

# Empirical Observations and Gait Theory

compiled from The Axis Syllabus  
for the AS International Research Community by Frey Faust

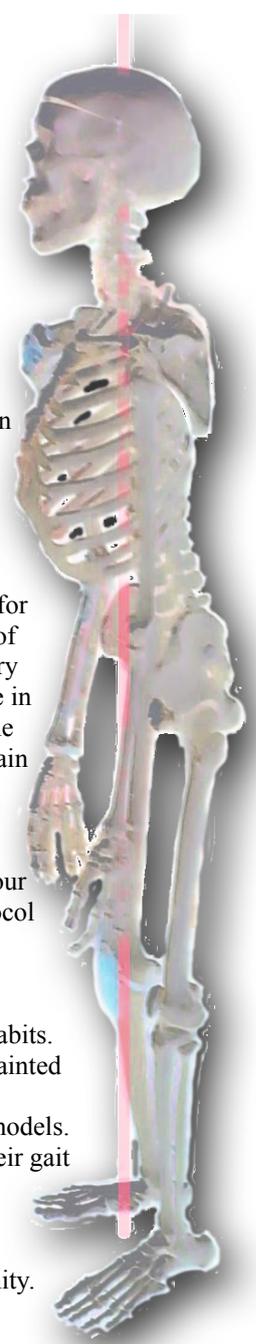
*“Walking teaches us how to dance” F.F.*

Walking, still our primary mode of transport, forms the base-pattern of most movements. Therefore, it is logical to assume, that the manner in which we ambulate will support or erode our health, and can also inhibit or enhance our capacity to adapt and learn new or more efficient ways of doing things. Considering how fundamental walking is, it is doubly remarkable how little is really known about it. It follows that gait or postural re-education is often irrelevant, or merely aesthetically oriented, or even sets habits that can be dangerous.

One potential source of these irrelevant teaching methods or precepts could be the simplistic models for walking that they are based on. Regardless of the standard outline of various phases, official models of walking are unrealistic. They do not detail the kinematic chains, nor any of the observed compensatory spinal movements, nor the Side-Bending phases that occur when steps are enlarged. They don't figure in the predominantly eccentric activity of the myo-fascial chains, nor does it map the collaboration of the arms in energy generation and management. There is little specificity as to why the limbs follow certain trajectory variants. Little of what is understood is carried into training practice or exercise design.

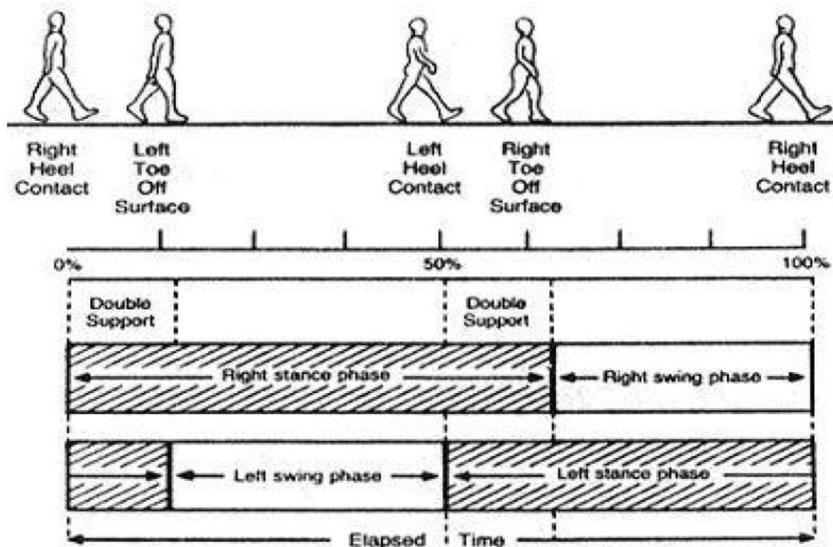
With this article we would like to submit these observations for general review, with the aspiration to update current walking models to the most recent technical understanding available. By ramping up our awareness of this fundamental movement pattern, we hope to outline a physiologically justified protocol for training towards greater performance while maintaining the human body's strength and health.

