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ICSC Lower Extremity Module 5
Section 1.1_ICSC05 Lower Limb
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Video Lesson: 41:18

This is a guide to pick up on normal and abnormal biomechanical limb behaviour of the lower limb. In this section, we will be looking at the hip, the knee, the ankle and foot complex, the general injuries, and Gait Analysis.

The Hip Complex. The hip joint is a very unique joint to the body, even though it has similarities to that of the shoulder joint, it also has its characteristic differences. We will be investigating the anatomy, structure, and function of the Coxafemoral Joint; the angles of importance; the hip joint pathology that we see in young athletes and hip joint degeneration in senior athletes; and possible ideas for rehabilitation.

The Anatomy of the Hip. The Hip joint or Coxafemoral joint is a diarthrodial ball and socket joint with three degrees of freedom, allowing flexion and extension in the sagittal plane; abduction and adduction in frontal plane motion; and medial or internal rotation and lateral or external rotation in the transverse plane.

The Anatomy of the Hip. The ilium, ischium, and pubis bones fuse to form the pelvis. They contribute to the structure of the acetabulum or cup-like socket that articulates with the head of the femur. The cup-like girdle is referred to as the innominate or Os Coxa. Ossification of the pelvis occurs at approximately 20 to 25 years of age. The lunate surface of the acetabulum is covered with hyaline cartilage and is the articulating surface with contact to the head of the femur. The base of the horse-shoe or the lunate surface is interrupted by the acetabular notch. The acetabular fossa is a non-articular portion and the femoral head does not contact this area.

Comparison of the Hip to the Shoulder Joint. There are quite a few similarities and differences between the shoulder and hip joints. The shoulder provides a stable base for hand mobility against gravity with precedence for open chain functions, and has a relatively weak capsule. The hip has a primary function to support the weight of the head, arms, and trunk. The capsule is strong and dense and contributes to joint stability. In this diagram, you can see the vast differences between the glenohumeral joint and the hip joint, where the anatomy provides the ability for the shoulder to have more flexibility with less stability and the hip to have more stability with slightly less flexibility. The Angles of Importance of the Hip Joint. The Center Edge Angle of Acetabulum. The Center Edge Angle is the measurement of inferior angulation of the acetabulum. It is measured by a line connecting the lateral room of the acetabulum and the center of the femoral head. This line forms an angle with the true vertical. The average measurements are 38 degrees in males and 35 degrees in females. A smaller center edge angle makes the acetabulum more vertically orientated and results in less coverage of the femoral head resulting in less joint stability.

The Angle of Acetabular Anteversion. The acetabulum faces laterally, inferiorly, and anteriorly. The magnitude of the anterior orientation is called the angle of acetabular anteversion. Pathological increase in angle of anteversion causes a decreased joint stability and an increased tendency for anterior dislocation of the head of the femur.

Femoral Angulations. The first of the femoral angulations we look at is the Angle of Femoral Inclination or Angle of Inclination. It occurs in the frontal plane between an axis through the femoral head and neck and the longitudinal axis of the femoral shaft. In early infancy, it is approximately 150 degrees and decreases to average of 125 degrees in the normal adult, and to approximately 120 degrees in the elderly. Normally, the greater trochanter lies at the level of the center of the femoral head. In pathological increase in angle, it is called coxa valga; and a pathological decrease in the angle is called coxa vara. The second of femoral angulations is the Angle of Femoral Torsion or Anteversion. The Angle of Torsion also known as the Angle of Anteversion occurs in the transverse plane between an axis through the femoral head and neck, and the axis through the distal femoral condyles which creates a twist in the femoral shaft. The angle decreases with age: in the newborn, it is approximately 40 degrees and it decreases to approximately 10 to 15 degrees in adults, with a range between seven degrees and 30 degrees. A pathological increase in the angle is called femoral anteversion; and a pathological decrease is called femoral retroversion.

Hip Joint Pathologies in the Young Athlete. Age is an important factor in the diagnosis of athletic injuries. Athletes are more susceptible to certain problems at certain ages. Young athletes with hip pain must be checked for: Leg-Calve-Perthe's Disease, Slipped Femoral Capital Epiphysis, Hip Dysplasia, and Juvenile Rheumatoid Arthritis. Most of these pathologies can be picked up on normal X-rays. So, therefore, think clearly and send your patients for an assessment using X-rays. Simple measurement tools such as the sentence line at the hip might give you an indication of possible problems.

