Unit – I

Concepts in Biomechanics

The word *biomechanics* can be divided into two parts: the prefix *bio*- and the root word *mechanics*. The prefix *bio*- indicates that biomechanics has something to do with living or biological systems. The root word *mechanics* indicates that biomechanics has something to do with the analysis of forces and their effects.

Human Movement is the theme and the focus of study in Biomechanics. *Movement, or motion* involves a change in place, position, or posture relative to some point in the environment. A thorough understanding of various aspects of human movement may facilitate

a) Better teaching
b) Successful coaching
c) More observant therapy
d) Knowledgeable exercise prescription
e) New research ideas

Therefore, biomechanics provides key information on the most effective and safest movement patterns, equipment, and relevant exercises to improve human movement. Further, it is also applied in injury prevention and rehabilitation.

Definitions

- Biomechanics is the study of forces and their effects on living systems
- Biomechanics is defined as the application of mechanical principles in the study of living organism.
- Biomechanics is the study of the structure and function of biological systems by means of the methods of mechanics.
- The study of forces acting on and generated within a body and the effects of these forces on the tissues, fluid, or materials used for the diagnosis, treatment, or research purposes
- Biomechanics has been defined as the study of the movement of living things using the science of mechanics.

Quantitative and Qualitative analysis

Analysis of human movement may be either quantitative or qualitative. *Quantitative* implies that numbers are involved, and *qualitative* refers to a description of quality without the use of numbers. After watching the performance of a standing long jump, an observer might qualitatively state, “That was a very good jump.” Another observer might quantitatively announce that the same jump was 2.1 m in length.

Both qualitative and quantitative descriptions play important roles in the biomechanical analysis of human movement. Biomechanical researchers rely heavily on quantitative techniques in attempting to answer specific questions related to the mechanics of living organisms. Clinicians, coaches, and teachers of physical activities regularly employ qualitative observations of their patients, athletes, or students to formulate opinions or give advice.

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Definition for Sports and Exercise Biomechanics

Sport and exercise biomechanics as the study of forces and their effects on humans in exercise and sport.

What are the Goals of Sports and Exercise Biomechanics?

1. The ultimate goal of Sports & Exercise biomechanics is performance improvement in exercise or sport.
2. A secondary goal of Sports & Exercise biomechanics is injury prevention and rehabilitation.

A. Performance improvement

1. Technique improvement
2. Equipment improvement
3. Training improvement

B. Injury Prevention & Rehabilitation

1. Techniques to reduce injury
2. Equipment design to reduce injury

A. Performance improvement

1. Technique improvement

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 student or athlete in order to improve the execution of a skill, or a biomechanics researcher may discover a new and more effective technique for performing a sport skill. In the first instance, teachers and coaches use qualitative biomechanical analysis methods in their everyday teaching and coaching to effect changes in technique. 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.

Application of biomechanical knowledge

When a coach, observe that gymnast is having difficulty in completing a double somersault in the floor exercise. Coach might suggest three things to the gymnast to help her successfully complete the stunt: (1) jump higher, (2) tuck tighter, and (3) swing her arms more vigorously before takeoff. These suggestions may all result in improved performance and are based on biomechanical principles. Jumping higher will give the gymnast more time in the air to complete the somersault. Tucking tighter will cause the gymnast to rotate faster due to conservation of angular momentum. Swinging the arms more vigorously before takeoff will generate more angular momentum, thus also causing the gymnast to rotate faster. In general, this is the most common type of situation in which biomechanics has an effect on the outcome of a skill. Coaches and teachers use biomechanics to determine what actions may improve performance.

New Technique

In 1968, most world-class high jumpers used the straddle technique (figure I.4*a*). But at the Olympics in Mexico City, the gold medalist in the high jump used a technique few had ever seen. Dick Fosbury, an American from Oregon State University, used a back layout technique to jump 7 ft 4 1/4 in. (2.24 m). The technique became known as the Fosbury Flop (figure I.4*b*). Its advantages over the straddle technique were its faster approach run and its ease of learning. No biomechanics researcher had developed this technique. Fosbury achieved success with it in high school and continued using and jumping higher with it despite its dramatic differences from the conventional straddle technique. His successes led others to adopt it, and now all world-class high jumpers use the Fosbury Flop.

2. Equipment improvement

Swimsuit design has changed performances in swimming. A hundred years ago swimmers competed in woolen swimsuits, and women's suits had skirts. The wool was replaced by silk and then by synthetic fibers, and the skirt disappeared as swimsuit manufacturers made their swimsuits slicker and more hydrodynamic. Perhaps the most dramatic advance in swimsuit design occurred in February 2008 when Speedo introduced its LZR Racer swimsuit. The Speedo LZR Racer was designed by Speedo scientists and engineers to minimize muscle vibration and reduce drag with compression panels that streamlined the shape of the swimmer. The LZR swimsuits had polyurethane panels and no stitched seams. Within six weeks of its introduction, 13 world records were set by swimmers wearing the Speedo LZR Racer. At the 2008 Beijing Olympic Games, swimmers wearing the Speedo suits set 23 world records and won more than 90% of all the gold medals in swimming.

The design of javelin using mechanics principles changed the event dramatically. In 1952, Frank "Bud" Held made the United States Olympic team in the javelin. At the 1952 Olympics in Helsinki, he placed ninth behind his American teammates, who won the gold and silver medals. Upon returning to the United States, Bud met with his brother, Dick Held, who had some engineering expertise, and together they designed and built a more aerodynamic javelin. The increased surface area of their new javelin gave it more lift, causing it to "fly" farther. In 1953, Bud Held used one of his javelins to break the existing world record for the javelin throw. The records continued to be broken as others began using the Held javelin. In 1955, the IAAF implemented rules that limited the size of the javelin so that further increases in its surface area and lift were constrained. Before 1953, the world record in the javelin was 258 ft 2 3/8 in. (78.70 m), set in 1938. With the use of modern aerodynamic javelins based on the Held design, the world record in the event eventually progressed to 343 ft 10 in. (104.80 m), in 1984. In 1986, the IAAF effectively reduced the distance of the men's javelin throw by again changing the rules governing construction of the javelin. The new specifications prevented the javelin from "sailing" so far. Despite this attempt to limit performances, by 1990 the world record with the new javelin rules exceeded 300 ft (91.44 m); and by the turn of the century, the record was 323 ft 1 in. (98.48 m). In 1999, the IAAF implemented similar changes to the rules governing the construction of the women's javelin. These are examples of application of mechanics to *limit* performance in a sport.

