0. As and when it moves, It is gliding. The 1 will come and connect with the 0. The 1 will shift here. And then the 1 will come and connect with the 0. Again, the 2 will shift here. And the 2 will come and connect with the 0. That is why, one articulating surface, which is the tibia, comes in contact with a series of points on the other surface, which is the femur. Without the gliding movement, we cannot perform flexion in the knee. I hope it is very clear in the animation. Up to 20 degrees, it is rolling. Up to 20 degrees, it is rolling, and after that, you can see the gliding motion, and then, in addition, it is rolling.

Next, we move on to spin

Spin:

A single point on one articular surface rotates about a single point on another articular surface. So, we will take the femur and tibia. So, in both the femur and tibia, we have only one point as zero.

Here, there are no multiple points because only in roll and glide do we require multiple points. It is going to rotate about this particular point in the transverse plane and vertical axis. The movement of roll, glide, and spin in the articular surfaces of the joint facilitates movement in all three different planes, such as flexion and extension, which is known as Osteokinematics.

Thank you. And see you in the next video