ICSC06 Upper Extremity Module 6
Part1 Basics of Biomechanics
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Welcome to the basics of biomechanics. This is a simple guide that will teach you the basic principles of biomechanics that we can later apply to the upper limb, the spine, and the lower limb. In this section, we will be looking at basic concepts in joint anatomy and the types of diarthrodial joints, joint function in the form of kinematic chains, and also arthrokinematics. We will also be looking at muscle and tendon physiology, muscle physiology and biomechanics, common injuries in muscle, injury grading of muscle, and related sports and rehabilitation. Before we go into the details of joints and anatomy, we need to know the fundamentals of anatomical positioning, the axis of rotation, and the anatomy of a synovial joint.

The axis of rotation. This is characterized by 3 lines that dissect the body. The X-axis is a line that runs transversely across the body from left to right, the Y-axis is a line that runs vertically through the body from cranial to caudal, and the Z-axis is a frontal line that runs from anterior to posterior. The X, Y, and Z axis combined in pairs form different planes. As you will see ahead of the slide, we will work in these planes and see what movements go about these planes.

The Sagittal Plane. This divides the body into left and right halves. It is demarcated by the Y and Z axis combined. The movements of flexion and extension move through this plane. If we had to visualize flexion at the shoulder joint, we would see an anterior movement of the upper extremity through the sagittal plane where there was a point of rotation about the X-axis at the center of rotation of the shoulder joint.

The Coronal Plane. This divides the body into anterior (ventral) and posterior (dorsal halves). It is demarcated by the Y and X axis combined. Movements of abduction and adduction are seen to move through this plane. If we had to visualize the abduction of the shoulder joint, we would see the upper limb being elevated through the coronal plane, laterally away from the body. The point of rotation would be seen at the shoulder joint rotating about the Z-axis.

The Transverse Plane. This divides the body into superior and inferior halves. It is demarcated by the X and Z axis combined. Movements of rotation move through this plane. If we had to visualize the medial rotation of the upper limb with the elbow bent, we would see a translation of the hand medially towards the tummy. This is a rotation at the center point of the joint about the Y-axis of the shoulder joint.

The anatomy of a typical diarthrodial joint is also known as a synovial joint. It is characterized by free-moving ends or epiphyses encapsulated within a synovial lined joint space. The articular surfaces are free to move relative to each other because of no connective tissue directly connecting the surfaces. The shape of the joint surface dictates the motion potential of the joints.

The Joint Structure. The structure of the joints of the human body reflects the functions that the joints are designed to serve. The demand on the limb or segment that needs to move will dictate the type, shape, and size of the joint needed. As the joints become larger and have more range of motion, the less stable the joint is. Therefore, we will see more stabilizing factors in some joints and less range of motion in others. This can be seen as an example in the shoulder joint or the glenohumeral joint, specifically, where there is an extensive range of motion but at the sacrifice of stability. The rotator cuff muscles and the rotator interval capsule have to apply different forces in order to stabilize the shoulder as accessory stabilizers for the joint.

These two diagrams are an example of how the joint functions and how the associated tissues replace the stabilization because of the joint shape. As said above, the glenohumeral joint is a large joint with very little stability in order to allow for large ranges of motion. The small stabilizers, being the rotator cuff muscles, and the rotator interval capsule maximize the ability as best as possible.

Here are a few examples of synovial joints and their specific locations: the condyloid joint which is found at the atlantooccipital joint; the ball and socket joint, found at the glenohumeral joint and the coccyx femoral joint; the gliding joint which is found in articular processes between vertebrae; the saddle joint which is found at the carpometacarpal joints; the pivot joint which is found at the dens of the axis between atlas and axis; and the hinge joint which is also found at the elbow.

Kinematic chains. This is a biomechanical term used for a series of rigid links that are interconnected by joints that allow the limb to move in a predictable manner. It can either be an open kinematic chain or a closed kinematic chain. In an open kinematic chain, one joint is able to move independently to the approximal joints and has the freedom to move through space. In a closed kinematic chain, the distal end of the limb is fixed but the segments are able to move. There is no net change in limb position but the movement has occurred--for example, when standing and shifting off balance yet you have not moved from your original position.