3. Training improvement

Biomechanics has the potential to lead to modifications in training and thus improvements in performance. This application of biomechanics can occur in several ways. An analysis of the technique deficiencies of an athlete can assist the coach or teacher in identifying the type of training the athlete requires to improve. The athlete may be limited by the strength or endurance of certain muscle groups, by speed of movement, or by one specific aspect of his technique. An example, a gymnast attempting an iron cross maneuver requires tremendous strength in the adductor muscles of the shoulder. A mechanical analysis of the maneuver would reveal this, but it is already obvious to gymnastics coaches and observers. In other sport skills, the strength requirements may not be so obvious.

Similarly, in figure skating provides another example of how biomechanical analysis can lead to changes in training and ultimately performance improvement. Training camps for junior female skaters held at the U.S. OlympicTraining Center in Colorado Springs in the mid-1980s included biomechanical analyses of the skaters attempting double and some triple jumps. Many of the skaters who attempted triple twisting jumps were unsuccessful. An initial analysis revealed that some were unsuccessful in the triples because they were not bringing their arms in tight enough to cause them to spin faster while they were in the air. Further biomechanical analysis revealed that they were unable to bring their arms in tight enough or quickly enough due to inadequate strength in their arm and shoulder musculature. After their training programs were modified to include upper body strength training to increase arm and shoulder strength, several of the skaters were able to complete triple jumps successfully in subsequent training camps.

B. Injury Prevention & Rehabilitation

1. Techniques to reduce injury

Tennis Elbow is an overuse type of injury that affects many novice tennis players. Biomechanics research has revealed that one cause of tennis elbow is overexertion of the Extensor carpi radialis brevis muscle. Several biomechanists identified faulty technique during backhand strokes as a possible reason for the overexertion. Tennis players who maintain a neutral wrist position during a backhand stroke are less likely to develop tennis elbow than those with flexed wrists.

2. Equipment design to reduce injury

Running Shoe industry - 1972 Olympics Frank Shorter of USA won gold in Marathon. This increased boom in running marathon resulted to increase running related injuries. Selection of running shoes plays vital role in running related injuries. Boom in biomechanics research on running and running shoes began in 1970. *Runners World* -Published results of biomechanical tests on running shoes conducted at university biomechanics laboratories. In 1980 established Nike Sports Research Laboratory to further the development of athletics and athletic shoes by means of studies in the biomechanics, exercise physiology, and functional anatomy. Running shoes – 1970 – too stiff for many inexperienced runners – impact injuries (shinsplints & Stress fractures). Soft shoes – failed to provide stability or control as the harder shoes – ankle, knee and hip joint injuries – increased Modern shoes after biomechanics research which provides stability as well as cushioning. This resulted in fewer running injuries.

The history of Sports Biomechanics

The history of sport biomechanics is partly the history of **kinesiology**. The word *kinesiology* was first used in the late 19th century and became popular during the 20th century, whereas the word *biomechanics* did not become popular until the 1960s. The roots of the word *kinesiology* give its definition as the study of movement, but in its present-day usage, kinesiology is defined as the study of human movement.

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Concepts in Biomechanics

Researchers concerned with the biomechanics of human movement were active throughout the 20th century, although the mechanics of human and animal motion have intrigued scientists since at least the time of Aristotle (see *De motu animalium* [in Smith and Ross 1912]). In the last decades of the 19th century, Etienne Jules Marey wrote *Le Mouvement* ([1895] 1972), in which he described the use of a variety of devices, including cameras and pressure-sensitive instruments, to measure and record forces and motions produced by man (and animals) in a variety of activities. His well-instrumented "biomechanics" laboratory was the precursor to modern biomechanics and exercise physiology laboratories.

By the 1960s, use of the term *biomechanics* became popular, and more people were involved in sport and exercise biomechanics research. In 1967, the First International Seminar on Biomechanics was held in Zurich, Switzerland. The majority of papers presented at this conference dealt with the mechanics of human movement. This seminar was a success, and international conferences on biomechanics have been held every two years since then. In 1968, the *Journal of Biomechanics* was first published. Several papers in the first volume of this journal dealt with sport biomechanics. During the 1960s, several graduate programs in biomechanics were established within physical education departments, and a few of these programs offered doctoral degrees.

In 1973, the International Society of Biomechanics was formed, followed closely by formation of the American Society of Biomechanics in 1977. Sport and exercise biomechanists were involved in the formation of each of these organizations, although the membership of the societies included scientists with a variety of interests. In the early 1980s, the International Society of Biomechanics in Sport was formed to represent the interests of sport biomechanists. In 1985, the *International Journal of Sports Biomechanics* began publication, and in 1992 it changed its name to the *Journal of Applied Biomechanics.* The most recent journal to exclusively feature sport biomechanics articles is *Sport Biomechanics,* whose first issue appeared in 2002.

Research in sport and exercise biomechanics increased steadily throughout the last few decades of the 20th century and into the 21st century. The number of people involved in sport and exercise biomechanics also increased tremendously during this time. One reason for this boom has been the advent of the modern digital computer, which allows for easier data collection and analysis from the high-speed film or video cameras and electronic force-measuring platforms used in biomechanics research. Without a computer, the time required to compute measurements accurately from film data and do quantitative biomechanical research was grossly excessive, accounting for the dearth of research in sport and exercise biomechanics before the 1960s. Anatomical research was not as difficult to complete, and thus courses in kinesiology were weighted toward applied anatomy. With the increase in sport and exercise biomechanics research in the last three decades, the content of many kinesiology courses has been reexamined, and mechanics is covered more thoroughly now. Many kinesiology courses have been renamed as biomechanics courses.

The organisation of Mechanics

- ❑ Knowledge of Mechanics is necessary
- ❑ Mechanics as the analysis of forces and their effects
- ❑ Mechanics is the science concerned with the effects of forces acting on objects. The objects concerned with in sport and exercise biomechanics

are humans and implements they may be manipulating in sport and exercise

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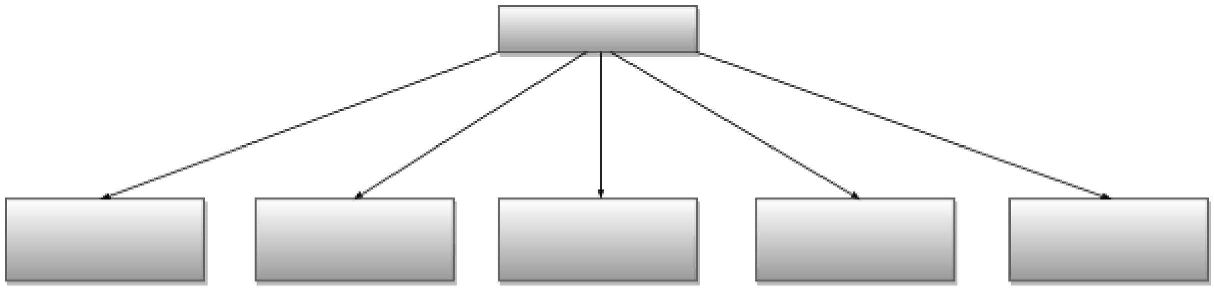
Concepts in Biomechanics



