COURSE GUIDE

KHE 417
BIOMECHANICS

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CONTENTS

Understanding the muscle -skeletal basis of human motion is important. We shall consider the roles played by bones joints and muscles in effecting human movement as well as consider the laws that govern motion, the phenomena of force production, speed and application of skills in sports.

INTRODUCTION

The course, Biomechanics is an important course for students studying Human motion with particular reference to the joints bones, muscles functions and skeletal bases of human motion. In this course, we will study the concepts and principles of biomechanics and human motion and knowledge required for understanding human motion. The overall goals of this course are to introduce you to both the study of the structure, function, and motion of mechanical study of plant systems using mechanics methods at a certain level with whole organisms to organs, cells, and cell organelles.

COURSE COMPETENCIES

This course aims at providing you with relevant historical information in each of Biomechanics components:

i. Analysis of muscle skeletal basis of Human Motion (joints, bones and muscles responsible for movement).
ii. Sports (principles, modes of movement, and locomotion forms) and
iii. Motion Concept (laws of motion, force and application to sports skills)

COURSE OBJECTIVES

On the successful completion of this course you will be able to:

- explain the concept of biomechanics
- describe anatomy of human movement
- state the biomechanics of human muscle skeletal basis
- discuss the kinetic concepts of human bone growth and development
- list some of the muscles responsible for human movement
- explain the principles and types of movement
- discuss the forms of locomotion and levels of
  Laws of motion
  Concept and production of force
  Application of force to specific sports

WORKING THROUGH THIS COURSE

You need to read this course material, each unit with good understanding, as well as to be able to state the objects of biomechanics, muscle skeletal responsible for human movement; joints bones; principles and types of sports; laws of motion; concept of force and application of force to specific sports skills.

Furthermore, you should be able to execute the self-assessment exercises in each of the units very correctly. This course material also provides you with references to relevant texts and links that can enhance your understanding of the units in the modules

STUDY UNITS

This course is divided into four Modules with eight study units.

MODULE 1

Unit 1 Concept of Biomechanics
Unit 2 Anatomy of Human Movement

MODULE 2

Unit 1 Understand the Biomechanics of Human Muscle Skeletal Basis
Unit 2 The Kinetic Concepts of Human Bone Growth and Development

MODULE 3

Unit 1 Principles and Types of Movement
Unit 2 Forms of Locomotion and Levels

MODULE 4

Unit 1 Laws of Motion
Unit 2 Concept and Production of Force

PRESENTATION SCHEDULE

Important dates are included in your course materials for completing and submitting your TMAs on time, as well as attending tutorials. It's important to note that you have to turn in all of your assignments by the deadline. You should stop falling behind on your assignments.

ASSESSMENT

Self-Assessment Tasks and assignments at the end of each study Unit, Tutor-Marked Assignments, and a written review are the three components of this course's assessment. You are required to use the knowledge collected during your course analysis in completing these assignments.

HOW TO GET THE MOST FROM THE COURSE

This course material helps you to read and learn at your own pace, regardless of time or place. You should deal with the content in the following logical order to get the most out of it:

1. Read each Unit step by step as arranged.
2. As you read the material for each Unit, note the key points in each Unit.
3. Refer to the links and texts provided.
4. After reading, attempt the assessment exercise given at each step.
5. You should obey all the rules and guiding instructions.

FACILITATION

Online facilitation would be made available to provide you with the opportunity to interact with your tutor and your colleagues across the world

COURSE INFORMATION

Course Code: KHE 417
Course Title: Biomechanics
Credit Unit: 2
Course Status: Non Elective
Course Blub:
Semester:
Course Duration:
Required Hours for Study

COURSE TEAM

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ICE BREAKER

Dear students, you are welcome to KHE417. This course focuses on the analysis of muscle skeletal basis of human motion with particular reference made to the joints bones and muscles responsible for human movement. Appropriate examples and pictures had been provided to make the content more realistic and connected to real-life situation. Have a wonderful study session.

MAIN COURSE

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MODULE 1

MODULE INTRODUCTION

Biomechanics is a concept that combines the prefix bio, which means "life," with mechanics, which is the analysis of force interactions. In the early 1970s, the word "biomechanics" was coined by the international scientific community to describe the science of studying the mechanical aspects of living organisms. The human body is the most widely studied living organism in the fields of kinesiology and exercise science. Internal forces created by muscles, as well as external forces acting on the body, are both studied. Biomechanics studies the anatomical structures using the methods of mechanics, a branch of physics concerned with the analysis of force behavior.

UNIT 1 CONCEPT OF BIOMECHANICS

CONTENTS

1.0 INTRODUCTION

In general, biomechanics is concerned with the application of classical mechanics to various biological problems. Biomechanics combines the field of engineering mechanics with the fields of biology and physiology. Basically, biomechanics is concerned with the human body. In biomechanics, the principles of mechanics are applied to the conception, design, development, and analysis of equipment and systems in biology and medicine. In essence, biomechanics is a multidisciplinary science concerned with the application of mechanical principles to the human body in motion and at rest.

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- discuss about biomechanics
- demonstrate how to prevent and treat sports injuries.

3.0 MAIN CONTENT

3.1 Concept of Biomechanics

The word biomechanics combines the prefix bio, which means "life," with mechanics, which is the analysis of force interactions. In the early 1970s, the word "biomechanics" was coined by the international scientific community to describe the science of studying the mechanical aspects of living organisms. The human body is the most widely studied living organism in the fields of kinesiology and exercise science. Internal forces created by muscles, as well as external forces acting on the body, are both studied.

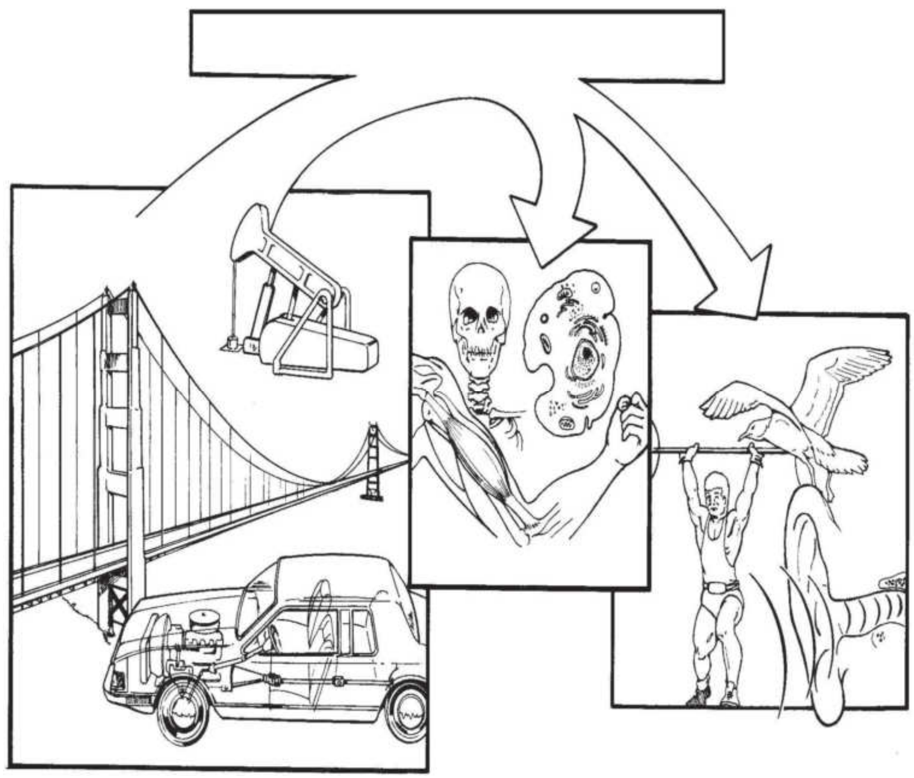

Fig.1.1: Concepts of Biomechanics

Bio mechanists use the methods of mechanics, the branch of physics involving examination of the behavior of forces, to research the anatomical and functional aspects of living organisms (Fig.1), and timing of movement, without reference to the forces that cause or result from the motion. The kinematics of an exercise or a sport skill execution is also known, more commonly, as form or technique. Whereas kinematics describes the appearance of motion, kinetics is the study of the forces associated with motion. Force can be thought of as a push or pull acting on a body. The study of human biomechanics may include questions such as whether the amount of force the muscles are producing is optimal for the intended purpose of the movement.

Although, biomechanics is relatively young as a recognised field of scientific inquiry, biomechanical considerations are of interest in several different scientific disciplines and professional fields.

Biomechanists may have studied zoology, orthopedic, cardiac, or sports medicine, biomedical or biomechanical engineering, physical therapy, or kinesiology, but they all share an interest in the biomechanical aspects of living things' structure and function. One of the sub-disciplines of kinesiology, the science of human movement, is biomechanics of human movement. While some biomechanists study ostrich locomotion, blood flow through constricted arteries, or micro mapping of dental cavities, this book focuses primarily on the biomechanics of human movement as seen through the eyes of the movement analyst. Biomechanics is also a scientific branch of sports medicine. Sports medicine is a broad concept that includes both the clinical and scientific aspects of physical activity and sport. The American College of Sports Medicine is an example of a group that fosters collaboration between scientists and clinicians interested in sports medicine. Importance of Biomechanics are stated below;

3.2 Important of Biomechanics

i. Knowledge of biomechanics helps to realise and understand the underlying principle of the efficient structure of the competitive sports performance.
ii. Knowledge of biomechanics helps in the improvement of motor qualities.
iii. Knowledge of biomechanics helps an athlete to conduct self-evaluation.
iv. Knowledge of biomechanics helps in formulation and understanding new rules and regulation of the sports, games and facilities, etc.
v. Knowledge of biomechanics helps in development and acceptance of new technique and skills.
vi. Knowledge of biomechanics helps in the selection of athlete/players for specific sports and games.
vii. Knowledge of biomechanics helps in the selection of equipment and facilities.
viii. Knowledge of biomechanics helps in the prevention, protection and rehabilitation from the sports injuries.
ix. It helps to identify the mechanical advantage and disadvantage of the human locomotion.
x. It helps in diagnostic teaching. xi. It helps in diagnostic coaching.
xi. xii. It helps in correcting postural deformities.

In-Text Questions

1. Define the term biomechanics.

3.3 Basic Concepts

Engineering mechanics is based on Newtonian mechanics, in which length, time, and mass are the fundamental concepts. They are absolute terms in the sense that they are self-contained. Length is a term used to quantitatively describe distance. Time is a term that is used to organise the flow of events. The quantitative measure of inertia is mass, which is a property of all matter. Inertia is the resistance of matter to alter its motion. The tendency of a body to sustain a state of rest or uniform motion is also known as inertia. Other essential mechanics principles are derived from the basic concepts rather than being absolute. These include force, moment or torque, velocity, acceleration, function, energy, strength, impulse, momentum, tension, and strain. Force can be characterised in several ways, such as mechanical disturbance or load. The motion of one body on another is known as force. It is the force that causes a body to move, deform, or both when it is applied to it. The rotational, bending, or spinning movement of a force applied to a body is measured in moment or torque. The time rate of change of position is known as velocity. Acceleration, on the other hand, is the rate at which velocity increases over time.

3.4 Why Study Biomechanics?

Scientists from many different areas (e.g. Kinesiology, Engineering, Physics, Biology, Zoology) are interested in biomechanics. Why are scholars from so many different academic backgrounds interested in animal movement? Biomechanics is interesting because many people marvel at the ability and beauty in animal movement. Some scholars have purely theoretical or academic interests in discovering the laws and principles that govern animal movement. Within kinesiology, many bio mechanists have been interested in the application of biomechanics to sport and exercise. The applications of biomechanics to human movement can be classified into two main areas: the improvement of performance and the reduction or treatment of injury

3.5 Improving Performance

Human movement performance can be enhanced in many ways. Effective movement involves anatomical factors, neuromuscular skills, physiological capacities, and psychological/cognitive abilities. Most kinesiology professionals prescribe technique changes and give instructions that allow a person to improve performance. Biomechanics is most useful in improving performance in sports or activities where technique is the dominant factor rather than physical structure or physiological capacity. Since biomechanics is essentially the body arch are performed poorly. The coach's experience tells him that his athletes is strong enough to perform this skill, but they must decide if the gymnast should concentrate on her takeoff angle or more back hyperextension in the block. The coach uses his knowledge of biomechanics to help in the qualitative analysis of this situation. Since the coach knows that a better arch affects the force the gymnast create sagainst the mat and affects the angle of take-off of the gymnast, he decides to help the gymnast work on her “arch” following the round off. Biomechanics research on sports techniques sometimes tends to lag behind the changes that are naturally occurring in sports. Athletes and coaches experiment with new techniques all the time. Students of biomechanics may be surprised to find that there is often limited biomechanical science of movement technique, biomechanics is the main contributor to one of the most important skills of kinesiology professionals: the qualitative analysis of human movement (Knudson & Morrison, 2002). Imagine a coach is working with a gymnast who is having problems with her back handspring.

The coach observes several attempts and judges that the angle of takeoff from the round off and studies on many techniques in many popular sports. The vast number of techniques, their variations, and their high rates of change and innovation tend to outdistance biomechanics research resources. Sport bio-mechanics research also lags behind the coaches and athletes because scientific re-search takes considerable time to conduct and report, and there is a lack of funding for this important research. There is less funding for biomechanical studies aimed at improving performance compared to studies focused on preventing and treating in-juries. Students looking for biomechanical research on improving sports technique of-ten will have fewer sources than students researching the biomechanics of injury. While technique is always relevant inhuman movement, in some activities the psychological, anatomical, or physiological factors are more strongly related to success. Running is a good example of this kind of movement.

3.6 Preventing and Treating Sports Injury

Movement safety, or injury prevention/treatment, is another primary area where biomechanics can be applied. Sports medicine professionals have traditionally studied injury data to try to determine the potential causes of disease or injury (epidemiology). Biomechanical research is powerful ally in the sports medicine quest to prevent and treat injury. Biomechanical studies help prevent injuries by providing information on the mechanical properties of tissues, mechanical loadings during movement, and preventative or rehabilitative therapies. Biomechanical studies pro-vide important data to confirm potential in-jury mechanisms hypothesised by sports medicine physicians and epidemiological studies. The increased participation of girls and women in sports has made it clear that females are at a higher risk for anterior cruciate ligament (ACL) injuries than males due to several biomechanical factors (Bo-den, Griffin, & Garrett, 2000). Continued biomechanical and sports medicine studies may help unravel the mystery of this high risk and develop prevention strategies. Engineers and occupational therapists use biomechanics to design work tasks and assistive equipment to prevent overuse in-juries related to specific jobs. Combining biomechanics with other sport sciences has aided in the design of shoes for specific sports (Segesser & Pforringer, 1989), especially running shoes (Frederick, 1986; Nigg,1986). Since the 1980s the design and engineering of most sports shoes has included research in company biomechanics labs. The biomechanical study of auto accidents has resulted in measures of the severity of head injuries, which has been applied in biomechanical testing, and in design of many kinds of helmets to prevent head in-jury (Calvano & Berger, 1979; Norman, 1983; Torg, 1992). When accidents result in amputation, prosthetics or artificial limbscan be designed to match the mechanical properties of the missing limb (KluteKallfelz, & Czerniecki, 2001).

Preventing acute injuries is also another area of biomechanics research. Forensic biomechanics involves reconstructing the likely causes of injury from accident measurements and witness testimony. Biomechanics helps the physical therapist prescribe rehabilitative exercises, assistive devices, or orthotics. Orthotics are support objects/braces that correct deformities or joint positioning, while assistive devices are large tools to help patient function like canes or walkers. Qualitative analysis of gait (walking) also helps the therapist decide whether sufficient muscular strength and control have been regained in order to permit safe or cosmetically nor-mal walking. An athletic trainer might observe the walking pattern for signs of pain and/or limited range of motion in an athlete undergoing long-term conditioning for future return to the field. An athletic coach might use a similar qualitative analysis of the warm-up activities of the same athlete several weeks later to judge their readiness for practice or competition.

3.7 Qualitative and Quantitative Analysis

Biomechanics provides information for a variety of kinesiology professionals to analyse human movement to improve effectiveness or decrease the risk of injury. How the movement is analysed falls on a continuum between a qualitative analysis and a quantitative analysis.

Quantitative analysis involves the measurement of biomechanical variables and usually requires a computer to do the voluminous numerical calculations performed. Even short movements will have thousands of samples of data to be collected, scaled, and numerically processed. In contrast, qualitative analysis has been defined as the "systematic observation and introspective judgment of the quality of human movement for the purpose of providing the most appropriate intervention to improve performance" according to Knudson & Morrison, (2002), .Analysis in both quantitative and qualitative contexts means identification of the factors that affect human movement Performance, which is then interpreted using other higher levels of thinking (synthesis, evaluation) in applying the information to the movement of interest. Solving problems in human movement involves high levels of critical thinking and an interdisciplinary approach, integrating the many kinesiology sciences. The advantages of numerical measurements of quantitative over those of qualitative analysis are greater accuracy, consistency, and precision. Most quantitative biomechanical analysis is performed in re-search settings; however, more and more devices are commercially available that in-expensively measure some biomechanical variables (e.g., radar, timing lights, timing mats, quantitative videography systems).Unfortunately, the greater accuracy of quantitative measures comes at the cost of technical skills, calibration, computation a and processing time, as well as dangers of increasing errors with the additional computations involved. Even with very fast modern computers, quantitative biomechanics is a labor-intensive task requiring considerable graduate training and experience. For these reasons and others, qualitative analysis of human movement remains the main approach kinesiology professionals use in solving most human movement problems. Whether your future jobs use qualitative or quantitative biomechanical analysis, you will need to be able to access biomechanical knowledge.

SELF-ASSESSMENT EXERCISE

Attempt the following question: -

i. What is biomechanics and how is it different from the two common meanings of kinesiology?

4.0 CONCLUSION

- Biomechanics is a multidisciplinary science concerned with the application of mechanical principles to the human body in motion and at rest.
- Biomechanics is concerned with the application of classical mechanics to various biological problems.

- Biomechanics combines the field of engineering mechanics with the fields of biology and physiology.
- Qualitative analysis of human movement remains the main approach kinesiology professionals use in solving most human movement problems.
- Quantitative biomechanical analysis is performed in research settings.
- Quantitative biomechanics is a labor-intensive task requiring considerable graduate training and experience.
- Biomechanics helps the physical therapist prescribe rehabilitative exercises assistive devices, orhotics.

5.0 SUMMARY

Biomechanics is a joint word that combines the prefix bio, which means life, while mechanics is the analysis of force interactions. The word biomechanics was formed by the international scientific community to describe the science of studying the mechanical aspects of living organisms. Biomechanics studies the anatomical structures using the methods of mechanics, a branch of physics concerned with the analysis of force behavior. Important of Biomechanics was explained into details such as the knowledge of biomechanics helps in the improvement of motor qualities, help an athlete to conduct self-evaluation, helps in the selection of equipment and facilities and also in correcting postural deformities etc.

Again, movement safety or injury prevention and treatment is another primary area which is dealt with appropriately because of its important in the study of kinesiology, Sports medicine professionals have traditionally studied injury data to try to determine the potential causes of diseases or injury.

Biomechanics studies help prevent injuries by providing information on the mechanical properties of tissues, mechanical loadings during movement, and preventative or rehabilitative therapies.

Qualitative and Quantitative analysis in the area of biomechanics provide information for a variety of kinesiology professionals to analyse human movement to improve effectiveness or decrease the risk of injury. The human movement is analyses falls on a continuum between a qualitative analysis and a quantitative analysis. Quantitative analysis involves the measurement of biomechanical variables and usually requires a computer to do the voluminous numerical calculations performed. While qualitative analysis has been defined as the systematic observation and introspective judgments of the quality of human movements for the purpose of providing the most appropriate intervention to improve performance.

6.0 TUTOR-MARKED ASSINMENT

1. What are the advantages and disadvantages of a qualitative biomechanical analysis?
2. What are the advantages and disadvantages of a quantitative biomechanical analysis?

7.0 REFERENCES/FURTHER READING

Duane V. Knudson, Craig Morrison (2002). *Qualitative Analysis of Human Movement.*:Human Kinetics Publisher.

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UNIT 2 ANATOMY OF HUMAN MOVEMENT

CONTENTS

1.0 INTRODUCTION

In this section, we will look at how we can define human movements, something to which we will return in more detail. Movements at the joints of the human musculoskeletal system are mainly rotational and take place about a line perpendicular to the plane in which they occur. This line is known as an axis of rotation. Three axes – the sagittal, frontal and vertical (longitudinal) – can be defined by the intersection of pairs of the planes of movement.

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- explain movement patterns in sport
- discuss fundamentals of joint movements anatomically
- explain the differences and the similarities between qualitative and quantitative
- describe the take-off board and its use.

3.0 MAIN CONTENT

A movement (M)is typically caused by a force(F) acting at a distance (r) from the center of rotation of a segment. A moment tends to cause a rotation and is defined by the cross-product function: Mr. F. Therefore, a moment is represented by a vector that passes through the point of interest (e.g., the center of rotation) and is perpendicular to both the force and distance vectors. For a two-dimensional analysis, both the force and distance vectors are in the plane of the paper, so the moment vector is always directed perpendicular to the page, with a line of action through the point of interest. Since it has only this one orientation and line of action, a moment is often treated as a scalar quantity in a two-dimensional analysis, with only magnitude and direction. Torque is another term that is synonymous with a scalar moment. From the definition of a cross product, the magnitude of a moment (or torque) is calculated as Mr. Fs in (). Its direction is referred to as the direction in which it would tend to cause an object to rotate. Although there are several different distances that can be used to connect a vector and a point.

In order to understand the origins of human movement, it is essential to under-stand anatomy. Anatomy is the study of the structure of the human body. Anatomy pro-vides essential labels for musculoskeletal structures and joint motions relevant to human movement. Knowledge of anatomy al-so provides a common "language" of the human body and motions for kinesiology and medical professionals. Anatomy is unimportant prerequisite for kinesiology professionals trying to improve movement, prevent or treat injury. Anatomy is primarily a descriptive field of study and is not, by itself, enough to explain the function of the musculoskeletal system in movement. Knowledge of anatomy must be combined with biomechanics to accurately determine the musculoskeletal causes or the "how "human movement is created. This chapter reviews key anatomical concepts, show functional anatomy traditionally classifies muscle actions, shows how biomechanics is needed to determine muscle function in movement, and discusses the first two of the nine principles of biomechanics: Range of Motion and Force Motion.

Body Planes It is also necessary to delineate the specific body planes of reference, since they will be used to describe structural position and directions of functional movement and position of reference, or anatomic position, has the body facing forward, the hands at the sides of the body, with the palms facing forward, and the feet pointing straight ahead. The body planes are derived from dimensions in space and are oriented at right angles to one another. The sagittal plane is vertical and extends from front to back, or from anterior to posterior. Its name is derived from the direction of the human sagittal suture in the cranium. The median sagittal plane, also called the midsagittal plane, divides the body into right and left halves. The coronal plane is vertical and extends from side to side. The name is derived from the orientation of the human coronal suture of the cranium. It may also be referred to as the frontal plane, and it divides the body into anterior and posterior components. The transverse plane is a horizontal plane and divides a structure into upper and lower components.

Axes of Movement

An axis is a line around which motion occurs. Axes are related to planes of reference, and the cardinal axes are oriented at right angles to one another. This is expressed as a three-dimensional coordinate system with x, y, and z used to mark the axes. The significance of this coordinate system is in defining or locating the ex-tent of the types of movement possible at each joint rotation, translation, and curvilinear motion. All movements that occur about an axis are considered rotational, whereas linear movements along an axis and through a plane are called translational. Curvilinear motion occurs when a translational movement accompanies rotational movements. The load that produces a rotational movement is called torsion; a force that produces a translational movement is called an axial or shear force.

3.1 Analysing Movement Patterns in Sports

As an undergraduate student in the earlier stages of your career. You will be familiar with human movement patterns from sport – when viewed live, or as a performer, coach or spectator – whether these are movement patterns of individuals or of teams as a whole. Most packages for qualitative video analysis make it easy to observe, and to compare, such movement patterns. Video recordings, still video sequences, and player tracking patterns in games are probably the most complex representations of sports movements that you will come across. It is only your familiarity with sports videos that enables you to understand such patterns – watch a video of a game or sporting activity for which you do not know the rules (environmental and task constraints), and the complexity of video representations of movement patterns becomes obvious. This is true not only for the movements of the segments of the body of one performer, which sports bio mechanists generally focus on, but also for the movement patterns of the players as a team. Sequences of still video frames are rarely used in analysing player movements and interactions in team games, such as rugby, netball and soccer, or in individual vs. individual games, such as squash or table tennis. To understand why, imagine tracking (using the Global Positioning System, for example), just a single point on each player in one extended squash rally or, worse still, for each player in a soccer team for just 10 minutes of play.

