The SPINAL ENGINE MEETS the BICAMERAL FOOT

Human, bipedal gait involves transferring load from one foot to the other, without the "Barbie Doll effect" where the head and trunk would be significantly displaced in the three cardinal planes. This would be very costly, energy wise. Instead, the head and trunk appear to move effortlessly through a single sagittal plane.

Human anatomy has evolved to a point where we are the most efficient walkers, the most adept endurance runners and we can rotate our entire body around a vertical axis in standing. These three unique human features have obvious survival and competitive benefits and share common biomechanical features. If any one component malfunctions the CNS will most certainly respond to maintain efficiency, in some cases creating the scenario of silent culprits versus noisy victims. While these features involve the entire body this presentation will focus on the biomechanical aspects of the lower half.

Initiation of gait is very expensive in terms of muscular energy. After a few steps a pendular gait is achieved, maintained by the '*spinal engine'*. Using the example of right leg mid-stance with left leg in swing through phase:

SPINAL ENGINE:

Beyond neutral hip extension, psoas changes from eccentric to isometric -> pulls lumbar spine into extension, left rotation and right-side bending. This, in turn pulls the sacrum into a forward torsion, in this case a left on left. At the same time, the momentum of the left swing through leg creates a simultaneous posterior torsion, a left on right. The resultant axis is vertical. The torsional energy created in is stored within the bones and soft tissues of the lumbar spine and pelvis, ready to be released upon right heel lift, initiating the right swing through phase.

The LEG ENGINE:

To avoid wasting energy to friction as the pelvis is rotating right in space, the right hip internally rotates as it close packs into extension. This sets up a secondary energy store as the joints, distal to the hips close pack into external rotation. At the superior tibiofibular joint, the fibula bows and glides posteriorly. This inert tissue energy store is also released at heel lift, to facilitate right leg swing through.

The BICAMERAL FOOT:

The foot has two separate functional units:

The lateral foot, consisting of the calcaneum, cuboid and 4th and 5th rays.

The medial foot consisting of the talus, navicular and the 1st 2nd and 3rd rays.

There are 3 phases of foot function during weight bearing:

1) Lateral foot phase (from heel strike to mid stance) absorbs initial impact and loading
2) Transference phase as the peroneus longus pulls the first ray down to set the sesamoids for weight bearing (this occurs mid stance to heel lift). The foot is now optimally flat (pronated) and has absorbed maximum torsional energy.
3) Medial foot phase (from heel lift to toe off) creates a rigid lever to help propel the body forwards and increase right limb length to counter a vertical drop. The foot is now optimally twisted (supinated).

BIOMECHANICAL SCREEN of the LOWER HALF of the BODY

Introduction:

The following biomechanical screen is not intended to replace the history and scanning examinations. Neither the logical, detailed examination of a structure or region of the body which has suffered obvious trauma or disease.

Rather, this assessment tool is designed for the more chronic patient whose dysfunction or symptoms have not been corrected by previous treatment or possibly, where the patient's discomfort does not have an obvious causation. A classic example would be the young athlete who attends with knee or foot pain, without a history of trauma and even though the pain generator has been identified (e.g, MCL; medial calcaneal tubercle), treatment has been ineffective.

This brings us back to the concept of 'noisy victims' (that bring the patients into the clinic) versus 'silent culprits' (non-symptomatic biomechanical dysfunctions that are causing tissue damage from a distance, anatomically speaking).

The basis of the screening examination are the three functions of the lower half that make humans quite unique from any other mammal i.e. ***striding*** (erect, bipedal human gait), ***endurance running*** and ***axial rotation around a vertical axis*** with fixed feet. Although both functions utilize similar biomechanical components, they are different enough to incorporate into a single screen. Since striding is recognized as the most efficient form of gait on Earth the main question is what anatomical/biomechanical features facilitate such

efficiency. Then, can we assume that if any of those features become dysfunctional the neuromuscular system will also become affected, potentially causing biomechanical and neuromuscular problems throughout the lower half of the body. For further detail into what these features are please read *'The hip bone's connected to the foot bone'*.

Performance of the screen:

The results of the scan are not intended to be diagnostic. Rather, it is intended to identify structures or regions of the body that will require further examination. In the first part of this paper the screen will be sequenced and performed as if there are no positives. In the second part the consequences of finding a positive will be reviewed i.e. what would be the clinically reasoned next steps?