For the material for this article, we relied mainly on empirical field-testing, in other words we took our findings into the class-room and attempted to bring the student to the point of questioning their habits. We used internal/external focus exercises, imposed conditions such as chairs and lines on the floor, painted the soles of our feet and used blind accompaniment, as well as anatomical study, discussion and felt discovery of the body's various structures and attributes through practice, pictures, text and skeletal models. We referenced these experiences through new and old clinical data. Not surprisingly, re-patterning their gait has allowed many of our members and students to recover from chronic injuries, to regain relatively pain-free mobility, as well as expand the range of options for moving they had to begin with. We feel that the results justify continued efforts to transmit the mechanical understanding of walking we are evolving to more people, as well as submitting our theories to testing and review by a larger community.



## STANDARD WALKING MODEL

- TWO MAIN PHASES**
- STANCE PHASE 60%
- SWING PHASE 40%
  
- 7 part GAIT CYCLE**
- IC initial contact (heel-strike)
- LR Loading Response
- MST Mid-Stance
- TST Terminal Stance
- PSW Pre-Swing
- TO Toe Off
- SP – Swing Phase
- IC initial contact



# 1. The Arch and the Sine-Wave, Fundamental Structures of the Foot



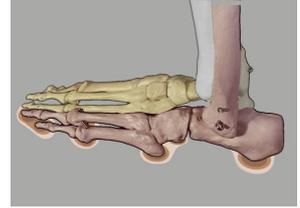
## A More Accurate Model of the Foot

Rather than only two, the foot has five cambered arches: three, main combined arches, plus two length-wise arches along it's lateral edge.

The foot has two principle skeletal systems denoting sequence of deployment:

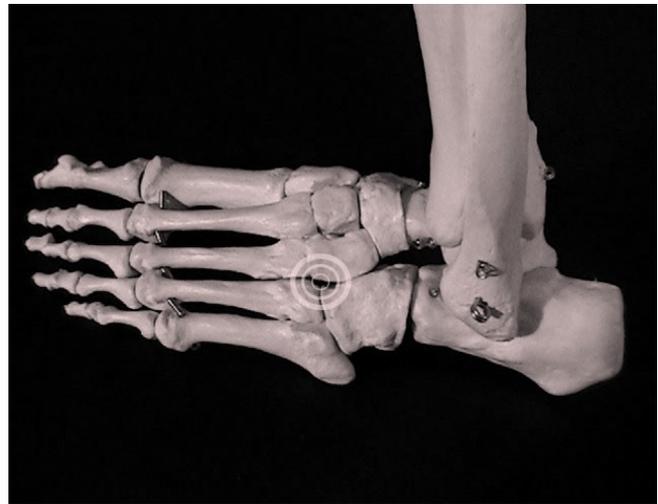
The Receptive Foot:  
 Calcaneus / Cuboid  
 4<sup>th</sup>+5<sup>th</sup> Metatarsals  
 4<sup>th</sup> +5<sup>th</sup> toes

The Propulsory Foot: Talus / Naviculare / 3<sup>rd</sup> Cunae-form  
 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> Metatarsals/toes



## Updated Load Model The Metatarsal Weight Distribution Center

The R and P systems stack at the ankle with the tibia, talus and calcaneus. From there they separate and bow out laterally and medially as they construct forward, and come together again to form a laterally descending roof at the 3<sup>rd</sup> cuneiform, cuboid and the 5<sup>th</sup> and 4<sup>th</sup> metatarsal, and spread out again from there through the metatarsals and toes. This mid-foot juncture is considered by the ASIRC to be the summit of the three main arches, and the weight distribution point for most active situations (Metatarsal Weight Distribution Center, or "Meta-Center"). Passing or centering the weight over the Meta-Center appears to enhance ankle and knee alignment, although we have noted a tendency to exaggerate arch stability in the introductory phase when a student first learns of the Meta-Center, sometimes resulting in "tired foot" syndrome.



