UNIT 8

FUNDAMENTALS OF KINESIOLOGY AND BIOMECHANICS IN SPORTS

Content

Learning Outcomes

Students are able to

- understand Kinesiology and Biomechanics with their application in sports.
- explain biomechanical principles and their utilization in sports and physical education.
- illustrate fundamental body movements and their basic patterns.
- learn about the Axis and Planes and their application with body movements.

Usain Bolt Is Still the World's Fastest Man

Usain St. Leo Bolt, or Usain Bolt as he is popularly known (born August 21, 1986, Montego Bay, Jamaica), is the Jamaican sprinter who won gold medals in the 100-meter and 200-meter races in an unprecedented three straight Olympic Games and is widely considered the greatest sprinter of all time.

At the 2008 Olympic Games, Bolt became the first man since American Carl Lewis in 1984 to win the 100 meters, 200 meters, and 4 × 100-meter relays in a single Olympics and the first ever to set world records (9.69 sec, 19.30 sec, and 37.10 sec, respectively) in all three events. (However, a failed drug test by one of his 4 × 100 teammates led to Bolt's having his gold medal in that event stripped.) His 0.66-sec winning margin in the 200-meter race was the largest in Olympic history. His 0.20-sec edge over the second-place finisher in the 100 meters, despite beginning his victory celebration about 80 meters into the race, was the largest since Lewis won by the same margin. At the 2009 world championships, Bolt shattered his 100-meter record, winning the event final in 9.58 sec. Four days later, he broke his 200-meter record by the same 0.11-sec margin to win a second gold medal at the world championships.

After Usain Bolt's victories with World Records in the Olympic Games in Beijing and then in the World Championship in Berlin, our desire to understand the reasons and the basis of his phenomenal running prowess is quite natural. Even an amateur is able to spot a noticeable difference in the running of Usain Bolt and his rivals. Bolt's running is light, playful, relaxed, and at the same time, impressively powerful.

What is it that defines the superiority of this talented sprinter? What does he do better than others, and what parameters of the environment is he using those others don't?

The analysis of Usain Bolt's running technique with the help of biomechanics, kinesiology, anthropometry, and other related sciences provides us with the supporting factors to understand the phenomena that contribute to such remarkable performance.

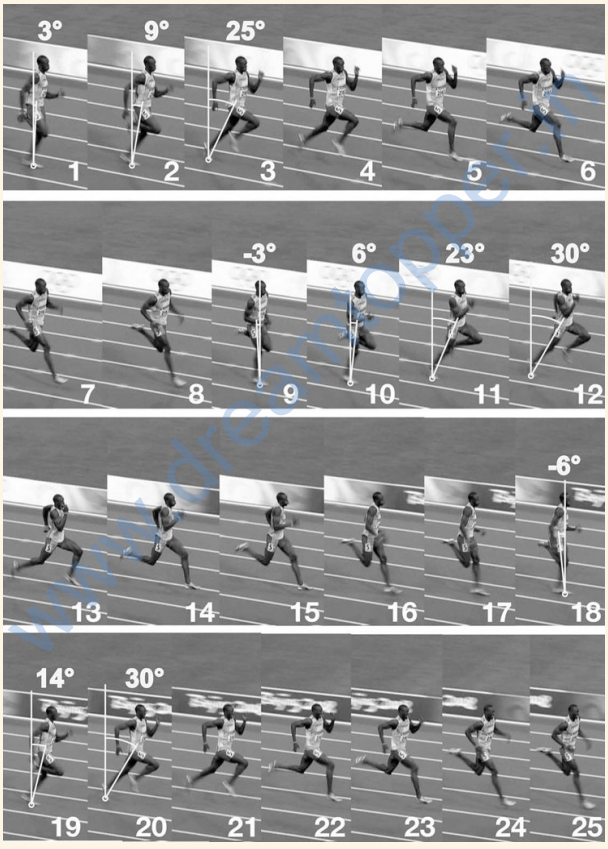
With his height of 6'5", Bolt is practically the tallest athlete in the World's sprinting history. To some extent, though not directly, it is reflected in the length of his running step. In the final heat on 100m in World Championship in Berlin, Bolt made 41 steps with an average length of 2.44m. His closest competitor Tyson Gay (height 5'11"), made 45.45 steps with an average length of 2.20.

The most crucial factor is that Bolt uses gravity, to be more exact, gravitational torque, as the leading factor that allows him to more effectively involve all other forces, working as a whole and highly effective system for horizontal repositioning

the athlete with high velocity.

Simply speaking, in his running, he uses the body's rotation around the point of support under the action of gravitational torque, which in essence is a free-falling of the body forward.

Therefore, Bolt is more effective as a sprinter. Using a unique speed table (developed together with professor A. Pianzin), which takes into account individual anthropometrical data of the athlete, his step frequency (cadence), etc., We got an average data of angles of falling of Usain Bolt and Tyson Gay in the final 100m of World Championship in Berlin. Bolt's calculated average angle in 100m with the time of 9.58 seconds was 18.5 degrees with an intermediate step frequency (cadence) of 4.28 steps per second (257 steps per minute), and Gay's, with the time of 9.71 seconds – 18.4 degrees, and step frequency (cadence) 4.68 steps per second (281 steps per minute).



Running sequence of Usain Bolt, please disregard the degrees and markers.

Image courtesy of Russian Track and Field Magazine.

At the fastest 20m segment of the distance between 60-80m, where Bolt had the highest speed of 12.42 m/s with the step frequency (cadence) of 4.4 steps per second (264 steps per minute), his angle of falling was reaching 21.4 degrees, the same as Gay's with the average speed 12.27 m/s and the step frequency 4.8 steps

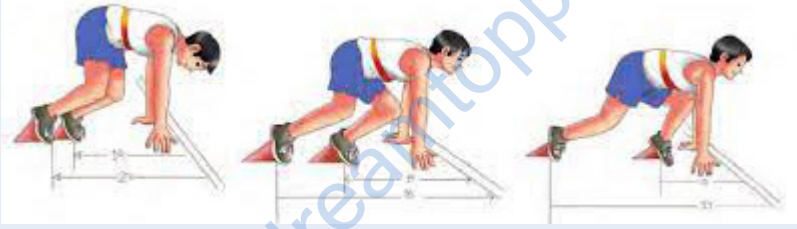
per second (288 steps per minute).

All of this makes sense, i.e., speaking in the language of physics, Bolt just more effectively transforms the rotational (angular) velocity of the body into horizontal. At the end of the day, it is not essential how – consciously or accidentally – Bolt came to this technique; the main thing is that his talent allowed him to perform very well. This technique allows him to use his genetic potential and natural gifts to the fullest and develop his psycho-emotional and mental abilities to the highest level.

Some prognosis about his possible progress. If he manages to increase his average step frequency of running to the level of his rivals, just to something around 4.5 steps per second (270 steps per minute) having the same average angle of falling, his result on 100m could be 9.11 seconds. Isn't it impressive? But he, so far, is dreaming "only" about 9.4 seconds!