ANALYSING MOVEMENT PATTERNS

Movement patterns would not be easy to analyse at first sight. Such movement patterns in games will not be considered further in this book – sports bio mechanists, to date, have rarely been involved in analysing such movement patterns. To appreciate why video recordings are complex, did you find it easy to follow all the flexion and extension descriptions for walking and running in the previous section? Could you easily perceive within-leg and between-leg coordination patterns in walking, or arm and leg coordination patterns in running, using these quenches above or videos from the book's website? If your answers to these questionnaires are sounding 'YES', then you are already a talented qualitative movement analyst! Many of us struggle at times to extract what we want from video or from selected video picture sequences; for one thing they contain so much information that is irrelevant to the patterns the movement analyst wishes to observe Quantitative biomechanical analysts are mainly interested in improving performance and reducing injury risk. They use a mixture of experimental and theoretical approaches to seek answers to such questions as: What is the best running technique to minimise energy expenditure? How should the sequence of body movements be coordinated in a javelin throw to maximise the distance thrown? Why are lumbar spine injuries so common among fast bowlers in cricket?, we can identify two fundamentally different approaches to experimental movement analysis in sport – qualitative analysis and quantitative analysis; the latter requires detailed measurement and evaluation of the measured data. Earlier unit in this book had a strong bias towards qualitative analysis whereas this chapter will focus mostly on quantitative analysis. The quantitative experimental approach often takes one of two forms, usually referred to as the cross-sectional and longitudinal approaches. A cross-sectional study, for example, might evaluate a sports movement by comparing the techniques of different sports performers recorded at a particular competition. This can lead to a better overall understanding of the biomechanics of the skill studied and can help diagnose faults in technique. An alternative cross-sectional approach, which is less frequently used, is to compare several trials of the same individual, for example a series of high jumps by one athlete in a competition or in a training session. This is done to identify the performance variables that correlate with success for that athlete. In a longitudinal study, the same person, or group, is analysed over a longer time to improve their performance; this probably involves providing feedback and modifying their movement patterns. Both the cross-sectional and the longitudinal approaches are relevant to the sports bio mechanist, although conclusions drawn from a cross-sectional study of several athletes cannot be generalised to a single athlete, or vice versa.

Movement analysts now use single-individual designs far more than in the past, recognising that group designs often obscure differences between individuals in the group and, indeed, the group mean may not apply to any single individual. After all, most athletes are mainly interested in factors that affect their performance or might be an injury risk for them. In a case study, a single person may be analysed on one or just a few occasions; this approach is often used when assessing an injured athlete. A single-individual design usually involves studying that person across time; multiple single-individual designs study individual members of a group of performers across time. This also gives the analyst a chance to use a group design simultaneously with the multiple single-individual study. In such studies, it has been recommended that, for reasonable statistical power, 20 trials per person should be analysed for a group of five performers; for a group of 10 performers, 10 trials each; for a group of 20, five trials each.

To give it a theoretical underpinning, an experimental study should be used in conjunction with a theoretical approach, such as the use of deterministic models or **Videography**

The main method currently used for recording and studying sports movements is digital videography. Cinematography – using cine film cameras – is now rarely used, and the same almost applies to the use of 'analog' video cameras; neither will be considered in any detail in this chapter. Motion analysis systems that automatically track skin markers are increasingly used in biomechanics research laboratories; these systems are many times more expensive than video analysis systems, are technically far more complicated, require far more expert operators and currently cannot be used outdoors during daylight hours. For these reasons, which usually mean that students in the earlier years of their study will not encounter such motion analysis systems, they are not dealt with in this book (interested readers should consult Milner (2007); A great strength of videography is that it enables the investigator to record sports movements not only in a controlled laboratory setting, but also in competition. It also minimises any possible interference with the performer. Indeed, performers can be 'videoed' without their knowledge, although this does raise ethical issues that will normally be addressed by your Institutional Research Ethics Committee. Quantitative analysis will often involve the bio mechanist having to digitise a lot of data. This process of 'coordinate digitisation' involves the identification of body landmarks used to aid the estimation of joint axes of rotation. In videography, particularly in three-dimensional studies, this will normally be done by the investigator manually digitising the required points using a computer mouse or similar device. Some video analysis systems can track markers in two dimensions, saving the investigator much time. Automatic marker-tracking systems, as their name implies, track markers automatically, and in three dimensions, although operator intervention may still be needed if too few cameras can see the marker during some part of the movement. Whichever way coordinate digitising is performed, the linear coordinates of each digitised point are recorded and stored in computer memory.

What Quantitative Analysts Measure

After digitising a movement sequence, linear and angular positions and displacements can be calculated and presented as a function of time – a time series. Some additional data processing will normally be performed to obtain displacements of the centre of mass of the performer's whole body Velocities and accelerations will also probably be obtained from the displacement data. As well as these time-series movement patterns, coordination diagrams such as angle–angle diagrams or phase planes can also be obtained; quantitative analysts often want to quantify such graphs, in contrast to the qualitative analyst, whose focus will be on their shape (topography). Quantitative analysts may also identify values of some variables at important instants in the movement to allow inter- or intra-performer comparisons.

These values, often called performance parameters or variables, are usually defined at the key events that separate the phases of sports movements, such as foot strike in running, release of a discus or bar release in gymnastics. They are discrete measures that, although they can be very important for that performer, discard the richness of movement information contained in time-series graphs or coordination diagrams. Computer visualisation of the movement will also be possible. These are quick and easy to produce but have ambiguities with respect to whether limbs are in front of or behind the body. In three-dimensional analysis, this can be partially overcome by filling in the body and using hidden line removal. Full solid-body modelling is even more effective in this respect, but computationally somewhat time-consuming. Solid-body models can also be made more realistic through the use of shading and surface rendering.

Quantitative Analysis

- What do we use for this?
- Image-based motion analysis, mostly using video or automatic marker-tracking systems plus, when occasion demands, electromyography and force or pressure plates or insoles
- Statistical modeling of technique or of movement patterns in games, artificial intelligence, computer simulation modeling.

Quantitative Movement Analysis and Notational Analysis Software Packages

- This is mainly used by researchers:
-

- To aid performance comparisons.
- To predict injury risk.
- To provide quantitative feedback.

Qualitative vs Quantitative Analysis

- Qualitative analysis describes and analyses movements non-numerically, by seeing movements as 'patterns', while quantitative analysis describes and analyses movement numerically.
- Quantitative analysis can sometimes appear more objective because of its 'data'; however, the accuracy and reliability of such data can be very suspect, particularly when obtained in competition.
- Qualitative analysis is often more strongly rooted in a structured and multi-disciplinary approach, whereas quantitative analysis can appear to lack a theoretical grounding and to be data-driven. Background to qualitative analysis to be objective and scientific, qualitative analysis needs to use a structured approach, moving from preparation, through observation, diagnosis–evaluation, to intervention(and review)

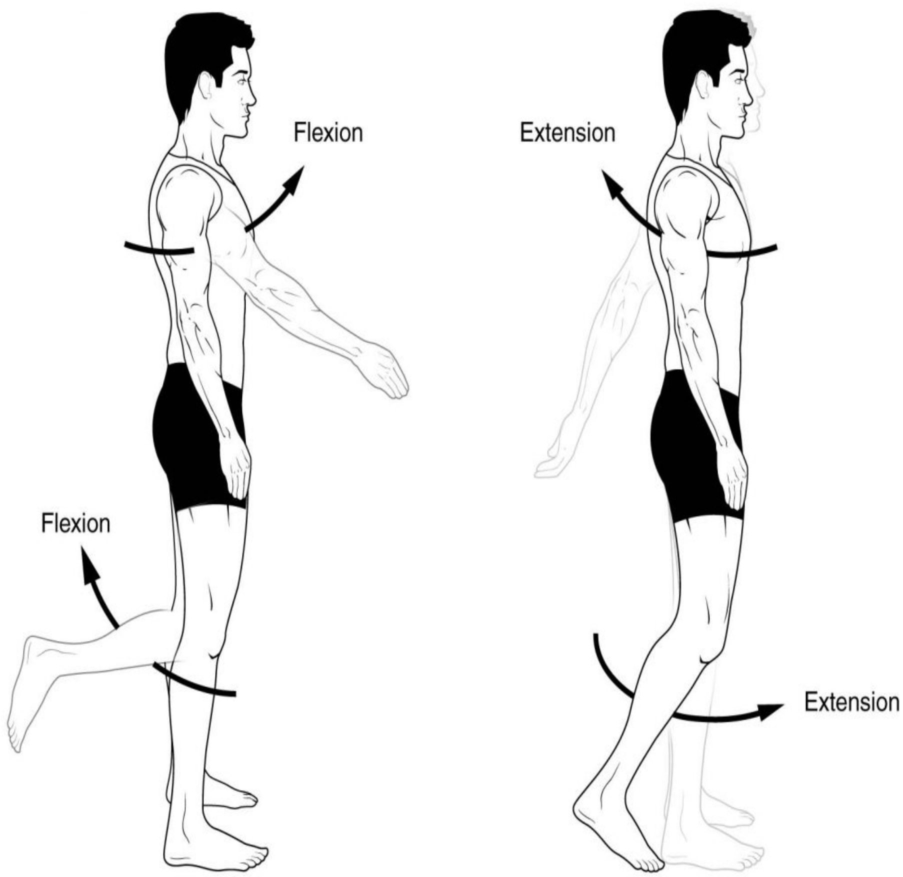
From the outset, the movement analyst should involve the coach, or whoever commissioned the analysis, ina 'needs analysis' and should keep the coach in the loop at all stages. Qualitative analysis requires applying basic biomechanical principles to the movement. We need to know what to observe; coaches have important knowledge and contributions to make here too. Qualitative analysts need an excellent grasp of the techniques – or movement inter-actions – in a specific sport or exercise; coaches have great depth and breadth of that knowledge. Deterministic models can give a theoretical basis to the analysis, which can otherwise become discursive. This modelling approach can be represented graphically so as to be coach-friendly. Good-quality digital video cameras are needed, with adequate frame rates and shutter speeds. This equipment is familiar to coaches and extra equipment is rarely necessary. Qualitative analysis should uncover the major faults in an unsuccessful performance by an individual or a team; it is the approach actually used by most coaches and teacher.

3.2 Fundamentals of Joint Movements Anatomically

Anatomical terms of movement are used to describe the actions of muscles upon the skeleton. Muscles contract to produce movement at joints, and the subsequent movements can be precisely described using this terminology. The terms used assume that the body begins in the **anatomical position**. Most movements have an opposite movement – also known as an antagonistic movement.

Flexion and Extension

Flexion and extension are movements that occur in the sagittal plane. They refer to increasing and decreasing the angle between two body parts: Flexion refers to a movement that decreases the angle between two body parts. Flexion at the elbow is decreasing the angle between the ulna and the humerus. When the knee flexes, the ankle moves closer to the buttock, and the angle between the femur and tibia gets smaller. Extension refers to a movement that increases the angle between two body parts. Extension at the elbow is increasing the angle between the ulna and the humerus. Extension of the knee straightens the lower limb.



Abduction and Adduction

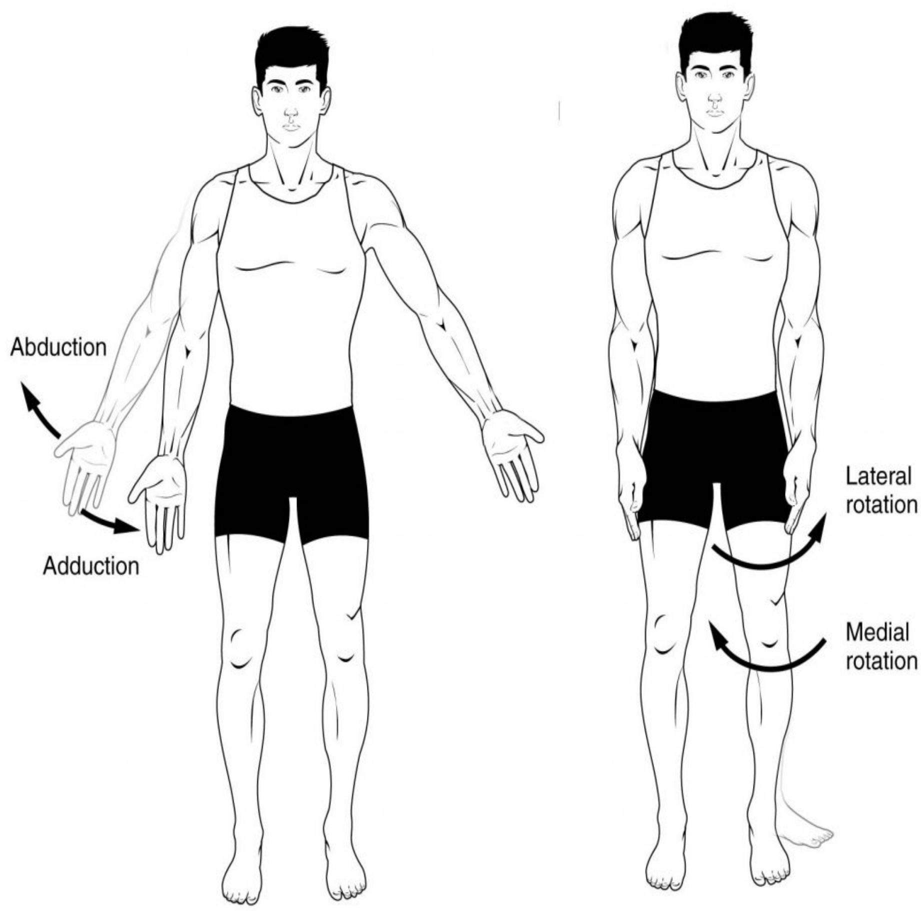
Abduction and adduction are two terms that are used to describe movements towards or away from the midline of the body. **Abduction** is a movement away from the midline – just as abducting someone is to take them away. For example, abduction of the shoulder raises the arms out to the sides of the body. **Adduction** on the other hand is a movement towards the midline. Adduction of the hip squeezes the legs together. In fingers and toes, the midline used is not the midline of the body, but of the hand and foot respectively. Therefore, abducting the fingers spreads them out.

Medial and Lateral Rotation

Medial and lateral rotation describe movement of the limbs around their long axis:

Medial rotation is a rotational movement towards the midline. It is sometimes referred to as internal rotation. Imagine these two scenarios, firstly, with a straight leg, rotate it to point the toes inward. This is medial rotation of the hip. Secondly, imagine you are carrying a tea tray in front of you, with elbow at 90 degrees. Now rotate the arm, bringing your hand towards your opposite hip (elbow still at 90 degrees). This is internal rotation of the shoulder.

Lateral rotation is a rotating movement away from the midline. This is in the opposite direction to the movements described above.



Elevation and Depression

Elevation refers to movement in a superior direction (e.g. shoulder shrug), **depression** refers to movement in an inferior direction.

Pronation and Supination

This is easily confused with medial and lateral rotation, but the difference is subtle. With your hand resting on a table in front of you, and keeping your shoulder and elbow still, turn your hand onto its back, palm up. This is the supine position, and so this movement is **supination**.

Again, keeping the elbow and shoulder still, flip your hand onto its front, palm down. This is the prone position, and so this movement is named **pronation**.

These terms also apply to the whole body – when lying flat on the back, the body is supine. When lying flat on the front, the body is prone.

Dorsiflexion and Plantarflexion

Dorsiflexion and plantarflexion are terms used to describe movements at the ankle. They refer to the two surfaces of the foot; the dorsum (superior surface) and the plantar surface (the sole).

Dorsiflexion refers to flexion at the ankle, so that the foot points more superiorly. The dorsum of the hand is the posterior surface, and so movement in that direction is **extension**. Therefore, we can say that dorsiflexion of the wrist is the same as extension.

Plantarflexion refers extension at the ankle, so that the foot points inferiorly. Similarly, there is a term for the hand, which is palmar flexion.

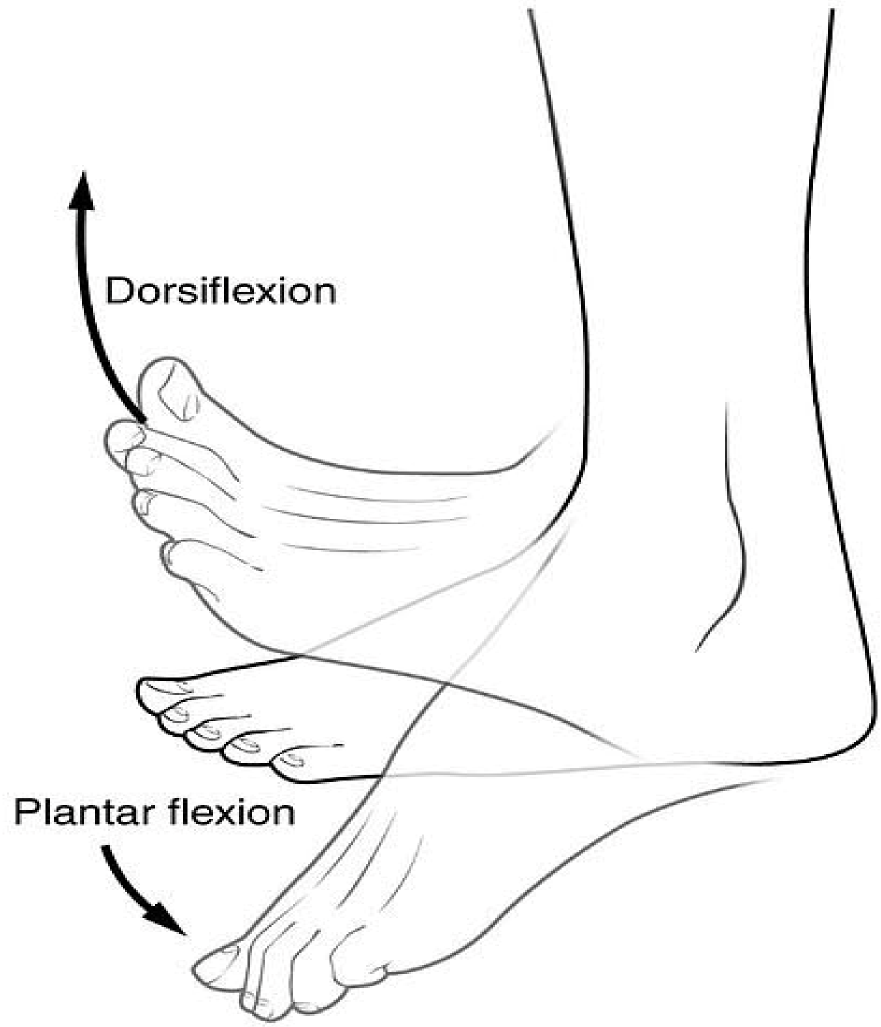


Fig. 1.2: Flection and Extension

Inversion and Eversion

Inversion and **eversion** are movements which occur at the ankle joint, referring to the rotation of the foot around its long axis.

Inversion involves the movement of the sole towards the median plane – so that the sole faces in a medial direction.

Eversion involves the movement of the sole away from the median plane – so that the sole faces in a lateral direction.

Opposition and Reposition

A pair of movements that are limited to humans and some species of apes, these terms apply to the additional movements that the hand and thumb can perform in these species.

Opposition brings the thumb and little finger together.
Reposition is a movement that moves the thumb and the little finger away from each other, effectively reversing opposition.

Circumduction
Circumduction can be defined as a conical movement of a limb extending from the joint at which the movement is controlled.It is sometimes talked about as a circular motion, but is more accurately conical due to the ‘cone’ formed by the moving limb.

Protraction and Retraction

Protraction describes the anterolateral movement of the scapula on the thoracic wall that allows the shoulder to move anteriorly. In practice, this is the movement of ‘reaching out’ to something.

Retraction refers to the posteromedial movement of the scapula on the thoracic wall, which causes the shoulder region to move posteriorly i.e. picking something up.

https://teachmeanatomy.info/the-basics/anatomical-terminology/terms-of-movement/

3.3 Skeletal Joints

The human body is rigid in the sense that it can maintain a posture, and flexible in the sense that it can change its posture and move. The flexibility of the human body is due primarily to the joints, or articulations, of the skeletal system. The primary function of joints is to provide mobility to the musculoskeletal system. In addition to providing mobility, a joint must also possess a degree of stability. Since different joints have different functions, they possess varying degrees of mobility and stability. Some joints are constructed so as to provide optimum mobility. For example, the construction of the shoulder joint(ball-and-socket) enables the arm to move in all three planes(triaxial motion). However, this high level of mobility is achieved at the expense of reduced stability, increasing the vulnerability of the joint to injuries, such as dislocations.

On the other hand, the elbow joint provides movement primarily in one plane (uniaxial motion), but is more stable and less prone to injuries than the shoulder joint. The extreme case of increased stability is achieved at joints that permit no relative motion between the bones constituting the joint. The contacting surfaces of the bones in the skull are typical examples of such joints. The joints of the human skeletal system may be classified based on their structure and/or function. Synarthrodial joints, such as those in the skull, are formed by two tightly fitting bones and do not allow any relative motion of the bones forming them. Amphiarthrodial joints, such as those between the vertebrae, allow slight relative motions, and feature an intervening substance(a cartilaginous or ligament us tissue) whose presence eliminates direct bone-to-bone contact. The third and mechanically most significant type of articulations are called diarthrodial joints which permit varying degrees of relative motion and have articular cavities, ligamentous capsules, synovial membranes, and synovial fluid. The articular cavity is the space between the articulating bones. The ligamentous capsule holds the articulating bones together. The synovial membrane is the internal lining of the ligamentous capsule enclosing the synovial fluid which serves as a lubricant. The synovial fluid is a viscous material which functions to reduce friction, reduce wear and tear of the articulating surfaces by limiting direct contact between them, and nourish the articular cartilage lining the surfaces. The articular cartilage, on the other hand, is a specialised tissue designed to increase load distribution on the joints and provide a wear-resistant surface that absorbs shock. Variousdiarthrodial joints can be further categorised as gliding (for example, vertebral facets), hinge (elbow and ankle), pivot (proximalradio ulnar), condyloid (wrist), saddle (carpometacarpal of thumb), and ball-and-socket (shoulder and hip).

The nature of motion about a arthrodial joint and the stability of the joint are dependent upon many factors, including the manner in which the articulating surfaces fit together, the properties of the joint capsule, the structure and length of the ligaments around the joint, and the number and orientation of the muscles crossing the joint.

Skeletal Muscles In general, there are over 600 muscles in the human body, accounting for about 45 of the total body weight. There are three types of muscles: cardiac, smooth, and skeletal. Cardiac muscle is the contractive tissue found in the heart that pumps the blood for circulation. Smooth muscle is found in the stomach, intestinal tracts, and the walls of blood vessels. Skeletal muscle is connected to the bones of the body and when contracted, causes body segments to move. Movement of human body segments is achieved as a result of forces generated by skeletal muscles that convert chemical energy into mechanical work. The structural unit of skeletal muscle is the muscle fiber, which is composed of myofibrils. Myofibrils are made up of actin and myosin filaments. Muscles exhibit viscoelastic material behavior. That is, they have both solid and fluid-like material properties. Muscles are elastic in the sense that when a muscle is stretched and released it will resume its original (un-stretched) size and shape. Muscles are viscous in the sense that there is an internal resistance to motion. A skeletal muscle is attached, via soft tissues such as a poneuroses and/or tendons, to at least two different bones controlling the relative motion of one segment with respect to the other. When its fibers contract under the stimulation of a nerve, the muscle exerts a pulling effect on the bones to which it is attached. Contraction is a unique property of the muscle tissue. In engineering mechanics, contraction implies shortening under compressive forces. In muscle mechanics, contraction can occur as a result of muscle shortening or muscle lengthening, or it can occur without any change in the muscle length.