### The Rim

- The 13 skeletal struts involved in support roles are ranged from medial-posterior at the heel, around the lateral side of the sole to medial-anterior.
- The support points are formed of paired protrusions of uneven sizes suggesting channels, i.e. the larger medial-anterior calcaneal tuberosity, that is paired with a smaller, lateral-posterior protrusion (see illustration here - right).
- Obvious lateral bias of the rim suggests a ramping, arch-conservative slalom for weight and momentum



### The Missing Support (Roll-through) Point

- The back end of the 5<sup>th</sup> metatarsal and the tarsal cuboid serve to bridge between heel and fore-foot, and are the mid-foot foundation for the cambered double arch of the receptive system.

### "Relever" - The Use of the Fore-Foot

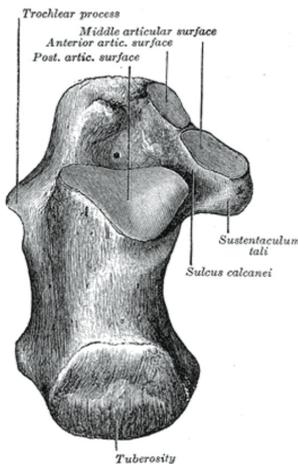
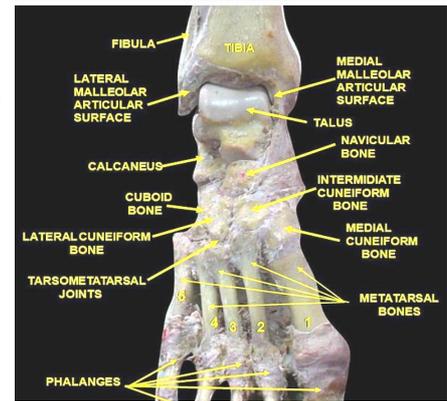
- Optimal support – load spread throughout the metatarsals, toes as secondary support. Third toe (Meta-Center Extension) can be generalized target for calibrating weight-distribution



## The Integrity of the Ankle Joints

Mid-range tibi-talar and calcaneo-talar joint motion is arch-conservative. The tibio-talar joint manages the flexion and extension of the tibia and the fibula, where the calcaneo-talar manages the internal and external rotation of the tibia during flexion and extension. The posterior aspect of the tibio-talar joint is narrower and higher on the medial side, while the anterior aspect is wider and higher on the lateral side. The wider anterior aspect offers more surface area for absorbing the strain of landing and take-off, indicating that high-stress is best managed over moderate dorsi-flexion. The anterior edge of the talus is also higher on the lateral side, while the posterior edge is higher on the medial side. During flexion of the ankle, the accumulation of more material on the lateral side pushes the lateral foot down and pulls the medial foot up.

During extension of the ankle, the accumulation of more material on the medial side pushes the medial foot down and pulls the lateral foot up. By pushing the medial foot lower in the Toe-Off phase as the ankle extends, the tilting joint surfaces insure the propulsive integrity of the fore-foot, and propose optimal support value at Initial Contact by pushing the lateral side of foot lower during the SP as the ankle flexes.



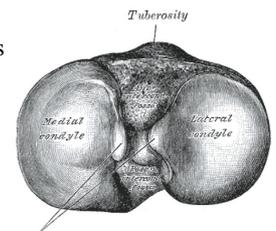
The calcaneo-talar joint complex (*see illustr., left*) includes three articular surfaces. The largest, or posterior subtalar joint (PSJ), the medial and anterior articular surfaces. The PSJ is a runs on a sloping diagonal over-curve from anterior/medial to posterior/lateral, while the other two joint surfaces build a medial-inferior to lateral superior ramp and serve as guides for movements traveling along the arc of the PSJ. Opposing the topography of the superior articular surface of the talus, the surface of the PSJ is higher on the lateral-posterior edge, and higher on the medial anterior edge, while both the dome of the talus and the PSJ start and end medial, while they arc laterally. The subtalar articular complex provides a multitude of optional trajectories for the talus, but mostly exists to manage the internal/external rotations of the tibia during knee flexion/extension. The subtalar movements therefore oppose the tibio-talar movements, producing torsion through the foot as part of the inferior limb's kinetic chain.