Extension Activity

In the sprinting events, there is a need to have an efficient start; look at the different types of start used by the sprinters in short-distance track events. Read the content below and discuss.



Discuss in group

- Identify different types of start in the short sprints.
- Why do different athletes use specific techniques?
- What are the scientific bases for specific techniques?
- Which technique is the best according to you and why?
- What are the kinesiological and biomechanical advantages of different techniques?

Note: Study of kinesiology and biomechanics will help you answer the following questions, and you will also be able to correlate the techniques and the human movements.

8.1.1 Concept of Kinesiology and Biomechanics

Sports activities are good for health, and everyone wants to remain fit, but only some people know the logic and facts involved in these fitness activities, or you can say

the technical points behind the same. Biology and Physics play a vital role in defining the technicalities behind movement. Coaches and teachers have been engaged with these technicalities and put them to best use in improving the performance of athletes. Knowledge of physical activity is learned through experience, scholarly study, and professional practice. In today's world of sports, knowledge of kinesiology and biomechanics plays a significant role in identifying, designing, and applying a training programme to achieve the best performance. So, insight into kinesiology and biomechanics will always help teachers, coaches, doctors, and sports professionals have the upper hand in their specialty areas.

Kinesiology is the scholarly study of human movement, and biomechanics is one of the many academic subdisciplines of kinesiology. Biomechanics in kinesiology involves the precise description of human activity and the analysis of human movement causes. The study of biomechanics is relevant to professional practice in many kinesiology professions. The physical educator or coach teaching movement techniques and the athletic trainer or physical therapist treating an injury use biomechanics to analyse movement qualitatively.

Kinesiology is 'the science of movement' or 'the study of movement.' It includes the study of movement through anatomy and mechanics, whereas Biomechanics is the 'analysis/ study of forces' and the 'application of the principles of physics and their effect on the human body. In short, we can say that biomechanics is the central part of kinesiology.

8.1.2 Meaning of Kinesiology in Sports

Kinesiology is derived from the Greek word kinesis, which means movement, and logos which means to study. Thus, kinesiology is a discipline that studies movements. It is a study of human movement and muscular function. The study of kinesiology seeks to understand the impact of muscle function on health. It draws upon the concepts for several sciences, including biomechanics, anatomy, physiology, and neuroscience. The study of Kinesiology seeks to understand the mechanism of human movement and pinpoint the specific muscle involved in a particular movement. The science of kinesiology views the human body as a machine that functions in a very purposeful way.

Kinesiology, or human kinetics, is a scientific study of human movement. Kinesiology addresses physiological, mechanical, and psychological mechanisms. Applying kinesiology to human health includes strength and coordination, sports psychology, methods of rehabilitation, such as physical and occupational therapy, and sports and exercise.

Do you Know

Aristotle (384-322 BC) is called "father of kinesiology." Aristotle wrote about three centuries before Christ, "the animal that moves makes its change of position by pressing against that which is beneath it. Hence, athletes jump further if they have the weights in their hands than if they have not, and runners run faster if they swing their arms, for in extension of the arms there is a kind of leaning upon the hands and wrists." Hart said, "from the point of view of mechanics, we may regard Aristotle's work as the starting point of a chain of thought which played an important part in the evolution of the subject."

Aristotle was the first to analyse and describe the complex process of walking, in which rotatory motion is transformed into translatory motion. Aristotle's treatise, Parts of Animals, Movements of Animals and Progression of Animals, described for the first time the actions of the muscles and subjected them to geometrical analysis. The ideas expressed by Aristotle were the forerunners of the ideas of Newton, Borelli, and others. His concepts of leverage, gravity, and laws of motion were remarkably accurate.

8.1.3 Definitions of Kinesiology

"Kinesiology refers to the whole scholarly area of human movement study, while biomechanics is the study of motion and its causes in living things."

"Kinesiology is a term formed by the combination of two Greek words, Kinesin, meaning to move, and logos, meaning to discourse." (Rasch & Burke, 1978). When viewed as a discipline, "kinesiology can be defined as studying the movement behaviour of all living organisms." (Burke R.K 1977).

8.1.4 Importance of Kinesiology in Sports

1. **Analysing human motion:** The knowledge of kinesiology offers future coaches/ trainers/ physical education teachers a clear insight into the analysis of human movement and helps them understand how motor skills and techniques can be improved to ensure successful participation in various physical activities. Example: analysing fundamental movements with reference to sports skills performed.
2. **Learning and improvement of motor skills:** With the knowledge of kinesiology, a coach or teacher learns the nature and effects of each physical activity. This enables him to select intelligently the exercise which will contribute to achieving the targeted aims for an individual, thereby improving the motor skills to the level of perfection. Example: Teaching and applying correct walking and running patterns for trainees and athletes.

3. **Applying anatomic background will help to prevent injuries:** With the knowledge of kinesiology, one can understand the nature and mechanism of most common musculoskeletal injuries. The appropriate preventive conditioning flexibility and muscle-strengthening exercises help prevent athletic injuries. Applying kinesiological principles to the acts of landing, falling, catching, etc., also, to some extent, prevents injuries on the sports fields. Similar know-how of the muscles will help design appropriate activities and exercises for re-educating the weak muscles during the treatment and rehabilitation of the injuries.

4. **Ensuring economy of movement:** Kinesiology helps analyse the physiological relation, energy utilization, and muscular contraction timing of the physical activity and exercises. The structure and mechanics of human performance are also not ignored in the financial world. Example: minimizing the body movement to regulate energy utilization and improve timing in long-duration activities.

5. **Ensuring effectiveness of movement:** Knowledge of the principles of kinesiology assists in recognizing and analysing the quality of awkward and skilful movements and correcting irregular movements so that movement efficiency can be achieved. Example: Analysing body positioning during snatch and correcting the technique to minimize the change of error in competition.

6. **Aiding clinical purposes like postural analysis, corrective exercise, and rehabilitation:** Kinesiology also helps to identify errors in posture through posture analysis and helps to correct them with the help of corrective exercises and rehabilitation. Example: Analysis of posture among students in school and correcting them if required, with the help of corrective exercise.

7. **Designing and teaching exercise and conditioning:** The importance of kinesiology is to aid the improvement of human structure through intelligent activities and efficient use of the body. The human system improves with the service provided it is used per the principles of kinesiology and efficient human motion. Kinesiology helps improve the individuals' general physical condition and fitness through routine exercise and conditioning design. Example: Teaching students the correct position during sit-ups while training and assessment of physical fitness.