Furthermore, the result of a muscle contraction is always tension: a muscle can only exert a pull. Muscles cannot exert a push. There are various types of muscle contractions: a concentric contraction occurs simultaneously as the length of the muscle decreases (for example, the biceps during flexion of the forearm);a static contraction occurs while muscle length remains constant (the biceps when the forearm is flexed and held without any movement); and an eccentric contraction occurs as the length of the muscle increases (the biceps during the extension of the forearm). A muscle can cause movement only while its length is shortening (concentric contraction). If the length of a muscle increases during a particular activity, then the tension generated by the muscle contraction is aimed at controlling the movement of the body segments associated with that muscle(eccentric contraction). If a muscle contracts but there is no segmental motion, then the tension in the muscle balances the effects of applied forces such as those due to gravity (isometric contraction).The skeletal muscles can also be named according to the functions they serve during a particular activity. For example, a muscle is called agonist if it causes movement through the process of its own contraction. Agonist muscles are the primary muscles responsible for generating a specific movement. An antagonist muscle opposes the action of another muscle. Synergic muscle is that which assists the agonist muscle in performing the same joint motion compression at the elbow, knee, and ankle joints vary with externally applied forces and with different segmental arrangements. How does the force on the femoral head vary with loads carried in the hand? What are the forces involved in various muscle groups and joints during different exercise conditions? The forces involved in the human body can be grouped as internal and external. Internal forces are those associated with muscles, ligaments, and tendons, and at the joints. Externally applied forces include the effect of gravitational acceleration on the body or on its segments, manually and/or mechanically applied forces on the body during exercise and stretching, and forces applied to the body by prostheses and implements. In general, the unknowns in static problems involving the musculoskeletal system are the joint reaction forces and muscle tensions. Mechanical analysis of a joint requires that we know the vector characteristics of tension in the muscle including the proper locations of muscle attachments, the weights or masses of body segments, the centers of gravity of the body segments, and the anatomical axis of rotation of the joint.

THE DIFFERENCES AND THE SIMILARITIES BETWEEN QUALITATIVE AND QUANTITATIVE PROBLEM-SOLVING APPROACH

Scientific research is usually aimed at providing a solution for a particular problem or answering a specific question. Even for the non-researcher, however, the ability to solve problems is a practical necessity for functioning in modern society. The use of specific problems is also an effective approach for illustrating basic biomechanical concepts.

Quantitative versus Qualitative Problems

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. Other examples of qualitative and quantitative descriptors are displayed. It is important to recognise that qualitative does not mean general. Qualitative descriptions may be general, but they may also be extremely detailed. It can be stated qualitatively and generally, for example, that a man is walking down the street. It might also be stated that the same man is walking very slowly, appears to be leaning to the left, and is bearing weight on his right leg for as short a time as possible. The second description is entirely qualitative but provides a more detailed picture of the movement. 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.

Solving Qualitative Problems

Qualitative issues usually occur during everyday activities. Questions such as what clothes to wear, whether to major in botany or English, and whether to research or watch television are all issues in the sense that they are uncertainties that will need resolution. Analysing human movement, whether to detect a gait phenomenon or to fine-tune a technique, is basically a problem-solving process. Is the body movement sequencing appropriate (or optimal) for executing the skill? Why does this elderly woman have a propensity to fall? Why is this shot putter not getting more distance? There are some examples of more basic questions: 1 Is there excessive pronation during the gait cycle's stance phase? 2. Is the ball released as soon as the elbow reaches full extension? 3. Does this person's m is tracking of the patella be alleviated by selective strengthening of the vastus medialis obliquus? The next step in evaluating a human movement is to collect data after one or more questions have been identified. The form of data most commonly collected by teachers, therapists, and coaches is qualitative visual observation data. That is, the movement analyst carefully observes the movement being performed and makes either written or mental notes. It is beneficial to prepare ahead as to the best distance(s) and perspective(s) from which to make the Observations in order to obtain the best observational data possible.

Solving Formal Quantitative Problems

Formal problems are effective vehicles for translating nebulous concepts into well-defined, specific principles that can be readily understood and applied in the analysis of human motion. People who believe themselves incapable of solving formal stated problems do not recognise that, to a large extent, problem-solving skills can be learned. Entire books on problem solving approaches and techniques are available. However, most students are not exposed to coursework involving general strategies of the problem solving process.

A simple procedure for approaching and solving problems involves 11 sequential steps:

1. Read the problem carefully. It may be necessary to read the problem several times before proceeding to the next step. Only when you clearly understand the information given and the question(s) to be answered should you undertake step 2.
2. Write down the given information in list form. It is acceptable to use symbols (such as v for velocity) to represent physical quantities if the symbols are meaningful.
3. Write down what is wanted or what is to be determined, using list form if more than one quantity is to be solved for.
4. Draw a diagram representing the problem situation, clearly indicating all known quantities and representing those to be identified with question marks. (Although certain types of problems may not easily be represented diagrammatically, it is critically important to carry out this step whenever possible to accurately visualise the problem situation.)

5. Identify and write down the relationships or formulas that might be useful in solving the problem. (More than one formula may be useful and/or necessary.)
6. From the formulas that you wrote down in step 5, select the formula(s)containing both given variables (from step 2) and the variables that are desired unknowns (from step 3). If a formula contains only one unknown variable that is the variable to be determined, skip step 7 and proceed directly to step 8.

7. If you cannot identify a workable formula (in more difficult problems),certain essential information was probably not specifically stated but can be determined by inference and by further thought on and analysis of the given information.

QUALITATIVE ANALYSIS OF SPORTS MOVEMENTS

Sports biomechanists use two main approaches to analysing human movement patterns in sport – qualitative and quantitative analysis. The previous section focused on qualitative analysis. A third approach fits somewhere between the two and is often known as semi quantitative analysis.

Uses of Qualitative Analysis?

- Video recording or observation.
- Other movement pattern representations, such as graphs, focusing on their patterns, not their quantification.
- Qualitative analysis software packages, such as silicon COACH□. Who uses this?
- Teachers, coaches, athletes, physiotherapists, gait analysts, and judges of 'artistic' sports, such as ice dance and gymnastics. Performance analysts' working with athletes and others.

3). Introduction to Sports Biomechanics

The following are the uses of Biomechanics:

- To differentiate between individuals or teams.
- To improve movement or performance, as in gait analysis and video analysis.
- To provide qualitative feedback. Semi-quantitative analysis what do we use for this?
- Mostly as for qualitative analysis plus some simple measurements such as: joint ranges of motion durations of sub-phases of the movement, such as the stance and support phases in running, and their ratios to the overall movement time distances,

such as stride length joint angles at key times, such as knee angle at take-off for a jump notation – goals scored, passes, etc.

SELF -ASSESSMENT EXERCISE

i. List and explain five different types of joints movement anatomically.

4.0 CONCLUSION

- Qualitative analysis describes and analyses movements non-numerically, by seeing movements as patterns, while quantitative analyses describes and analyses movement numerically.
- Quantitative analysis can sometimes appear more objective because of its data; however, the accuracy and reliability of such data can be very suspect, particularly when obtained in competition.
- Qualitative analysis is often more strongly rooted in a structured and multi-disciplinary approach, whereas quantitative analysis can appear to lack a theoretical grounding and to be data- driven. Background to qualitative analysis is to be objective and scientific, qualitative analysis needs to use a structured approach, moving from preparation, through observation, diagnosis-evaluation (and review).
- Skeletal muscles have over 600muscles in the human body, accounting for 45% of the total body weight.
- The three types of muscles; cardiac, smooth and skeletal were discussed.
- Movement of human body segments is achieved as a result of forces generated by skeletal muscles that convert chemical energy into mechanical work,
- The skeletal muscles can also be named according to the functions they serve during a particular activity e.g., a muscle is called agonist if it causes movement through the process of its own contractions. While antagonist muscle opposes the action of another muscle, synergic muscle is that which assists the agonist muscle in performing the same joint motion compression at the elbow, knee, and ankle joints vary with externally applied forces and with different segmental arrangements.

5.0 SUMMARY

Anatomy is the study of the structure of the human body, it provides essential labels for musculoskeletal structures and joint motions relevant to human movement. Knowledge of anatomy also provides a common language of human body and motions for kinesiology and medical professionals.

Anatomy is primarily a descriptive field of study and is not by itself, enough to explain the function of the musculoskeletal system in movement. Knowledge of anatomy must be combined with biomechanics to accurately determine the musculoskeletal causes or the how human movement is created.

Body planes, it is also necessary to delineate the specific body planes of reference, since they will used to describe structural position and directions of functional movement and position of reference, or anatomic position, has the body facing forward, the hands at the sides of the body, with the palms facing forward, and the feet pointing straight ahead.

Movements that occur about an axis are considered rotational, whereas linear movements along an axis and through a plane are called translational. Curvilinear motion occurs when a translational movement accompanies rotational movement.

The human body is a rigid in the sense that it can maintain a posture, and flexible in the sense that it can be change its posture and move. The flexibility of the human body is due primarily to the joints, or articulations, of the skeletal system. The primary function of joints is to provide mobility to the musculoskeletal system, providing mobility, a joint must possess a degree of stability. Since different joints have different functions, they possess varying degrees of mobility and stability.

Scientific research is usually aimed at providing a solution for a particular problem or answering a specific question. Even for the non-researcher, however, the ability to solve problems is a practical necessity for functioning in modern society. The use of specific problems is also an effective approach for illustrating basic biomechanical concepts.

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.

Both qualitative and quantitative descriptions play important roles in the biomechanics 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.

6.0 TUTOR-MARKED ASSIGNMENT

1) List and explain differences between qualitative and quantitative analyses in human movement;
2) List and explain different movements pattern in sports.

7.0 REFERENCES/FURTHER READING

Peter M. McGinnis (2013). Biomechanics of Sport and Exercise (3rd ed). ISBN: 13:978-0-7360-7966-2

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Shirl J. Hoffman (2009): Introduction to Kinesiology : Study physical activities. www.humankinetics.com

Answer to Module 1 Unit 1 In-Text Question: (Define the term biomechanics). Biomechanics is a multidisciplinary science concerned with the application of mechanical principles to the human body in motion force among other human movement activities.

In general, a material can be categorised as either a solid or fluid. Solid materials can be rigid or deformable. A rigid body is one that cannot be deformed. In reality, every object or material does undergo deformation to some extent when acted upon by external forces. In some cases, the amount of deformation is so small that it does not affect the desired analysis. In such cases, it is preferable to consider the body as rigid and carry out the analysis with relatively simple computations.

The analysis of forces on rigid bodies at rest or traveling at a constant velocity is known as statics. The subject of dynamics is bodies in motion. Kinematics is a branch of dynamics that studies the geometry and time-dependent aspects of motion without taking into account the forces that cause it. Kinetics is founded on kinematics and takes into account the effects of forces and masses. The study of the external effects of forces on rigid bodies, bodies for which deformation (change in shape) can be ignored, is the subject of statics and dynamics. The dynamics of deformable bodies, on the other hand, is concerned with the relationships between externally imposed loads and their internal effects on the body. This field of applied mechanics does not presume that the bodies of interest are rigid, but considers the true existence of their material properties. The mechanics of deformable bodies has close links with the field of material science which deals with the atomic and molecular structure of materials. Deformable body mechanics concepts play an important role in the design of structures and system parts. In general, deformable body mechanics analyses are more difficult to conduct than rigid body mechanics analyses.

MODULE 2

UNIT 1 THE BIOMECHANICS OF HUMAN MUSCLE SKELETAL BASIS

CONTENTS

1.0 INTRODUCTION

Muscle is the only tissue capable of actively developing tension. This characteristic enables skeletal, or striated, muscle to perform the important functions of maintaining upright body posture, moving the body limbs, and absorbing shock. Because muscle can only perform these functions when appropriately stimulated, the human nervous system and the muscular system are often referred to collectively as the neuromuscular system. This chapter discusses the behavioral properties of muscle tissue, the functional organization of skeletal muscle, and the biomechanical aspects of muscle function

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- explain behavioral properties of the musculo
- explain Structural Organization of Skeletal Muscle
- explain Skeletal Muscle Function

3.0 MAIN CONTENT

3.1 Behavioral Properties of the Musculo Tendinous

Extensibility, elasticity, irritability, and the ability to build stress are the four behavioral properties of muscle tissue. Both muscles, including human cardiac, smooth, and skeletal muscle, as well as the muscles of other mammals, reptiles, amphibians, birds, and insects, share these characteristics.

Extensibility and Elasticity

The properties of extensibility and elasticity are common to many biological tissues. Extensibility is the ability to be stretched or to increase in length, and elasticity is the ability to return to normal length after a stretch. Following a stretch, muscle elasticity returns it to its normal resting length, allowing stress to be smoothly transferred from muscle to bone. Muscle has been defined as having two major components in terms of elastic behavior. When a muscle is passively stretched, the Parallel Elastic Part (PEC) formed by the muscle membranes provides resistance. When a tensed muscle is stretched, the series elastic part (SEC) in the tendons acts as a spring to store elastic energy. The membranes and tendons that make up muscle elasticity are called that way because they are parallel to and in series (or in line) with the muscle fibers that provide the contractile portion. The SEC is thought to be largely responsible for the elasticity of human skeletal muscle. Modeling experiments show that when a countermovement (knee flexion) occurs immediately before a leap, the height of the jump increases due to increased elasticity of the SEC in the lower extremity muscles (35).Other studies that support the rise in muscle force after stretching have discovered that the PEC contributes to some of the force enhancement (40). The viscous property of both the SEC and the PEC allows muscle to stretch and recoil in a time-dependent manner. When a muscle group, such as the hamstrings, is stretched statically over time, the muscle lengthens, increasing joint range of motion. Similarly, when a muscle group is extended, it does not necessarily return to its resting length, but rather shortens over time. Gender has no bearing on this viscoelastic response.

Irritability and the Ability to Develop Tension

Irritability is another of muscle's distinguishing characteristics, as is the ability to react to a stimulus. Electrochemical stimuli, such as an action potential from the attaching nerve, or mechanical stimuli, such as an external blow to a part of a muscle, affect muscles. Muscle stress develops as it is triggered by a stimulus. Muscle tissue has only one behavioral characteristic: the capacity to produce stress. Contraction, or the contractile portion of muscle function, has been used to explain the production of stress by muscle in the past. The ability to shorten in length is known as contractility.

3.2 Structural Organisation of Skeletal Muscle

The human body comprises approximately 434 muscles, which account for 40–45 percent of the body weight of most adults. On the right and left sides of the body, muscles are distributed in pairs. Body movements and posture are regulated by around 75 muscle pairs, with the rest involved in tasks such as eye control and swallowing. The anatomical and physiological features of the muscle influence biomechanical factors such as the developed force and the amount of time that the force can be sustained when stress is developed in the muscle.

Muscle Fibers

A single muscle cell is called a muscle fiber because of its thread like shape. The membrane covering the muscle fiber is often called the sarcolemma, and the specialised cytoplasm is termed sarcoplasm. Every fiber's sarcoplasm comprises numerous nuclei and mitochondria, as well as numerous thread-like myofibrils that run parallel to one another. The myofibrils contain two types of protein filaments, which when arranged in a particular way; create the striated pattern that gives skeletal muscle its name. The naming of these structures for reference was prompted by observations of improvements in the visible bands and lines in skeletal muscle during muscle contraction through the microscope. The sarcomere is the basic structural unit of the muscle fiber, compartmentalised between two Z lines. An M line cuts each sarcomere in half. The A bands are made up of dense, rough myosin filaments that are encircled by six small, smooth actin filaments. The bands are made up entirely of thin actin filaments. Attachment to Z lines, which bind to the sarcolemma, keeps the protein fragments in place in both bands. The H regions, which only contain thick myosin filaments, are located in the middle of the A bands. The thin actin filaments from either end of the sarcomere slip toward each other during muscle contraction. The Z lines travel toward the A bands, which retain their original size under a microscope, while the I bands narrow and the H region vanishes. During muscle contraction, cross-bridges, which are projections from the myosin filaments, form physical linkages with the actin filaments, with the amount of linkages proportional to both force input and energy expenditure. Adults have a lot of difference in the length and diameter of muscle fibers within muscles. Some muscle fibers run the length of the muscle, while others are much shorter. From birth to adulthood, skeletal muscle fibers grow in length and diameter. Resistance training with few repetitions of large loads can also increase fiber diameter in adults of all ages.

3.3 Skeletal Muscle Function

The amount of tension present in an activated muscle is constant throughout the muscle's duration, as well as in the tendons and at the sites of the musculotendinous attachments to bone. The muscle's tensile force pulls on the attached bones, creating torque at the joints where the muscle crosses. The direction of any resulting movement is determined by the net torque present at a joint, according to the laws of vector addition. Torques may be caused at a joint by the weight of the attached body segment, external forces acting on the body, and tension in any muscle crossing a joint.

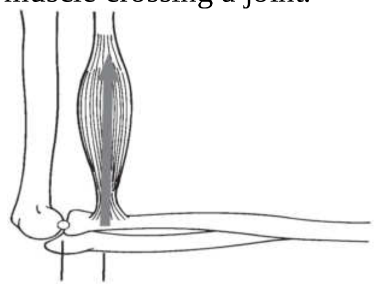

Fig. 2.1: Tension in Muscle Crossing a Joint

Recruitment of Motor Units

The central nervous system has a complex control system that allows the speed and magnitude of muscle contraction to be matched to the movement's requirements, allowing for smooth, delicate, and precise movements. ST motor units are supplied by nerves that have lower thresholds and are easier to activate, whereas FT motor units are supplied by nerves that are more difficult to activate.

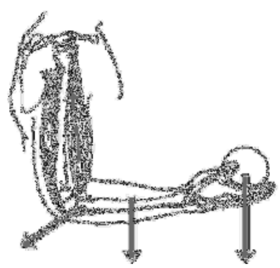

Fig. 2.2: Muscle Contraction

Consequently, the ST fibers are the first to be activated, even though the resulting limb movement is rapid. As the force requirement, speed requirement, or length of the operation increases, motor units with higher thresholds are gradually enabled, with Type IIa, or FOG, fibers inserted before the Type IIb, or FG, fibers. There is a range of ease of activation within each fiber category, and the central nervous system can selectively activate more or less motor units. The central nervous system can almost exclusively recruit ST fibers during low-intensity exercise. Type IIa and then Type IIb motor units are triggered as operation progresses and fatigue sets in, until all motor units are active.

Tension Development

As muscular strain creates a torque at a joint that is greater than the resistive torque, the muscle shortens, changing the angle at the joint. As a muscle contracts, the contraction is concentric, and the resultant joint movement is in the same direction as the muscle's net torque. A single muscle fiber has the ability to shorten to around half of its normal resting length. Muscles can also become tense without being shortened. Muscle length remains unchanged and no movement occurs at the joint if the opposing torque at the joint crossed by the muscle is equal to the torque provided by the muscle (with zero net torque present). Isometric contractions occur as muscular stress develops but there is no shift in muscle length. Bodybuilders use isometric tension to demonstrate their muscles during competitions because tension raises the diameter of the muscle. Isometric stress in muscles on opposite sides of an arm, such as the triceps brachii and biceps brachii, raises the cross-sectional area of the tensed muscles, even if there is no movement at the shoulder or elbow joints. The muscle lengthens when opposing joint torque exceeds that generated by muscle tension. The contraction is eccentric when a muscle lengthens when it is stimulated to develop stress, and the direction of joint motion is opposite that of the net muscle torque. During the elbow extension or weight lowering process of a curl exercise, eccentric stress develops in the elbow flexors. The eccentric tension serves as a braking mechanism to regulate movement speed. Without the involvement of eccentric tension in the muscles, the forearm, wrist, and weight will drop in an uncontrolled way because of the force of gravity. Training in the same exercise mode enhances the ability to build stress under concentric, isometric, and eccentric conditions.

Roles Assumed by Muscles

Just one thing an activated muscle can do is generate stress. We often speak in terms of the function or position that a given muscle is carrying out when it acts in conjunction with other muscles crossing the same joint because one muscle seldom acts in isolation. An agonist, or mover, is a muscle that contracts and induces movement of a body segment at a joint. Since a movement sometimes involves several muscles, the distinction between main and assistant agonists is often made. The brachialis and biceps brachii, for example, serve as primary agonists during the elbow flexion process of a forearm curl, with the brachioradialis, extensor carpi radialislongus, and pronatorteres acting as assistant agonists. (1)Both one-joint muscles acting as agonists either produce stress at the same time or remain dormant (2) Muscles that have opposite behavior to the agonists can serve as antagonists or opposers by inducing odd agitation at the same time as the agonists cause movement.

Agonists and antagonists are also found on opposing sides of a joint. During elbow flexion, when the brachialis and the biceps brachii are primary agonists, the triceps could act as antagonists by developing resistive tension.

When the triceps are the agonists during elbow extension, the brachialis and biceps brachii can act as antagonists. While antagonist muscles do not sustain constant tension during skilled movement, antagonists often provide controlling or braking acts, particularly at the end of quick, forceful movements. Agonists are most active during deceleration, or negative acceleration, while agonists are most active during acceleration of a body part. Simultaneous quadriceps and hamstring strain growth helps to stabilise the knee against potentially harmful rotational forces. Internal force, such as stress in other muscles, or external force, such as the weight of an object being lifted, are also possibilities. During waterskiing, the rhomboids serve as stabilisers by developing tension to hold the scapulae secure against the pull of the tow rope. Muscles also serve as a neutraliser in a fourth role. Neutralisers stop unwanted side effects from occurring when agonists develop concentric tension. If a muscle induces both flexion and abduction at a joint but only flexion is required, a neutraliser causing adduction will remove the unwanted abduction. As the biceps brachii experiences concentric strain, it induces both elbow flexion and forearm supination. The pronator teres act as a neutralizer to counteract the supination of the forearm if only elbow flexion is needed. The cooperative acts of several muscle groups functioning sequentially and in concert are characteristic of human movements. Even the basic task of raising a glass of water from a table, for example, necessitates the use of many different muscle groups in various ways. The scapular muscles, as well as the flexor and extensor muscles of the wrist, play a stabilising role.The flexor muscles of the fingers, elbow, and shoulder perform the agonist function. Horizontal abductors such as the middle deltoid and supraspinatus act as neutralisers because the major shoulder flexors, the anterior deltoid and pectoralis major, also produce horizontal adduction. Antagonist behavior in the elbow extensors can also help to regulate movement speed during the motion. Gravity is the primary mover when the glass of water is returned to the table, with antagonist action in the elbow and shoulder flexors regulating movement speed.

Two-Joint and Multijoint Muscles

Many muscles cross two or more joints in the human body. The biceps brachii, long head of the triceps brachii, hamstrings, rectus femoris, and a variety of muscles that cross the wrist and all finger joints are examples. Since the amount of stress in a muscle is generally constant throughout its length and at the sites of its tendinous attachments to bone, these muscles influence motion at both or all of the crossed joints at the same time. The position and direction of the muscle's attachment relative to the joint, as well as the tightness or laxity present in the muscle, determine the effectiveness of a two-joint or multi-joint muscle in inducing movement at any joint crossed in the musculo tendinous unit, and the actions of other muscles that cross the joint. Two-joint muscles can produce force with a significant transverse component, while one-joint muscles produce force primarily in line with a body section. However, there are two drawbacks to the operation of two-joint and multi-joint muscles. They are unable to shorten to the degree necessary to achieve a full range of motion at all crossed joints at the same time, a condition known as active insufficiency. When the wrist is in flexion, the finger flexors can't make a fist as tight as they can when it's in neutral. When the locations of both joints are crossed, the muscles become extremely slackened, and certain two-joint muscles are unable to generate any force. Another issue is that most people's two-joint and multi-joint muscles are unable to extend to the degree appropriate for maximum range of motion in the opposite direction at all crossed joints. Passive insufficiency is the term for this condition. If the fingers are not completely extended, for example, a wider degree of hyperextension is likely at the elbow. Similarly, due to the change in gastrocnemius tightness, a greater range of ankle dorsiflexion can be achieved while the knee is in flexion.

FACTORS AFFECTING MUSCULAR

FORCE GENERATION

The magnitude of the force produced by muscle is also influenced by the rate at which the muscle shortens, the length of the muscle when stimulated, and the time since the muscle was stimulated. These factors have been extensively studied because they are important determinants of muscle power.

Force–Velocity Relationship

The velocity of the muscle's shortening or lengthening is regulated by the maximum force that it can produce, with the relationship shown in the concentric and eccentric zones of the graph, respectively. Hill defined this force velocity relationship for concentric tension production in muscle for the first time in 1938. Since the relationship only applies to maximally activated muscle, it does not extend to other everyday activities. As a consequence, the force–velocity relationship does not mean that moving a strong resistance at a high speed is difficult. The magnitude of maximal isometric stress increases with muscle strength. If the resistance is raised; this is the maximum amount of force that a muscle can produce before lengthening. Regardless of the degree of maximal isometric stress, the general form of the force–velocity curve remains the same. The force–velocity relationship does not mean that moving a light load at a slow speed is difficult. The majority of daily activities necessitate sluggish, regulated submaximal load movements. Volitional regulation of muscle shortening velocity is possible with submaximal loads. Only the appropriate number of motor units is switched on. For example, depending on the regulated pattern of motor unit recruitment in the muscle groups involved, a pencil can be picked up quickly or slowly from a desktop. Human skeletal, smooth, and cardiac muscle, as well as muscle tissues from other mammals, have all been subjected to force–velocity tests. The general trend holds true for all forms of muscle, including the tiny muscles that cause insect wings to flutter rapidly. The maximum force at zero velocity and the maximum velocity at a minimal load differ depending on the size and form of muscle. The form of the concentric portion of the curve corresponds to the rate of energy output in a muscle, despite the fact that the physiological basis for the force–velocity relationship is unknown.