## 2. Neutrality, Asymmetry and the Structure of The Knee and Hip

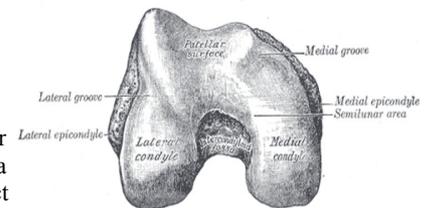
### Knee - Challenging the Linear Flexion Theory



The knee, along with all other joints in the human body, is a fundamentally asymmetrical structure. The medial condylar compartment is larger than the lateral compartment, and offers a posterior-medial to anterior-lateral arcing track, while the smaller, rounder lateral compartment offers the rotational axis. Accepted current understanding of knee kinematics includes an external rotation of the tibia in extension, and an internal rotation of the tibia in flexion, while the femur rotates externally in flexion and internally in extension. These rotations reflect the loosening of the collateral and tightening of the cruciate ligaments in flexion (int rotation of tibia/ ext. rot. of femur) and the tightening of the collateral and loosening of the cruciate ligaments in extension. Modern clinical testing places the axis of internal and external rotation in the knee at the center of the lateral meniscus. The lateral meniscus is thicker and more doughnut-shaped, and more mobile than its medial counterpart, and attaches in two places to the intercondyloid eminence, allowing the lateral meniscus to adapt to and offer support in a myriad number of articular



relationships. The thinner, immobile medial meniscus attaches in three places, strapping in place to the tibial plateau, where it serves as a guide-rail for flexion and extension. The longer, medial femoral condylar ramp adds weight to this observation. The arcing curve of this side of the femoral condyle suggests the perimeter of the knee-joint's rotational moment arm, while the lateral condyle presents an oval bulge to operate the joint's approximate rotational center. Another argument for the lateral loading of the knee-joint is the hitherto disregarded role of the Fibula as a bony spring. As compression builds through the leg, the fibula deforms and twists with the impact forces, bolstering lateral side in the flexion phase.



“the fibula bears no weight” Kapanji's Error –this theory over-turned in several 2008 clinical tests – for example: “The Knee Joint Center of Rotation is Predominantly on the Lateral Side during Normal Walking” -Seungbum Koo1 and Thomas P. Andriacchi - Department of Mechanical Engineering, Stanford University, Stanford, CA Bone and Joint Center, Palo Alto VA, Department of Orthopedic Surgery, Stanford University, Stanford, CA.

Moderate or 35 to 90 degree flexion of the knee provides more support surface within the joint for load and shock distribution, full flexion focuses the full compression of the body's mass and what ever ground shock forces are being managed to a small area of the joint. Optimal Q-Angle (quadricep-angle) assures healthy patellar tracking. OQA is established by bringing stepping foot close to center of body-mass, as well as counter-rotation of lumbar/pelvic unit (appropriate hip and spine mechanics)



