The Lower Extremity

Humans are biped. We contact and connect to the earth as we sit, stand, and walk upon it. Upright means we have to navigate onto the ground below us and to orient up towards the vertical within earth's gravitational field. Our nervous systems allow this through our righting, equilibrium weight bearing and weight shifting reactions. Gross motor behavior can be defined as posture, transition within postures, and locomotion in prone, supine, sitting, all 4's, standing. The efficiency of balance depends on our intent, our awareness of sensation and space, and the skill of these gross motor activities. Our nervous system's plasticity, maturity, and experiences play into its effectiveness. Our upright movements depends on our skills of rooting. This ability to connect into the ground is the foundation for our trunk, head, and arms upright orientation. When we keep our center of gravity within the support of our limbs or sit bones, we balance within a posture. When we move towards the outside or even outside our center of gravity, we control our momentum in movement.

Biomechanics

Biomechanics is the relationship of the parts in alignment and movement. This includes not only the gross movement of one bone upon another, but also the intricate movement of one joint surface upon another [Arthrokinematics] . They are a very complex series of actions depending on the structure as well as our intent. The shape of the joint surface influences the movement of the bones. All joints are ball and socket, following concave / convex relationships.

These movements are described as:

- roll [tire on dry road]
- slide [tire skidding on ice]
- roll + slide = glide

Joint Play is the amount of space within a joint. In the loose packed position there is the most space between articular surfaces, the most range of movement between bones, and the most joint play.

In the closed packed position, there is the least amount of space between articular surfaces, the most stability for weight bearing, and the least joint play.

Concave/convex relationships are about how the socket can glide over the ball or how the ball glides over socket. Impingement is the compression of one joint into the other because there is not a slide in the opposite direction of the roll. The ball has to slide away from the direction of the roll to clear its articular surface over the socket. There has to be enough space as well to glide normally.

Closed Chain Reactions are the movement behaviors in weight bearing and weight shifting. These are the complex reactions of the entire body when upper and lower extremities ground through the floor, as in many asanas. Open chain reactions are movement behavior in free space. Here the arms and legs move about open space on the foundation of the trunk. The whole body is involved in all open and closed chain reactions.

Bones

The hind foot consists of the calcaneus and the talus. The calcaneus is the heel, a primary weight bearing bone in contact with the ground. The talus orients leg over heel as a torque convertor.

The mid foot consists of 5 tarsal bones. There are 3 arches. The transverse arch is the side to side arch. It is not a true arch, supported by tendons, ligaments shapes forefoot into alignments The medial arch is from the head of first metatarsal to medial cuneiform, navicular and finally to calcaneus. This is not a true arch, supported by tendons and ligaments. The lateral arch, a true arch, is from back of 4th and 5th metatarsals through cuboid to the calcaneus.

The forefoot consists of 5 metatarsals and 14 phalanges [including hallux.] The 1st ray is from the cuneiform to the 1st metatarsal to the hallux. Sesamoid bones in the flexor tendons are the important weight bearing surfaces of the ball of the big toe.

The ankle is the medial malleolus of the tibia, and the lateral malleolus is of the fibula. The talus forms a saddle that the medial and lateral malleolus mortise fits into.

The knee has a concave tibia/meniscus that joins a convex femur. A normal adult has 10 ° valgus. Knock knees [valgus] and bowleg [varus] are the normal variations of knee alignment. The femur has usually 15 ° internal rotation in the shaft [anteversion]. The medial condyle is larger radius that lateral condyle. The neck angle 125 °. It is 150 ° at birth before the stresses of weight bearing increase the angle to 150°. The tibia is a thick crest of bone to meet the femur. The meniscus creates greater concavity. The fibula has the fibular head proximally and the lateral malleolus distally. The patella is sesamoid bone imbedded in quad tendon, which increases the angle to better extend the tibia on the femur. The fibular joint is upper joint of tibia/fibula. Its insertion point of TLF, biceps femoris, and peroneals.