MUSCULAR STRENGTH, POWER, AND ENDURANCE

The force-generating characteristics of muscle are discussed within the principles of muscular strength, capacity, and endurance in functional assessments of muscular function. These muscle function characteristics have important consequences for performance in a number of strenuous physical activities, such as splitting wood, throwing a javelin, or hiking up a mountain trail. Maintaining sufficient muscle strength and stamina is critical for carrying out everyday tasks and preventing injury in senior citizens and individuals with neuromuscular disorders or injuries.

Muscular Strength

When scientists excise a muscle from an experimental animal and electrically stimulate it in the lab, the force produced by the muscle can be directly calculated. Our understanding of the force–velocity and length–tension relationships for muscle tissue is primarily derived from regulated experimental work of this kind. However, it is difficult to precisely determine the force exerted by a given muscle in the human body. The most popular method of calculating "muscular strength" is to calculate the maximum torque produced by an entire muscle group at a joint. Muscular strength is thus defined as a function of a functional muscle group's collective force-generating capability. Muscular strength is the ability of a particular muscle group to produce torque at a specific joint.

Muscular strength is just one component of physical fitness. Along with cardiovascular fitness, muscular endurance, flexibility and body composition, muscular strength can provide several health benefits. Muscular strength refers to the amount of force a muscle can produce and is usually measured by the maximum amount of force a muscle can produce in a single effort (maximal effort). The amount of muscle strength which can be achieved depends on gender, age, and inherited physical attributes. While strong muscles are essential for any athletic endeavour, strong muscles can benefit everyone in some way.

Strong muscles can have direct and indirect benefits on health and include:

1. Ease of movement
2. Good posture
3. Easier performance of work, everyday activities, and exercise
4. Easier performance of recreational activities
5. Stronger tendons and ligaments, and bones
6. Decreased risk of injury
7. Decreased risk of falls

Health Benefits of Muscular Strength

1. Muscles support your skeleton and enable movement.
2. Strong muscles in your legs, buttocks, back, abdomen, chest, and shoulder provide a person with the strength to stand up straight and maintain good posture.
3. Strong muscles enable functional movements associated with everyday living.
4. Many recreational activities such as skiing and kayaking require strength in particular muscle groups such as legs or upper body.
5. When muscles are strong the associated tendons which attach muscles to bone, and ligaments, which attach bone to bone are usually also strong. Exercises which strengthen muscles are associated with strengthening bones.
6. Strong muscle, tendons, ligaments and bones decrease the risk of injury as the body is better able to respond to falls or extra loads which the body experiences.
7. Back pain can be prevented or reduced by strengthening back muscles.
8. Arthritis can be alleviated by strengthening muscles around the joints that are affected, and strength training may be therapeutic for people with chronic pain.
9. Good muscle strength can also increase work capacity so that an individual does not tire easily, and can improve athletic performance.

10. During an emergency, strong muscles enable an individual to work beyond their normal capacity. Daily tasks, such as lifting and moving heavy items, can be made easier if an individual has good muscular strength.
11. Parents and grandparents need strong muscles to life infants and young children...follow the link to the full article to learn more.

Muscular Endurance

Muscle endurance refers to a muscle's ability to maintain tension over time. The stress can be constant, like when a gymnast does an iron cross, or it can vary cyclically, like when rowing, riding, or cycling. The greater the stamina, the longer the time stress is applied. While maximum muscular strength and power are distinct terms, muscular endurance is less well understood since the force and speed specifications of the exercise have a significant impact on the amount of time it can be sustained. Large numbers of repetitions against relatively light resistance are usual in muscular endurance training. This method of training does not result in an increase in muscle fiber diameter.

Benefits to Endurance Training:

1. Increased metabolism as physical tasks can be completed for longer
2. Reduced fatigue when exercising
3. Good posture
4. Fewer injuries
5. Less chance of back problems due to built endurance of trunk muscles
6. Better sporting performance
7. Refined training techniques for many exercises

How to Increase Muscular Endurance?

Weight training – aim to complete a movement for at least 12 repetitions. If your muscles are exhausting sooner, then the weight is too heavy and you are building strength not endurance. You can use either machines or free-weights to improve your muscular endurance.

Exercise slowly and controlled – avoid jerky movements and throwing the weights about. Lower the resistance slowly when training through the complete range of motion. Many people make the mistake of thinking as they are trying to perform higher repetitions that they should just move faster.

Regular exercise – if you want to improve endurance you need to train on a regular basis. Ideally on a daily basis, work on completing the minimum 12 reps, taking a short rest and then repeating for at least 3 sets on each major muscle group.

Challenge the body – you need to ensure it doesn't become too easy. When comfortable performing repetitions of an exercise, do one of the following: increase weight used, number of reps, number of sets or reduce the length of the rest period.

Move better – the more efficiently you are moving the easier it will be to increase your endurance. For beginners it is key to start with simple movements when performing resistance training and building this up. Start on machines and progressing to free-weights is a great way to do this. If you think of your running technique, the more fluid this is the longer you will be able to perform as you will be working far more efficiently.

Muscle Fatigue

Muscle fatigue is characterised as a reduction in a muscle's maximum force capacity caused by exercise. Fatigability can also be defined as the polar opposite of endurance. The more a muscle fatigues, the lower its endurance. The rate at which a muscle fatigues is affected by a variety of factors, including the form and intensity of exercise, the various muscle groups involved, and the physical environment in which the operation takes place. Furthermore, inside a single muscle.

The structure of muscle fibers and the pattern of motor unit activation both influence the rate at which a muscle fatigue. However, this is an emerging field of expertise, with a large amount of related research underway. Muscle fatigue is characterised by a decrease in muscle force output capacity, a decrease in velocity, and prolonged relaxation of motor units between recruitment. When a muscle fiber is unable to produce tension when activated by its motor axon, it has reached total exhaustion. Fatigue can also affect the motor neuron, preventing it from generating an action potential.

Causes of Muscle Fatigue

Exercise and other physical activity are a common cause of muscle fatigue. Other possible causes of this symptom include:

1. Addison's disease
2. Age
3. Anaerobic infections

4. Anemia
5. Anxiety
6. Botulism
7. Cerebral palsy
8. Chemotherapy
9. Chronic fatigue syndrome (CFS)
10. Dehydration
11. Depression
12. Fibromyalgia
13. Hepatitis C
14. HIV
15. Hypothyroidism
16. Influenza (the flu)
17. Lack of exercise
18. Lactic acid production
19. Medications
20. Mineral deficiency
21. Muscular dystrophy
22. Myasthenia gravis
23. Myositis (muscle inflammation)
24. Poor muscle tone due to a medical condition
25. Pregnancy
26. Sleep deprivation
27. Stroke
28. Tuberculosis

Muscle fatigue symptoms

Muscle fatigue can occur anywhere on the body. An initial sign of this condition is muscle weakness. Other symptoms associated with muscle fatigue include:

1. Soreness
2. Localised pain
3. Shortness of breath
4. Muscle twitching
5. Trembling
6. A weak grip
7. Muscle cramps

Treating muscle fatigue

The following should be considered in the treatment of muscle fatigue;

1. Your muscle fatigue will improve with rest and recovery.

2. Staying hydrated and maintaining a healthy diet can also improve your recovery time,
3. Protect against muscle fatigue and weakness, and ensure you have enough nutrients to promote healthy muscle function.
4. Be sure to stretch before and after strenuous activity.
5. Warming up can loosen your muscles and protect against injury.
6. If your muscle fatigue persists, hot and cold therapy are techniques that can reduce inflammation and discomfort.

Other cases of muscle fatigue may require medical attention. Depending on your diagnosis, your doctor may prescribe anti-inflammatory or antidepressant medications. If your muscle fatigue is more severe, you doctor may recommend physical therapy to increase your mobility and speed your recovery. Discuss your options with your doctor before pursuing treatment.

COMMON MUSCLE INJURIES

Muscle injuries are common, with most being relatively minor. Thankfully, healthy skeletal muscle has a high potential for self-repair. The activation of a complex collection of cellular and molecular responses is required for skeletal muscle regeneration. Satellite cells, which are skeletal muscle stem cells, play a critical role in the formation of new muscle tissue.

Strains

Overstretching of muscle tissue induces muscular strains. An active muscle is usually overloaded, and the severity of the injury is proportional to the size of the overload and the rate of overloading. Mild, moderate, and serious strains exist. Mild strains are characterised by a sensation of tightness or stiffness in the muscle and cause minimal structural damage. A partial tear in the muscle tissue causes discomfort, fatigue, and some loss of function in second-degree strains. There is extreme muscle tearing, functional loss, and accompanying hemorrhage and swelling with third-degree sprains. The hamstrings are the muscles in the human body that are most often stressed. Hamstring strains are especially troubling for athletes because they take a long time to heal and have a roughly one-third recurrence rate within the first year after returning to competition. According to study, eccentric exercises with heavy loads should be emphasised in hamstring injury prevention and recovery programs.

Contusions

Compressive forces incurred during impacts cause contusions, or muscle bruises. They are made up of hematomas that have developed within the muscle tissue. A serious muscle contusion, or one that is frequently affected, can lead to the development of myositis ossificans, a much more serious disorder. The presence of a calcified mass inside the muscle is myositisossifi cans. After three or four weeks, the fibroblasts recruited during the healing process appear to distinguish into osteoblasts, with calcification evident on a radiograph. Desorption of the calcified mass normally starts after six or seven weeks, though a bony lesion in the muscle will remain.

Cramps

Muscle cramps have an etiology that is unclear, but potential causes include electrolyte imbalances, calcium and magnesium shortages, and dehydration. Cramps can also happen as a result of direct impacts. Cramps can cause mild to extreme muscle spasms, as well as varying degrees of pain.

SELF-ASSESSMENT EXERCISE

i. List and describe different skeletal muscle functions you know.
ii. Describe the behavioral properties of the musclotendinous unit.
iii. List and describe different roles of a muscle in the body.

4.0 CONCLUSION

- Four behaviors properties of muscle tissue, such as Extensibility, Elasticity, Irritability and ability to build stress are discussed.
- Both muscle including human cardiac, smooth, and skeletal muscle as well as the muscles of other mammals, reptiles, amphibians, birds, and insects, share these four characteristics.
- The anatomical and physiological features of the muscle influence biomechanical factors such as the developed force and the amount of time that the force can be sustained when stress is developed in the muscle.
- A single muscle cell is called a muscle fiber because of its thread like shape. The membrane covering the muscle fiber is often called the sarcolemma, and the specialised cytoplasm is termed sarcoplasm.
- The amount of tension present in an activated muscle is constant throughout the muscle's duration as well as in the tendons and at the sites of the musculotendinous attachments to bone.

- The central nervous system has a complex control system that allows the speed and magnitude of muscle contraction to be matched to the movement's requirements, allowing for smooth, delicate, and precise movements.
- As muscular strain creates a torque at a joint that is greater than the resistive torque, the muscle shortens, changing the angle at the joint.
- Common muscle injuries such as strains, contusions, cramps etc. are discussed appropriately.

5.0 SUMMARY

Muscles in mammals, reptiles, amphibians, birds, and insects, share the same characteristics such as Irritability, Elasticity, Extensibility and the ability to build stress, these four behavioural properties are common in all. The skeletal muscle performs lots of function such as the amount of tension present in an activated muscle is constant throughout the muscle's duration. The muscle's tensile force pulls on the attached bones, creating torque at the joints where the muscle crosses. The direction of any resulting movement is determined by the net torque present at a joint, according to the laws of vector addition.

As a muscle contracts, the contraction is concentric, and the resultant joint movement is in the same direction as the muscle's net torque, a single muscle fiber has ability to shorten to around half of its normal resting length. Muscles can also become tense without being shortened.

An agonist, or mover, is a muscle that contracts and induces movement of a body segment at a joint. Since a movement sometimes involves several muscles, the distribution between main and assistant agonist is often made.

The magnitude of the force produced by muscle is also influenced by the rate at which the muscle shortens, the length of the muscle when stimulated, and the time since the muscle was stimulated. Strong muscles can have direct and indirect benefits on health of an individual in various ways such as; providing good posture, ease movement, decreased risk injury, easier performance of work, everyday activities and even exercise etc.

Muscular endurance refers to a muscle's ability to maintain tension over time, the stress can be constant, like when a gymnast does an iron cross etc. the ways to increase muscular endurance were fully discussed such as; having weight training, regular exercise, challenge the body and move better etc.

Muscle fatigue is characterised as a reduction in a muscle's maximum force capacity caused by exercise. Fatigability can also be defined as the opposite of endurance. The more a muscle fatigues, the lower its endurance. The rate at which a muscle fatigue is affected by a variety of factors, including the form and intensity of exercise, the various muscle groups involved, and the physical environment in which the operation takes place. Causes of muscle fatigue such as Addison's disease, Age, Anaerobic infections, Anxiety, Medications, etc. were discussed. Symptoms before fatigue are soreness, Localised pain, Muscle twitching and muscle cramps etc. muscle injuries are common with most being relatively minor are skeletal muscle has a high potential for self-repair, such injuries are strains, cramps and contusions etc.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe how strong muscles can be of benefit to an individual health benefit.
2. List and explain different health benefits of muscular strength you know.

7.0 REFERENCES/FURTHER READING

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UNIT 2 THE KINETIC CONCEPTS OF HUMAN BONE GROWTH AND DEVELOPMENT

CONTENTS

1.0 INTRODUCTION

In this part, we'll look at how bone's material composition and structural organisation affect how it reacts to mechanical loading. Bone's composition and structure provide a material that is solid despite its light weight.

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- explain composition and Structure of Bone Tissue
- enumerate the types of Bones
- describe Bone Growth and Development
- explain Bone Response to Stress

3.0 MAIN CONTENT

3.1 Composition and Structure of Bone Tissue

Bone's material composition and structural organisation have an effect on how it reacts to mechanical loading. Bone's composition and construction provide a substance that is both solid and light in weight. Components of the material

Calcium carbonate, calcium phosphate, collagen, and water are the primary components of bone. The proportions of these materials differ depending on the age and health of the bone. Calcium carbonate and calcium phosphate make up about 60–70% of dry bone weight. These minerals are the main determinants of bone's compressive strength and stiffness. Bone tissue contains a large amount of water, which contributes to bone strength. As a result, scientists and engineers researching the material properties of various forms of bone tissue must be certain that the bone specimens they are examining do not become dehydrated. Water brings nutrients to and waste products away from the living bone cells within the mineralised matrix as it passes through the bones. Water also carries mineral ions to and from bone, where they are stored and later used by the body tissues. Organisational Structure The percentage of bone mineralisation varies depending on the individual's age as well as the type of bone in the body. The proportion of calcium phosphate and calcium carbonate in porous bone is lower, and the proportion of non-mineralised tissue is higher. Based on porosity, bone tissue is divided into two groups. Cortical bone is produced when the porosity of the bone is minimal, with non-mineralised tissue occupying 5–30% of the total volume of the bone. Spongy, cancellous, or trabecular bone has a relatively high porosity, with no mineralised tissue occupying 30 percent to greater than 90 percent of the bone thickness. Trabecular bone is made up of cells filled with marrow and fat that have a honeycomb shape of mineralised vertical and horizontal bars called trabecular. The porosity of bone is of concern because it has a direct impact on the tissue's mechanical properties. Cortical bone is stiffer than trabecular bone due to its higher mineral content, so it can withstand more stress but less strain or relative deformation. Trabecular bone is spongier than cortical bone, so it can handle more pressure before fracturing. The structure of a bone is determined by its function. The long bones' shafts are made up of hard cortical bone; it can withstand a greater amount of stress before fracturing. The structure of a bone is determined by its function. The long bones' shafts are made up of hard cortical bone. The vertebrae's shock-absorbing ability is aided by their relatively high trabecular bone content. Both cortical and trabecular bone are anisotropic, meaning they react to forces from different directions with different strength and stiffness. Bone is the most resistant to compressive stress and the least resistant to shear stress.

Bone is a mineralised connective tissue that exhibits four types of cells: osteoblasts, bone lining cells, osteocytes, and osteoclasts. Bone exerts important functions in the body, such as locomotion, support and protection of soft tissues, calcium and phosphate storage, and harboring of bone marrow. Despite its inert appearance, bone is a highly dynamic organ that is continuously resorbed by osteoclasts and neoformed by osteoblasts. There is evidence that osteocytes act as mechanosensors and orchestrators of this bone remodeling process. The function of bone lining cells is not well clear, but these cells seem to play an important role in coupling bone resorption to bone formation. Bone remodeling is a highly complex process by which old bone is replaced by new bone, in a cycle comprised of three phases: initiation of bone resorption by osteoclasts, (2) the transition (or reversal period) from resorption to new bone formation, and (3) the bone formation by osteoblasts. This process occurs due to coordinated actions of osteoclasts, osteoblasts, osteocytes, and bone lining cells which together form the temporary anatomical structure called basic multicellular unit (BMU).

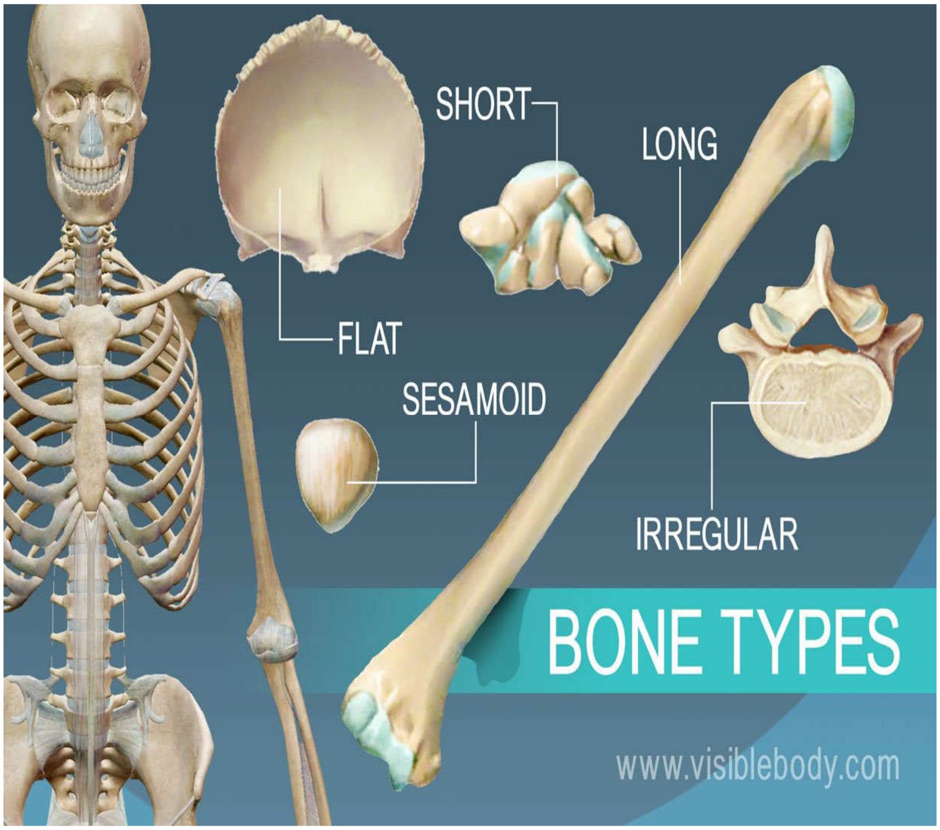
Normal bone remodeling is necessary for fracture healing and skeleton adaptation to mechanical use, as well as for calcium homeostasis. On the other hand, an imbalance of bone resorption and formation results in several bone diseases. For example, excessive resorption by osteoclasts without the corresponding amount of functioner bone by osteoblasts contributes to bone loss and osteoporosis, whereas the contrary may result in osteopetrosis. Thus, the equilibrium between bone formation and resorption is necessary and depends on the action of several local and systemic factors including hormones, cytokines, chemokines, and biomechanical stimulation. Recent studies have shown that bone influences the activity of other organs and the bone is also influenced by other organs and systems of the body, providing new insights and evidencing the complexity and dynamic nature of bone tissue. In this review we will address the current data about bone cells biology, bone matrix, and the factors that influence the bone remodeling process.

3.2 Types of Bones

The 206 bones of the human body have unique structures and shapes that enable them to perform specific functions. The central or axial skeleton and the peripheral or appendicular skeleton are the two parts of the skeletal system. The axial skeleton contains the bones that shape the axis of the body, which are the skull, the vertebrae, the sternum, and the ribs. The other bones form the body appendages, or the appendicular skeleton. Bones are often divided into groups based on their general shapes and functions. The carpals and tarsals are the only small bones that are roughly cubical. These bones act as shock absorbers and have minimal gliding motions. Flat bones are also described by their name. These bones protect underlying organs and soft tissues and also provide large areas for muscle and ligament attachments. The flat bones include the scapulae, sternum, ribs, patellae, and some of the bones of the skull. Irregular bones have different shapes to fulfill special functions in the human body. For example, the vertebrae provide a bony, protective tunnel for the spinal cord; offer several processes for muscle and ligament attachments; and support the weight of the superior body parts while enabling movement of the trunk in all three cardinal planes. The sacrum, coccyx, and maxilla are other examples of irregular bones.

Long bones form the framework of the appendicular skeleton. They consist of a long, roughly cylindrical shaft (also called the body, or diaphysis) of cortical bone, with bulbous ends known as condyles, tubercles, or tuberosity's. A self-lubricating articular cartilage protects the ends of long bones from wear at points of contact with other bones. Long bones also contain a central hollow area known as the medullary cavity or canal. The long bones are adapted in size and weight for specific biomechanical functions. The tibia and femur are large and massive to support the weight of the body. The long bones of the upper extremity, including the humerus, radius, and ulna, are smaller and lighter to promote ease of movement. Other long bones include the clavicle, fibula, metatarsals, metacarpals, and phalanges.

DIAGRAM OF DIFFERENT TYPES OF BONES



http://www.visiblebody.com/url?sa
Fig. 2.3: Types of Bone

3.2 Bone Growth and Development

Bone growth begins early in fetal development, and living bone is continually changing in composition and structure during the life span. Many of these changes represent normal growth and maturation of bone. Longitudinal growth of a bone occurs at the epiphyses, or epiphyseal plates. The epiphyses are cartilaginous discs found near the ends of the long bones. The diaphysis (central) side of each epiphysis continually produces new bone cells. During or shortly following adolescence, the plate disappears and the bone fuses, terminating longitudinal growth.

Most epiphyses close around age 18, although some may be present until about age 25.Circumferential Growth Long bones grow in diameter throughout most of the life span, although the most rapid bone growth occurs before adulthood. The internal layer of the periosteum builds concentric layers of new bone tissue on top of existing ones. At the same time, bone is resorbed or eliminated around the circumference of the medullary cavity, so that the diameter of the cavity is continually enlarged. This occurs in such a way that both bending stress-es and torsional stresses on the bones remain relatively constant. These changes in bone size and shape are the work of specialised cells called osteoblasts and osteoclasts, which respectively form and resorb bone tissue. In healthy adult bone, the activity of osteoblasts and osteoclasts is largely balanced. Adult Bone Development There is a progressive loss of collagen and increase in bone brittleness with aging. Thus, the bones of children are more pliable than the bones of adults. Bone mineral normally accumulates throughout childhood and adolescence, reaching a peak at about age 25–28 in women and age 30–35 in men. Following this peak, researchers disagree as to the length of time that bone density remains constant. However, an age-related, progressive decline in bone density and bone strength in both men and women may begin as soon as the early twenties. This involves a progressive diminishment in the mechanical properties and general toughness of bone, with increasing loss of bone substance and increasing porosity. Trabecular bone is particularly affected, with progressive disconnection and disintegration of trabecular compromising the integrity of the bone’s structure and seriously diminishing bone strength. These changes are much more pronounced in women than in men, however. In women, there is a notable decrease in both volume and density of cortical bone, and a decrease in the density of trabecular bone with aging. Approximately 0.5–1.0% of bone mass is lost each year, until women reach about age 50 or menopause. Following menopause, there appears to be an increased rate of bone loss, with values as high as 6.5% per year reported during the first five to eight years. Although similar changes occur in men, they do not become significant before a more advanced age. Women at all ages tend to have smaller bones and less cortical bone area than do men, although volumetric bone mineral density is similar for both genders.