Hip Joint Pathologies in the Senior Athlete. Peripheral Degenerative Joint Disease is most commonly found at the hip joint in the seasoned or senior athletes. The most common symptoms are groin pain on activity or chronic gluteal pain and spasm. It's usually picked up on Passive Range of Motion assessment with the patient experiencing pain or crepitus. Most commonly it is found in runners and lunging sports.

The Knee Joint. In these slides, we will be looking at the anatomy, structure, and function of the knee; the Tibiofemoral Joint Anatomy; the menisci; the ligaments of the knee; the important mechanisms of the knee; and the Patellofemoral joint.

The Anatomy of the Knee. It is one of the largest joints in the body, and the most complex. It is a double condyloid joint, with two degrees of freedom, allowing flexion and extension in the sagittal plane around the transverse axis; and medial and lateral rotation in the transverse plane around a vertical axis. The complexity of the knee joint comes from the fact that it has ligamentous support both extra-articularly and intra-articularly. The ligaments themselves are restraints both on the outside of the knee and inside retaining forces of translation and shifting.

The Distal Femur. The medial and lateral condyles on the distal femur form the proximal part of the knee joint. They are large and have an obvious curvature anteroposteriorly and convex in the frontal plane. The condyles are separated by the intercondylar notch or fossa and joined anteriorly by the patella groove. The femoral shaft is not aligned in a true vertical position and it is angled so that the femoral head is medial to the femoral condyles. The lateral articular surface is not as large as the medial surface. Therefore, the medial condyle extends further distally than the lateral, so that the distal end of the femur is essentially level in anatomical position.

The Tibia. The distal knee joint is composed of two concave, asymmetrical tibial condyles. The articular surface of the medial condyle is approximately 50% larger than the lateral condyle, which corresponds with the femoral condyles. The articular cartilage of the medial tibial condyle is approximately three times thicker than the lateral. The two articular condyles are separated by the intercondylar tubercles.

The Function of the Knee. In a closed kinematic chain, the knee works with the hip and ankle to support the body weight in the static erect posture. It works dynamically to move and support the body in setting and squatting, as well as when supporting the transfer of weight during ambulation. In an open kinematic chain, the knee provides mobility for a foot in space. The incongruence in the knee joint structure is accompanied by an accessory joint structure that enhances congruence and assists in the balance between mobility and stability.

The Menisci. They are two asymmetrical fibrocartilaginous joint discs, which are located between the condyles of the femur and the tibia. The medial meniscus is semicircular in presentation, and the lateral meniscus is a 4/5th ring in presentation. Both are wedge-shaped which are thick peripherally and thin centrally. They open towards the intercondylar area. They increase the radius of curvature of the tibia condyles and therefore, generate congruence in the knee joint. They distribute weight-bearing forces. They reduce friction between the segments and there are shock absorbers.

The Ligaments of the Knee. The Anterior Cruciate Ligament or ACL. The ACL runs from the anterior tibia, superiorly and posteriorly, and attaches to the posterior inner aspect of the lateral femoral condyle. It is comprised of two subdivisions of the ligament: your Anterior Medial Band or AMB, and the Posterior Lateral Band or PMB. With valgus loading, both ACL bands increased tautness with increased flexion. The ACL is the primary restraint to anterior displacement of the tibia on the femoral condyles. It has a minor role to play in restraining medial and lateral forces to the knee. Injury to the ACL can result in: increased anterior tibial translation, especially between zero degrees and 90 degrees of flexion; increase in valgus tibia rotation, between 30 degrees and 90 degrees of flexion; increase in lateral tilt of the patella with flexion; increase in lateral shift of the patella with flexion. The Quadriceps are antagonistic to the ACL, but if the hamstrings are co-contracting, it will reduce the forces through the ACL. Therefore, the hamstring complex decreases anterolateral tibial translation independent of the ACL. In this diagram, you can see the difference between a normal ACL and an injured ACL. With regards to the injury, try to picture, how the knee would shift or deviate without the restraint of the ACL ligament.

The Posterior Cruciate or PCL. The PCL runs superiorly and anteriorly to the inner aspect of the medial femoral condyle. It is the primary restraint to posterior displacement to the tibia beneath the femur. If a posterior directed force is applied, the tibia will also rotate laterally, i.e., the PCL plays a role in locking the knee which is critical for stabilization. Maximum loading occurs in the PCL with the knee fully extended and a posterior translatory force applied to the tibia. It also restrains varus and valgus forces. The hamstrings and gastrocnemius muscles are antagonistic, whereas the quadriceps and popliteus muscles are synergistic to the actions of the PCL. The restraining system for knee extension includes: the PCL, the posterior joint capsule, the LCL, the posterior oblique ligament, the MCL with the meniscus attached, the posterior medial and posterior lateral menisco-tibial bands, and the posterior menisco-fibular ligament.