8. **Discovering and recognizing the underlying principles of movement:** Kinesiology is the fundamental science in preparation of professionals in the area of human motion, whether they are in physical education, physical therapy, athletic training, or any other related profession. It provides us knowledge about various parts of the locomotor system. In kinesiology, we get to learn about the particular muscles, bones, and joints that are involved in a particular movement, and to what extent; what principles of mechanics are involved in

the exercises or the activities; what is the effect of gravity and other forces on the muscular system; and how the bones serve as the anatomic levers in the human body and how the muscles provide the necessary force to move the body levers. Kinesiology thus helps us learn and analyse all these aspects and the movements of the human body and discover their underlying principles to improve performance.

9. **Designing and teaching fundamental movements:** Physical educators and coaches apply the knowledge of kinesiology mainly to the movements of the normal body. However, physical educators and the therapists, have one common application in studying kinesiology; they are both concerned with posture and body mechanics of daily life skills and analysing the anatomical and mechanical basis of movement.

10. **Acquiring self-realization about own performance:** Since each sports person has his abilities and potentialities kinesiology helps the coaches and selectors match the performer to the activity and the activity to the performer. Example, basketball players can analyse if they need to correct to improve their jumping ability, which can improve their performance.

11. **Enables effective teaching of motor skills (fundamental motor and specialized motor skills):** Kinesiology helps prepare the physical educator to teach effective performance in both fundamental and specialized motor skills. Perfecting the performance refers to mastery and perfection in the technique and defining standards of skill. On the other hand, perfecting the performer means that an individual sportsperson is made perfect in the given act. The intelligent selection of the methods, skills, and activities help perfect the performer and performance.

12. **Ensures evaluation of exercise and activity and their effect on the human structure:** Physical educators or coaches, who deal with physical development or motor skills, are aided in their job by the knowledge and understanding of kinesiological principles. These help them assess and evaluate the extent of effect produced by exercise and movement to achieve the purpose for which these were prescribed.

13. **Providing benefit to physiotherapists and physical medicine professionals:** Knowledge of kinesiology has a three-fold purpose both for the professionals of physical education and physical medicine in the analysis and modification of human movement. Kinesiology enables them to help their trainees or clients perform with optimum "safety," "effectiveness," and "efficiency." "Safety" should be a significant concern for all the movement professionals while designing or selecting movements or activities to avoid doing any harm to the body

8.2.1 Meaning of Biomechanics

The word biomechanics (1899) and the related biomechanical (1856) come from the Ancient Greek bios that means life and mechanike or mechanics refers to the study of the mechanical principles of living organisms, particularly their movement and structure.

Biomechanics is the study of the mechanics related to the functional and anatomical analysis of biological systems, mainly of humans. Study of biomechanics is necessary to study the body's mechanical characteristics and principles and to understand its movements.

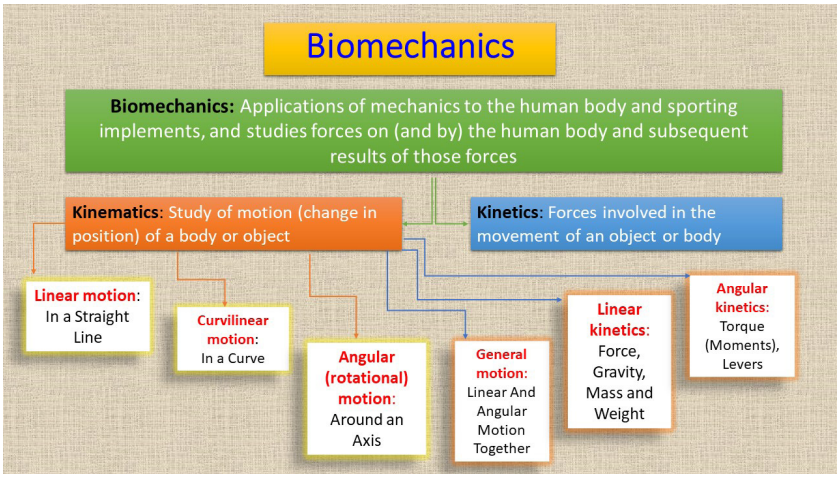
Within "mechanics" there are two sub-fields of study. One is statics which is the study of systems that are in a state of constant motion either at rest (with no motion) or moving with

a constant velocity; and the second one is dynamics, which is the study of systems in motion in which acceleration is present, which may involve kinematics and kinetics.

Kinematics is the study of the motion of bodies with respect to time, displacement, velocity, and speed of movement either in a straight line or in a rotary direction. Whereas, Kinetics is the study of the forces associated with motion, including forces causing motion and forces resulting from motion.

Sports biomechanics is a quantitative-based study and analysis of professional athletes, sportspersons and sports activities in general. In simple terms, it describes the physics of sports. In this subfield of biomechanics, the laws of mechanics are applied to sporting events through mathematical modeling by means of computer simulation, and measurement in order to gain a greater understanding of athletic or sporting performance.

In simple words, sports biomechanics can be expressed as the science of explaining how and why the human body moves in the way that it does



Do you Know

Do you know how much strain you put on your body when pushing, pulling, or lifting to move and handle patients with manual aids? Musculoskeletal disorders continue to be an issue among health personnel, and it is more important than ever that we realize that patient transfers present a serious risk of work injuries.

A biomechanical calculation is a method that calculates how large the load on the musculoskeletal system is in any given situation. For example, it is possible to calculate how much strain is on the discs in the lumbar region if a person is standing with a straight back tilted forwards 45 degrees.

To calculate that, we need some values first:

- Height and weight of the person performing the transfer
- How many degrees the person is bending forwards during the transfer
- How much the patient being transferred weighs
- And how far the reaching distance is

For example, we might have a situation with a person who weighs 80 kilos, is 186 cm tall, and is bending 45 degrees forward, lifting a weight, weighing 10 kilos, at a reaching distance of 30 cm. This case will result in a strain of approx. 255 kg on the disc in the lumbar region (or the weight of the object).

8.2.2 Definitions of Biomechanics

Biomechanics has been defined as studying the movement of living things using the science of mechanics (Hatze, 1974).

"The area of study wherein knowledge and methods of mechanics are applied to the structure and function of the living human system."

"Biomechanics is the science concerned with the internal and external forces acting on a human body and the effects produced by these forces". James. G. Hay

8.2.3 Importance of Biomechanics in Sports

1. **Basis for analysing the efficient structure of competitive performance:** Human movement performance analysis can be done in many ways; biomechanics is essentially the science of movement technique and tends to be most utilized in sports where technique is a dominant factor rather than the physical structure or physiological capacities (Analysis the performance of 9.63 at the 2012 London Olympics by Usan Bolt). Following are some of the areas where biomechanics is applied to analyse the efficient structure of competitive performance are given below:

- GAIT Analysis
- Cinematography,
- Videography,
- Electromyography (EMG),
- Accelerometer,
- Dynamometry,
- Electrogoniometry
- The analysis of sport and exercise equipment, e.g., shoes, surfaces, and rackets.

2. **Practical organization of the process of the sport's technical profession:** Sports professionals use technology that helps assess an athlete's performance, using data to track performance, health, and leveraging visual tools that can show how athletes at all levels can improve. Knowledge of Biomechanics helps them apply such tools and obtain data in training, treatment and achieving optimum performances.