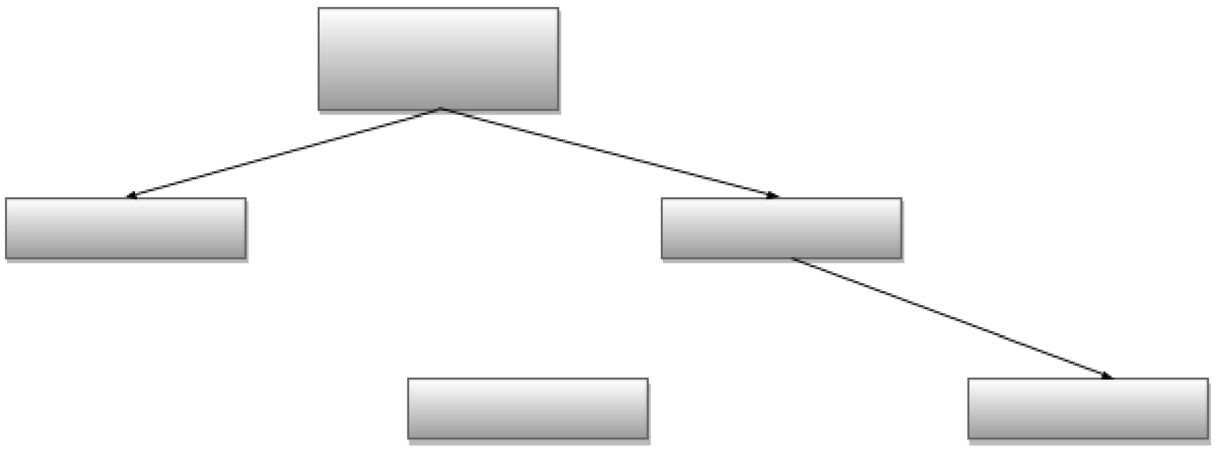
Rigid Body Mechanics – Objects are assumed to be perfectly rigid

Deformable Body Mechanics - Body mechanics, the deformation of objects is considered

Fluid Mechanics - Fluid Mechanics is concerned with the mechanics of liquids and gases

Relativistic Mechanics – Relativistic mechanics is concerned with Einstein's theory of relativity

Quantum Mechanics - Quantum mechanics is concerned with quantum theory



In rigid-body mechanics, the objects being investigated are assumed to be perfectly rigid; that is, they do not deform by bending, stretching, or compressing. In describing and explaining the gross movements of the human body and any implements in sport and exercise, we will consider the segments of the human body as rigid bodies that are linked together at joints. In reality, the segments of the body do deform under the actions of forces. These deformations are usually small and don't appreciably affect the gross movements of the limbs or the body itself, so we can get away with considering the body as a system of linked rigid bodies.

Statics - Branch of mechanics dealing with systems in a constant state of motion

Dynamics - Branch of mechanics dealing with systems subject to acceleration

Kinematics - Study of the description of motion, including considerations of space and time

Kinetics - study of the action of forces

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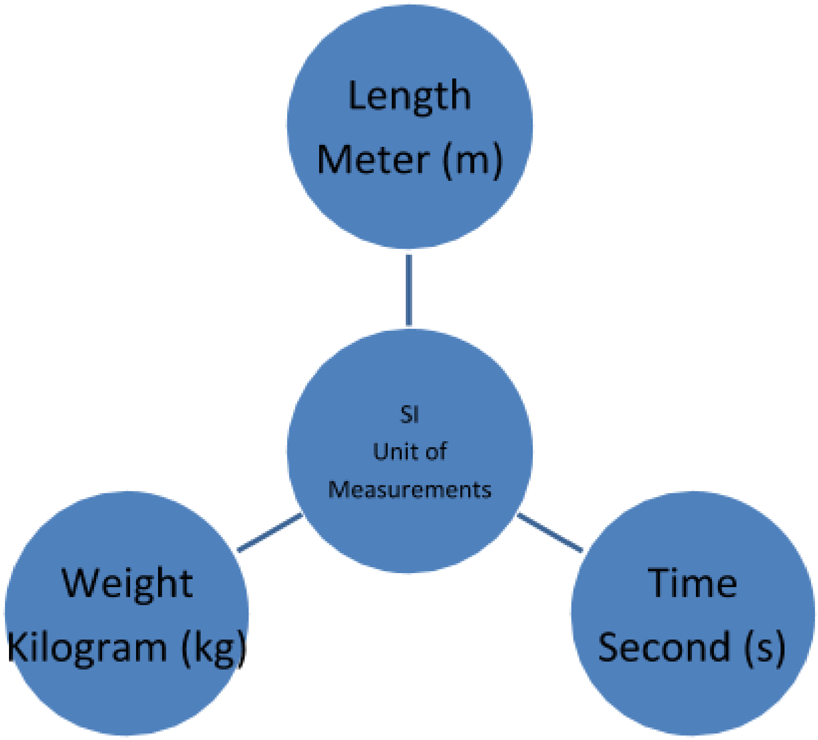
Concepts in Biomechanics

Units of measurements used in Mechanics

The fundamental dimensions used in mechanics are length, time, and mass. The SI units of measurement for these dimensions are the meter (m) for length, the second (s) for time, and the kilogram (kg) for mass. All the other dimensions we will be using in biomechanics are derived from these three fundamental units.