This diagram depicts the anatomical location of the PCL when the knee is flexed. It is very difficult to see in the neutral position. Try to imagine where the tibia would drift to if the PCL was injured.

The Colateral Ligaments of the Knee. The lateral Collateral Ligament or LCL. It attaches between the lateral femoral epicondyle and posteriorly to the head of the fibula. It resists varus forces and adduction stresses on the knee. It also limits lateral rotation of the tibia in conjunction with the posterior lateral capsule and popliteus muscles. It has the most substantial effect of restraint at 35 degrees of knee flexion.

The Medial Collateral Ligament or MCL. It attaches between the medial femoral epicondyle and inserts into the medial aspect of the tibial condyle. It slants slightly anteriorly. It resists valgus forces or stresses on the knee. It especially works when the knee is slightly flexed and the other structures make a lesser contribution to resistance of valgus stress. The MCL checks the lateral rotation of the tibia. It acts as a backup restraint to pure anterior displacement of the tibia when the ACL is insufficient or absent. Here is a diagram depicting the collateral ligaments in anatomical position. Try to Vision the forces or the translation of the knee joint with the absence or weakness of these ligaments.

Important Mechanisms of the Knee. Tib-Fem alignment. The long axis of the femur is oblique directed inferiorly and medially. The axis of the tibia is almost vertical. This creates an angle, at the knee medially between 185 degrees and 190 degrees and creates a normal physiological valgus at the knee joint. Therefore, there is a balance of weight distribution on lateral and medial condyles as might be expected in bilateral static stance.

Important Mechanisms of the Knee. Genu Valgus or Genu Varus. If the tib-fem angle is greater than 195 degrees, it is called the genu valgum or knock knees position. This will increase compressive forces laterally and increase tensile forces medially. If the tib-fem angle is less than 180 degrees. it is considered genu varum or bow leg position. This increases compressive forces medially and tensile forces laterally. Even a mild genu varum can increase compression on the medial meniscus by at least 25%.

The Q-angle. This is the net effect of the pull of the quads and the patellar ligament on the patella. This is the angle formed between a line connecting the ASIS to the midpoint of the patella and a line connecting the tibial tuberosity and the midpoint of the patella. It usually measures 10 to 15 degrees with the leg in extension. In females, they may have a greater angle due to the wider pelvic anatomy. A Q-angle of 20 degrees or more is considered abnormal and creates excessive lateral forces on the patella which can lead to pathological changes and suggest patellar instability.

The Patellofemoral Joint. The patella is the largest sesamoid bone in the body and forms the least congruent joint in the body. The posterior surface of the patella can be divided into two separate facets: the medial and lateral articular facets. The medial facet may be further divided into a larger medial and much smaller most medial odd facet. The patella is seemed to slide distally on the femur during flexion and proximally on the female during knee extension. In patellar tilt, the patella seems to rotate around the vertical axis. The patella also rotates around an anterior-posterior axis but the apex of the patella is attached to the tibial tuberosity via a tendon, and therefore medial rotation that the patella causes the inferior pole of the patella to follow the medial tibial rotation. In lateral rotation, the patella causes the inferior pole of the patella to remain lateral with the tibia. This diagram is a longitudinal section of the knee joint. You can see the intercommunicating into joint spaces and you can see the articulations between the tibia femoral joint and the patellofemoral joint.

Important Mechanisms of the Knee. The Screw Home Mechanism. When the femur extends from full flexion back to approximately 30 degrees of flexion, the smaller lateral femoral condyle is at complete range of motion. The extension continues in order to return the need to zero degrees flexion because the larger medial condyle continues to roll or glide posteriorly, although the lateral side has halted. This results in the lateral rotation of the tibia on the femur, when non-weight-bearing, and medial rotation of the femur on the tibia whhen in weight-bearing position. This pivots the femur about the fixed lateral condyle of the tibia when weight bearing, and this is most evident in the last five degrees of extension. the mechanism may be assisted by increased tension in the ligaments as the knee reaches full extension. This medial rotation is not voluntary and not produced by muscle action. It is this rotation that accompanies the end of extension and brings the knee joint into the close-packed position. It is also known as the locking mechanism or screw home mechanism. This mechanism is an important pointer when dealing with a patient who has no signs of knee instability, but chronic knee pain.

The Ankle and Foot Complex. In these slides, we will be looking at the anatomy, structure, and function of the ankle and foot complex; the Mortise joint; the Subtalar joint; Forefoot and Hindfoot behavior with pronation and supination and the compensating mechanisms in pronation and supination twist; and the Plantar Fascia.