### ***The Hip Joint – Scrapping Lies and Legends***

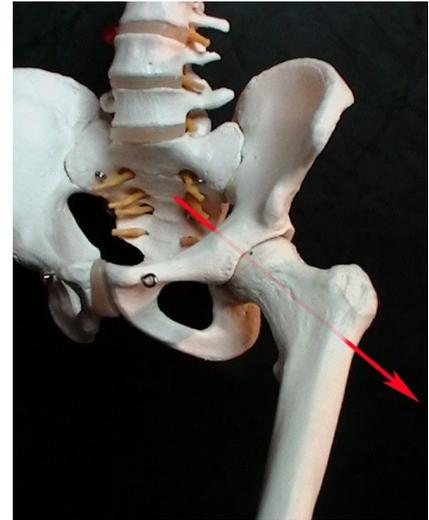
As with all other articular constructions in the body, the hip-joint retains the rounded asymmetry that is the engineering benchmark of all organic life. This notwithstanding, many training approaches that include stretches, insist on mono-planar flexions, extensions, abductions and rotations, and often encourage extreme mobility. Many exercises that are supposedly designed to strengthen and coordinate the hip-joint for enhanced performance revolve around the mono-planar strategy. This reductionist tendency is a logical culprit when we are looking for sources of the epidemic of articular distress in our society, since mono-planar motions carry the joint towards less-than-optimal

positions, where their support value is diminished. If these motions are practiced into ingrained habit, they may become deep-seated reflex, presenting a prohibitive challenge to re-education when injury occurs. Happily, the evidence for a more appropriate treatment of the hip-joint can be at least partially deduced from an examination of its structure.

### ***The Fallacy of “Parallel” and the Re-Discovery of the Hip-Axis***

The articular surface-match of the femoral head and acetabular lunula (cartilage), presents the vertical axis of the femoral neck on anterior to posterior, superior to inferior diagonal with respect to the overall mass of the innomate. Maintenance of the VA of the femoral neck (Hip-Axis) during flexion/extension sends femoral shaft on arcing trajectories that second foot and knee kinematics:

- flexion-phase: thigh moves on posterior-anterior, medial-lateral arc
- extension-phase: thigh moves on anterior-posterior, medial-lateral arc



The deployment of the Hip-Axis would allow the articular surfaces to stay matched throughout the various phases of walking. This is easily verifiable with any skeletal model, or real skeleton. For the contrary, parallel flexions of the hip can lead to internally rotated hip flexion at heel-strike (see picture: left); because the resulting internal rotation during the flexion phase removes part of the surface of the femoral head from its matching relationship with the acetabular surface and accents the medial thrust of the femoral shaft as it slopes down from the hip-joint. This would lead to excessive loading of the lateral condylar compartment of the knee, and thus more strain and load will be passed on to the medial collateral ligament and its accompanying muscles, and to the arch of the foot through the fibular articulation and the lateral edge of the tibio-talar. In other words, a parallel flexion can be cited as placing excessive strain on the arch of the foot, and on the adductors of the knee.



Less-than-optimal walking habits can prove dangerous in more energy-intensive activity, i.e. running. Parallel flexion is often accompanied by reversal of contralateral hip mechanics. In this picture (right), the left hip is dropped, even before the receptive right foot has made contact. Landing like this would ostensibly place concentrated strain on the medial superior edge of the femoral head and the lateral-superior edge of the acetabulum, reducing the support-value of the right hip joint. Impact forces will be absorbed through the superior anterior lip of the labrum, and spread through the fascia latae and the gluteus minimus, medius

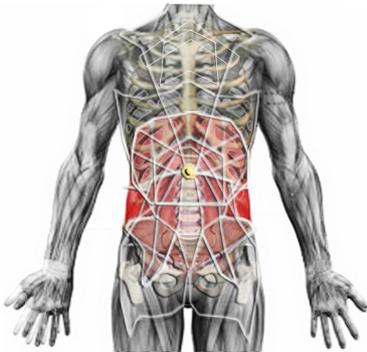
Near extended hip flexion is the common range in which most people walk normally. Given the initial linking angles of the pelvis, a neutral operational stance would look slightly externally rotated at the level of the feet. The slight external rotation makes bio-mechanical sense when we consider the contralateral motion of the torso, that turns the swing-phase hip towards the mid-line, rotating the proximal side of the hip-joint internally, while the forward swinging femur rotates the distal side of the joint externally. Objectively, the receiving hip-joint is externally rotated at heel strike. The moderately extended rear hip is therefore objectively internally rotated. While the hip-axis is a well-known anatomical feature of the hip joint, the insistence on mono-planar training approaches and rehab exercises relative to walking are rampant.