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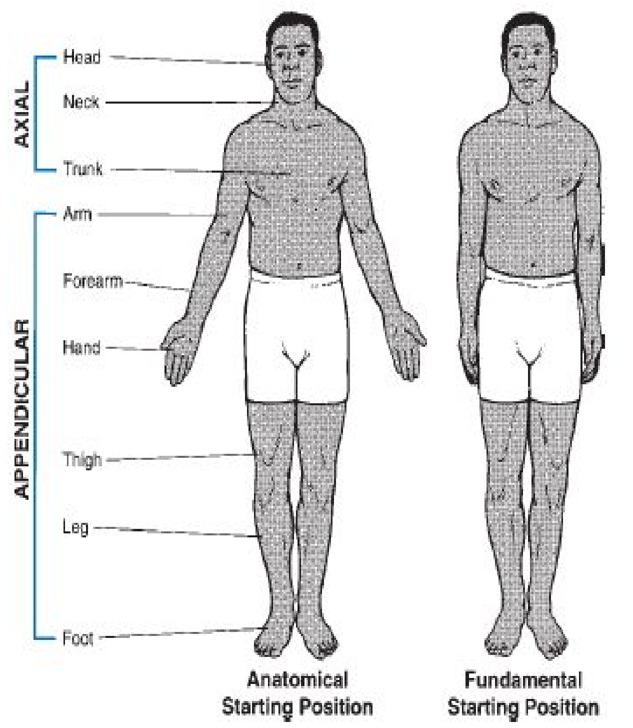
Concepts in Biomechanics

Anatomical Position

- The head, neck, and trunk are segments comprising the main part of the body, or the **axial** portion of the skeleton.
- The upper and lower extremities are termed the **appendicular** portion of the skeleton.
- The **anatomical position**, has been a standard reference point used for manyyears by anatomists, biomechanists, and the medical profession.In this position, the body is in an erect stance with the head facing forward, arms at the side of the trunk with palms facing forward, and the legs together with the feet pointing forward. Some biomechanists prefer to use what is called the **fundamental position** as the reference position.
- A **relative angle** is the included angle between the two segments



Superior: Closer to the head

Inferior: Farther away from the head

Anterior: Toward the front of the body

Posterior: Toward the back of the body

Medial: Toward the midline of the body

Lateral: Away from the midline of the body

Proximal: Closer in proximity to the trunk

Distal: At a distance from the trunk

Superficial: Toward the surface of the body

Deep: Inside the body and away from the body surface

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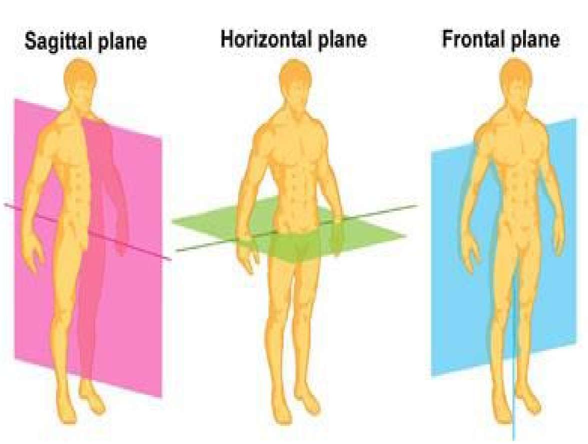
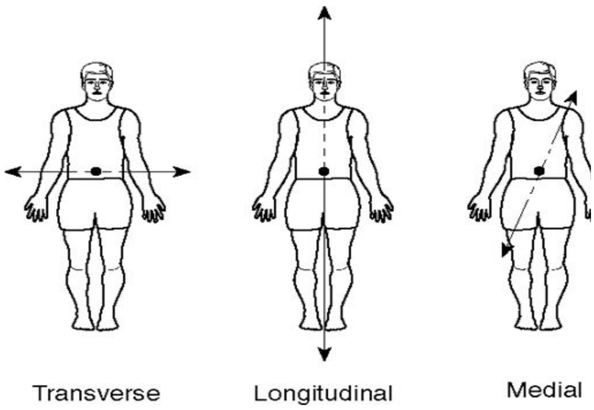
Planes & Axes

- To help understand movements, scientists use specific terms to describe the way the body moves. Human movement takes motion in a plane and about an axis
- Human movement takes motion in a plane and about an axis
-





- The motion is the change in position of an object with respect to its surroundings in a given interval of time.
- Because axes extend indefinitely, so does the plane.
- Any movement that takes place in that space is called planar motion.

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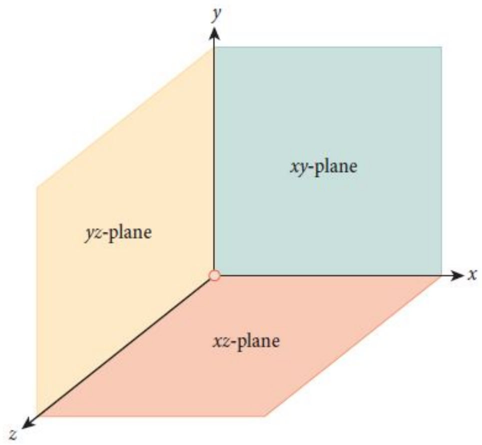

We live in a 3-D world. Because each axis represents a dimension and two perpendicular axes represent a plane, you can create three planes. If you have an *x-, y-, and z-axis, you can create xy-, xz-, and yz-planes*

- The *z-axis if the rotation is in the xy-plane*
- The *y-axis if the rotation is in the xz-plane*
- The *x-axis if the rotation is in the yz-plane*

Human movements are described in three dimensions based on a series of planes and axis. There are three planes of motion that pass through the human body.