Hip joints are the most concave and therefore the most stable, between the anterior superior iliac spine [ASIS] and the greater trochanter [GT], and parallel to the pubis. The psoas crosses in front, and medial to sartorius and rectus.

Plantar ligament holds the calcaneus to the ball of the foot. It limits eversion, and supports longitudinal arch. The lateral collateral ligaments of ankle are 3 bands hold the fibula to the calcaneus, talus. The medal collateral ligaments [deltoid] hold the tibia to the calcaneus. The talocalcaneal ligament holds the talus to the calcaneus. They are taut in inversion, and slack in eversion. The interosseous ligament holds the tibia to the fibula.

The knee capsular ligament [joint capsule] envelops the end of the tibia and the femur. This contains the synovial membrane and synovial fluid. This ligament thickens on its sides into collateral ligaments called the medial and lateral collateral ligaments. Valgus is medial stress by pushing from the lateral to medial direction. Varus is lateral stress caused by pushing from the medial to the lateral direction. The posterior fibers of both collaterals stretch in genu recravatum [hyperextension]. Anterior fibers stretch in full flexion. The cruciates of the knee are aligned like a cross. Anterior cruciate ligament [ACL] guides tibial internal rotation, external rotation, and extension [screw home], as well as, limits knee in hyperextension. The posterior cruciate ligament [PCL] drags tibia around femur in flexion [taut in all degrees of flexion], and prevents the posterior slip of tibia in flexion. The iliofemoral ligament [Y ligament], allows the "screw home" action of femur into the hip socket, while limiting extension, and internal rotation.

The muscles attached to the ASIS are the rectus, the sartorius, and the tensor fascia lata [TFL]. The deep rotators of hip are 7 small muscles. The quadriceps and hamstrings are some of the longest and largest muscles of the body. At the fibular head, the iliotibial band, the biceps tendon, the collateral femoral ligament, the peroneals, and the anterior tibialis meet. The pes anserine is the tendons of the sartorius, the semitendinous, and the medial collateral ligament. The peroneals support the lateral arch, support the transverse arch, and

stabilize the hallux. The sling muscles of medial arch are anterior tibialis and posterior tibialis. The foot intrinsics consists of 4 layers.

Normal Biomechanics of the Biped

In grounding, we push or release downward into the earth. Gravity pulls us onto the earth at a angle perpendicular to its horizontal. As in standing, we need to root vertically down to rise vertically up in gravity. As we push at any angle less than or greater than the perpendicular, we cause our center to move in the opposite direction. As in dog pose, we push the ball of our hand down and forward, then our belly will lift up and back. As we walk, we fall forward and catch our forward momentum. As we run, we propel ourselves forward and catch our forward momentum. We can direct the push from our center of gravity in our pelvis through the legs through the ball and heel of our foot into the floor. The angle of the arm or leg relative the horizontal is the same angle that continues into the earth. We can even direct our rooting into the earth, by tailing or curving the root to pull or push our center in more subtle ways.

Disassociation is the ability to move one body part from another body part. Righting reactions orient our trunk and head to the vertical as when an infant holds his head steady while propped on his mothers knee. We use the balance organs of the inner ear [otoliths and maculae]. Optical righting reactions orient us to the horizon of our visual field as do birds and cats. Equilibrium reactions keep our center of gravity within the support of our limbs or sit bones by weight shifting or countermovements.

Open chain reactions are our non weight-bearing movements. In our foot, supination is our closed packed position, our more stable alignment of foot for support in weight bearing.

- rearfoot inversion
- midfoot supination
- forefoot adduction

Pronation is more unstable; therefore, better able to receive the shock of weight bearing.

- rearfoot eversion
- midfoot pronation
- forefoot abduction

Subtalar neutral is when the vertical talus of the hind foot line up evenly under tibia / fibula mortise. Perfectly formed bones hit floor at heel and ball in subtalar neutral.