### **3. Anatomical Center / a more accurate model for coordination enhancement**

#### ***The Legend of the Core Unit and the Immovable CoG***

The most proximal point of the human body has long been confused with the *Center of Gravity* (CoG). The reference for the CoG is the erect standing position, with the hips at near-full extension. Even though it is known that the CoG of an object is only as constant as that object's volume or shape, anatomists, martial artists and dancers alike have insisted on the illusion that the CoG was immovable, and also the most proximal point of the body. This misperception may have given rise to the mis-conception that there were some muscles or structures near this point that were “core”. Although little or no anatomical basis for this notion exists, the idea

that there is an isolated “core unit” has accumulated a number of unfounded but nevertheless widely practiced and even institutionalized training methods. These methods are all based on the reinforcement of lower abdominal muscle groups through name-branded exercises that had little or no relationship to real-life activity. The focus on the lower abdomen as “core”, or “center” may have also given rise to a generalized over-use of the articular potential lumbar, and an under-use of the lower thoracic. In our observation, students and athletes tend not to be aware that they can also extend, flex, rotate and flex laterally in the lower thoracic spine. They tend to depend on the lumbar for all of these motions, even though it is a well-established fact that the lumbar does not willingly rotate. Also well documented are the injuries to the lumbar spine and an epidemic of pain in the lower back.

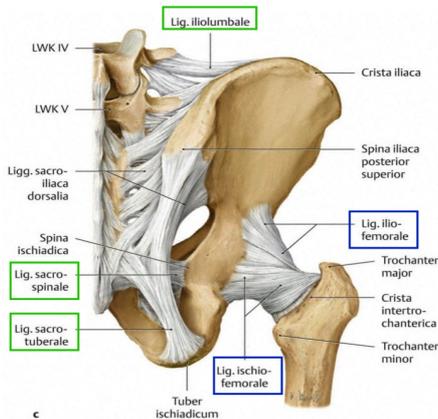


Training regimes for the pelvic floor, psoas or abdominal wall have turned up blank or equal to any other physical activity as a remedy for LBP or other stability issues (see: “Core Stabilization – Fact or Fallacy” Robert Burgess BEd, PT, PhD, Feldenkrais Practitioner / “The Myth of Core Stability”, Professor Eyal Lederman). The AS research community suggests that the solar-plexus zone, or mid-spine area between T-8 and T-12 (see image left), provide the criteria for an anatomical “center”, being the organ hub, and the intersection of major mayo-fascial systems that connect the upper and lower limbs.

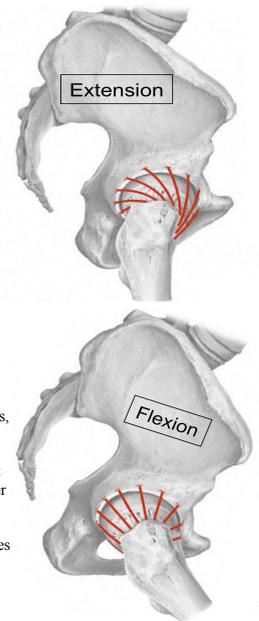
The mythical “neutral” starting point – standing on two parallel feet, hips extended, torso erect, has long been touted as the panacea for answers to coordination problems, alternatively because “balance is the most advantageous starting point for moving”, or because the discovery of the legendary “center” is the “key to finding the source of all movement”. Esoteric platitudes do not provide explanations or practical assistance, which are usually worked out by the individual, as we can see time and again in extraordinary movers as they discard these “rules” for more functional strategies.