3.3 Bone Response to Stress

Other changes that occur in living bone throughout the life span are un-related to normal growth and development. Bone responds dynamically to the presence or absence of different forces with changes in size, shape, and density. This phenomenon was originally described by the German scientist Julius Wolff in 1892:The form of a bone being given, the bone elements place or displace them-selves in the direction of functional forces and increase or decrease their mass to reflect the amount of the functional forces. Bone Modeling and Remodeling According to Wolff's law, the densities and, to a much lesser extent, the shapes and sizes of the bones of a given human being are a function of the magnitude and direction of the mechanical stresses that act on the bones. Dynamic mechanical loading causes bones to deform or strain, with larger loads producing higher levels of strain. These strains are translated into changes in bone shape and strength through a process known as remodeling. Remodeling involves desorption of fatigue-damaged older bone and subsequent formation of new bone. Bone modeling is the term given to formation of new bone that is not preceded by desorption, and is the process by which immature bones grow. Adult bones gain or lose mass in accordance with Wolff's law. When strain on a bone exceeds a certain threshold, new bone is laid down at the strain sites, and overall bone mass and density are increased. When strain magnitudes stay below a lower threshold, bone remodeling occurs, with bone removed close to the marrow. Strain magnitudes in between these two thresholds occur in what is termed the "lazy zone" and do not trigger bone adaptation. Remodeling can occur in either "conservation mode," with no change in bone mass, or "disuse mode," with a net loss of bone mass characterised by an enlarged marrow cavity and thinned cortex.

Bone is a very dynamic tissue, with the modeling and remodeling processes continuously acting to increase, decrease, or reshape bone. The modeling and remodeling processes are directed by osteocytes, cells embedded in bone that are sensitive to changes in the flow of interstitial fluid through the pores resulting from strain on the bone. Dynamic loading resulting from high-level impact produces a high rate of deformation that best pushes Fluid through the bone matrix. It is for this reason that activities involving high levels of impact are best at stimulating bone formation. In response to the motion of fluid within the bone matrix, osteocytes trigger the actions of osteoblasts and osteoclasts, the cells that respectively form and resorb bone. A predominance of osteoblast activity produces bone modeling, with a net gain in bone mass. Bone remodeling involves a balance of osteoblast and osteoclast action or a predominance of osteoclast activity, with associated maintenance or loss of bone mass. Approximately 25% of the body's trabecular bone is remodeled each year through this process. Strains resulting from an activity such as walking are sufficient to provoke bone turnover and new bone formation. Thus, bone mineralisation and bone strength in both children and adults are a function of stresses producing strains on the skeleton. Since body weight provides the most constant mechanical stress to bones, bone mineral density generally parallels body weight, with heavier individuals having more massive bones. Adults who gain or lose weight tend to also gain or lose bone mineral density. However, a given individual's physical activity profile, diet, lifestyle, and genetics can also dramatically influence bone density. Factors such as lean body mass, muscle strength, and regular participation in weight-bearing exercise have been shown to exert stronger influences on bone density than weight, height, and race. Dynamic loading during participation in gymnastics has been shown to affect bone size and strength more than muscle mass. Even in young, nonathletic children, bone appears to remodel in response to the presence or absence of physical activity. The malleability of bone is dramatically exemplified by the case of an infant who was born in normal physical condition but missing one tibia, the major weight-bearing bone of the lower extremity. After the child was walking for a time, X-rays revealed that modeling of the fibula in the abnormal leg had occurred to the extent that it could not be distinguished from the tibia of the other leg. Another interesting case is that of a construction worker who had lost all but the fifth finger of one hand in a war injury. After metacarpal and phalanx of the remaining finger had been modeled to resemble the third finger of the other hand. Bone Hypertrophy Although cases of complete changes in bone shape and size are unusual, there are many examples of bone modeling, or bone hypertrophy, in response to regular physical activity. The bones of physically active individuals tend to be denser and therefore more mineralised than those of sedentary individuals of the same age and gender. Moreover, the results of several studies indicate that occupations and sports particularly stressing a certain limb or region of the body produce accentuated bone hypertrophy in the stressed area. For example, professional tennis players display not only muscular hypertrophy in the tennis arm but also hypertrophy of that arm's radius. Similar bone hypertrophy has been observed in the dominant humerus of baseball players. It also appears that the greater the forces or loads habitually encountered, the more dramatic the increased mineralisation of the bone. In one study involving collegiate female athletes in basketball, volleyball, soccer, track, and swimming, the athletes participating in high-impact sports (basketball and volleyball) were found to have higher bone mineral densities and bone formation values than the swimmers. In another investigation, the bone mineral densities of trained runners and cyclists were compared to those of sedentary individuals of the same age. Compared to the non-exercisers, the runners were found to have increased bone density, although this was not true for the cyclists. Among older women, both yard work and weight training have been found to be strong predictors for bone density, with jogging, swimming, and calisthenics being weak predictors. On the whole, the research evidence suggests that physical activity involving impact forces is necessary for maintaining or increasing bone mass. Competitive swimmers, who spend a lot of time in the water where the buoyant force counteracts gravity, may have bone mineral densities lower than those of sedentary individuals. Bone Atrophy is a bone hypertrophies in response to increased mechanical stress, it displays the opposite response to reduced stress. When the normal stresses exerted on bone by muscle contractions, weight bearing, or impact forces are reduced, bone tissue atrophies through remodeling. When bone atrophy occurs, the amount of calcium contained in the bone diminishes, and both the weight and the strength of the bone decrease. Loss of bone mass due to reduced mechanical stress has been found in bedridden patients, sedentary senior citizens, and astronauts. Four to six weeks of bed rest can result in significant decrements in bone mineral density that is not fully reversed after six months of normal weight-bearing activity. Bone demineralisation is a potentially serious problem. From a biomechanical standpoint, as bone mass diminishes, strength and thus resistance to fracture also decrease, particularly in trabecular bone. The results of calcium loss studies conducted during the Skylab flights indicate that urinary calcium loss is related to time spent out of the earth's gravitational field. The pattern of bone loss observed is highly similar to that documented among patients during periods of bed rest, with greater bone loss in the weight-bearing bones of the 32 years, the lumbar spine and lower extremity than in other parts of the skeleton. During one month in space, astronauts lose 1–3% of bone mass, or approximately as much bone mass as postmenopausal women lose in a year. It is not yet clear what specific mechanism or mechanisms are responsible for bone loss outside of the gravitational field. Research has consistently documented a negative calcium balance in astronauts and experimental animals during space flight, with reduced intestinal absorption of calcium and increased excretion of calcium. It is not known, however, whether this is caused by an increase in bone remodeling, a decrease in bone remodeling, or an imbalance between osteoblast and osteoclast activity. It appears that the normal balance between formation and desorption of bone becomes disturbed, with an initial increase in osteoclast activity followed by a prolonged decrease in osteoblast activity. One hypothesis is that these changes in bone remodeling are precipitated by changes in bone blood flow related to being outside of the gravitational field. More research on this topic is clearly needed. It remains to be seen if measures other than the artificial creation of gravity can effectively prevent bone loss during space travel. Astronauts' current exercise programs during flights in space are designed to prevent bone loss by increasing the mechanical stress and strain placed Loss of bone mass during periods of time spent outside of the earth's gravitational field is a problem for astronauts.

Some bones using muscular force. However, the muscles of the body exert mainly tensile forces on bone, whereas gravity provides a compressive force. Therefore, it may be that no amount of physical exercise alone can completely compensate for the absence of gravitational force. Recent research shows that resistive exercise combined with whole- body vibration may be an effective countermeasure for preventing muscle atrophy and bone loss during space flight. Researchers hypothesize that low-amplitude; high-frequency vibration stimulates muscle spindles and alpha Moto neurons, which initiate muscle contraction. The effects of several months' intervention treatment with whole-body vibration appear to include improved bone mineral density resulting from increased bone deposition coupled with decreased bone re-sorption, with bone density particularly improved in the femur and tibia. Since joints support the body weight positioned above them, the magnitude of skeletal loading varies from joint to joint during both resistance exercise and vibration.

OSTEOPOROSIS Bone atrophy is a problem not only for astronauts and bedridden patients but also for a growing number of senior citizens and female athletes. Osteoporosis is found in most elderly individuals, with earlier onset in women, and is becoming increasingly prevalent with the in-creasing mean age of the population. The condition begins as osteopenia, reduced bone mass without the presence of a fracture, but often progresses to osteoporosis, a condition in which bone mineral mass and strength are so severely compromised that daily activities can cause bone pain and fracturing.

COMMON BONE INJURIES

Because of the important mechanical functions performed by bone, bone health is an important part of general health. Bone health can be impaired by injuries and pathologies. A fracture is a disruption in the continuity of a bone. The nature of a fracture depends on the direction, magnitude, loading rate, and duration of the mechanical load sustained, as well as the health and maturity of Estrogen and testosterone deficiencies promote the development of osteoporosis.

Fractures are classified as simple when the bone ends remain within the surrounding soft tissues and compound when one or both bone ends protrude from the skin. When the loading rate is rapid, a fracture is more likely to be comminuted, containing multiple fragments. Avulsions are fractures caused by tensile loading in which a tendon or ligament pulls a small chip of bone away from the rest of the bone. Explosive throwing and jumping movements may result in avulsion fractures of the medial epicondyle of the humerus and the calcaneus. Excessive bending and torsional loads can produce spiral fractures of the long bones. The simultaneous application of forces from opposite directions at different points along a structure such as a long bone generates a torque known as a bending moment, which can cause bending and ultimately fracture of the bone. A bending moment is created on a football player's leg when the foot is anchored to the ground and tacklers apply forces at different points on the leg in opposite directions. When bending is present, the structure is loaded in tension on one side and in compression on the opposite side. Be-cause bone is stronger in resisting compression than in resisting tension, the side of the bone loaded in tension will fracture first. Torque applied about the long axis of a structure such as a long bone causes torsion, or twisting of the structure. Torsion creates shear stress throughout the structure, when a skier's body rotates with respect to one boot and ski during a fall, torsional loads can cause a spiral fracture of the tibia. In such cases, a combined loading pat-tern of shear and tension produces failure at an oblique orientation to the longitudinal axis of the bone. Since bone is stronger in resisting compression than in resisting tension and shear, acute compression fractures of bone (in the absence of osteoporosis) are rare. However, under combined loading, a fracture. According to Shier, Butler, and Lewis (1996) said a greenstick fracture is incomplete, and the break occurs on the convex surface of the bend in the bone. A fissured fracture involves an incomplete longitudinal break. A comminuted fracture is complete and fragments the bone. A transverse fracture is complete, and the break occurs at a right angle to the axis of the bone. An oblique fracture occurs at an angle other than a right angle to the axis of the bone. A spiral fracture is caused by twisting a bone excessively. Under excessive bending loads, bone tends to fracture on the side loaded in tension.

THE BIOMECHANICS OF HUMAN BONE GROWTH AND DEVELOPMENT

Resulting from a torsional load may also be impacted by the presence of a compressive load. An impacted fracture is one in which the opposite sides of the fracture are compressed together. Fractures that result in depression of bone fragments into the underlying tissues are termed depressed. Since the bones of children contain relatively larger amounts of collagen than do adult bones, they are more flexible and more resistant to fracture under day-to-day loading than are adult bones. Consequently, greenstick fractures, or incomplete fractures, are more common in children than in adults. A greenstick fracture is an incomplete fracture caused by bending or torsional loads. Stress fractures, also known as fatigue fractures, result from low- magnitude forces sustained on a repeated basis. Any increase in the magnitude or frequency of bone loading produces a stress reaction, which may involve micro damage. Bone responds to micro damage by remodeling: First, osteoclasts resorb the damaged tissue; then, osteoblasts deposit new bone at the site. When there is not time for the repair process to complete itself before additional micro damage occurs, the condition can progress to a stress fracture. Stress fractures begin as a small disruption in the continuity of the outer layers of cortical bone but can worsen over

time, eventually resulting in complete cortical fracture. In runners, a group particularly prone to stress fractures, about 50% of fractures occur in the tibia and approximately 20% of fractures are in the metatarsals, with fractures of the femoral neck and pubis also reported. Increases in training duration or intensity that do not allow enough time for bone remodeling to occur are the primary culprits. Other factors that predispose runners to stress fractures include muscular fatigue and abrupt changes in either the running surface or the running direction.
Epiphyseal Injuries About 10% of acute skeletal injuries in children and adolescents involve the epiphysis. Epiphyseal injuries include injuries to the cartilaginous impacted pressed together by a compressive load. Stress fracture resulting from repeated loading of relatively low magnitude stress reaction progressive bone pathology associated with repeated loading

Basic Biome chanic

Epiphyseal plate, the articular cartilage, and the apophasis. The apophyses are the sites of tendon attachments to bone, where bone shape is influenced by the tensile loads to which these sites are subjected. The epiphyses of long bones are termed pressure epiphyses and the apophyses are called traction epiphyses, after the types of physiological loading present. Both acute and repetitive loading can injure the growth plate, potentially resulting in premature closure of the epiphyseal junction and termination of bone growth. Another form of epiphyseal injury, osteochondrosis, involves disruption of blood supply to an epiphysis, with associated tissue necrosis and potential deformation of the epiphysis. The cause of the condition is poorly understood. Osteochondrosis occurs most commonly between the ages of 3 and 10 and is more prevalent among boys than girls. Osteochondrosis of an apophysis, known as apophysitis, is often associated with traumatic avulsions. Common sites for apophysitis are the calcaneus and the tibial tubercle at the site of the patellar tendon attachment, where the disorder is referred to respectively as Sever’s disease and Osgood-Schlatter’s disease.

SELF-ASSESSMENT EXERCISE

i. Describe different types of bones you know.
ii. Describe two common bone injuries.

4.0 CONCLUSION

- Bone's material composition and structural organisation have an effect on how it reacts to mechanical loading. Bone's composition and construction provide a substance that is both solid and light in weight.
- The bone composition is calcium carbonate; calcium phosphate, collagen, and water are the primary components of bone.
- Calcium carbonate and calcium phosphate make up about 60-70% of dry bone weight. These minerals are the main determinants of bone's compressive strength and stiffness.
- Bone tissue contains a large amount of water, which contributes to bone strength.
- Bone is a mineralised connective tissue that exhibits four types of cells: Osteoblasts, Bonelininingcells, Osteocytes, and Osteoclasts. Bone exerts important functions in the body, such as locomotion, support and protection of soft tissues, calcium and phosphate storage, and harboring of bone marrow.
- The 206 bones of the human body have unique structures and shapes that enable them to perform specific functions. The central or axis skeleton and the peripheral or appendicular skeleton are the two parts of the skeletal system.
- Bone growth begins early in fetal development, and living bone is continually changing in composition and structure during the life span. Many of these changes represent normal growth and maturation of bone.
- Bone responds dynamically to the presence or absence of different forces with changes in size, shape, and density.
- Bone health is an important part of general health; bone can be impaired by injuries and pathologies. A fracture is a disruption in the continuity of a bone.

5.0 SUMMARY

Bone is an important and dynamic living tissue. Its mechanical functions are to support and protect other body tissues and to act as a system of rigid levers that can be manipulated by the attached muscles. Bone's strength and resistance to fracture depend on its material composition and organisational structure. Minerals contribute to a bone's hardness and compressive strength, and collagen provides its flexibility and tensile strength. Cortical bone is stiffer and stronger than trabecular bone, whereas trabecular bone has greater shock-absorbing capabilities. Bone is an extremely dynamic tissue that is continually being modeled and remodeled in accordance with Wolff's law. Although bones grow in length only until the epiphyseal plates close at adolescence, bones

continually change in density, and to some extent in size and shape, through the actions of osteoblasts and osteoclasts. Osteoporosis, a disorder characterized by excessive loss of bone mineral mass and strength, is extremely prevalent among the elderly. It affects women at an earlier age and more severely than men. It is also present in an alarming frequency among young, eating-disordered, amenorrheic female athletes. Although the cause of osteoporosis remains unknown, the condition can often be improved through hormone therapy, avoidance of negative lifestyle factors, and a regular exercise program.

6.0 TUTOR-MARKED ASSIGNMENT

1) List and explain five mechanical functions of a bone.
2) List and explain five factors that can predispose a runner to stress fractures.
3) Describe how bones response to stress.

7.0 REFERENCES/FURTHER READING

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MODULE 3

INTRODUCTION

Movement is the temporary or permanent displacement of a body or its parts from its original position. Living beings and parts thereof move in response to stimulus from outside or from within the body. Locomotion, on the other hand, is the displacement of the entire body from one place to another. It is a characteristic feature of all animals, Protoctista and zoospores and zoogametes of lower plants.

UNIT 1 PRINCIPLES AND TYPES OF MOVEMENT

CONTENTS

1.0 INTRODUCTION

Principles and Types of Movement

Movement is one of the significant features of living beings. Animals and plants exhibit a wide range of movements. Streaming of protoplasm in the unicellular organisms like Amoeba is a simple form of movement. Movement of cilia, flagella and tentacles are shown by many organisms. Human beings can move limbs, jaws, eyelids, tongue, etc. Some of the movements result in a change of place or location. Such voluntary movements are called **locomotion**. Walking, running, climbing, flying, swimming are all some forms of locomotors movements. Locomotors structures need not be different from those affecting other types of movements. For example, in Paramecium, cilia helps in the movement of food through cytopharynx and in locomotion as well. Hydra can use its tentacles for capturing its prey and also use them for locomotion. We use limbs for changes in body postures and locomotion as well. The above observations suggest that movements and locomotion cannot be studied separately. The two may be linked by stating that all locomotion's are movements but all movements are not locomotion's.

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- analyse enthusiastically about movement patterns in sport
- state the fundamentals of defining joint movements anatomically
- discuss the differences – and the similarities – between qualitative and quantitative analysis of sports movements
- describe, from video observation or pictorial sequences, some simple sport and exercise movements, such as walking, running, jumping and throwing.

3.0 MAIN CONTENT

3.1 Types of Movement

Movement types are generally paired, with one directly opposing the other. Body movements are always described in relation to the anatomical position of the body: upright stance, with upper limbs to the side of body and palms facing forward.

Flexion and Extension

Flexion and **extension** are movements that take place within the sagittal plane and involve anterior or posterior movements of the body or limbs. For the vertebral column, flexion (anterior flexion) is an anterior (forward) bending of the neck or body, while extension involves a posterior-directed motion, such as straightening from a flexed position or bending backward. **Lateral flexion** is the bending of the neck or body toward the right or left side. These movements of the vertebral column involve both the symphysis joint formed by each intervertebral disc, as well as the plane type of synovial joint formed between the inferior articular processes of one vertebra and the superior articular processes of the next lower vertebra.

In the limbs, flexion decreases the angle between the bones (bending of the joint), while extension increases the angle and straightens the joint. For the upper limb, all anterior motions are flexion and all posterior motions are extension. These include anterior-posterior movements of the arm at the shoulder, the forearm at the elbow, the hand at the wrist, and the fingers at the metacarpophalangeal and interphalangeal joints. For the thumb, extension moves the thumb away from the palm of the hand, within the same plane as the palm, while flexion brings the thumb back against the index finger or into the palm. These motions take place at the first carpometacarpal joint. In the lower limb, bringing the thigh forward and upward is flexion at the hip joint, while any posterior-going motion of the thigh is extension. Note that extension of the thigh beyond the anatomical (standing) position is greatly limited by the ligaments that support the hip joint. Knee flexion is the bending of the knee to bring the foot toward the posterior thigh, and extension is the straightening of the knee. Flexion and extension movements are seen at the hinge, condyloid, saddle, and ball-and-socket joints of the limbs

Hyperextension is the abnormal or excessive extension of a joint beyond its normal range of motion, thus resulting in injury. Similarly, **hyperflexion** is excessive flexion at a joint. Hyperextension injuries are common at hinge joints such as the knee or elbow. In cases of "whiplash" in which the head is suddenly moved backward and then forward, a patient may experience both hyperextension and hyperflexion of the cervical region.

Abduction and Adduction

Abduction and **adduction** motions occur within the coronal plane and involve medial-lateral motions of the limbs, fingers, toes, or thumb. Abduction moves the limb laterally away from the midline of the body, while adduction is the opposing movement that brings the limb toward the body or across the midline. For example, abduction is raising the arm at the shoulder joint, moving it laterally away from the body, while adduction brings the arm down to the side of the body. Similarly, abduction and adduction at the wrist moves the hand away from or toward the midline of the body. Spreading the fingers or toes apart is also abduction, while bringing the fingers or toes together is adduction. For the thumb, abduction is the anterior movement that brings the thumb to a 90° perpendicular position, pointing straight out from the palm. Adduction moves the thumb back to the anatomical position, next to the index finger. Abduction and adduction movements are seen at condyloid, saddle, and ball-and-socket joints

Circumduction

Circumduction is the movement of a body region in a circular manner, in which one end of the body region being moved stays relatively stationary while the other end describes a circle. It involves the sequential combination of flexion, adduction, extension, and abduction at a joint. This type of motion is found at biaxial condyloid and saddle joints, and at multiaxial ball-and-sockets joints

Rotation

Rotation can occur within the vertebral column, at a pivot joint, or at a ball-and-socket joint. Rotation of the neck or body is the twisting movement produced by the summation of the small rotational movements available between adjacent vertebrae. At a pivot joint, one bone rotates in relation to another bone. This is a uniaxial joint, and thus rotation is the only motion allowed at a pivot joint. For example, at the atlantoaxial joint, the first cervical (C1) vertebra (atlas) rotates around the dens, the upward projection from the second cervical (C2) vertebra (axis). This allows the head to rotate from side to side as when shaking the head "no." The proximal radioulnar joint is a pivot joint formed by the head of the radius and its articulation with the ulna. This joint allows for the radius to rotate along its length during pronation and supination movements of the forearm.

Rotation can also occur at the ball-and-socket joints of the shoulder and hip. Here, the humerus and femur rotate around their long axis, which moves the anterior surface of the arm or thigh either toward or away from the midline of the body. Movement that brings the anterior surface of the limb toward the midline of the body is called **medial (internal) rotation**. Conversely, rotation of the limb so that the anterior surface moves away from the midline is **lateral (external) rotation**

Supination and Pronation

Supination and pronation are movements of the forearm. In the anatomical position, the upper limb is held next to the body with the palm facing forward. This is the **supinated position** of the forearm. In this position, the radius and ulna are parallel to each other. When the palm of the hand faces backward, the forearm is in the **pronated position**, and the radius and ulna form an X-shape.

Supination and pronation are the movements of the forearm that go between these two positions. **Pronation** is the motion that moves the forearm from the supinated (anatomical) position to the pronated (palm backward) position. This motion is produced by rotation of the radius at the proximal radioulnar joint, accompanied by movement of the radius at the distal radioulnar joint. The proximal radioulnar joint is a pivot joint that allows for rotation of the head of the radius. Because of the slight curvature of the shaft of the radius, this rotation causes the distal end of the radius to cross over the distal ulna at the distal radioulnar joint. This crossing over brings the radius and ulna into an X-shape position. **Supination** is the opposite motion, in which rotation of the radius returns the bones to their parallel positions and moves the palm to

the anterior facing (supinated) position. It helps to remember that supination is the motion you use when scooping up soup with a spoon
Dorsiflexion and Plantar Flexion

Dorsiflexion and **plantar flexion** are movements at the ankle joint, which is a hinge joint. Lifting the front of the foot, so that the top of the foot moves toward the anterior leg is dorsiflexion, while lifting the heel of the foot from the ground or pointing the toes downward is plantar flexion. These are the only movements available at the ankle joint

Inversion and Eversion

Inversion and eversion are complex movements that involve the multiple plane joints among the tarsal bones of the posterior foot (intertarsal joints) and thus are not motions that take place at the ankle joint. **Inversion** is the turning of the foot to angle the bottom of the foot toward the midline, while **eversion** turns the bottom of the foot away from the midline. The foot has a greater range of inversion than eversion motion. These are important motions that help to stabilize the foot when walking or running on an uneven surface and aid in the quick side-to-side changes in direction used during active sports such as basketball, racquetball, or soccer

Protraction and Retraction

Protraction and **retraction** are anterior-posterior movements of the scapula or mandible. Protraction of the scapula occurs when the shoulder is moved forward, as when pushing against something or throwing a ball. Retraction is the opposite motion, with the scapula being pulled posteriorly and medially, toward the vertebral column. For the mandible, protraction occurs when the lower jaw is pushed forward, to stick out the chin, while retraction pulls the lower jaw backward.