Ankle dorsiflexion is the closed packed position. Plantarflexion is the loose packed position.

Knee extension range is from 5-10 ° hyperextension to 140 ° of flexion. The last 20 ° of extension, femur internally rotates [screws home] as it glides on tibia because medial femoral condyle larger and ACL. The tibia glides forward on femur, checked by ACL. Knee extension is the closed packed position. The meniscus is a shock absorber. In flexion, the femur derotates [externally rotates] to break out of close pack position. The tibia glides on femur with anterior gapping towards end of flexion. Loose packed position allows internal/external rotation of tibia on femur.

The patella glides in condyle during last 30 ° of extension. It is pulled by vastis medialis obliquis [VMO] then the vastis lateralis.

The hip shows all planes of movement [glides]. The movement of the femur on ilium is called flexion, extension, rotation. Normally, the femur glides in the opposite direction as the direction the limb’s movement. The movement of the ilium on the femur is seen as inflare,

outflare, anterior and posterior torsion.

The spirals of lower extremities are the synergistic movement of the entire extremity grounding into the earth.

The inner spiral is the internal rotation pattern.

• perineum back with inner groins and inner thigh back
• back thighs and sit bones widening
• internally rotating the whole leg into the inner foot rooting
• outer arch lifting
• ball of big toe / inner heel grounding
• little toe extends forward

The outer spiral is the external rotation pattern.

• perineum forward with outer thighs back
• front thighs widening and groins softening
• externally rotating the whole leg into the outer foot rooting
• outer / back heel grounding
• inner arch lifting
• big toe extends forward

Closed Chain Reactions are seen as stance. There is a mechanical plumb line alignment from the ear, shoulder, hip, knee, to the ankle. The closed packed position is hip external / internal rotation, knee extension, ankle dorsiflexion, subtalar supination. The foot attempts to stay in contact with floor. The whole extremity and body reacts as a kinetic chain to weight bearing as supination / pronation or external / internal spiral.

Co-contraction can be considered as a component weight-bearing. Weight shifting is the complex set of reactions when the center of gravity is moved within the support structures. Standing can be viewed as a mechanical event with a myriad of closed and loose packed positions, joint glides, co-contractions, weight shifts, righting, and equilibrium reactions. But the skill of standing can be so much more.

Tadasana is a conscious skillful stance. There are many versions or interpretations of tadasana.

One rajasic stance is the Iyengar tadasana.

• inner thighs back
• tail bone forward
• engage quads
• 4 corners of feet press into ground
• lift the front of the lumbar spine, back of the sternum and clavicle

"Rocket" pose is a rajastic, energetic tadasana.

• ground and rise into space beyond crown of head
• inner spiral pressing through big toe ball and outer heel presses down
• perineum rotates forward with thighs back

Yet there is a tamasic to sattvic mountain pose.

• widen as inhale
• let go, release through outer feet as exhale
• rise upwards through the diaphragms through the space above head

Abnormal Biomechanics

Abnormal structure of bones in feet and legs creates recurrent or persistent demand for compensation resulting in pathology. Bones are shaped by forces placed in utero from baddha konasana to eversion[malasana] against uterine wall. Movement can be unskillful in the context of certain structures as well as from unawareness.

- hindfoot varus - calcaneus inverted when in subtalar neutral
- hindfoot valgus - calcaneus everted when in subtalar neutral
- forefoot varus - 1st ray above plane of floor when in subtalar neutral
- forefoot valgus - 5th ray above plane of floor when in subtalar neutral

In early stance, hindfoot varus causes midfoot pronation to keep heel in contact with floor. In midstance, hind and forefoot varus needs midfoot pronation to keep heel and 1st ray on floor. In late stance, forefoot varus causes midfoot in pronation to keep 1st ray on the floor during push off.