1. The sagittal plane

2. The frontal plane

3. The transverse (horizontal) plane

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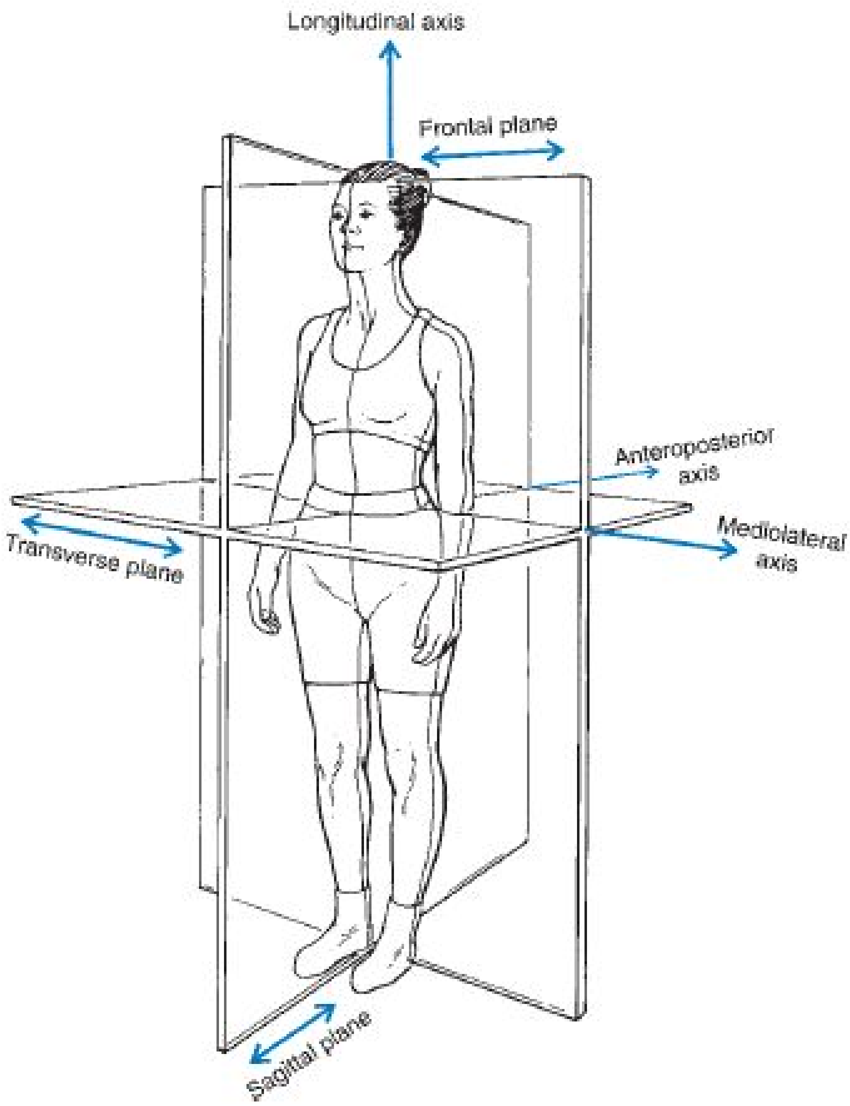

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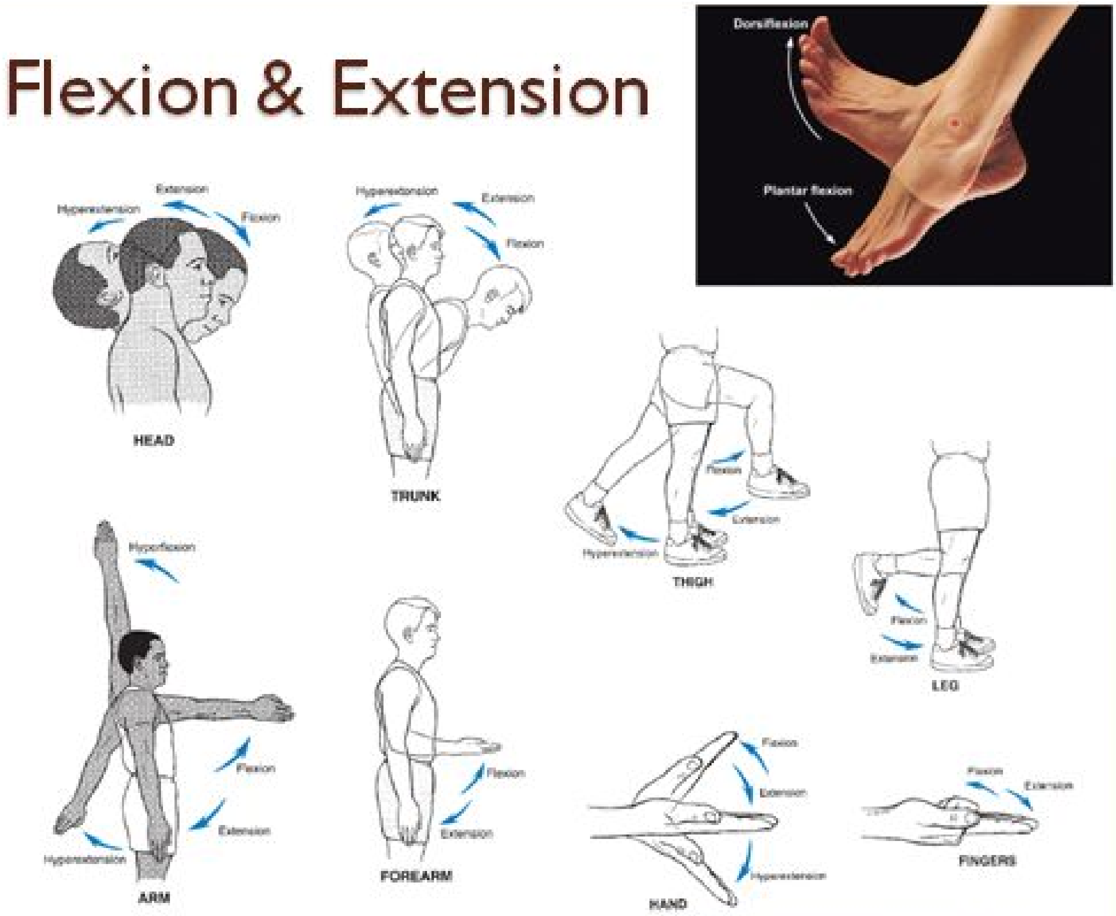
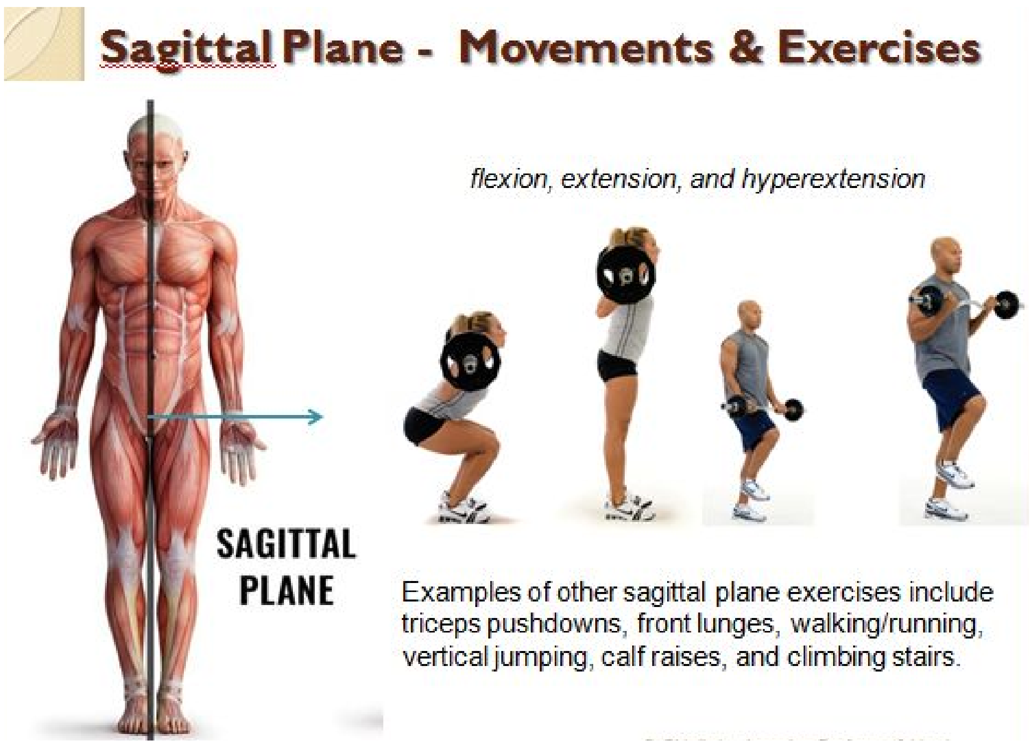