Depression and Elevation

Depression and **elevation** are downward and upward movements of the scapula or mandible. The upward movement of the scapula and shoulder is elevation, while a downward movement is depression. These movements are used to shrug your shoulders. Similarly, elevation of the mandible is the upward movement of the lower jaw used to close the mouth or bite on something, and depression is the downward movement that produces opening of the mouth

Excursion

Excursion is the side to side movement of the mandible. **Lateral excursion** moves the mandible away from the midline, toward either the right or left side. **Medial excursion** returns the mandible to its resting position at the midline.

Superior Rotation and Inferior Rotation

Superior and inferior rotation are movements of the scapula and are defined by the direction of movement of the glenoid cavity. These motions involve rotation of the scapula around a point inferior to the scapular spine and are produced by combinations of muscles acting on the scapula. During **superior rotation**, the glenoid cavity moves upward as the medial end of the scapular spine moves downward. This is a very important motion that contributes to upper limb abduction. Without superior rotation of the scapula, the greater tubercle of the humerus would hit the acromion of the scapula, thus preventing any abduction of the arm above shoulder height. Superior rotation of the scapula is thus required for full abduction of the upper limb. Superior rotation is also used without arm abduction when carrying a heavy load with your hand or on your shoulder. You can feel this rotation when you pick up a load, such as a heavy book bag and carry it on only one shoulder. To increase its weight-bearing support for the bag, the shoulder lifts as the scapula superiorly rotates. **Inferior rotation** occurs during limb adduction and involves the downward motion of the glenoid cavity with upward movement of the medial end of the scapular spine.

Opposition and Reposition

Opposition is the thumb movement that brings the tip of the thumb in contact with the tip of a finger. This movement is produced at the first carpometacarpal joint, which is a saddle joint formed between the trapezium carpal bone and the first metacarpal bone. Thumb opposition is produced by a combination of flexion and abduction of the thumb at this joint. Returning the thumb to its anatomical position next to the index finger is called **reposition.**

3.2 Defining Human Movements

Various terms are used to describe the three mutually perpendicular intersecting planes in which many, although not all, joint movements occur. The common point of intersection of these three planes is most conveniently defined as either the centre of the joint being studied or the centre of mass of the whole human body. In the latter case, the planes are known as cardinal planes – the sagittal, frontal and horizontal planes – as depicted and described below. Movements at the joints of the human musculoskeletal system are mainly rotational and take place about a line perpendicular to the plane in which they occur. This line is known as an axis of rotation. Three axes – the sagittal, frontal and vertical (longitudinal) – can be defined by the intersection of pairs of the planes of movement, as in. The main movements about these three axes for a particular joint are flexion and extension about the frontal axis, abduction and adduction about the sagittal axis, and medial and lateral (internal and external) rotation about the vertical (longitudinal) axes.

The sagittal plane is a vertical plane passing from the rear (posterior) to the front (anterior), dividing the body into left and right halves, as in. It is also known as the anteroposterior plane. Most sport and exercise movements that are almost two-dimensional, such as running and long jumping, take place in this plane The frontal plane is also vertical and passes from left to right, dividing the body into posterior and anterior halves, as in. It is also known as the coronal or the mediolateral plane.

- The horizontal plane divides the body into top (superior) and bottom (inferior) halves. It is also known as the transverse plane.
- The sagittal axis passes horizontally from posterior to anterior and is formed by the intersection of the sagittal and horizontal planes.
- The frontal axis passes horizontally from left to right and is formed by the intersection of the frontal and horizontal planes.
- The vertical or longitudinal axis passes vertically from inferior to superior and informed by the intersection of the sagittal and frontal planes. The movements of body segments are usually defined from the fundamental oranatomical reference postures – or positions – demonstrated by the athlete in. Note that the fundamental position is similar to a ‘stand to attention’, as is the anatomical position, except that the palms face forwards in the latte, By and large, this chapter focuses on movements in the sagittal plane about the frontal (or mediolateral) axis of rotation. Consider viewing a personside on, he bends his elbow and then straightens it. We call these movements’ flexion and extension, respectively, and they take place in the sagittal plane around the frontal axis of rotation.

Flexion is generally a bending movement, with the body segment – in the case of the elbow, the forearm – moving forwards. When the knee flexes, the calf moves backwards. The movements at the ankle joint are called plantar flexion when the foot moves downwards towards the rear of the calf, and dorsiflexion when the foot moves upwards towards the front of the calf. The movement of the whole arm about the shoulder joint from the anatomical reference position is called flexion, and its return to that position is called extension; the continuation of extension beyond the anatomical reference position is called hyperextension. The same terminology is used to define movements in the sagittal plane for the thigh about the hip joint. These arm and thigh movements are usually defined with respect to the trunk. Sports biomechanics normally use the convention that the fully extended position of most joints is 180°; when most joints flex, this angle decreases. Clinical bio-mechanists tend to use an alternative convention in which a fully extended joint is 0°, so that flexion increases the joint angle. We will use the former convention throughout Movements in the frontal plane about a sagittal axis are usually called abduction away from the body and adduction back towards the body, as in For some joints, such as the elbow and knee, these movements are not possible, or are very restricted. Movements in the horizontal plane about a vertical axis are usually called medial (or internal) and lateral (or external) rotation for the limbs, and rotation to the right or to the left for the trunk. The movements of the whole arm forwards from a 90°abducted position are horizontal flexion in a forward's direction and horizontal extension in a backwards direction.

3.3 Some Fundamental Movements

These people include the young and the old, male and female, who are shown walking, running, jumping and throwing in various conditions. These include: locomotion on a level and inclined treadmill Andover ground; vertical and broad jumping; underarm, sidearm and overarm throwing; indifferent footwear and clothing; and with and without skin markers to identify centres of rotation of joints. When analysing any human movement, ask yourself, 'What is the "constraints" on this movement?' The constraints can be related to the sports task, the environment or the organism. This 'constraints-led' approach serves as a very strong basis from which to develop an understanding of why we observe particular movement patterns. In the video examples and the sequences in the figures below, an environmental constraint might be 'over ground' or 'treadmill' (although this might also be seen as a task constraint). Jumping vertically to achieve maximum height is clearly a task constraint. Organismic constraints are, basically, biomechanical; they relate to a given individual's body characteristics, which affect their movement responses to the task and environ-mental constraints. These biomechanical constraints will be affected, among many other things, by genetic make-up, age, biological sex, fitness, injury record and stage of rehabilitation, and pathological conditions. Not surprisingly, the movement patterns observed when one individual performs a specific sports task will rarely be identical to those of another person; indeed, the movement patterns from repetitions of that task by the same individual will also vary – this becomes more obvious when we quantitatively analyze those movements, but can be seen qualitatively in many patterns of movement. These variable responses, often known as movement variability, can and do affect the way that movement analysts look at sports movements. The qualitative descriptions in the following sections will not, therefore, apply to every adult, but will apply to many so-called 'normal'. The developmental patterns of maturing children up to a certain age show notable differences from those for an adult, as in. A first step in the analysis of a complex motor skill is often to establish the phases into which the movement can be divided for analysis. For example, the division of a throwing movement into separate, but linked, phases is useful because of the sheer complexity of many throwing techniques. The phases of the movement should be selected so that they have a biomechanically distinct role in the overall movement, which is different from that of preceding and succeeding phases. Each phase then has a clearly defined biomechanical function and easily identified phase boundaries, often called key events. Although phase analysis can help the understanding of movement patterns, the essential feature of all sports movements is their wholeness; this should always be borne in mind when undertaking any phase analysis of a movement pattern.

Walking

Walking is a cyclic activity in which one stride follows another in a continuous pattern. We define a walking stride as being from touchdown of one foot to the next touchdown of the same foot, or from toe-off to toe-off. In walking, there is a single-support phase, when one foot is on the ground, and a double-support phase, when both are. The single-support phase starts with toe-off of one foot and the double-support phase start with touchdown of the same foot. The duration of the single-support phase is about four times that of the double-support phase. Alternatively, we can consider each leg separately. Each leg then has a stance and support phase, with similar functions to those in running. In normal walking at a person's preferred speed, the stance phase for one leg occupies about 60% of the whole cycle and the swing phase around40% in normal walking, the average durations of stance and swing will be very similar for the left and right sides. In pathological gait, there may be a pronounced difference between the two sides, leading to arrhythmic gait patterns. These illustrate differences between males and females, between young and older adults and young children, between over ground and treadmill locomotion and at different speeds and treadmill inclines, and with various types of footwear.

3.4 Movement Patterns

Most of you (readers of this book) will be undergraduate students in the earlier stages of your career. You will be familiar with human movement patterns from sport – when viewed live, or as a performer, coach or spectator – whether these are movement patterns of individuals or of teams as a whole. An example for an individual sport can be presented as a sequence of still video frames, as in most packages for qualitative video analysis make it easy to observe, and to compare, such movement patterns. Video recordings, still video sequences, and player tracking patterns in games are probably the most complex representations of sports movements that you will come across. It is only your familiarity with sports videos that enables you to understand such patterns – watch a video of a game or sporting activity for which you do not know the rules (environmental and task constraints), and the complexity of video representations of movement patterns becomes obvious. This is true not only for the movements of the segments of the body of one performer, which sports biomechanics generally focus on, but also for the movement patterns of the players as a team. Sequences of still video frames are rarely used in analysing player movements and interactions in team games, such as rugby, netball and soccer, or in individual vs. individual games, such as squash or table tennis. To understand why, imagine tracking (using the Global Positioning System, for example), just a single point on each player in one extended squash rally or, worse still, for each player in a soccer team for just 10 minutes of play. The resulting movement patterns would not be easy to analyse at first sight. Such movement patterns in games will not be considered further in this book – sports biomechanics, to date, have rarely been involved in analysing such movement patterns. To appreciate why I say that video recordings are complex, did you find it easy to follow all the flexion and extension descriptions for walking and running in the previous section? Could you easily perceive within-leg and between-leg coordination patterns in walking, or arm and leg coordination patterns in running, using the sequences above or videos from the book’s website? If your answers to these questions are a resounding ‘YES’, then you are already a talented qualitative movement analyst. Many of us struggle at times to extract what we want from video or from selected video picture sequences; for one thing they contain so much information that is irrelevant to the patterns the movement analyst wishes to observe.

3.5 Comparison of Qualitative and Quantitative Movement Analysis

Biomechanics provides information for a variety of kinesiology professions to analyse human movement to improve effectiveness or decrease the risk of injury. How the movement is analysed falls on a continuum between a qualitative analysis and a quantitative analysis. Quantitative analysis involves the measurement of biomechanical variables and usually requires a computer to do the voluminous numerical calculations performed. Even short movements will have thousands of samples of data to be collected, scaled, and numerically processed. In contrast, qualitative analysis has been defined as the "systematic observation and introspective judgment of the quality of human movement for the purpose of providing the most appropriate intervention to improve performance" (Knudson & Morrison, 2002). Analysis in both quantitative and qualitative contexts means identification of the factors that affect human movement performance, which is then interpreted using other higher levels of thinking (synthesis, evaluation) in applying the information to the movement of interest. Solving problems in human movement involves high levels of critical thinking and an interdisciplinary approach, integrating the many kinesiology sciences.

The advantages of numerical measurements of quantitative over those of qualitative analysis are greater accuracy, consistency, and precision. Most quantitative biomechanical analysis is performed in research settings; however, more and more devices are commercially available that inexpensively measure some biomechanical variables (e.g., radar, timing lights, timing mats, quantitative videography systems).

3.6 Key Mechanical Concepts

Mechanics

Before delving into how humans move, there are several mechanical terms and concepts that must be clarified. Mechanics is the branch of physics that studies the motion of objects and the forces that cause that motion. The science of mechanics is divided into many areas, but the three main areas most relevant to biomechanics are: rigid-body, deformable-body, and fluids.

In rigid-body mechanics, the object being analysed is assumed to be rigid and the deformations in its shape so small they can be ignored. While this almost never happens in any material, this assumption is quite reasonable for most biomechanical studies of the major segments of the body. The rigid-body assumption in studies saves considerable mathematical and modelling work without great loss of accuracy. Some biomechanists, however, use deformable-body mechanics to study how biological materials respond to external forces that are applied to them. Deformable-body mechanics studies how forces are distributed within a material, and can be focused at many levels (cellular to tissues/organs/ system) to examine how forces stimulate growth or cause damage. Fluid mechanics is concerned with the forces in fluids (liquids and gasses). A biomechanist would use fluid mechanics to study heart valves, swimming, or adapting sports equipment to minimise air resistance.

Application

Even though qualitative and quantitative analyses are not mutually exclusive, assume that qualitative versus-quantitative biomechanical analysis is an either/or proposition in the following exercise. For the sports medicine and athletics career areas, discuss with other students what kind of analysis is most appropriate for the questions listed. Come to a consensus and be prepared to give your reasons (cost, time, accuracy, need, etc.) for believing that one approach might be better than another.

The Major Branches of Mechanics Used in Most Biomechanical Studies

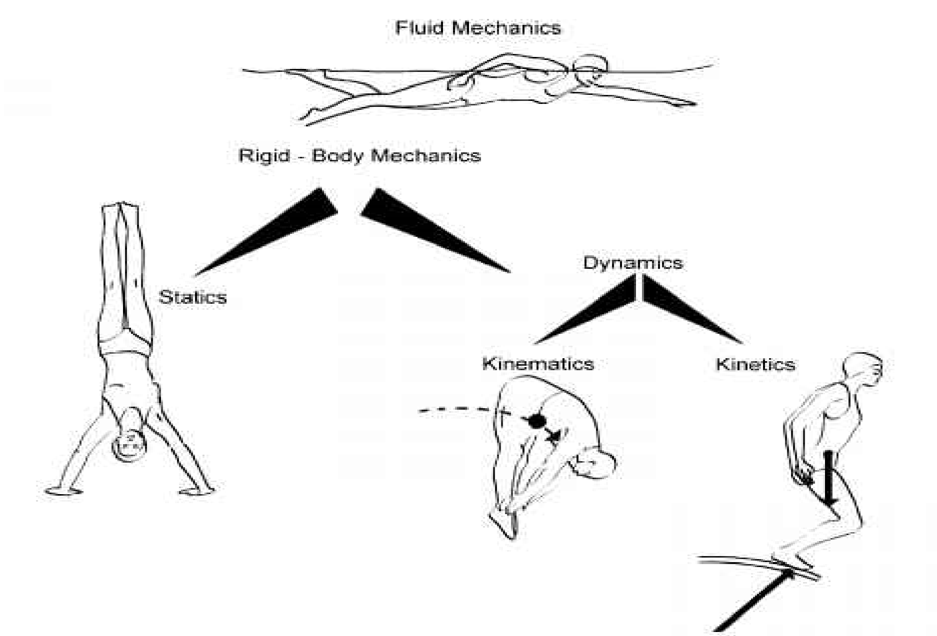
Most sports biomechanics studies are based on rigid-body models of the skeletal system. Rigid-body mechanics is divided into statics and dynamics. Statics is the study of objects at rest or in uniform (constant) motion. Dynamics is the study of objects being accelerated by the actions of forces. Most importantly, dynamics is divided into two branches: kinematics and kinetics. Kinematics is motion description. In kinematics the motions of objects are usually measured in linear (meters, feet, etc.) or angular (radians, degrees, etc.) terms. Examples of the kinematics of running could be the speed of the athlete, the length of the stride, or the angular velocity of hip extension. Most angular mechanical variables have the adjective "angular" before them. Kinetics is concerned with determining the causes of motion. Examples of kinetic variables in running are the forces between the feet and the ground or the forces of air resistance. Understanding these variables gives the track coach knowledge of the causes of running performance. Kinetic information is often more powerful in improving human motion because the causes of poor performance have been identified. For example, knowing that the timing and size of hip extensor action is weak in the take-off phase for a long jumper may be more useful in improving performance than knowing that the jump was shorter than expected.

Biomechanics often uses some of the most complex kinds of mathematical calculations, especially in deformable-body mechanics. Fortunately, most of the concepts and laws in classical (Newtonian) rigid-body mechanics can be understood in qualitative terms. Scalars are variables that can be completely represented by a number and the units of measurement. The number and units of measurement (10 kg, 100 m) must be reported to completely identify a scalar quantity. It makes no sense for a track athlete to call home and say, "Hey mom, I did 16 and 0"; they need to say, "I made 16 feet with 0 fouls." The number given a scalar quantity represents the magnitude or size of that variable. Vectors are more complicated quantities, where size, units, and direction must be specified.

Biomechanics commonly uses directions at right angles (horizontal/vertical, longitudinal/transverse) to mathematically handle vectors. Calculations of velocity vectors in a two-dimensional (2D) analysis of a long jump are usually done in one direction (e.g., horizontal) and then the other (vertical). The directions chosen depend on the needs of the analysis. When adding scalars with the same units, one plus one is always equal to two. Another important point related to vectors is that the sign (+ or -) corresponds to directions. A -10 lb force is not less than a +10 lb force; they are the same size but in opposite directions. The addition of vectors to determine their net effect is called the resultant and requires right-angle trigonometry.

There are two important vector quantities at the root of kinetics: force and torque. A force is a straight-line push or pull, usually expressed in pounds (lbs) or Newtons (N). The symbol for force is F. Remember that this push or pull is an interactional effect between two bodies. Sometimes this "push" appears obvious as in a ball hitting a bat, while other times the objects are quite distant as with the "pull" of magnetic or gravitational forces. Forces are vectors, and vectors can be physically represented or drawn as arrows. The important characteristics of vectors (size and direction) are directly apparent on the figure. The length of the arrow represents the size or magnitude (500 N or 112 lbs) and the orientation in space represents its direction (15 degrees above horizontal).

The corresponding angular variable to force is a moment of force or torque. A moment is the rotating effect of a force and will be symbolised by an M for moment of force or T for torque. This book will use the term "torque" synonymously with "moment of force." This is a common English meaning for torque, although there is a more specific mechanics-of-materials meaning (a torsion or twisting moment) that leads some scientists to prefer the term "moment of force." When a force is applied to an object that is not on line with the centre of the object, the force will create a torque that tends to rotate the object.



https://www.barnardhealth.us/qualitative-analysis/fundamentals-of-biomechanics-and-qualitative-analysis.html

Methods of Movement Analysis

A number of methods are used in analysing movement. The method selected depends on the knowledge and experience of the observer and the context in which the analysis is being performed. The three main methods of analysing the biomechanics of sport movements are movement phases, free body diagrams and deterministic models. Movement phases and free body diagrams are more frequently used by coaches and sports scientists, whereas deterministic models are used in more complex movement analysis and therefore more often in sports research.

Movement Phases

A sport movement, especially for ballistic actions such as hitting, throwing and kicking, generally contain three main phases:

Preparation

Execution

Follow-through

The preparation phase contains all of the movements that prepare an athlete for the performance of the skill, such as the backswing during cricket batting and the run-up in long jumping. The execution phase is the performance of the actual movement that often includes a point of contact with an object (e.g., contact of the baseball bat and ball), the release of an object (e.g., discus) or a flight phase (e.g., long jump). Finally, the follow-through refers to all of the movements that occur after the execution phase (e.g., leg lift after kicking a football) that slow the body's momentum to prevent injury, to get ready for another movement or both. These three main phases are often further broken into sub phases or key elements.

Overarm throwing such as baseball pitching has three sub phases for the preparation phase: the wind-up, the stride and arm cocking. Similarly, a standing shot in netball has three preparation sub phases: stabilisation and preparation, aiming and loading. Other more complicated sport actions such as gymnastics vaulting can also be broken into movement phases, sub phases and points of interest.

Gymnastics vaulting contains seven general phases: (1) the run-up; (2) the transition, which typically includes a hurdle step but may be also preceded by a round-off; (3) the board contact phase; (4) the pre-flight phase; (5) the table (horse) contact phase; (6) the post flight phase; and (7) the landing. The board contact phase can be broken into two sub phases, the downward compression (loading and storage of energy in the springs) of the board and the upward reaction (recoil of the springs imparting energy back to the gymnast). A point of interest, for example, is the gymnast's take-off angle from the board and the table contact angle at the end of the pre-flight phase.

Free Body Diagrams

A free body diagram is a visual diagram of the expected or predicted movement pattern; it is usually drawn as a simple stick figure. Coaches and researchers often use the technique to describe a sub phase or point of interest in a movement pattern. Coaches may use free body diagrams to communicate to athletes or to illustrate to other coaches what they believe is good technique.

In research, a free body diagram defines the extent of the analysis and identifies the significant forces involved in the action using arrows, along with the directional coordinates relevant to that movement pattern (e.g., a two-dimensional or three-dimensional coordinate system). The free body diagram typically shows only the forces acting on the system and not those within the system (e.g., muscle forces).

Deterministic Models

A deterministic model is a concept map that describes the biomechanical factors determining a movement or action, starting with the primary performance factor(s) (e.g., jump displacement for long jump, race time in sprinting), followed by a breakdown into secondary factors (or derivatives) and so on. Hence, a deterministic model can have many levels.

Regardless of the technique employed, movement analysis requires careful planning. These techniques may also suit qualitative or quantitative analyses of movement. Qualitative analysis assesses the technical quality of the movement (e.g., rhythm, posture), whereas quantitative techniques assess the movement using numbers (e.g., angles, distance, speed, force).

https://us.humankinetics.com/blogs/excerpt/methods-of-movement-analysis

SELF-ASSESSMENT EXERCISE

i. Describe different types of fundamental movements you know.

4.0 CONCLUSION

- Movement is one of the significant features of living beings. Human beings can move limbs, jaws, eyelids, tongue, etc. some of the movements result in a change of place or location.
- Locomotion is one of the voluntary movements which can be walking, running, climbing, flying, swimming. Movement and locomotion are two words linked together by stating that all locomotion's are movements but all movements are not locomotion's.
- Movement at the joints of the human musculoskeletal system is mainly rotational and takes place about a line perpendicular to the plane in which they occur.
- The common point of intersection of these three planes is the Centre of the joint being studied or the Centre of mass of the whole human body and they are known as cardinal planes (sagittal, frontal and horizontal planes).
- The likely constraints on movement such as the sport task, the environment and the organism (genetic make-up, age, sex, fitness and injury records, etc.)

5.0 SUMMARY

Movement is the temporary or permanent displacement of a body or its parts from its original position. While locomotion is the displacement of the entire body from one place to another. Movement is one of the significant features of living beings and all animal and plants exhibit a wide range of movements.

Terms are used to describe the three mutually perpendicular intersecting planes in which many, although not all, joint movement occur. The three cardinal planes are as follows:- sagittal, frontal and horizontal planes.

Most sport and exercise movements that are almost two-dimensional, such as running and long jumping, take place in this plane the frontal plane is also vertical and passes from left to right. Dividing the body into posterior and anterior halves, as in. it is also known as the coronal or the mediolateral plane.

Sports biomechanics normally use the convention that the fully extended position of most joint is 180 degrees; when most joints flex, this angle decreases. Clinical biomechanist tend to use alternative convention in which a fully extended joint is 0, so that flexion increases the joint angle.

6.0 TUTOR-MARKED ASSIGNMENT

1. List and describe six different voluntary movements you know.
2. List three types of constraint that can affect an individual movement patterns.

7.0 REFERENCES/FURTHER READING

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UNIT 2 FORMS OF LOCOMOTION AND LEVELS

CONTENTS

1.0 INTRODUCTION

The human musculoskeletal and neural-motor system is highly optimised for efficient locomotion. Efficiency, stability and voluntary modulation of human gait are a result of a combination of features spanning the human musculoskeletal, sensorimotor and neural systems. Salient aspects of these systems include (1) the functional morphology, (2) the synergistic coordination of motor activity, (3) the phase dependent modulation of muscle activity and (4) cognitive skills. On the one hand, the functional morphology is highly optimised for efficient biped locomotion as it allows exploiting the inherent dynamics to reduce energy consumption and control effort, and result in natural looking motions. Also a contribution of this functional morphology is the capability of self-stabilisation, since the elastic properties of muscles and tendons increase stability without active control. On the other hand, the synergistic feed-forward motor patterns, be it activated at kinetic or kinematic events or due to learned timing, create coordinated synergies of movement. Whilst feedback control occurs at various levels of complexity regarding the extension of perception and deployment of muscle action, phase-dependent modulation is a function of the current task or phase of motion and as a result reflex action can be modulated, reinforced, or suppressed. Eventually, cognition plays a crucial role in learning and predicting the sensory consequences of actions, helping to deal with feedback time delays and allowing for planning the appropriate compensative actions (active and passive)

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- analyse enthusiastically about Functional Morphology of the Human Musculoskeletal System
- identify the Role of Reflex Function for Stabilisation of Locomotion.