Also up for revision is an endemic insistence on pelvic retroversion, which is synonymous with lumbar flexion, and sacro-iliac nutation. This posture offers less-than-optimal support-value in the landing or impact phase. A moderate (neutral) lumbar curvature, as well as the moderate anterior tilt of the torso, anteverts the pelvis, flexing the hips. Pelvic anteversion brings the highest part of the acetabular wall to bear over the femoral head.

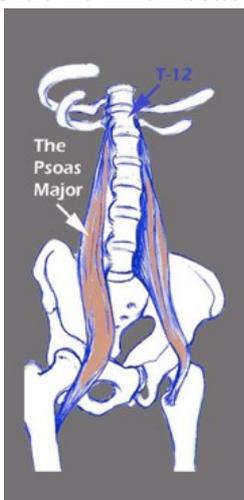
Slight retraction of the lower body and slight anteversion of the upper body lifts the center of gravity towards the solar-plexus, off-loading the pelvic floor, loading more strain towards the pubic symphysis. The slight protraction of the torso, and simultaneous retraction of the pelvis insure the stabilized neutrality of the lumbar spine



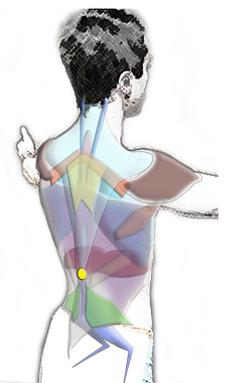
As you can see in the drawings to the right using red lines to indicate the fiber-line of the hip-ligaments, the upright position actually brings the hip-joint into near full extension, tightening the articular ligaments, decreasing mobility, adding powerful resistance to any further motion. A 30 to 90 degree flexion however, loosens the ligaments, and in the standing situation, engages most of the muscles that support and drive the lower body, promising supported mobility with a well-defined back-end stabilizer to prevent hyper-extension. The tightening of ligaments and other myo-fascial connections provides stored kinetic energy for the swing-phase. Therefore, the odd tendency in many training approaches to try to undo this natural inhibition to movement past the extension-phase is perplexing, as these practices may very likely result in producing a dangerous laxity at end ranges.



### Clue 4 / The Psoas - Hip Function



The psoas works eccentrically to first internally rotate and adduct the extended femur during hip extension, beginning its influence with Mid-Stance, with the most pronounced internal rotation occurring after Terminal-Stance at Pre-Swing. The psoas then works to externally rotate the hip joint during the Swing and Impact phases, culminating at Mid-Stance. As the lower body twists contra-laterally with the upper body, the psoas rotates the legs counter to the direction of the hip: i.e. the hip swings back and medially, externally rotating its anterior side, while the psoas produces the internal rotation of the femur. The opposite occurs during Swing phase. The psoas is part of a nexus of important structural myo-fascial connections that span out into the entire body. The larger and more evident of these are: The lats, the lumbo-thoracic erector-spinae, the QL, the diaphragm, the serratus inferior, the erector spinae and the trapezius, who's distal insertion is also T-12. This entire system is involved in creating forces that check the contra-lateral torsion of the torso, and assist in swinging the legs and arms. For the activities involving walking, the psoas is perhaps one of the the most fundamental myo-fascial bulwarks, but its suggested trajectories for the spine, arms and legs are seconded at every level, and supported by the most outlying structure. Walking phases are therefore intimately linked to the fiber-line pulls and tensile resistance the psoas and co. produce, as well as conditioned by the shape and angular disposition of the joints, who's topography and ligamental tethers guide and limit the masses of the body as they plunge through the earth's gravitational field. Allowance



T-12: myofascial intersection

for variations of structurally suggested pathways enhance the collaborative use of all muscles, in a harmonious partnership with the bones. Packed together with the fat, nerves, arteries and veins, a well organized movement tightens or loosens the whole matrix, without compromising the body's tensegrity.

Understanding that walking represents the matrix of all human movement possibilities, the primary question I ask myself when designing preparatory exercises or choose movements: does the regimen or approach underwrite or counter the body's own inbuilt ambulatory solutions?