Flexion & Extension
Dorsiflexion
Plantar flexion
HEAD
TRUNK
THIGH
LEG
ARM
FOREARM
HAND
FINGERS


Sagittal Plane - Movements & Exercises
flexion, extension, and hyperextension
SAGITTAL PLANE
Examples of other sagittal plane exercises include triceps pushdowns, front lunges, walking/running, vertical jumping, calf raises, and climbing stairs.

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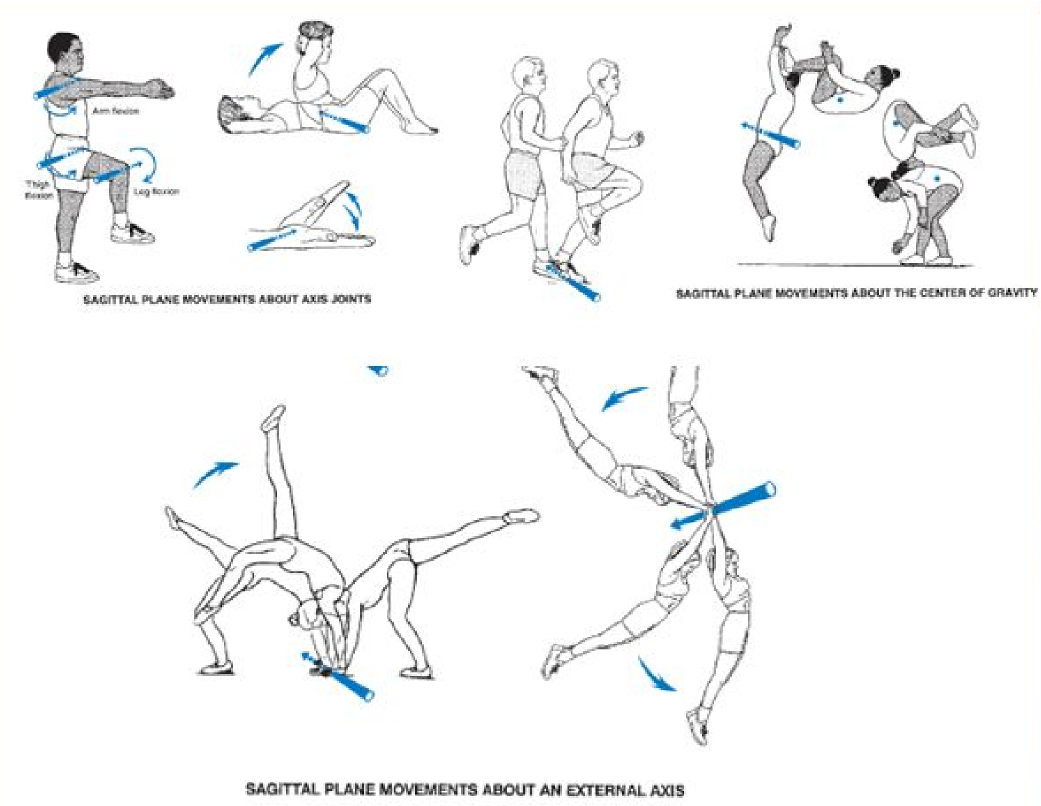


- **Flexion** is a bending movement in which the relative angle of the joint between two adjacent segments decreases.

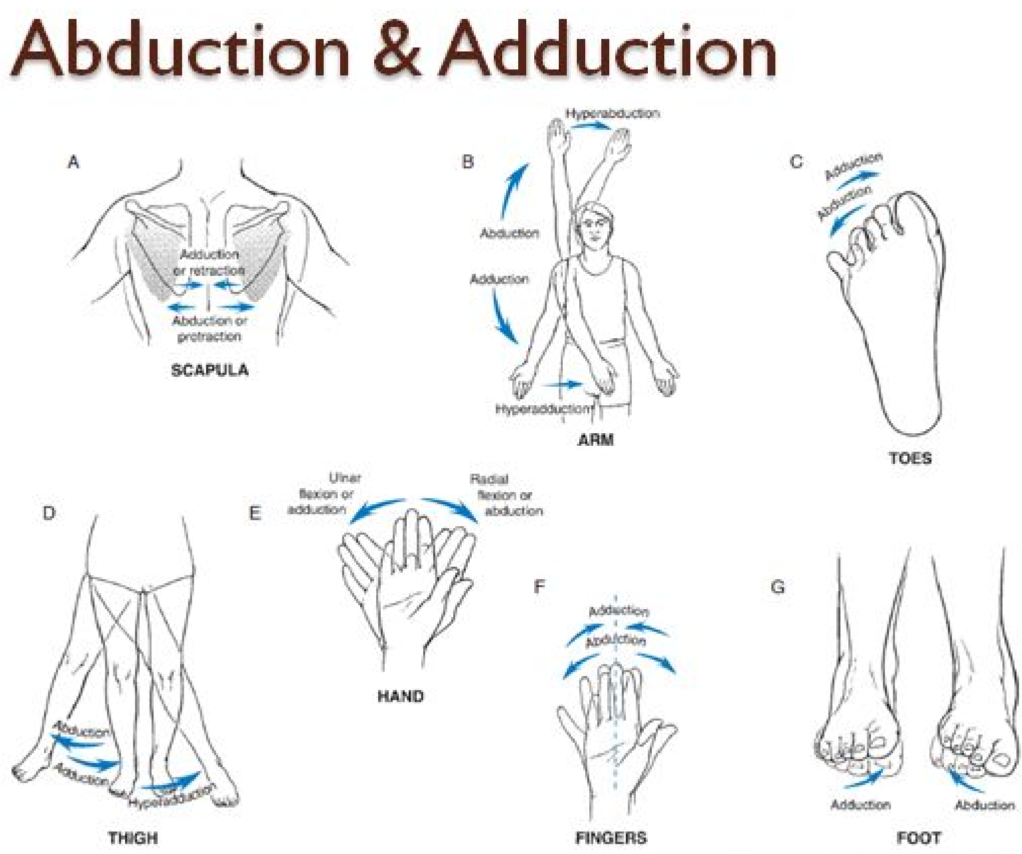
- **Extension** is a straightening movement in which the relative angle of the joint between two adjacent segments increases as the joint returns to the zero or reference position.