3.0 MAIN CONTENT

3.1 Functional Morphology of the Human Musculoskeletal System

Research on the biomechanics of human locomotion provides valuable insights into basic principles for motor control. Human legged locomotion is so efficient partially because it does not power movements with independent motor actions at each joint. Muscles often span multiple joints, which results in energy-saving and power transfers when a movement simultaneously requires negative power at one joint and positive power at another joint. This allows making effective use of passive elastic properties to generate part of the required force or power without metabolic cost, especially when muscle-tendon units span multiple joints. Furthermore, multiple muscles spanning a joint allow efficient modulation of joint stiffness during dynamic movements, making fast adaptation to uneven surfaces and terrains possible. Passive dynamic walking introduced, as a model, in under-actuated bipedal walkers and robots shows emerging, natural-looking walking gait with remarkable similarities to human walking. In this regards, passive dynamic walking, first introduced by Mc Geer, exploits the mechanical potential energy gained while walking down a slope, showing a stable gait without any or limited control or actuation. Limit Cycle (LC) walking machines represent a step forward in this direction. They combine the exploitation of passive dynamics with minimal feed-forward actuation in order to replenish energy losses and to increase stability. Examples of LC walking prototypes have been developed by TU Delft, Cornell University and MIT. The Cornell and Delft bipeds demonstrate that basic walking can be accomplished with extremely simple control and very low energy consumption. However, due to absence of feedback control, passive dynamics bipeds cannot react to disturbances or external forces, even though human-like gait is achieved, walking is unstable as all other stabilisation mechanisms found in humans are still lacking.

3.2 Role of Reflex Function for Stabilisation of Locomotion

Bipedal plantigrade walking in humans is unique compared to digitigrade locomotion in animals, in that the stance phase is made by ground contact first by the heel, then the foot sole and finally the toes. In addition, Pons, Moreno, Torricelli and Taylor afforded by maximal activation of the quadriceps muscle mediated via reflex mechanisms, focused to maintain balance during sudden perturbations. These reflex mechanisms are even more important to maintain balance during walking on uneven surfaces, and are mainly organised at the Trans cortical level in humans. Activity within reflex pathways during normal walking is organised to mediate an opposite effect on the ankle and knee extensor Moto neuron pools. As such under normal conditions reflex mechanisms are organised to permit maximal quadriceps muscle activation with knee joint stabilisation during the early stance phase, in addition to inhibition of ankle extensor muscle hyperactivity. Specifically at the beginning of the stance phase, quadriceps contraction is maintained by a combination of control mechanisms including facilitation of GpI-II afferent input from Tibialis Anterior (in addition to Biceps muscle activation), excitatory cutaneous input from the foot, and reduced recurrent and presynaptic inhibition. In parallel prevention of Triceps Surae hyperactivity is mediated via an almost total absence of IA heteronymous connections, a strong increase in presynaptic inhibition of Ia terminals, and a strong propriospinal mediated inhibition of plantar flexors evoked from intrinsic plantar muscle activation. Stabilisation of the ankle joint during the stance phase is mediated by low activity within recurrent and reciprocal Ia inhibitory mechanisms between ankle muscles. In addition, stretch reflexes evoked within the Tibialis Anterior and Soleus muscles and mediated at the spinal and Trans cortical level, may contribute significantly to stabilisation during the stance phase.

A separate set of control mechanisms are important for walking during unexpected perturbations, with an important role for afferent muscle and/or cutaneous feedback necessary to regain stabilisation. Under such conditions, stretch-induced responses provide stability during the stance phase, important for example when the ground may give way or during foot slip, while cutaneous reflex activity is organised to permit foot clearance from an unexpected obstacle. Importantly reflex reactions under conditions of external perturbation are mediated mainly via Trans cortical pathways, which allows for an additional level of voluntary control during the perturbation to either stop movement or to shift weight onto the other leg. Significant stretch reflex responses mediated by GpIa or II afferents, or as trans cortical responses, are mostly active during the stance but not swing phase. Additional ankle support is mediated via antagonistic ankle muscle stretch reflexes via heteronymous Ia input. In contrast, activation of low-threshold cutaneous reflex responses in ankle and knee flexors during the swing phase, are probably mediated via spinal, spino-bulbo-spinal and trans cortical control mechanisms, which also depend on the stimulation of specific skin areas. In general, cutaneous reflexes are tuned to withdraw the perturbed leg away from the perturbing stimulus, while maintaining voluntary muscle function during walking.

3.3 Modular Control of Movement

According to the hypothesis of modular control muscle activations appear to be ruled by a low-dimensional set of descending inputs mediated by arrays of weighted connections, namely muscle synergies. Experimental evidences in animals and humans, over a wide range of motor functions, have mathematically confirmed this hypothesis, showing that multiple EMG can be reconstructed by the combination of a few activations and muscle synergy vectors. For instance, in locomotion, 4 to 5 motor modules (synergies) are sufficient to accurately describe the activity of all the main muscles involved. Nevertheless, the physiological plausibility of this hypothesis is still controversial. Several questions have been coming out during the last years in the scientific community. Do muscle synergies and activations correspond to real neural mechanisms? Is the dependency between muscle activations just a result of biomechanical constraints? Can muscle synergies reflect specific neuromuscular pathologies? In order to answer these and more questions, different experimental approaches have been proposed. Here, we classify them into in-vivo and in-vitro approaches. In-vivo approaches rely on the analysis of biomechanical and muscular behavior of biological structures. Kutch and Valero-Cuevas presented an experiment on a cadaveric human hand to show that synergistic patterns come out with no need of any neural intervention. Increasing studies rely on the analysis of neurologically impaired people to show correlations between neural injury and muscle synergy organisation. More recently, experiments in force-field scenarios have been proposed as a way to find correlation between muscle synergies and motor learning. None of the proposed studies have given a clear demonstration on the neural origin of the synergistic behavior, possibly because all these in-vivo approaches are characterised by an intrinsic difficulty of separating the biomechanical constraints from the neural factors. In addition, during in-vivo experiments, many unknown mechanisms intervene - such as sensory feedback processing, inter limb coordination, spasticity and other neurologically related mechanisms - which may mask the targeted principles. In-vitro approaches are gaining relevance as a valuable tool to validate specific mechanisms while minimising unknown factors. The two main actors of this kind of approach are neuro-musculoskeletal modeling and robotics. Neuro-musculoskeletal modeling is a very powerful method that permits to predict the effects of muscular activity on multi-limb dynamics, as well as to simulate the neural drive and its effect on muscle dynamics. This approach has been mainly used to demonstrate a clear correlation between synergies and motor functions. Recently, an interesting comprehensive integration of human biomechanical principles within a synergistic control framework has been also proposed in simulated environment. In comparison to neuro-musculoskeletal modeling, robotics permits on the one hand to create real-life representation of the human neuro-musculoskeletal system, which allow dealing with uncertainties and dynamics that are difficult to reproduce in simulated environments. On the other hand, the technical limitations of the robotic solutions prevent them to reproduce the high degree of freedom of human musculoskeletal system. In our opinion, the complementary potentials of in-vitro and in-vivo approaches can be integrated to find out effective solutions for the validation of the modular control hypothesis. The biomechanics of Locomotion is the result of an intricate coupling between the neural dynamics and the body dynamics, and many fundamental aspects of locomotion control including gait transition, control of speed and direction, cannot be fully understood by investigating the locomotor circuit in isolation from the body it controls. A body has indeed its own dynamics and intrinsic frequencies with complexion-linear properties, to which the neural signals must be adapted for efficient locomotion control. As observed byroboticist Marc Raibert, the central nervous system does not control the body, it can only make suggestions. The body is a redundant system with many muscles per joint, and several muscles acting on more than one joint. Muscles serve as actuators, brakes, stiffness regulators, and stores of elastic energy. During locomotion, the frequencies, amplitudes, and phases of the signals sent to the multiple muscles must be well orchestrated. In most vertebrates, complex coordination is required not only between different joints and limbs, but also between antagonist muscles which combine periods of co activation for modulating the stiffness of the joint, and periods of alter-nation for actuating the joint. In legged locomotion, the dynamics of a leg can be approximated by a pendulum model during walking, and aspring-mass model during running. These models allow one to relate several features, such as resonance frequencies, to the length and stiffness of the legs, and are able to describe the mechanics of legged locomotion surprisingly well in many animals. The importance of the mechanical properties of the body is illustrated by research on passive walkers. Passive walkers are legged machines (some with knees and arms) which transform potential energy from gravity into kinetic energy when walking down a gentle slope. When correctly designed, these machines do not require any actuation or control for generating a walking gait, which in some cases, can be strikingly human-like.

SELF-ASSESSMENT EXERCISE

i. describe different types of fundamental movements you know.
ii. List and describe different voluntary movements you know.

4.0 CONCLUSION

- The human musculoskeletal and neural-motor system is highly optimised for efficient locomotion and they both work hand I hand.
- Efficiency, stability and voluntary modulation of human gait are a result of a combination of features spanning the human musculoskeletal and neutral systems.
- Contribution of the functional morphology is the capacity of self-stabilisation, since the elastic properties of muscles and tendons increase stability without active control.
- Important of multiple muscles spanning a joint allow efficient modulation of joint stiffness during dynamic movements, making fast adaptation to uneven surfaces and terrains possible.
- Passive dynamic walking introduced, as a model, in under actuated bipedal walkers and robots shows emerging,naturallooking walking gait with remarkable similarities to human walking.
- Bipedal plantigrade walking in humans is unique compared to digitigrade locomotion in animals, in that the stance phase is made by ground contact first by the heel, then the foot sole and finally the toes.
- Relex mechanisms are even more important to maintain balance during walking on uneven surfaces, and are mainly organised at the trans cortical level in humans.
- Modular control of movement was confirmed since the approach has been mainly used demonstrate a clear correction between synergies and motor functions.
- Passive walkers are legged machine which transform potential energy from gravity into kinetic energy when walking down a gentle slope.

5.0 SUMMARY

The human musculoskeletal and neural-motor systems are highly optimised for efficient locomotion. Efficiency, stability and voluntary modulation of human gait are a result of a combination of features spanning the human musculoskeletal, sensorimotor and neutral systems.

Salient aspects of these systems include: the functional morphology, the synergistic coordination of motor activity, and cognitive skills.

A contribution of this functional morphology is the capability of self-stabilisation, since the elastic properties of muscles and tendons increase stability without active control. Again, cognition plays a crucial role in learning and predicting the sensory consequences of actions, helping to deal with feedback time delays and allowing for planning the appropriate compensative actions.

Muscles often span multiple joints, which results in energy-saving and power transfers when a movement simultaneously requires negative power at one joint and positive power at another joint. This allows making effective use of passive elastic properties to generate part of the required force or power without metabolic cost, especially when muscle-tendon units span multiple joints.

The reflex mechanisms are even more important to maintain balance during walking on uneven surfaces, and are mainly organised at the trans cortical level in humans. Activity within reflex pathways during normal walking is organised to mediate an opposite effect on the ankle and knee extensor motor neuron pools.

The biomechanics of locomotion is the result of an intricate coupling between the neutral dynamics and the body dynamic, and many fundamental aspects of locomotion control including gait transition, control of speed and direction, cannot be fully understood by investigating the locomotion circuit in isolation from the body it controls.

The body is a redundant system with many muscles per joint, and several muscles acting on more than one joint. Muscles serve as actuators, brakes, stiffness regulators, and stores of elastic energy. During locomotion, the frequencies, amplitudes, and phrases of the signals sent to the multiple muscles must be well orchestrated.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe different functional morphology of the human musculoskeletal system you know,
2. Mention and describe different role of reflex function for stabilisation of locomotion.

7.0 REFERENCES /FURTHER READING

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Ref. J.L. Pons, Member, IEEE, J.C. Moreno, D. Torricelli and J.S. Taylor-**Principles of human locomotion: a review**

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MODULE 4

CONTENTS

1.0 INTRODUCTION

Is it best to observe walking gait from a side view, front view, or back view? From what distance can a coach best observe a pitcher's throwing style? What are the advantages and disadvantages of analysing a movement captured on video? To the untrained observer, there may be no differences in the forms displayed by an elite hurdler and a novice hurdler or in the functioning of a normal knee and an injured, partially rehabilitated knee. What skills are necessary and what procedures are used for effective analysis of human movement kinematics? One of the most important steps in learning a new subject is mastering the associated terminology. Likewise, learning a general analysis protocol that can be adapted to specific questions or problems within a field of study is invaluable. In this chapter, human movement terminology is introduced, and the problem-solving approach is adapted to provide a template for qualitative solving of human movement analysis problems

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this chapter, you will be able to:

- state the kinds of motion experienced by the human body, and describe the factors that cause and modify motion
- identify and properly use the terms that describe linear and rotary motion: *position*, *displacement*, *distance*, *speed*, *velocity*, and *acc eleration*
- explain the interrelationships that exist among displacement, velocity, and aceleration, and use the knowledge of these interrelationships to describe and analyse human motion
- describe the relationship between linear and rotary movement, and explain the significance of this relationship to human motion
- identify the critical kinematic components that would be used to fully describe the skillful performance of a selected motor task.

If we are to understand the movements of the human musculoskeletal system and the objects put into motion by this system, we need first to understand the concepts of motion itself. There are questions that demand answers, they include:

a. What is motion?
b. What determines the kind of motion that will result when an object or a part of the human body is made to move?
c. How is motion described in mechanical terms?
d. How do these generalities about motion apply to movements of the musculoskeletal system?
e. How does one know that motion is occurring?

3.0 MAIN CONTENT

3.1 Motion

Motion is the act or process of changing place or position with respect to some reference object. Whether a body is at rest or in motion depends totally on the reference, global or local. When a person is walking down the street or riding a bicycle or serving a tennis ball, it seems obvious that movement is involved. Less obvious is the motion status of the sleeping passenger in a smoothly flying plane or of an automobile parked at a curb. On the other hand, if the bicycle is the reference point, the person riding it is at rest relative to the bicycle, and the sleeping passenger is at rest with respect to anything in the plane. The relative motion of each is defined in relation to the specific reference object or point. It is possible, therefore, to be at rest and in motion at the same time relative to different reference points. The sleeping passenger is at rest relative to the plane and in motion relative to the earth. Furthermore, the relative motion of two bodies depends entirely on their relative velocities through space. Two joggers running at 8 km/hr in the same direction are at rest with respect to each other. However, if one jogs at 8 km/hr and the other at 10 km/hr, the slower jogger would be considered to be at rest with respect to the other.

3.2 Categories of Motion

Quick revise
There are three main categories:

- Linear Motion is when all of a body moves in a line (straight or curved) with all parts moving in the same direction.
- Angular Motion is when a body or part of it moves in a circle (or part of) about a point called the axis of rotation.
- General Motion is a combination of linear and angular motion.

Linear Motion &Biomechanics

Fig. 4.1: Linear Motion

Linear motion means motion in a straight line (as opposed to circular motion or rotation). In order to talk about linear motion scientifically, we need to be familiar with mass, distance, displacement, speed, velocity, and acceleration. Here we consider Newton's laws of motion, mass, inertia, momentum, speed, velocity, distance, displacement and graphs of motion.

Speed and Velocity

This explains the difference between distance and displacement, vector and scalar quantities as well as speed and velocity in sport and how to do calculations. What is the difference between distance and displacement? Displacement is how far away a body has moved from its starting point.

Acceleration

Acceleration is the rate at which a body changes its velocity and, similarly to velocity, it is a vector quantity which means it has a direction as well as a magnitude. It is measured in m/s/s or metres per second per second (metres per second squared – ms-2).

Newton's Laws of Motion

Sir Isaac Newton stated three laws that explain the relationship between force and movement. Having a good understanding of Newton's laws, that can be applied to sporting situations, will allow you to gain a deeper understanding of sports techniques.

Mass, Inertia, and Momentum

Inertia is the reluctance of a body to change whether it is moving or not and is related to its mass. Once a body is moving the momentum of the body is a product of its mass multiplied by its velocity.

Fig. 4.2: Mass, Inertia and Momentum

Angular Motion

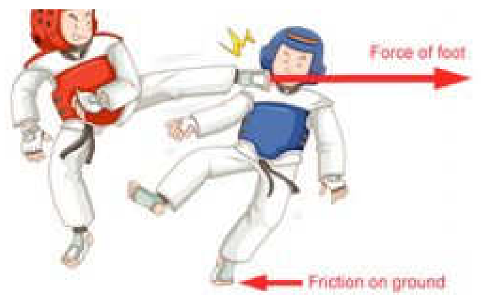

Fig. 4.3: Angular Motion

3.3 Types of Motion

Rectilinear, Circular and Periodic Motion - with examples

- Rectilinear Motion: Motion of the object in straight line path is called rectilinear motion. For example: Motion of train on track, motion of ants in a straight path, motion of freely falling stone from top of the building towards the ground.

When we require only one co-ordinate axis along with time to describe the motion of a particle it is said to be in linear motion or rectilinear motion. Some examples of linear motion are a parade of soldiers, a train moving along a straight line, and many more.

Distance and Displacement

So now that we have learned about linear motion we will discuss two terms related to change in position. These are called – 'Distance' and 'Displacement'.

Distance is defined as, the total path length covered during a journey

- Circular Motion: Motion of object in a circular path is called circular motion. For example: Children moving in a circle, motion of Earth around the Sun.
- Periodic Motion: Motion of a object which repeats itself after a certain period of time is called periodic motion. For example: Motion of Earth around the sun is periodic as well as circular as it repeats it motion after time of 365 days. Motion of simple pendulum is periodic. Motion of minute and second hand in a watch is periodic.
-

Examples of different Types of Motion

Types of Motion	Examples
1Rectilinear	a) March past by the soldiers in straight line. b)Motion of falling objects from certain height
2Circular	a) Motion of satellites around planets. b) Motion of car turning to a curved track
3Rotational	a) Motion of giant wheel b) Motion of wheels of moving vehicle
4Periodic	a) Motion of simple pendulum b) Motion of Earth on its own axis.

SELF -ASSESSMENT EXERCISE

i. Describe different types of motion experienced by the human body.
ii. Describe how individuals can know that motion is occurring.

4.0 CONCLUSION

- Motion is the act of changing place or position with respect to some reference object, whether a body is at rest or in motion depends totally on the situation.
- The relative motion of two bodies depends entirely on their relative velocities through space,
- The three mainly categories of motion are: linear, Angular and General motion.
- Speed and velocity explain clearly that the difference between distance and displacement, vector and scalar quantities as well as speed and velocity in sport and how to do calculations.

5.0 SUMMARY

One of the most important steps in learning a new subject is mastering the associated terminology. Likewise, learning a general analysis protocol that can be adapted to specific questions or problems within a field of study is invaluable. Human movement's terminology was also introduced and the problem-solving approach is adapted to provide a template for qualitative solving of human movement analysis problems.
Motion is the act or process of changing place or position with respect to some reference object. Whether a body is at rest or in motion depends totally on the reference, global or local. When a person is walking down the street or riding a bicycle or serving a tennis ball, it seems obvious that movement is involved. Less obvious is the motion status of the sleeping passenger in a smoothly flying plane or of an automobile parked at a curb.

The three categories of motion are as follows: linear motion which h means motion in a straight line. In this case you need to familiarise yourself with mass, distance, displacement, speed, velocity and acceleration. Angular motion is when a body or part of it moves in a circle about a point called the axis of rotation. General motion is a combination of linear and angular motion.

6.0 TUROR-MARKED ASSIGNMENT

1. Define Motion?
2. Describe types of motion you know.

7.0 REFERENCES/FURTHER READING

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Peter McGinnis (2013): Biomechanics of Sport and Exercise. (3rd ed.) Thomas-shore, Inc. web site: www. Humankinetics.com/Biomechanics of Sport and Exercise.

UNIT 2 CONCEPT AND PRODUCTION OF FORCE

CONTENT

1.0 INTRODUCTION

What is Force?

Force is a word for pushing or pulling. If I push on something or pull on it, then I am applying a force to it. Force makes things move or, more accurately, makes things change their motion. Two natural forces that we have experienced are the force of gravity and magnetic forces magnetic forces.

These two forces act at a distance and do not require direct contact between the objects to function. Gravity produces a force that pulls objects towards each other, like a person towards the ground. It is the force that keeps the Earth revolving around the sun and it's what pulls you toward the ground when you trip.

Fig. 4.4: Force

2.0 INTENDED LEARNING OUTCOMES (ILOS)

By the end of this unit, you will be able to:

- identify Principles of force in sports
- state General Principles of Force
- discuss the Principles concerning Athlete-Product Force.

3.0 MAIN CONTENT

3.1 Principles of Force in Sports

Principles of force offer guidance for teaching sport techniques and leveraging training strategies that require the development of force--pushing or pulling. Force is the product of the mass (weight) and acceleration of an object or person. These principles and examples concern (a) general applications, (b) athlete-produced force, and (c) force dissipation.

3.2 General Principle of Force General Principles of Force

1. Total force (velocity) is the sum of all the forces contributed by each body part. In any explosive skill, each force in sequence should be applied at the peak of the previous force. Examples include throwing a ball and performing a power clean, shooting in handball.
2. Force is used more economically when it is applied constantly and evenly. For example, a swimmer moves more efficiently when moving at constant speed and with smooth application of force. Or a 400-meter relay runner or middle-distance races.
3. All forces should be applied in the intended direction. Deviations from the required line of force waste energy. For example, a runner who points his toes outward or bounces excessively exerts wasted force and energy. A racket player losing focus.
4. Greater velocity is generated if force is applied over a longer distance. For example, an outfielder can generate greater force for throwing to home plate by using a long winding up, rotating the trunk, shifting body weight from the back leg to the front, and following through.

3.3 Principles Concerning Athlete-Product Force

1. To achieve maximum force, use larger muscles in the lower body before actions of the trunk and upper body. For example, the

force of a punch in boxing or throwing is greater when initiated from the lower body and hips, rather than from the shoulders.

2. Maintain a firm base of support to develop maximum force for throwing and striking. For example, a tennis player can generate a more powerful stroke if the feet are firmly set against the surface of the court.
3. Force generated by muscles can be increased by increasing initial tension before a contraction. This increase in force production is called *elastic recoil,* or the *stretch-shortening cycle.* For example, drawing the arm back to pitch a ball or throw a javelin places the muscles of the throwing arm on stretch, increasing the force of contraction upon the initiation of the throw.
4. Executing a follow through at the end of a throwing or striking action maximises force generation and eliminates the tendency to decelerate prematurely. For example, reversing the feet at the end of the shot put or discus maximises acceleration while helping prevent fouling.

3.3 Principles Concerning Force Absorption

Fig. 4.5: Force Absorption

1. The force of a blow can be diminished by distributing the force over a greater time, distance, or area. For example, flexing the joints or rolling on the ground can help an athlete absorb the shock of landing at the end of jump or fall.
2. Transferring momentum from vertical to horizontal can reduce force over a longer time and greater surface area. For example, football players fall and roll to dissipate the force of hitting the ground.

3. Catching objects should be accomplished by extending the arms and fingers, flexing to absorb force and reduce the velocity of the object, and grasping with the fingers to secure the object.

Mechanical Principles: The Rules of Sport Skill Technique

Introduction

Mechanical principles applied to sports are rules that govern the efficient execution of skills. Using these rules as guides, athletes can build excellent technique and gain the greatest mechanical advantage. Newton's Laws of Motion are the foundation for these mechanical principles, which must be applied in concert with other sports training principles to achieve higher levels of sport performance.

Principles from the Law of Inertia

1. To achieve skilled movements, athletes must effectively combine linear and angular motion. For example, a discus thrower's body must move in a straight path from the back to the front of the ring while rotating with increasing velocity.

2. When two or more motions are required, athletes must execute movements continuously in sequence. For example, if a javelin thrower hesitates or stops at the end of the approach just prior to the throw; the advantage of the approach is lost.

3. Athletes can increase mass and/or velocity to realise proportional gains in momentum. For example, if a football player gains both weight and speed, it is more difficult for an opposing player to alter his path.

4. Transfer momentum efficiently from each segment to the whole body**.** For example, a sprinter coming out of the starting blocks uses the driving action of his or her arms to contribute to the total momentum and direction of the body.