Muscle and tendon physiology. In order to understand muscle behavior, we need to understand the smallest contractile unit of the muscle. This is known as the Sarcomere. It is a small fibrous structure formed by I-bands and A-bands. It is composed of actin and myosin. It has a sarcoplasmic reticulum that provides calcium in order to create a polar bond between actin and myosin heads in order to mediate muscle contraction. In order to understand gross muscle contraction, we need to understand the concept of muscle length-tension relationships. In this diagram, we can see the relative link between the length of muscle tissue and the ability to contract as muscle contractile tissue. We have an optimal zone that is needed for maximal actin and myosin interaction.

If the actin and myosin are packed too closely together, the sarcomere is unable to contract as there is a restriction of space, therefore, the sarcomere is rendered useless. If the actin and myosin are separated too far apart, there is no ability for the calcium to create the polar bond and linkage, and therefore, there is no contraction as there is no linkage between actin and myosin.

Active and passive inhibition. This is, too, a biomechanical concept that describes the behavior of muscle when set in anatomical fields. Active inhibition is where the muscle contracts to the point where it is unable to move the limb any further due to soft tissue obstruction. The muscle is self-able to generate a contraction but unable to move further. In passive inhibition, the muscles are not able to contract eccentrically as the limb is stretched beyond the anatomical limits of the sarcomere. The muscle is unable to initiate contraction unless the length is reduced.

Muscle physiology and biomechanics. The muscles are our powerhouses and our movers of the body, because of this, they tend to fatigue easily and can potentially get injured. By looking at the behavior of muscle in contraction, we are able to determine when a muscle is injured or underperforming due to altered mechanics and general muscle pain syndromes such as Delayed Onset Muscle Soreness. Muscle testing is a simple and effective method of assessing muscle behavior and potential injury.

The factors that affect muscle strength are motor-unit summation and increase rate coding. In motor-unit summation, the more motor units the muscle uses to contract, the more summative contraction can be achieved. We see this in explosive forceful contractions such as that in sprinting. In increase rate coding, increasing the right to fire each specific motor unit increases the total rate of recovery and reconstruction of the muscle. This is seen in a gradual build-up of muscle contraction such as applying weight in weightlifting.

The factors affecting muscle tension are primarily dictated by the number of muscle fibers in that unit: the size of the fibers, i.e. the larger the fibers, the more tension that can be generated; specific tension per cross-sectional area, i.e. smaller slow twitch fibers generate approximately 1.73kg of tension per square centimeter, and larger fast twitch fibers generate about 2.23kg of tension per square centimeter.

Common muscle injuries are usually seen as muscle strains. These are the most common and most feared by any athlete. They may occur due to overuse (e.g. repetitive motion such as pitching in baseball) or due to forceful overloading in sports activity (e.g. hamstring strain during the launch of the plate in a long jump). They are graded from grades 1 to grade 3.

This is a simple grading scale that can be used to understand and note what type of muscle strain you are dealing with. In a grade 1 muscle strain, minor or microscopic tissue damage is noted. It is painful for the patient. They usually experience a severe cramp or spasm. It is not usually palpable, and it usually takes about

7 to 10 days for normal recovery, back to 100% function. In grade 2 muscle strain, it is a moderate or macroscopic or partial thickness tear of muscle tissue. It is extremely painful for the patient. There is a muscle cramp or spasm. It is palpable by torn fibers in the muscle tissue and rehabilitation is required for 10 to twenty-one days for normal recovery, usually between 80 and 100 percent return of normal muscle function depending on the thickness of the tear. Grade 3 muscle strength is usually a severe maximal or full thickness tear of the muscle tissue. The patient usually doesn't feel much pain initially due to the loss of tension. It is usually a physical muscle deformity as the muscle has had a full thickness tear. The muscle sheath or fascia may still remain attached to the tendon. Surgery and rehabilitation are usually required with a 3-week to 6 months recovery.