3. **Essential for the effective organization of the development of motor abilities:** Sports and games focus on reaching maximum efficiency in motor abilities connected to a particular sports discipline. Motor abilities can be described as relatively stable sets of inner genetic presuppositions needed to carry out locomotive activities. They include force, speed, endurance, coordination, and flexibility. Knowledge of biomechanics helps a coach and teacher understand and apply systematic training for development.

4. **For Diagnostic teaching:** Diagnostic teaching is the process of discovering an athlete's individual abilities, needs, and objectives and prescribing requisite learning assessments. Instructors monitor the trainee's understanding and performance before, during, and after teaching a lesson. Reviewing can inform instructors of their efficacy when conducting assessment and guide them towards areas they need to emphasize in class to aid the athlete's understanding of the material for better learning.

5. **For diagnostic coaching:** Training diagnostics examines and evaluates training and organizational performance through systematic assessments, analysis, and data collection. Knowledge of biomechanics helps a coach and a trainer design training schedule.

6. **For self-evaluation of athletes:** The ultimate aims of an athlete – optimal athletic performance, and reduced risk for injury – go hand-in-hand. The better an athlete's technique through each movement, the better she/he is likely to perform and the more she/he will avoid injuries. Using biomechanics, athletes can look at every tiny detail of how they run, jump, throw, change directions,

and many other related tasks. The information is invaluable. Example: if an athlete is not optimally bending her/his knees during a jumping or landing task, she/he can focus their training to improve their performance through motor learning and improved strength and balance training.

7. **Designing and accepting equipment:** Advances in sports equipment have revolutionized athletic competition with engineers developing equipment that can enhance performance. Biomechanics not only helps in designing new equipment but also tends to measure the efficiency and effectiveness of equipment as per training requirements. Example: T-shirts, studs, spikes, swimming costumes, hockey sticks, different-sized footballs, and low-weight helmets for protection.

8. **Evaluate and change the rules and regulations:** Biomechanics is the study of the structure and function of biological systems using the methods of "mechanics," which is the branch of physics and mechanics involving analysis of the actions of forces. Thus, the laws of mechanics are applied to human biomechanics to have a better understanding of athletic performance through mathematical modelling, computational simulation, and experimental measurement. During such analysis, rules and regulations can be modified for the athlete's safety and performance enhancement.

9. **Evaluate new techniques:** The most common method for improving performance in many sports is to improve an athlete's technique. The application of biomechanics to improve technique may occur in two ways: Teachers and coaches may use their knowledge of mechanics to correct actions of a trainee or athlete to improve the execution of a skill, or a biomechanics researcher may discover a new and more effective technique for performing a sport skill by introducing new technologies. In the first instance, teachers and coaches use qualitative biomechanical analysis methods in everyday teaching and coaching to effect changes in old techniques with the new ones. In the second instance, a biomechanics researcher uses quantitative biomechanical analysis methods to discover new techniques, which then must be communicated to the teachers and coaches who will implement them.

10. **Select techniques about their suitability to the athletes:** Likewise, biomechanics help in developing new techniques in different games and sports; it also helps in selecting techniques for an athlete based on the one most suitable for them which will help them to improve their technical efficiency and bring performance in competition. Example: For a sprinter who is short, a bullet start is preferable in short-distance sprinting events as it helps them to have an efficient start with effective block clearance time and force impulse on the front and rear starting blocks as well as take-off velocity and acceleration

11. **Selection of players:** Biomechanics helps in understanding the complete human body. Knowledge of biomechanics provides the teachers and coaches with a better understanding of the human body in terms of structural and functional qualities as also the various internal and external forces that affect movement. This understanding helps a teacher and coach to select the players according to the requirements of the sport. Example: short players for gymnastics and tall players for Volleyball etc.

12. **Design and develop exercises for the best outcome:** Employing the principles of Biomechanics enhances performance by utilizing mechanical principles to improve an individual's technique, decide the exercise they use, and modify specific training protocols that the coach or trainer implements to help an individual achieve their utmost potential. Biomechanics is used to develop an exercise that improves performance and reduces the chance of injury since it is designed based on how the body is going to adapt to the biomechanical stress placed upon it. Example: Instead of a full-squat an athlete can perform a half-squat with less stress on the knee joint and lower back muscles.

13. **Prevention and rehabilitation of injuries:** Injuries are fairly common on the sports field. However, a good knowledge of biomechanics helps in preventing injury in various ways. Example, analysis of the runner's style of running, her/his arm swing, foot strike, and even trunk leaning will determine the cause of injury. In fact, just as biomechanics is useful in identifying what forces may have caused an injury, it also helps determine how to prevent the injury from recurring. It also helps in the process of rehabilitation of injuries by helping determine the exercises that may help in the process of rehabilitation. Biomechanics is used to provide the basis for changes in techniques, equipment, and training to prevent injuries.

I. **Tick the correct options**

1. The science that deals with the movement aspect of the human body is known as

   a. Physiology

   b. Anatomy

   c. Botany

   d. Kinesiology

2. The scientific study of the human or non-human body movements it is known as

   a. Physiology

   b. Anatomy

c. Biology

d. Kinesiology

3. Sports biomechanics can be described as-

a. Mechanics of sports

b. Kinesiology

c. Physics of sports

d. Sports dynamics

II. **Answer the following questions briefly.**

1. Define Kinesiology.

2. Define Biomechanics.

3. List the importance of Kinesiology in sports.

III. **Answer the following questions in 150-200words.**

1. Explain the importance of Biomechanics in the field of sports.

2. Explain the importance of Kinesiology in the field of sports.

3. 'Knowledge of biomechanics helps in the selection of players', Discuss in the context of any one game of your choice.

4. 'Knowledge of kinesiology help to design and teach fundamental movements', justify.

5. What do you understand by the concept of sports biomechanics? Write in your own words with suitable examples from sports?

Extension Activity

Working in groups, identify the activities in you school, among yourself, where you can relate biomechanics and kinesiology, and list any five below.

S. No.	Activities	Relationship
1.		
2.		
3.		
4.		
5.		

8.3.1 Principles of Biomechanics in Sports

The nine principles of biomechanics constitute the minimum number of core principles that can be applied to all human movements. The principles can be organized into

ones dealing primarily with the creation of movement (process) and ones dealing with the outcome of various projectiles (product). These principles are based primarily on the work of several bio-mechanists (Norman, 1975; Hudson, 1995) who have developed generic biomechanical principles for all human movements. Many biomechanics books have proposed general principles for all movements (Meinel & Schnabel, 1998); various categories of human movements like throwing, catching, and running (e.g., Broer & Zernicke, 1979; Dyson, 1986; Kreighbaum & Barthels, 1996; Luttgens & Wells, 1982); or specific movements (e.g., Bunn, 1972; Groves & Camaione, 1975). Some bio-mechanists believe that general principles applicable to all sports are difficult to identify and have limited practical application due to unique goals and environmental contexts of skills (Hochmuch & Marhold, 1978).