Excessive pronation is caused by

- hindfoot/forefoot varus
- bowlegs / knock knees
- internal tibial / femoral torsion - anteversion
- out toe

contributes to

- hallux valgus or limitus
- unstable midtarsal joint [talo-navicular, calcaneo-cuboid
- 2nd, 3rd metatarsal head callus or pain or stress fracture
- medial knee stress
- mcl strain
- medial meniscus tear
- acl strain
- patellar tracking problems
- hip internal rotation
- SI posterior torsion

Excessive supination

- tight plantar fascia leading to plantar fasciitis
- ankle sprain
- hypermobile 1st ray

The S/I and the knee compensate by moving excessively if the hip or groin movement is limited. A hypermobile subtalar joint [pronated ankle] collapses the knee into increased valgus. Limited knee joint play allows no room for the normal glides. Joint surface compressions can result.

The Yogic viewpoint is that poor grounding, unstable ankles, valgus or hyperextended knees, tense groins brings on pain and dysfunction.

Lower Extremity Pain and Dysfunction

Hallux valgus is the big toe adducting inward toward the 2nd toe. There is no 1st ray stability. The pull of peroneal longus ineffective in pronation. It can not withstand normal valgus stresses of walking. Late stance toe off when in marked out toe is a greater valgus stress.

Shoes are a big part of the problem.

- 33% of people in cultures wearing shoes have hallux valgus
- 88% are women
- 1.9% of people in cultures without shoes have hallux valgus

Eventually increasing valgus changes the hallux flexor brevis into an adductor.

Toe pain can been seen as hammer toes. The top of the toes callus or break down because of weak foot intrinsics. Too tight shoes further aggravate the condition. Claw toes wear out the bottom or tips of the toes. Weak foot intrinsics also are a cause here. People may claw their toes for balance.

Plantar fascitis is a common problem seen with a symptom of heel pain.. When there is no bony support of arches because of pronation, there is too much reliance on fascia and ligaments. Pain is in the medial aspect of front heel. The stress or tearing of the medial plantar fascia also may produce heel spurs or inflamed bursa.

A heel bruise has pain directly under calcaneus. Decreased effectiveness of heel fat pad does not pad the calcaneus from weight bearing stress. A heel cup may help redistribute the fat pad.

Achilles tendonitis can be caused by a tight gastrocnemius. Microtears from weight bearing start the stiffness- weakness inflammation cycle.

Forefoot pain and dysfunction is seen at the 2nd and 3rd metatarsal head. They press into floor upon weight bearing. 1st ray doesn't accept weight when unstable from pronation. 1st ray may be forced into dorsiflexion. Callus, inflammation, stress fracture are possible. Sesamoiditis is the inflammation of the sesamoid bones under 1st ray. If the stress in uneven, inflammation, osteoarthritis, or stress fractures are possible.

Knee pain and dysfunction can be a result of poor biomechanics. Valgus strain affect the MCL, medial capsule, medial meniscus, and ACL. A collapse into gravity associated with ankle pronation is a slow insidious way. An acute trauma from lateral blow, or torque after foot is fixed is the fast way. Hyperextension strain involves posterior capsule, ACL, PCL and pain in anterior tibia.

Capsular fibrosis can result from immobility following trauma or inflammation. The thickening and adhesions of the capsule will decrease joint play; therefore, decrease joint glides. There is a loss of internal rotation of femur on tibia in extension. This mechanical stress wears away the joint surface.

The medial meniscus tear has 3 times more surgeries the lateral tear. Only the outside of the meniscus is vascularized, so healing is only on outer edge. In flexion, posterior meniscus presses between tibia and femur. In extension, tibia glides forward on femur. Valgus / pronation increases medial strain. While extending from deep flexion, the meniscus may be held back by posterior meniscal compression while the femur moves forward. This injury occurs when rising from a squat as do carpet layers and baseball catchers. Tears will continue to irritate within the joint as a loose body.