Tendonitis or tendonosis. These are inflammatory conditions that affect the tendons directly. The most common mechanism of injury is due to overuse or increase leverage on the tendons in sports such as record-based sports. The most common forms are usually tennis elbow, golfer's elbow, and jumper's knee.

The grading of tendon strains is similar to that of what we saw in muscle. Grade one, again, is minor or microscopic tissue damage. This is painful for the patient. It is not palpable and has a 7 to 10-day recovery period usually with non-steroidal anti-inflammatory drugs and/or compression. In grade 2 tendon strains, it is a moderate or macroscopic effect on the tendon tissue. It is extremely painful for the patient. There is a palpable deficit in the tendon usually in the form of swelling such as in tenosynovitis. Rehabilitation is required and it is commonly called enthesopathy. Grade 3 tendon strain is known as severe or maximal or full thickness tears of the tendon. It is usually associated with avulsion fractures as it is usually affected at the tenderness junction between the bone and the tendon.

Delayed Onset Muscle Soreness or DOMS. This is where the products of collagen break down from intense rapid training that may act as a chemotactic agent and inflammatory marker causing macrophages to travel into the muscle tissue and begin an inflammatory response. The macrophages are nonspecific phagocytes and break down imperfect and normal cells, thus causing tissue damage. Hydroxyproline or OHP is a urine marker for early-onset DOMS. If DOMS is severe enough that it affects large amounts of tissue, the degradation will be seen by a rise of Creatine Kinase and may lead to Rhabdomyolysis or other complications.

Common treatments for DOMS include cryotherapy, regular stretching, ultrasound, light-low resistance exercise, hyperbaric therapy, compression, massage therapy, and drugs in the form of non-steroidal anti-inflammatory drugs.

Ligament physiology. The ligaments are the primary restraints and guides for the joints. They provide the main line of support for normal joint motion. They are the last line of defense for joint hyperextension and instability. They are subject to continuous loading and are most affected by the phenomenon of creep. Creep is a physiological phenomenon where there is tissue distortion over a period of time when a constant force is applied over a long period of time. We see this in general ligament laxity, the winner's shoulder is overused or overstretched.

Common injuries of ligaments include ligament sprains. They are commonly due to joint malposition during a weight-bearing exercise. The most common version is the inversion sprain of the ankle, commonly in running and in stop-or-start sports such as netball or basketball. Joint hyperextension and instability. There is usually an overload of the ligaments which may induce capsular stretching. There is also joint dislocation which is commonly in contact sports due to the force of impact and it commonly happens in juvenile-level sports where the ligaments are still stretching due to bone growth.

As seen before with a muscle injury, we refer to a grade 1, grade 2, or grade 3 grading system for ligament damage. In grade 1 ligament sprains, you will see minor or microscopic tissue damage. It is painful for the patient. They usually experience acute or moderate swelling and minor hematoma formation. It is not usually palpable defect. The joint stability is usually maintained but they may have minor instability masked by exaggerated apprehension and pain. It takes about 7 to 10 days to heal and the weight-bearing or proprioception is affected.

In a grade 2 ligament sprain, there is moderate or macroscopic partial-thickness tearing. It is extremely painful for the patient. There is a large or significant swelling and hematoma. The muscle cramp or spasm may mask instability but instability is seen easily with the naked eye. When the joint is placed under pressure or weight-bearing, it is unbearable for the patient, and proprioception is affected. Immobilization is required as soon as possible. In a grade 3 ligament sprain, there is severe or maximal tissue tearing. The patient does not feel pain initially due to the loss of tension. There is gross joint instability which is commonly seen and may also see repetitive joint dislocation if associated with a joint displacement. The proprioception is completely disrupted and may affect voluntary joint control. Surgery is commonly required with rehabilitation.

For more information on related sports and rehabilitation, please refer to the following text for a basic understanding of rehabilitative exercises and chiropractic therapies in order to treat some of the injuries discussed.

Thank you for taking the time to learn about the basics of biomechanics. I hope this information serves you well and helps you guide and assess your patients correctly and efficiently, and also improved your own standard of practice.

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