8.3.2 The Nine Biomechanics Principles are:

1. Force-Motion
2. Force-Time
3. Inertia
4. Range of Motion
5. Balance
6. The Coordination Continuum
7. Segmental Interaction
8. Optimal Projection
9. Spin

1. **Principle of Force-Motion:** The Force-Motion Principle states that it takes unbalanced forces (and the subsequent torques they induce) to create or modify our motion. Unbalanced forces act on our body, or an object, creating or modifying movement. A free-body diagram is a simplified model of any system or object drawn with significant forces acting on the object. Forces must act first before changes in motion can occur. Force-Motion Principle suggests that muscle groups that primarily contribute to interest motion should be trained. Example: Standing still- forces acting on a person are equal and because of this there is no movement.

2. **Principle of Force-Time :** The Force-Time Principle states that modification of movement depends on the timing of force application as much as the size of the forces used to create it. It is not only the amount of force that can increase the motion of an object, as also the amount of time over which power can be applied to affect the resulting motion. Increasing the time to use force is also essential in slowing down objects (catching) and landing safely. (Impulse = Force x Time. The greater the time of which force is applied the greater

the resulting motion.) Example: Using the sweep shot in hockey wherein more force and time are applied giving it much more power than a hit.

3. **Principle of Inertia :** Inertia can be defined as the property of all objects to resist changes in their state of motion. The linear and angular inertia measures are mass (m) and moment of inertia (I). We will see that inertia can be viewed as a resistance to motion in the traditional sense, but this property can also be used to an advantage when modifying movement or transferring energy from one body segment to another. Example: To stop a shotput or a netball travelling through the air a force must be applied to it. The force is much higher to stop a shotput because it is heavier than a netball. Therefore, the shotput has more inertia.

4. **Principle of Range of Motion:** Range of Motion is the overall motion used in a movement; it could be linear or angular motion of the body segments. The purpose of some movements might require that somebody segments limit range of motion, while others requiring maximum speed or force might require more extensive ranges of motion. Increasing the range of motion in a movement can effectively increase speed or gradually slowdown from a high speed. Since moving through a range of motion takes time, this principle is related to the force-time principle. The Range-of-Motion Principle states that less range of motion is most effective for low-effort (force and speed) and high-accuracy movements. In contrast, a more excellent range of motion favours maximum efforts related to rate and overall force production. Example: Reduced Range-of-Motion (R.O.M) = Throwing a dart and Increased (R.O.M) = Throwing a javelin

5. **Principle of Balance:** Balance is a person's ability to control their body position relative to some support base. Stability and mobility of body postures are inversely related. In other words, the degree of control over stability or instability depends on several biomechanical factors. It relates to centre of gravity, stability, and equilibrium. To increase stability, increased base of support and lower centre of gravity increases mass of the body. Line of gravity should fall in the middle of your base of support for maximum stability. Example: Sumo wrestlers have a very wide and low stance to maximise their stability when wrestling. They also train to have an extremely large mass.

6. **Principle of Coordination Continuum:** How the muscle actions and body segment motions are timed in a human movement is usually referred to as coordination. The Coordination Continuum principle says that determining the optimal timing of muscle actions or segmental motions depends on the movement's goal. More simultaneous muscle actions and joint rotations are usually observed if high forces are the movement's goal. Low-force and high-speed movements tend to have more sequential muscle and collective efforts. These strategies (simultaneous/sequential) can be viewed as a continuum,

with the coordination of most motor skills falling somewhere between these two strategies. Example: Simultaneous = weight lifting and Sequential= Base Ball Pitcher

7. **Principle of Segmental Interaction:** The principle of Segmental Interaction says that the forces acting in a system of linked rigid bodies can be transferred through the links and joints. Muscles usually work in short bursts to produce torques that are precisely coordinated to complement the effects of torques created by forces at the joints. (Transfer, summation, sequential). Example: In Golf and Tennis shots, the player uses his body parts in order to create maximum power. (Begins with the largest, slowest, and strongest segments and works through to the slowest and fastest segments).

8. **Principle of Optimal Projection:** The biomechanical principle of optimal projection says an optimal range of projection angles for a specific goal for most human movements involving projectiles. There is an optimal angle of projection to achieve a specific goal. Maximum speed/distance of an optimal angle=45 degrees. Example: maximum distance can be achieved by hitting a golf ball on a level plane this causes the golf ball to be hit at exactly 45 degrees.

9. **Principle of Spin:** The principle of Spin or rotations applies largely to projectiles, and particularly sports balls. Spin is desirable on thrown and struck balls because it stabilizes flight and creates a fluid force called lift. This lift force is used to create a curve or counter gravity, which affects the trajectory and bounce of the ball. Spin stabilizes the orientation of the ball, which ensures aerodynamically efficient flight. Example: A tennis player putting a top spin on a ball to make it drop quicker.

Extension Activity

Discuss with your group

- How can the study of sports biomechanics help a coach to train their trainee in a better scientific manner?

Design a poster to show the importance of sports biomechanics in Physical Education and Sports

I. **Tick the correct options**

1. _____ is a person's ability to control their body position relative to some support base.

   a. Inertia

   b. Balance

   c. Spin

   d. None form above

2. Simultaneous = weight lifting and Sequential = Base Ball Pitcher is an example of

   a. Inertia

   b. Balance

   c. Spin

   d. Coordination Continuum

3. Using the sweep shot in hockey, wherein more force and time are applied, gives it much more power than a hit and is an example of which Principle of Biomechanics.

   a. Force-Motion

   b. Force-Time

   c. Range of Motion

   d. Segmental Interaction

II. **Answer the following questions briefly.**

1. Define principle of optimal projection.

2. Define principle of force-time.

III. **Answer the following questions in 150-200words.**

1. List down the principles of biomechanics and explain any 2 in detail.

8.4.1 Kinetics and Kinematics in Sports

The human body has evolved to its present form through many mutations. It may be unique concerning its anatomy and physiology, but the same laws and principles that govern all other animate and inanimate objects in the universe are also applicable to humans. All motor skills are performed with an implement (bat or racket) or without being influenced by one. In most instances, a number of these physical laws and principles are commonly considered mechanical laws and principles, and they may be classified as static or dynamic involving, on the one hand, objects in a state of static equilibrium and, on the other, objects in motion. Dynamics is further subdivided into Kinematics and Kinetics.

Sports biomechanics is traditionally divided into the study of kinetics and kinematics. Kinetics is the study of the relationships between the forces acting on the body and how those forces affect motion. Kinematics is the geometry of objects' motion, including displacement, velocity, and acceleration. In simple terms, kinetics studies the muscles that cause movement (gravity, friction, etc.), while kinematics describes the motion (velocity, acceleration, etc.)