The Anatomy of the Mortise Joint or Talocrural Joint. The ankle is the most congruent joint in the body and therefore, can withstand compression forces during gait up to 450% of body weight with little incidents of primary degenerative arthritis. The Mortise or talocrural joint is made up of the tibiotalar and the talofibular surfaces of the joints. It is a synovial hinge joint with a capsule and associated ligaments. It has a single oblique axis with one degree of freedom in dorsiflexion and plantarflexion.

The Anatomy of the Subtalar Joint. The Subtalar joint or Talocalcaneal Composite Joint is formed by three separate plane articulations between the talus superiorly and the calcaneus inferiorly. It also provides triplanar movement around a single joint axis in the form of pronation or supination. The function is to balance between dampening rotational forces imposed by the body weight and maintaining contact with the foot of the supporting surface. The three articulations on the superior surface of the talus are the posterior talocalcaneal articulation, which is the largest; and the medial and anterior articulations which are smaller. Between the posterior medial and anterior articulations is a bony tunnel formed by a sulcus or concave groove known as the tarsal canal.

The Essence of Forefoot and Hindfoot Behavior. How do you get triplanar movement at the Subtalar Joint? When the talus moves on the posterior facets of the calcaneus, the articular surface of the talus moves in the same direction as the bone moves; but at the medial and anterior facets, the talus surface moves opposite to the movement of the bone, therefore motion of the talus is a complex twisting or screw-like motion. Triplanar movement to the talus is then considered to be around a single oblique joint axis. Therefore, the subtalar joint is essentially a uniaxial joint with one degree of freedom, in the sense of supination and pronation.

Forefoot and Hindfoot Behavior. In pronation in non-weight-bearing, pronation is composed of the component of calcaneal motions of adduction, eversion and dorsiflexion. In weight-bearing, pronation consists of calcaneal eversion, talar adduction, and plantar flexion, not calcaneal adduction and dorsiflexion. Supination in non-weight bearing is composed of component calcaneal motions of adduction, inversion, and plantar flexion. In weight-bearing, supination consists of calcaneal inversion, talar abduction, and dorsiflexion, not calcaneal adduction and plantar flexion.

Pronation Twist. This is a mechanism to compensate for hindfoot supination in weight-bearing and maintaining contact with the foot with the ground. The hindfoot and Transverse Tarsal joints are both locked into supination. Adjustment to the forefoot position must be left entirely to Tarso-Metatarsal joints. The four foot tends to lift medially and press into the ground laterally. The first and second rays will plantar flex and the fourth and fifth will dorsiflex.

Supination Twist. This occurs as compensation for substantial hindfoot pronation in weight bearing, and thus, to maintain contact of the foot with the ground. The Transverse Tarsal Joint will generally supinate to counter-rotate the forefoot but it can only supinate to a limited degree. If range of the Transverse Tarsal Joint supination is not sufficient to meet the demands of pronating force, the medial forefoot will press into the ground and the lateral side will tend to lift. The 1st and 2nd rays up pushed into dorsiflexion, while the 4th and 5h rays will plantarflex in order to keep contact with the ground. This results in forefoot inversion. The whole foot undergoes an inversion rotation about a hypothetical axis at the 2nd ray as a supination twist of the tarso-metatarsal joints.

Gait Analysis. A simple understanding of Gait is important. We will be looking at normal gait, gait initiation, determinant factors of gait, gait diagrams, and the Running Gait.

Normal gait is rhythmic and characterized by alternating propulsive and retropulsive motions of the lower extremities. The lower extremities essentially support and carry the heads, arms, and trunk, i.e. 75% of your body weight. In gait, the head, arms, and trunk must not only be balanced over one extremity but must also be transferred from one extremity to the other. These activities require coordination, balance, intact kinesthetic and proprioceptive senses, and the Integrity of the joints and muscles.

Three main tasks are involved in walking: weight acceptance, single limb support, and swing limb advancement. It is needed to support the weight of the body on one lower extremity and to swing one extremity forward in order to progress. These tasks thus include the following tasks: maintenance of support of the head, arms, and trunk against gravity; maintenance of upright posture and balance; and the control of foot trajectory to achieve safe ground clearance and gentle heel contact.

The Gait cycle can be divided into two separate main phases: one, the stance phase, and two, the swing phase. The stance phase is divided further into: heel strike, the flat foot, midstance, terminal stance, and the toe off or pre-swing phase. The swing phase can be subdivided into three main points: acceleration or initial swing, the midswing, and the deceleration or terminal swing phases. In this diagram, you can see the merge between the stance phases and the swing phases, and the sub-phases. Also the shifting weight and balance across the body. We also have a diagram from the top of the head where you can see how the limb is swung forward while stance is maintained.