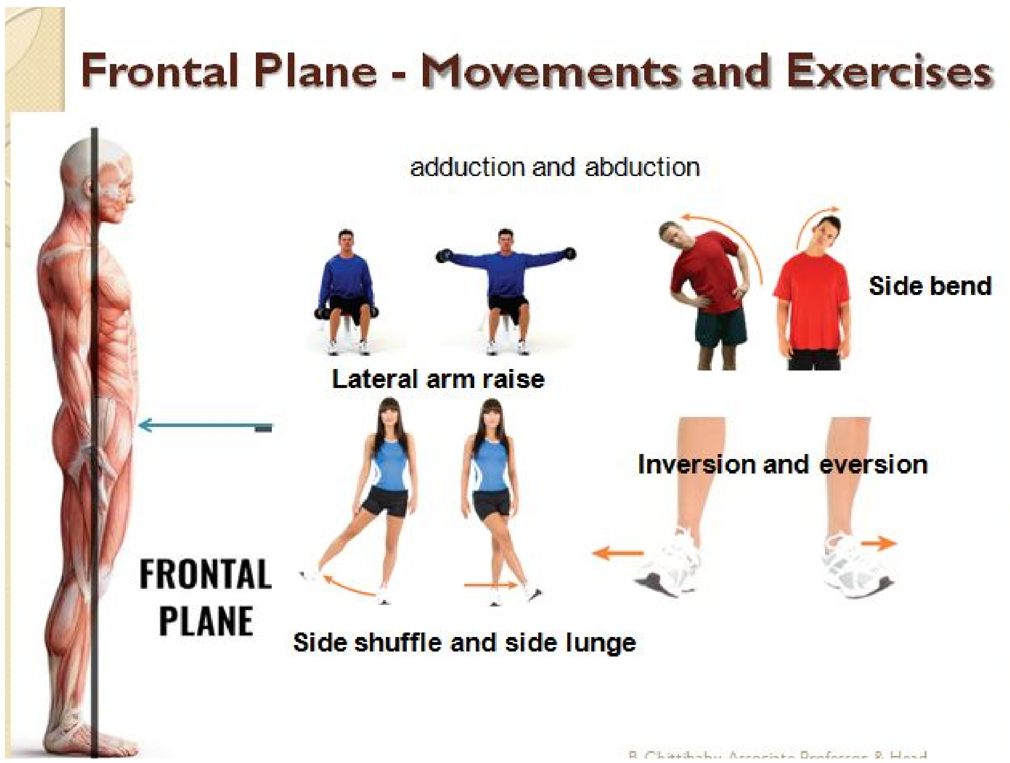
- A person can also perform **hyperflexion** if the flexion movement goes beyond the normal range of flexion.

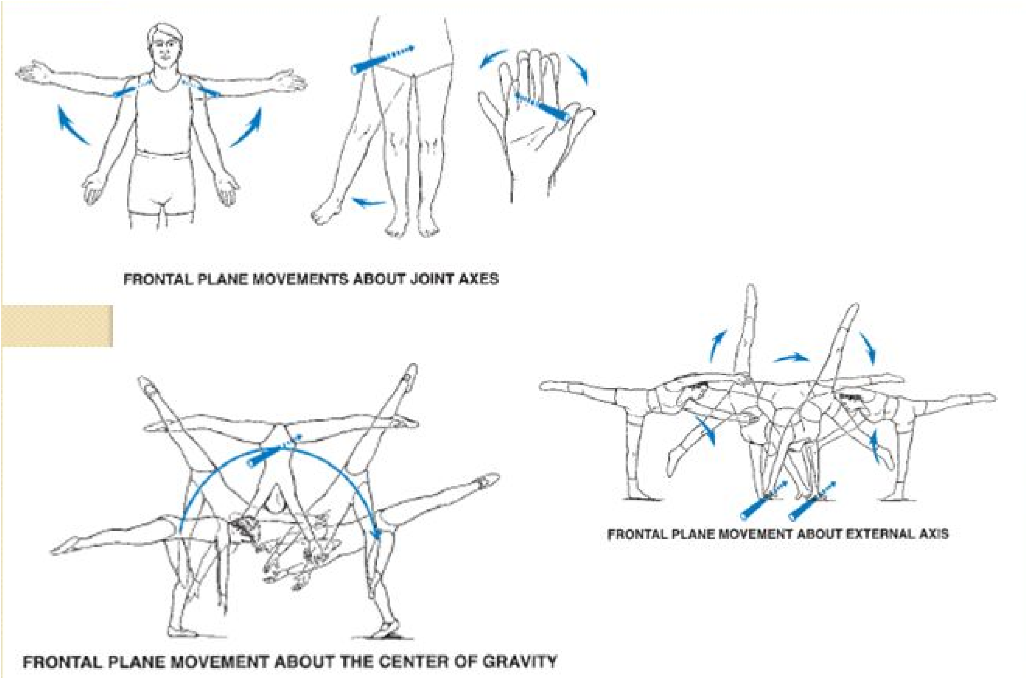
- **Hyperextension** can occur in many joints as the extension movement continues past the original zero position.

- **Plantarflexion** is the movement in which the bottom of the foot moves down and the angle formed between the foot and the leg increases.

- **Dorsiflexion** is the movement of the foot up toward the leg that decreases the relative angle between the leg and the foot.