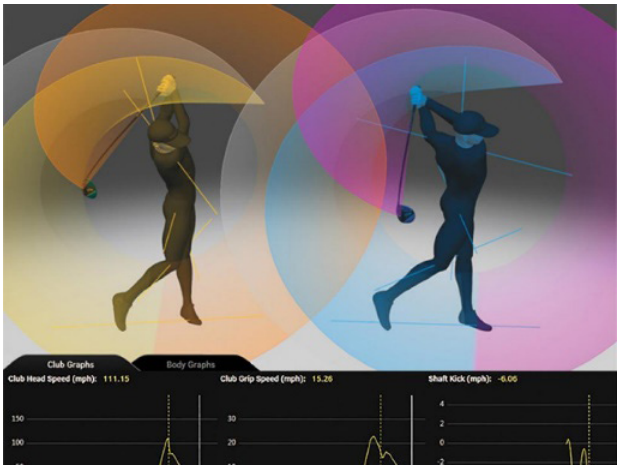
Kinematics analyses motion in terms of time, displacement, velocity, or acceleration. In the language of science, it is the geometry of motion, describing the above four states of motion as they occur either in a straight (linear) line or in a rotary (angular) direction. Thus, we can sat that Kinematics is the mechanics of motion without reference to the forces causing that motion – so only from a geometrical point of view. This is the displacement and velocity of your body's segments and joints.

Kinetics is the action of forces in producing or changing motion. This considers the influence of various interacting objects and how they react with one another. Therefore, we can say that Kinetics is that aspect of dynamics that considers the force that causes objects or bodies to move. Force may be a pull or a push. All levers in the human body are pull-type machines, but in performing skills, the element of inspiration becomes a mechanical part of the actual skill, like the hand's force that 'pushes' the shot. Human levers produce force to overcome resistance, and this action is working. Kinetics considers the forces which cause motion and includes Newton's three 'Laws of Motion. For example, in the study of the golf swing, kinematics focuses on details of the swing 'motion' such as the shape of the clubhead, its path, position of the body and club at various swing events, velocities of the body parts and club, and the timing of slow-down of the body for speed-up of the club. To accurately describe the swing motion, it is essential to measure it accurately. Therefore measurement of motion is one of the central aspects of kinematics.

Do you Know?

Kinematics and kinetics are sub-areas of biomechanics. Kinematics is the study of the description of motion, while kinetics is the study of the explanation of motion. In kinematics, the focus is on the object's motion, while kinetics focuses on the cause of motion dealing with the 'why.'

Fundamental kinematic quantities include time, position, displacement (distance), velocity (speed), and acceleration. In addition to these, shapes of trajectories of various points on the body, club, and orientation of motion planes of multiple body segments and clubs are also kinematic issues. A complex motion of an object can be resolved into the linear motion of the centre of mass (COM) of the body and the angular motion of the body about its COM, which is also a kinematic issue. The kinematic sequence plot is based on the angular velocity patterns of body segments, lines, and clubs.



Picture source: https://www.golfdigest.com/story/stuff-gears-golf

Do you Know?

The Fundamental Differences Between Kinetics and Kinematics

S.No.	Attributes	Kinetics	Kinematics
1.	Definition	Kinetics is the study of motion considering the mass and external forces as well.	Kinematics is not dependent upon the mass of the object.
2.	Relation	It attempts to determine the relationship between the motion of bodies caused by inertial force and the mass of a body.	Kinematics is about simply describing motion. Such as velocity, displacement, time, and acceleration.
3.	Study	Study of the motion caused by forces, gravity, friction, torque	To determine the "how" of motion.
4.	Nature	It attempts to get at the cause.	It is descriptive and based on observation
5.	Treated	Treated in terms of energy transformations	Treated geometrically
6.	Example	A person sitting inside the train. A child running around in the house, running fan	A Moving Train Parabolic locus traced by a football. A stone hitting the ground.
7.	Uses	Concept of gas laws, fluid dynamics, physical chemistry	Classical mechanics in terms of engineering.

I. **Tick the correct options**

1. The kinematics analyses motion in terms of
   a. Time
   b. Displacement
   c. Velocity
   d. All of the above
2. Sports biomechanics is traditionally divided into the study
   a. Kinetics
   b. Kinematics
   c. Both a and b
   d. None of the above

II. **Answer the following questions briefly.**

1. Define Kinetics.
2. Define Kinematics.
3. List the importance of Kinesiology in sports.

III. **Answer the following questions in 150-200words.**

1. List down the difference of kinetics and kinematics.

8.5.1 Movement

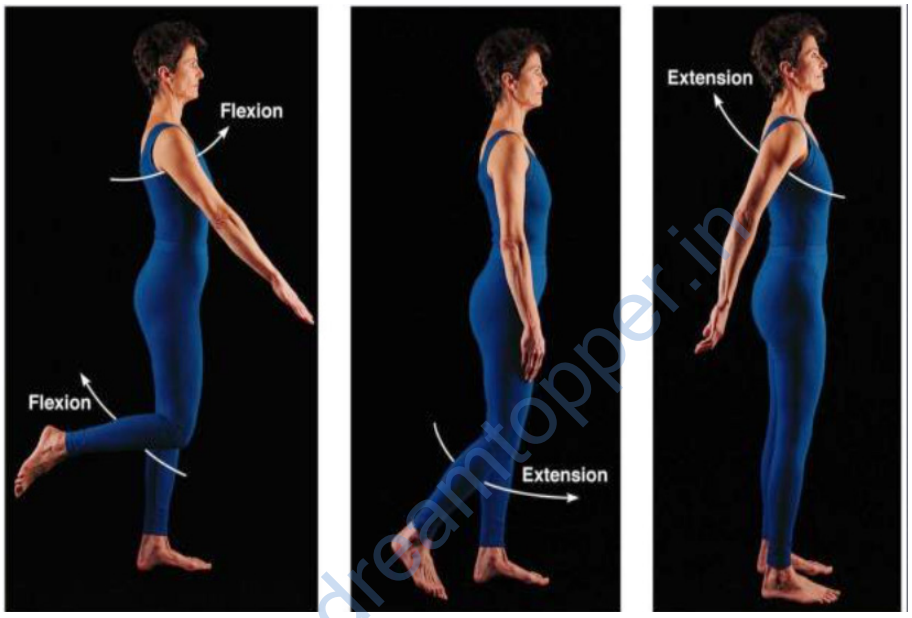
Movement or motion is the act of moving, change of place or posture, or transference, by any means, from one situation to another. Humans can move from one place to another through coordinated movements and postures. The movement produced by the human body due to the contraction of muscles and bending of bone joints is called human movement. Human movements are controlled by the nervous system. Hence, human movement incorporates the use of muscles, ligaments, joints, and bones.