Gait Initiation. This begins in the erect standing posture with an activation of the tibialis anterior muscle and the vastus lateralis muscle. in conjunction with an inhibition of the gastrocnemius muscles. Bilateral concentric contractions of the tibialis anterior result in a sagittal torque that inclines the body anteriorly from the ankles. The Center of Pressure is now described as shifting either posteriorly and laterally towards the swing foot or posteriorly and medially towards the supporting limb. Abduction of the swing hip occurs simultaneously with contractions by the tibialis anterior and the vastus lateralis and produces a coronal torque that propels the body towards the support limb. The support limb hip and knee flex a few degrees. This causes an anterior movement of the body and medially towards the support limb. This anterior medial shift frees the swing limb so that it can leave the ground. The end of the gate initiation activity ends when either the stepping or swing extremity lifts off the ground or when the heel strikes the ground.

Determinant Factors of Gait. Distance and Time Variables. Stance time is the amount of time that elapses during the stance phase of one extremity in a gait cycle. Single-support time is the time that elapses during the period when only one extremity is on the supporting surface in a gait cycle. Double-limb support time is the amount of time that a person spends with both feet on the ground during one gait cycle. Stride time or duration is the amount of time it takes to accomplish one stride. Step time is the amount of time spent during a single step measured in seconds per step. Cadence is the number of steps taken by a person per unit of time, measured as the number of steps per second or per minute. Speed or Walking Velocity is the rate of linear forward motion of the body. Acceleration is the rate of change of velocity with respect to time. Speed is usually referred to as slow or fast stepping.

Distance Variables. Stride length is the linear distance between two successive events that are accomplished by the same lower extremity during gait. It's measured from the point of heel strike of one lower extremity to the next heel strike of the same extremity. Step length is the linear distance between two successive points of contact of opposite extremities. This is where it's measured from heel strike of one extremity to the heel strike of the opposite extremity. Width of walking base is found by measuring the linear distance between the midpoint of the heel of one foot in the same point on the other foot. Degree of toe out represents the angle of foot placement and may be found by measuring the angle formed by each foot's line of progression and a line intersecting the center of the heel and the second toe. The angle measured is approximately seven degrees.

Phases of the Gait Cycle. The gait cycle includes the activities that occur from the point of initial contact of one lower extremity to the point at which the same extremity contacts the ground again. During one gait cycle, each extremity passes through two phases: one, a single stance phase, and two, a single swing phase. The stance phase begins at the instance that one extremity contacts the ground and continues only as long as some portion of the foot is in contact with the ground. This makes up 60% of the gait cycle. The swing phase begins as soon as the toe of one extremity leaves the ground and ceases just before heel strike or contact of the same extremity on the ground. This makes up 40% of the gait cycle. A period of double-limb support occurs when the lower extremity of one side of the body is beginning at stance phase and the other extremity on the opposite side is ending its stance phase. There are two periods of double support in a single gait cycle. During double support, both lower extremities are in contact with the ground at the same time.

In the diagram below, we have broken down the stance and swing phases of both limbs. As you can see, they run synchronously and timelessly. Note that the initiation of the left-sided stance phase starts roughly at 75% of the right-sided stance phase completion. Therefore, when there is swing phase there Is no interruption of the stance phase of the opposite side. It is always important to note and take good care in watching the pattern of gait when assessing a patient. This can give you pointers of where the problem is located that is disturbing the gait cycle, the structures that are not performing in the correct manner, and also the ease of movement in both your injured patients and your performance athletes. This does occur in marathon walkers, runners, and sprinting athletes.

The Running Gait. In the running gait cycle, maximum power is achieved with minimum contact and resistance from the ground. This is achieved by explosive contractions from the hamstrings and triceps suri muscle groups, and the quadriceps, glutei and ankle dorsiflexors alternating between the roles of synergists and antagonists, in order to spring load the lower limbs for propulsion. Minimum resistance is achieved by bringing both limbs into the air as a double float phase instead of the double stance phase seen in the conventional walking gait cycle.

You can see in the diagrams below the difference of the running gait compared to that of the walking gait. Also, take note that your swing phase now becomes 60% of your running gait cycle compared to its 40% contribution in walking gait cycle, and your stance phase goes into 40% in your running gait cycle compared to its 60% contribution in the walking gait cycle. Also, take note, the double float or the floating position that occurs instead of the double stance phase in walking gait cycle.

Thank you for your time in today’s lesson. All the best for the rest of the modules.

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