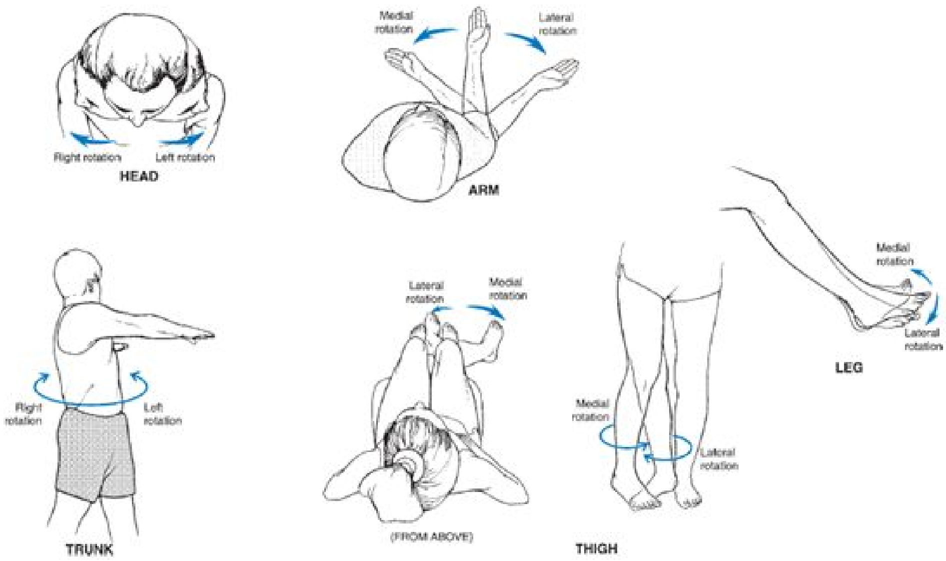

Abduction & Adduction
A
Adduction or retraction
Abduction or protraction
SCAPULA
B
Hyperabduction
Abduction
Adduction
Hyperadduction
ARM
C
Adduction
Abduction
TOES
D
Abduction
Adduction
Hyperadduction
THIGH
E
Ulnar flexion or adduction
Radial flexion or abduction
HAND
F
Adduction
Abduction
FINGERS
G
Adduction
Abduction
FOOT


Frontal Plane - Movements and Exercises
adduction and abduction
Lateral arm raise
Side bend
Inversion and eversion
Side shuffle and side lunge
FRONTAL PLANE

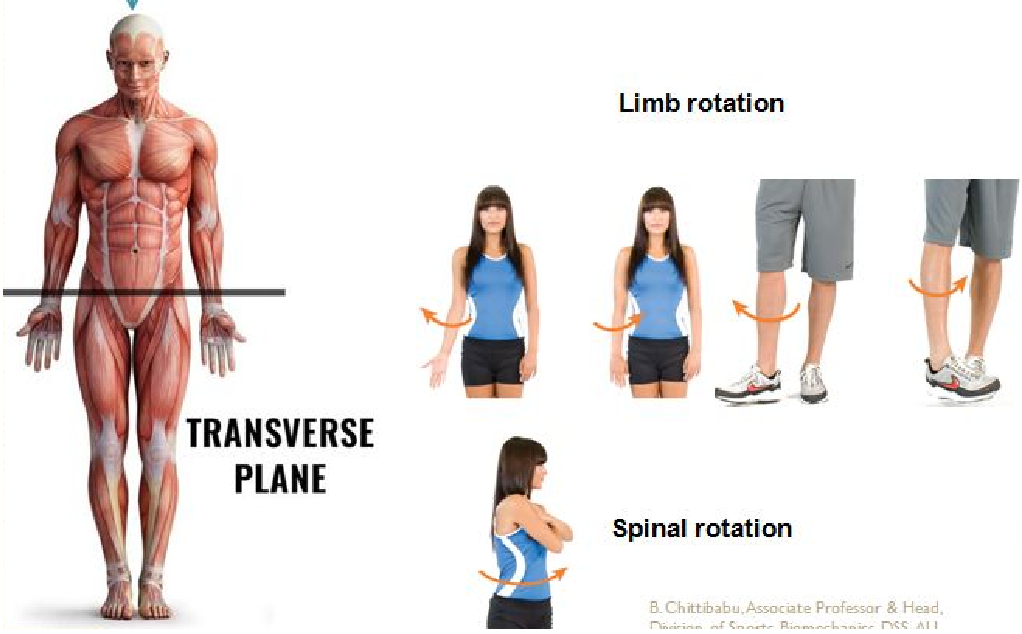


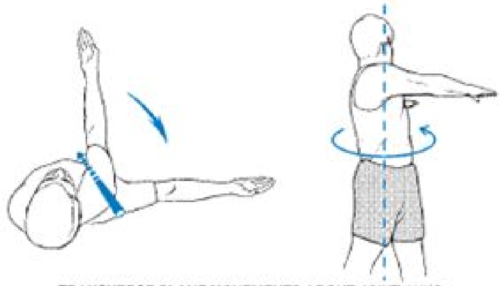
- **Abduction** is a movement away from the midline of the body or the segment
- **Hyperabduction** can occur in the shoulder joint as the arm moves more than 180° from the side all the way up past the head.
- **Adduction** is the return movement of the segment back toward the midline of the body or segment.
- **Hyperadduction** occurs frequently in the arm and thigh as the adduction continues past the zero position so that the limb crosses the body.
- **Inversion** of the foot takes place when the medial border of the foot lifts so that the sole of the foot faces medially toward the other foot.
- **Eversion** is the opposite movement of the foot: The lateral aspect of the foot lifts so that the sole of the foot faces away from the other foot.

Rotations

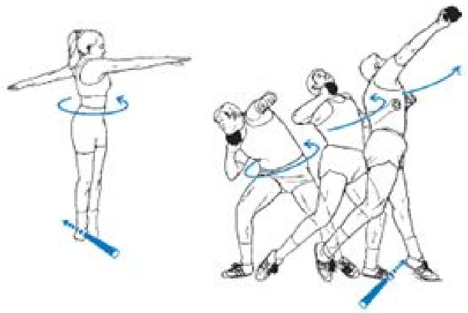


Transverse Plane – Movement & Exercises

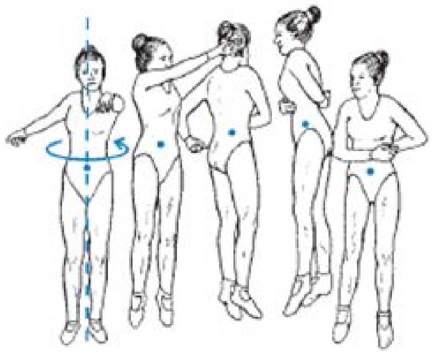




TRANSVERSE PLANE MOVEMENTS ABOUT JOINT AXES



TRANSVERSE PLANE MOVEMENTS ABOUT AN EXTERNAL AXIS



TRANSVERSE PLANE MOVEMENTS ABOUT THE CENTER OF GRAVITY

- A **rotation** can be either medial (also known as internal) or lateral (also known as external). Rotations are designated as right and left for the head and trunk only.

- **Supination** is the movement of the forearm in which the palm rotates to face forward from the fundamental starting position. **Pronation** is the movement in which the palms face backward. Supination and pronation joint movements have also been referred to as *external* and *internal rotation*, respectively.