Movement is one of the things that differentiates a living thing from a non-living thing. As referred to earlier, movement is the change in the position of an object. In the human body, it takes place when the living organism moves a body part or a combination of parts to bring about a change in position. We use the term locomotion to describe the movement which results in the change of position of the whole organism. It is important to understand the difference between the two - movement and locomotion - in relation to living things.

There are a variety of movements that happen in the human body, e.g., the movement of eyelids, heart muscles, jaw, and teeth. In addition, more complicated movements are performed in sports and games. To understand such basic to complex movement let's discuss the fundamentals of movement first.

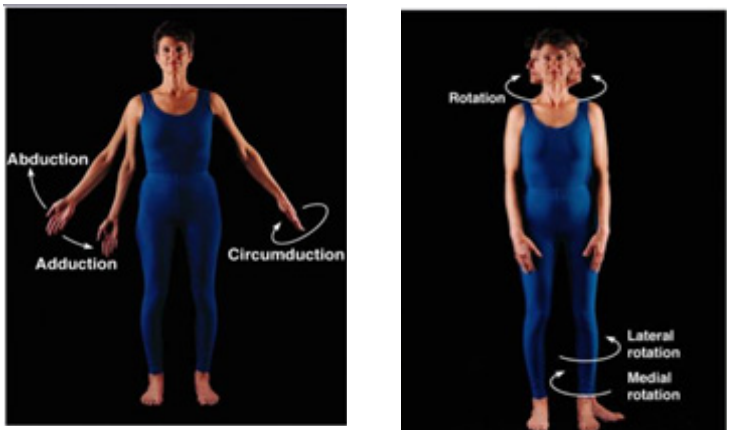
8.5.2 Types of Body Movements

1. **Flexion-** it is the bending of flexing a limb. Closing/ decreasing the angle at the moving joint.
2. **Extension-** it is straightening or extending a limb. Opening/ increasing the angle at the joint. It is the opposite movement of flexion.



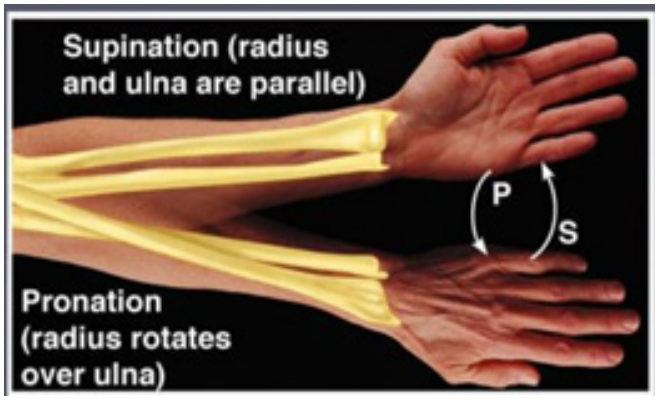
Picture source: https://www.slideserve.com/garan/body-movements

3. **Abduction: -** Moving a Limb away from the body's centreline.
4. **Adduction: -** Moving a Limb towards the body's centreline is called adduction.
5. **Rotation:** It is the movement around the long axis.



Picture source: https://www.slideserve.com/garan/body-movements

6. **Circumduction:** It combines flexion, extension, abduction and adduction. Usually this movement occurs at ball and socket joints like shoulder joint, hip joint, etc.
7. **Pronation:** It means turning the palm down.
8. **Supination:** It means turning the palm up.



Picture Source: https://www.slideserve.com/garan/body-movements

8.5.3 Axis and Planes

In kinematics, the limbs or segments of the body are assumed to rotate about the joints, with no translational, or sliding, movement. While this is not strictly correct, it offers a usable approximation of the actual joint motion. The joint serves as an axis (a line around which something can rotate), and associated with the axis is a plane, (like a sheet of paper perpendicular to the axis), in which the rotational movement takes place.

For a better understanding of the axis and planes of movement, we must know the following terminologies:

- Anterior/ Ventral- towards the front of the body
- Posterior/Dorsal- towards the back of the body
- Superior/Cranial- towards the head of the body or upper part of the body.
- Inferior/Caudal- towards the lower part of the body.
- Medial- towards the midline of the body (inner side).
- Lateral- away from the midline of the body (outer side).

8.5.4 Plane

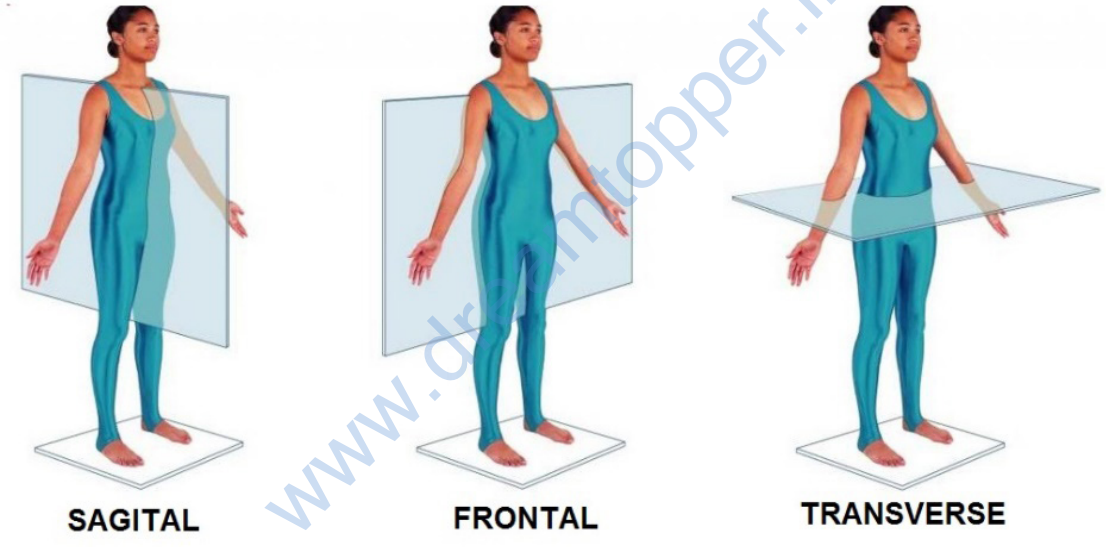
A single plane divides the entire body into two parts. There are three planes of motion in which our body moves. Most of our moments are not straight up or down or side to side or in a single direction etc., especially in sports.

a. **Sagittal plane (Median plane): -** It lies vertically and divides the body into right and left parts. Flexion and extension types of movement occur in this plane. Example: kicking a football, chest pass in netball, walking, jumping, and squatting.

b. **Frontal plane (lateral or coronal plane): -** It also lies vertically and divides the body into anterior/ Ventral- and posterior/ Dorsal- parts. Abduction and adduction movements occur in this plane. Example, jumping jack exercises, raising and lowering arms and legs sideways, and cartwheel.

c. **Transverse plane (horizontal plane): -** It lies horizontally and divides the body into superior and inferior parts. Rotation types of movement occur in this plane. Example, hip rotation in a golf swing, twisting in a discus throw, pivoting in netball, and spinning in skating.