Fig. 4.6: Application of Law of Inertia

Principles from the Law of Acceleration

1. Acceleration is proportional to force. For instant, a sprinter increases acceleration by increasing the force that he applies against the track. Increasing force by 20% causes a 20% increase in acceleration. If he could lose fat weight but maintain the same level of force (power), acceleration would also increase. Then the performance will be recognised.
2. Maximum acceleration is achieved when all body forces are coordinated in the intended direction. Body actions that do not contribute to a skill should be minimised to prevent wasted energy from productive movements. For example, a swimmer coordinates the body actions to generate maximum force while minimising unnecessary movements that cause excessive bobbing or lateral deviations.
3. When rotating, lengthening the radius slows the rotation and shortening the radius increases rotation. For example, a diver rotates faster when the tuck is tightened, creating a shorter body radius. A pike produces slower rotation because the radius is longer.
4. When jumping, the path in the air is set upon take off. Once a long jumper is in the air, his or her arms or legs may cause body rotation, but the flight path is not affected.

Principles from the Law of Counterforce

1. Maximise counterforce with stable surfaces. If a surface is stable, it offers the same amount of force back as is generated against it. The less stable the surface, the less counterforce is returned. For example, sand does not offer a stable surface for running as compared to a concrete surface.
2. To achieve maximum jumping height, push directly downward upon take off. The direction of counterforce is directly opposite that of the applied force, and the applied force is most effective when it is perpendicular to the supporting surface because "give" is minimised.
3. Maximise total force. When batting (or for other striking skills), the total force at impact depends upon the both the momentum of the bat and the momentum of the ball.
4. Stay in contact with the ground. In activities involving throwing, pushing, pulling, or striking, one or both feet should be kept in firm contact with the ground until the force application is complete.

Stability Principles and Balance in Sports
Introduction

Stability principles give athletes rules about holding positions and staying on balance when running. They guide training for improving firmness of positions both for static balance and dynamic balance. An athlete's center of gravity is the exact middle of the body around which it can rotate freely in any direction without problem and where the weight balanced on all opposite sides. It exists at a point along the midline of the body at about 55% of the athlete's height.

Stability Principles

1. To maintain balance when still, the athlete's center of gravity must remain over the base of support. For example, beginning a free weight lifting movement, such as the squat, requires the lifter to hold a standing position.
2. To regain balance when lost, an athlete can enlarge the base of support and reposition the center of gravity over it. Example: Placing the feet wider to prevent falling after being pushed helps recover balance.
3. When lifting or carrying an object, shift the body weight in order to maintain balance. Example: Lean in the opposite direction when carrying a heavy equipment bag.
4. For greatest stability in all directions, the center of gravity should be over the center of the base of support. Example: Holding a handstand requires the hips to remain toward the center of the base formed by the hands.
5. An athlete can become more stable by lowering the center of gravity. Example: A shot-put follow- through involves bending the knees to prevent fouling and falling.
6. The greater the friction between the supporting surface and the athlete's body, the greater the ability to maintain balance. Example: Wearing shoes that prevent excessive sliding on a playing surface.
7. Shifting the center of gravity toward an approaching force increases an athlete's ability to maintain balance. Example: A football lineman shifts weight toward the opposing line prior to the snap.
8. An opponent can be forced to lose balance if pushed or pulled in the direction where the center of gravity is closest to the edge of the base of support. Example: Boxers can lose balance when weight is shifted back on the heels.
9. For positions of readiness, the shorter the distance the center of gravity must move to clear the base of support, the more rapidly the body can be put in motion in that direction. Example:

Sprinters in the "set" position shift their weight in the direction of the race.

Types of Contact Forces

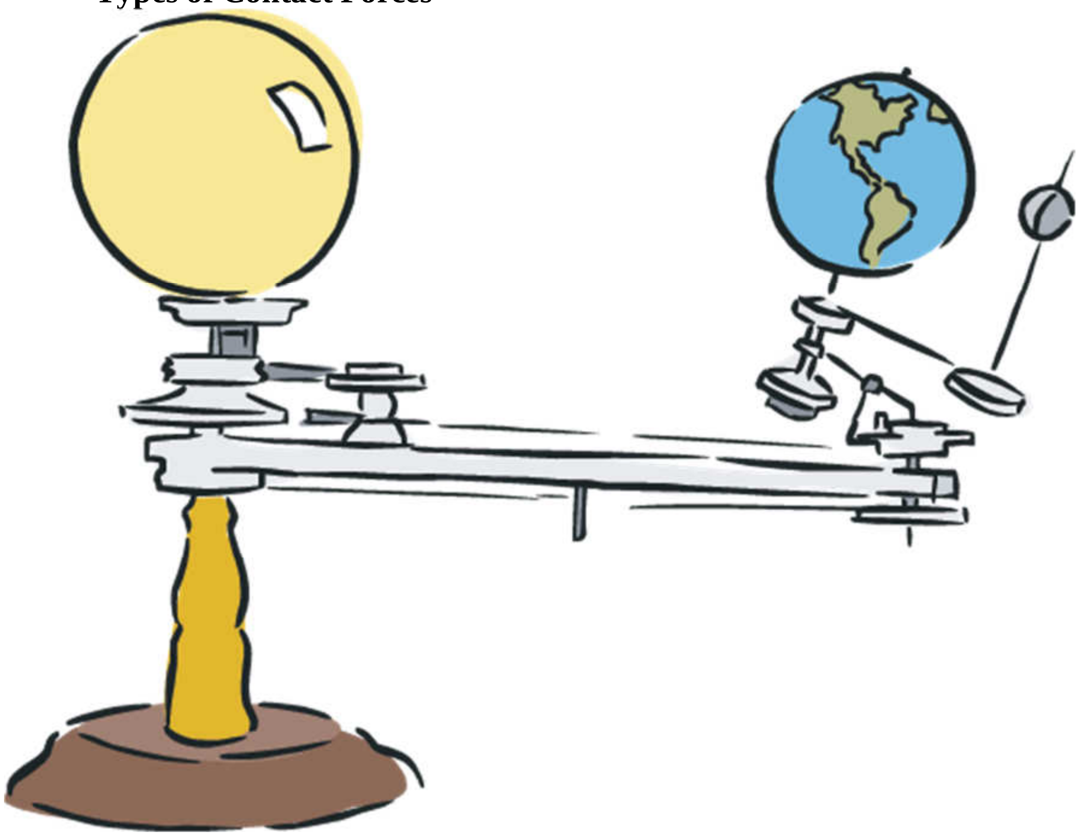

Fig. 4.7: Force and Motion

Motion makes the world go 'round. Motion makes the moon go 'round too. In fact, motion makes lots of things go. When we think of motion we often think of cars, bicycles, kids running, basketballs bouncing and airplanes flying. But motion is so much more. Motion is important to our lives and impacts so many things that we do. Motion is the changing of position or location. But motion requires a force to cause that change. Let's learn about force and motion and the effects of these physical laws in our world.

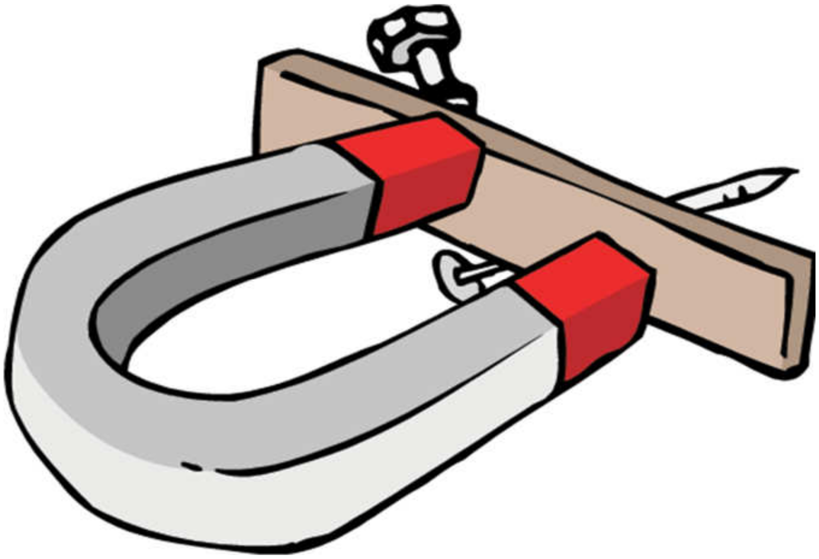

Fig. 4.8: Magnetism Force

Magnetism produces a force that can either pull opposite ends of two magnets together or push the matching ends apart. A magnet also attracts objects made of metal.

Types of Contact Forces

There are 6 kinds of forces which act on objects when they come into contact with one another. Remember, a force is either a push or pull. The 6 are:

- normal force
- applied force
- frictional force
- tension force
- spring force
- resisting force

Normal Force

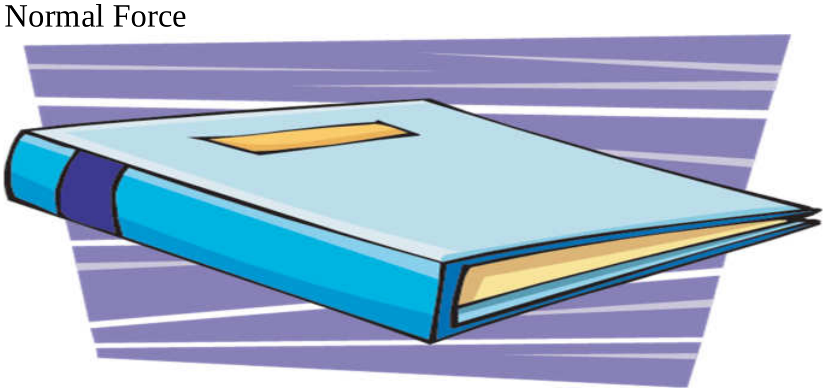

Fig. 4.9: Normal Force

A book resting on a table has the force of gravity pulling it toward the Earth. But the book is not moving or accelerating, so there must be opposing forces acting on the book. This force is caused by the table and is known as the normal force. You can "see" the normal force in some situations. If you place a thin piece of wood or plastic (a ruler works) so that it is supported by both ends (by books perhaps) and place a small heavy object in the centre, the piece of wood will bend. Of course it wants to straighten out so it exerts an upward force on the object. This upward force is the normal force. You can feel the force yourself if you push down in the centre of the piece of wood. The harder you push, the more the wood bends and the harder it pushes back.

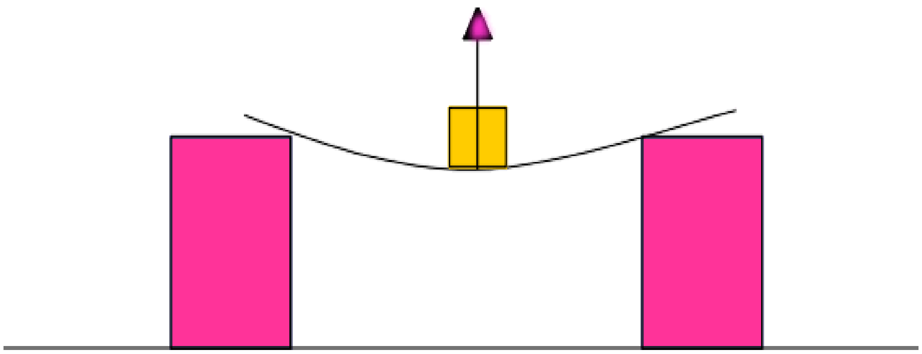

Fig. 4.10: Normal Force

Applied Force

Fig. 4.11: Applied Force

Applied force refers to a force that is applied to an object such as when a person moves a piece of furniture across the room or pushes a button on the remote control. A force is applied.

Frictional Force

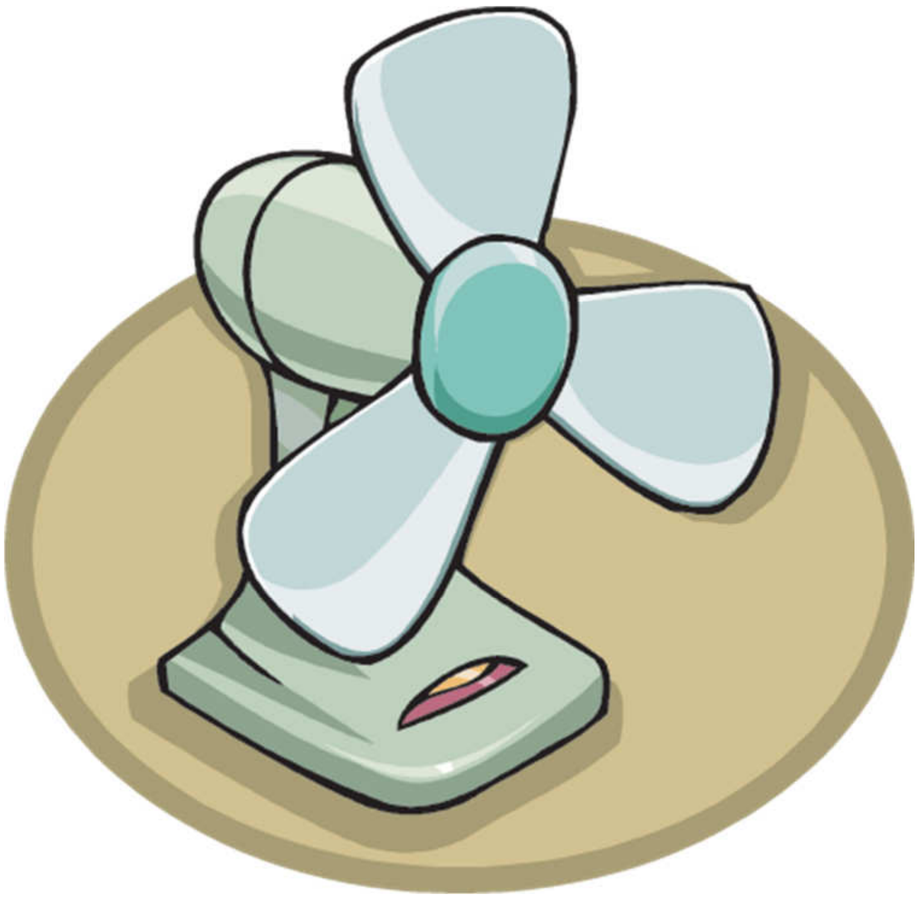

Fig. 4.12: Frictional Force

Frictional force is the force caused by two surfaces that come into contact with each other. Friction can be helpful as in the friction that allows a person to walk across the ground without sliding or it can be destructive such as the friction of moving parts in a motor that rub together over long periods of time.

Tension Force

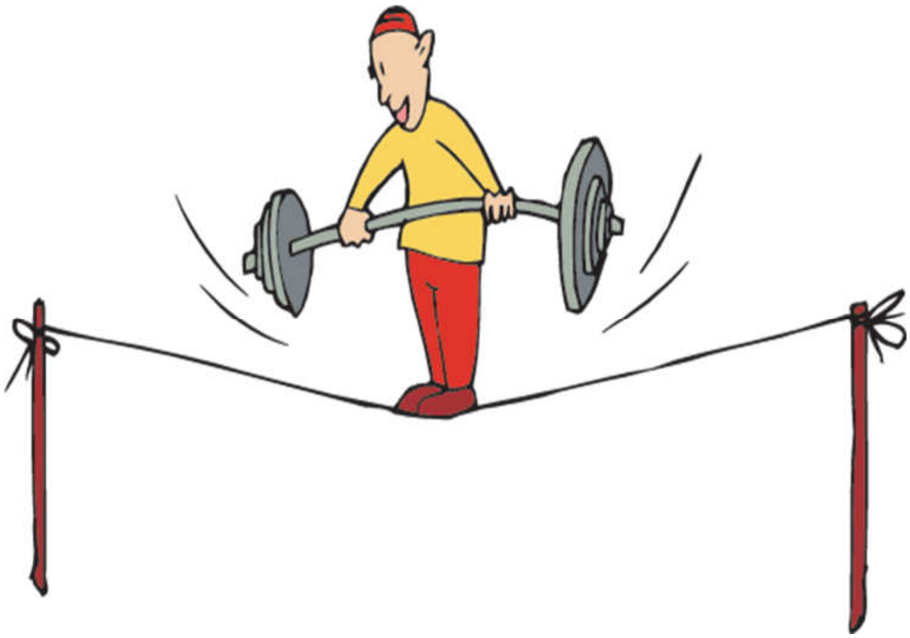

Fig. 4.13: Tension Force

Tension force is the force applied to a cable or wire that is anchored on opposite ends to opposing walls or other objects. This causes a force that pulls equally in both directions.

Spring Force

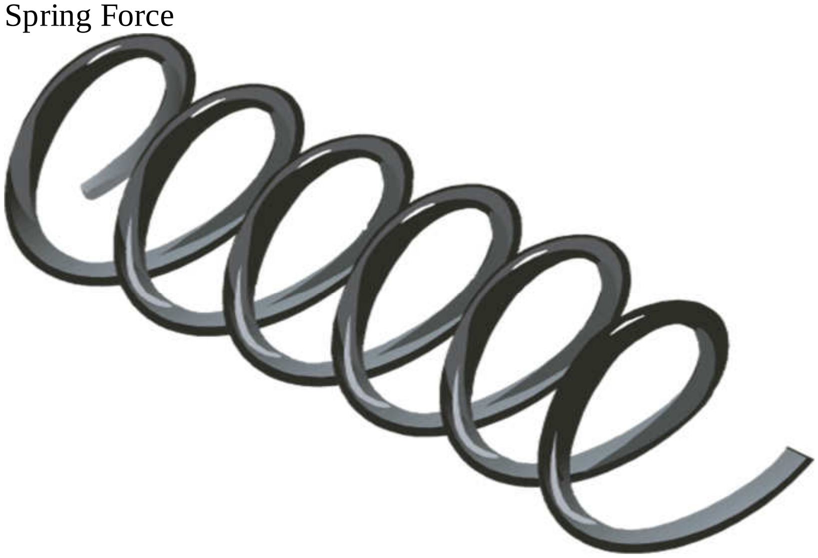

Fig. 4.14: Spring Force

The spring force is the force created by a compressed or stretched spring. Depending upon how the spring is attached, it can pull or push in order to create a force.

Resisting Forces

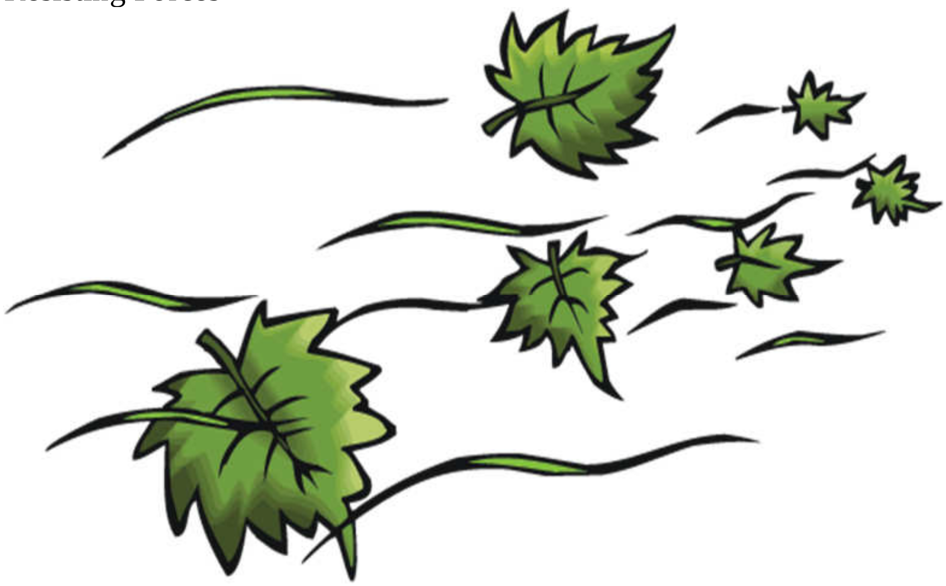

Fig. 4.15: Resisting Force

Resisting force: like air resistance or friction change motion. Whether the forces actually stop or slow something depends upon your point of view. Air friction makes a leaf travel along in the wind. When you pick up a pencil, it's friction with your fingers that gets the pencil in motion. In each case, the friction makes the two things (like the air and the leaf) move together.

Inertia

Inertia is actually not a force at all, but rather a property that all things have due to the fact that they have mass. The more mass something has the more inertia it has. You can think of inertia as a property that makes it hard to push something around.

Friction

Fig. 4.16: Friction Force

Friction is a force that happens when objects rub against one another. Say you were pushing a toy train across the floor. It doesn't take much effort or force, because the toy is light. Now if you try to push a real train. You probably can't do it because the force of friction between the train and the ground is more intense, therefore, the heavier the object, the stronger the force of friction.

Velocity

Fig. 4.17: Velocity

Velocity is the speed of an object in one direction. If an object turns a corner, it changes its velocity because it is no longer moving in its original direction.

Newton's Laws of Motion

The three laws explained how the concepts of force and motion work.

Newton's First Law

Newton's first law of motion states: A body in motion tends to remain in motion; a body at rest tends to remain at rest unless acted on by an outside force. So, if an object is moving – its inertia (mass) will tend to keep it in motion, and if something is at rest, its inertia will tend to keep it at rest.

Example of first law of motion

Place a ball in a box and slowly push the box. Abruptly stop the box. The ball will keep moving. According to Newton's first law, an **object** in motion tends to stay in motion unless acted upon by an unbalanced outside force, so the ball keeps rolling even though the box has stopped.

Newton's Second Law

Newton's second law of motion states that a force, acting on an object, will change its velocity by changing either its speed or its direction or both. If your basketball goes rolling into the street and is hit by a bike, either the ball will change direction or its speed or both. It will also be true for the bike.

For an object with a constant mass m, the second law states that the force F is the product of an object's mass and its acceleration a: F = m * a. For an external applied force, the change in velocity depends on the mass of the object.

Example of second law of motion

Riding your bicycle is a good example of this law of motion at work. Your bicycle is the mass and your leg muscles pushing on the pedals of your bicycle is the force.

Newton's Third Law

The third law is probably the best known of Newton's laws. It states that for every force and action, there is an equal and opposite reaction. This is what causes cannon to recoil when it fires. The 'kick' from the firing of the ammunition is what makes the cannon jump backwards.

Examples of Newton's third Law

When you jump off a small rowing boat into water, you will push yourself forward towards the water. The same force you used to push forward will make the boat move backwards. When air rushes out of a balloon, the opposite reaction is that the balloon flies up.

SELF -ASSESSMENT EXERCISE

i. Describe the general practices of force in sports.
ii. Describe the principle concerning the athlete-product force.

4.0 CONCLUSION

- Force is a word for pushing or pulling for instant if I push an object or pull on it, then I am applying a force to it.
- Principles of force offer guidance for teaching sport techniques and leveraging training strategies that require the development of force--pushing or pulling. Force is the product of the mass (weight) and acceleration of an object or person. These principles

and examples concern (a) general applications, (b) athlete-produced force, and (c) force dissipation.

- Force is used more economically when it is applied constantly and evenly. For example, a swimmer moves more efficiently when moving at constant speed and with smooth application of force. Or a 400-meter relay runner or middle-distance races.

- Greater velocity is generated if force is applied over a longer distance. For example, an outfielder can generate greater force for throwing to home plate by using a long winding up, rotating the trunk, shifting body weight from the back leg to the front, and following through.

5.0 SUMMARY

Force is a word for pushing or pulling. If I push on something or pull on it, then I am applying a force to it. Force makes things move or more accurately, makes things change their motion. Two natural forces that we have experienced are the force of gravity and magnetic forces magnetic forces. There are 6 kinds of forces which act on objects when they come into contact with one another. The types of forces are as follows: Normal, Applied, Frictional, Tension, Spring and Resisting force. Mechanical principles applied to sports are rules that govern the efficient execution of skills. Using these rules as guides, athletes can build excellent technique and gain the greatest mechanical advantage. Newton's Laws of Motion are the foundation for these mechanical principles, which must be applied in concert with other sports training principles to achieve higher levels of sport performance.

To achieve maximum force, use larger muscles in the lower body before actions of the trunk and upper body. For example, the force of a punch in boxing or throwing is greater when initiated from the lower body and hips, rather than from the shoulders.

Force generated by muscles can be increased by increasing initial tension before a contraction. This increase in force production is called *elastic recoil,* or the *stretch-shortening cycle.* For example, drawing the arm back to pitch a ball or throw a javelin places the muscles of the throwing arm on stretch, increasing the force of contraction upon the initiation of the throw.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the stability principles and balance in sports
2. List and explain the six kinds of forces you know.
3. Enumerate the principles of law of acceleration in sport.

7.0 REFERENCES/FURTHER READING

https://www.sport training-adviser.com/sportbiomechanics.html

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