Attempts into lotus can compress the articular surface of the inner knee. The meniscus and joint surfaces are susceptible to compression because the femur does not move well enough relative to the ilium. The femur moves too much relative to the tibia into compression. Ascending and descending stairs typically reproduce patellar pain.

Anterior knee pain is typically patellar pain. The patella glides too laterally in last 30 ° of extension. Imbalance of vastis lateralis to VMO and tighter lateral retinaculum cause the tracking problem. Increased valgus/pronation contributes to lateral tracking.

Hip socket pain is a result of poor tracking of ball in socket. When there is too little joint play for normal slides and glides, the joint surfaces degenerate with uneven excessive compression.

Hatha Yoga as Motor Skill

As bipeds we need to skillfully ground, center and lift. These actions can place either abnormal, excessive, or compressive stress or therapeutic, provocative, or restoring stress to our bodies. Posture and movement will diagnose the mechanical stress vulnerabilitiesupon evaluation. Posture and movement can be injurious or therapeutic. We must be aware of what specific posture and movementcan what specific dysfunction and pain. And we must learn the motor skills that are therapeutic. Yoga looks at posture and movement as a whole, not isolated contractions or disassociations.

Yoga looks at the actions of ground, center, and lift in relationships amongst each other. To accomplish this, one has to work daily with intention. Attention to breath, body sensation, mental images of inner actions, not muscular contractions are necessary.

Structure certainly influences posture and movements. Yoga views movement as inner actions of energy in the context of structure. Breath draws ones awareness to energy or prana. Prana also moves as a result of images with the body in context to the ground, gravity, and space. Movement from within is much more skillful, as in steady, fluid, and graceful. Control from the surface of alignment and muscle contraction is inefficient because it does not consider all the relationship of the parts. It does not look at the quality of movement in terms of dullness and tension. The nervous system is designed to control movement not muscles.

The lower extremity is extremely important in all biped movement obviously. The skill of rooting can not be separate from centering and lifting. The steadiness of posture and the control of momentum is best considered in the context of all three of these inner actions.

Poor rooting skills in the lower extremities can cause compression in pelvis and spinal joints. Also poor rooting skills cause overuse and misuse of the lower extremity structures themselves. Yoga works on developing these grounding skills as part of an entire pose. Alignment, joint glides, muscle activity, sensory feedback, intention are all considered in the whole of movement in poses. Poses can be considered as the relationship amongst the inner actions of grounding, centering, and lifting.

Yoga deals with foot and ankle problems by rooting into the 4 corners of each foot through the inner and outer spirals. Ones needs to learn to ground through the ball of the big toe as part of the inner spiral, while grounding through the outer heel, part of the outer spiral. 1st ray issues, hallux problems need active peroneals to stabilize the big toe to handle the varus, valgus stress of shoes, and walking.

Inner spiral rooting prevent outer ankle sprains. Rooting activates foot intrinsics and tibialis and peroneals. Rooting aligns the mid and hindfoot reducing compressive pronation and supination or plantar fascia strain.

Poor rooting stress the knee in many ways. Abnormal weight bearing movement through the

knee causes or perpetuates many of the meniscal and ligamentous strains and joint degeneration. Weight bearing demands skillful grounding and a freedom of movement in the joint above: the hip. Reduce range of motion in femur / acetabulum causes compressive stress in the knee especially in loose packed positions of flexion as in sitting.

Patellar tracking problems also need a balanced spiral rooting relationship.

We look at students/ patients in terms of their body type, vulnerabilities to movement stress, quality of present movement, ability to focus kinesthetic sensation. Students have to figure out how to explore posture and movement to manage their movement inefficiency, to stop perpetuating inflammation and degeneration of structure, and to start using posture as relieving and finally healing. Abnormal biomechanics creates mechanical stress that are the cause of much of the lower extremity movement pathology. Modalities and manual therapy are necessary in reducing the acuteness of strain, inflammation, and degeneration. But only until, someone realizes what specific postures and movements cause or perpetuate their dysfunction or pain, are they really healed.

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