"The centre of gravity may be defined as the point at which the three planes of the body intersect each other".



Picture Source: https://apki.or.id/klasifikasi-gerak-sendi-bagian-4/

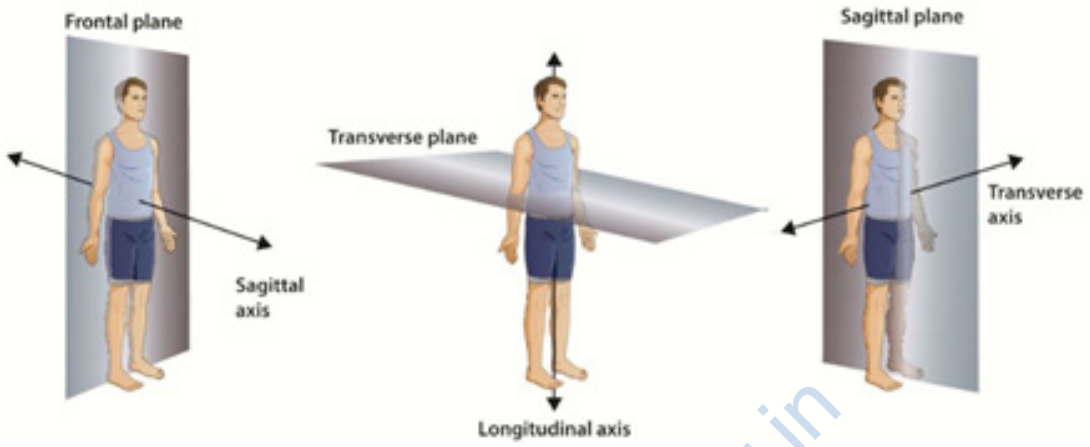
8.5.5 Axis

An axis is a point or straight line around which an object moves or moment of the body segments occurs. There are three axes of rotation, and each axis is perpendicular to the plane.

a. **Sagittal axis: -** It is also called the anteroposterior axis. It passes horizontally from posterior to anterior. It is perpendicular to the frontal plane. The movements that occur in this axis are abduction and adduction.

b. **Frontal axis (transverse axis): -** It is also known as the horizontal and mediolateral axis. It is perpendicular to the sagittal plane. It runs from side to side. Flexion and extension are the movements taking place in this axis.

c. **Vertical axis (longitudinal axis): -** It is perpendicular to the transversal plane. It passes vertically from inferior to superior. Typically, rotation types of movement take place on this axis.



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8.5.6 Concept and its application in Body Movements

Movement is generally referred to by the particular plane it occurs in. An example of this would be a description of walking as a sagittal plane movement. In reality, this is only a description of the gross direction of movement. At the individual joint level, movement will occur in all three planes, not solely in the sagittal plane. Example, during walking, the hip will be flexing/extending in the sagittal plane, adducting/abducting in the frontal plane, and internally/externally rotating in the transverse plane.

The same concept applies to all the individual joints in the lower limbs. The movement that you effectively "see" does not represent what is occurring in terms of motor control and force absorption within all three planes. Example, the most apparent hip movement is expressed in the sagittal plane during gait. Still, there is an interplay between eccentric force absorption and concentric force production in all three planes at the joint. The hip subtly decelerates internal rotation and adduction and accelerates external rotation and abduction.

This simultaneous movement can be seen as one motion with three components – it can be termed tri-planar motion. The exercise professional must be comfortable with the concepts of tri-planar motion and the fact that all functional movements

are three-dimensional. However, it is biomechanically understood that description in single plane terms is most useful when generalizing gross movement patterns.

Examples of dominant planes, motions, and axis in gross movements

Plane	Motion	Axis	Example
Sagittal	Flexion/extension	Frontal	Walking Squatting Overhead press
Frontal	Abduction/abduction Side flexion Inversion/eversion	Sagittal	Star jump Lateral arm raises Side bending
Transverse	Int-rotation/ ext-rotation Horizontal flexion/extension Supination/pronation	Vertical	Throwing Baseball swing Golf swing

Do you know?

All body movements occur in different planes and around different axes. A plane is an imaginary flat surface running through the body. An axis is an imaginary line at right angles to the plane, about which the body rotates or spins.

Extension Activity

Now identify the plane and axis in the picture below:

Or

Perform front-roll, back-roll, and cartwheel. Write on which plane and axis these movements took place.

Movements	Axis	Planes
Front-roll		
Back-roll		
Cartwheel		

I. **Tick the correct options.**

1. The term flexion refers to
   a. bending
   b. turning
   c. twisting
   d. straightening
2. Extension is
   a. bending
   b. turning
   c. twisting
   d. straightening
3. Moving away from the reference axis is known as
   a. Flexion
   b. Extension
   c. Abduction
   d. Adduction
4. Bringing the body part closer to the reference axis is called
   a. Flexion
   b. Extension
   c. Abduction
   d. Adduction
5. The plane which divides the body into a left and a right is called
   a. Coronal plane
   b. Sagittal plane
   c. Vertical plane
   d. Transvers plane

II. **Answer the following questions briefly.**

1. What is plane of movement?
2. Which plane and axis is involved while we kick a football.
3. Differentiate between flexion and extension.

III. **Answer the following questions in 150-200 words.**

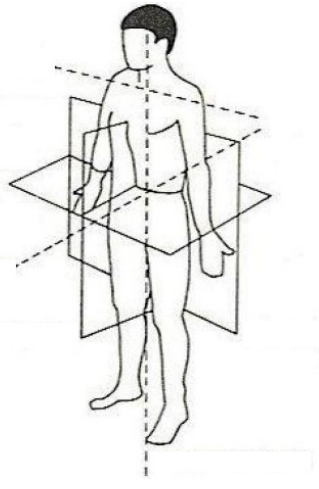
1. Differentiate between abduction and adduction.
2. How does knowledge of movement and its type contribute for graceful movement?

IV. **Working in groups, complete the following table on biomechanics and sports.**

What is sports biomechanics?	How do we apply biomechanics in sports?	What are the principles of bio-mechanics?	What are the advantages a) for coaches b) for sportspersons

V. **Case Study**

Fundamentals of kinesiology and Biomechanics in Sports.



On the basis of given picture answer the following questions

(a) Identify and label the planes and axis

(b) A vertical plane that divides the body into left and right side is known as _____.

(c) _____ axis runs from left to right through the centre of the body.

(d) Sagittal axis is also known as_____axis.

(e) _____ plane passes through the middle of the body and divides the body horizontally in the upper and lower half.

VI. **Art Integration – Making Powerpoint Presentation**

The mechanics of physical activity during dance include all the fundamental movements, which help us in full-body coordination. Keeping in view the importance of fundamental movement, make a PowerPoint presentation on the topic "Fundamental Movements and Dance Moves" and present it in your classroom.

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