PATIENT **STANDING** starting position:

The patient begins the screen in standing, feet under the hip joints. Contact between the ground and the soles of the feet remains static. Therapist will move into positions necessary for efficient observation. Patient must be attired in such a way that a maximum of the lower half is visible. Obviously, shoes and socks are off.

While observing the feet and ankles:

The patient is asked to raise onto toes (both feet) and then perform a semi-squat. Do the feet go into a 'twisted' position in plantarflexion and into a 'flattened' position in semi-squat. Range of ankle motion is also noted.

The patient is then asked to axially rotate (keeping feet planted) first to the right and then left. The shape of the feet is again observed. The ipsilateral foot should become more cavus, or twisted, and the contralateral foot more planus or flattened.

While palpating tibial tubercles and head of the fibulae:

Feel for approximation on ipsilateral axial rotation and divergence with contralateral axial rotation.

While observing the thoracic and lumbar spines:

As the patient axially rotates there should be a clear change in the side bending between the thoracic curve (ipsilateral side bend) and the lumbar curve (contralateral side bend). Depending upon age and mobility, the patient's change in the lumbar spine may simply flatten, rather than actually reverse into an opposite curve. So, the lumbar spine may appear to reverse the curve or simply appear to straighten out. A positive would be when there is a continuous side bending curve from upper thorax to pelvis.

While observing the lumbar spine:

The patient is asked to side bend right and then left. If there is a side bending curve in both directions (even though the curves may not have the same arc), then there is no segmental restriction in the lumbar spine (since, for example, with right side bending the right Z-joints are extending and the left Z-joints flexing).

The patient is then asked to flex and extend. Since there are no segmental restrictions, if a loss of flexion and/or extension is noted a segmental loss of stability is suspected.

PATIENT **SUPINE** starting position:

Patient lies in supine with hips and knees extended if possible. As an indicator of hip rotator muscle balance (or imbalance) the resting position of the feet is observed.

Assessing SIJ 'spring':

Therapist's palms cup the ASIS on both innominates while the digits wrap around the iliac crests. By manoeuvring the therapist's arm direction, the innominates can be rotated both anteriorly and posteriorly on opposite sides simultaneously to assess the ***'spring'*** of the pelvis.

Assessing tracking of hip flexion:

Patient's leg is grasped by the heel and back of the knee. ***Passively***, the knee and hip are flexed keeping the tibia and femur in the same sagittal plane. As 90 degrees of hip flexion is approached, does the leg stay, without rotation, in a sagittal plane? If it does, then as the hip flexes during the swing through phase the calcaneum is correctly set for heel strike.

Assessing the knee:

For efficient striding the knee must be able to fully extend (*slight hyperextension*) for close packing. This effectively makes the tibia and femur into one long lever arm, necessary at heel strike and mid-stance.

Therapist fixates patient's femur to the bed while other hand uses the calcaneum to test slight hyperextension with conjunct external rotation.

PATIENT in **PRONE**:

To assess hip extension the therapist stands on the side of the hip to be assessed, with patient close to the edge of the bed. Therapist's forearm closest to the pelvis fixates patient's sacrum. The other hand wraps around the front of the patient's thigh and lifts leg into hip extension and internal rotation simultaneously.

FLOW CHART of the LOWER HALF SCREEN

TESTS in STANDING

Toe raise/semi-squat → stability/mobility	Decreased ankle d/f or p/f →	Assess ankle
	Foot not flattening/twisting → Move to next test	
Axial rotation (FOOT) →	Consistent decrease flat/twist → test intertarsal mobility	
	Inconsistency with toe raise/squat → intertarsal stability tests	
Axial rotation (Tib/fib) ->	Loss of mobility -> manip	

Axial rotation (Th/L) → No reversal of curve → move to next test

Lumbar sp side bend → If normal bilat assess T10/11&T11/12 PIVM for rotation

If hypomobile rotn → manipulate

If T10/T11&T11/12 rotn normal → rebalance PSOAS ms

If lumbar side bend restricted → H & I test using relevant side bending only. Consistent restriction → manipulate in neutral followed by appropriate MET.

If Th/L and lumbar side bend tests normal move to next test

Lumbar sp flex/ext → If lumbar side bend tests OK and lumbar flex/ext tests are full and painless → lumbar spine biomechanically OK. If ROM decreased or painful → suspect instability.

TESTS in SUPINE

SIJ 'spring' test full → If +ve for motion and pain and patient is within a risk group →

SIJ assessment

If +ve, painless and patient not in a risk group → MET/manip

If-ve move to next test

Hip 'tracking' test → If +ve check internal rotation @ 90 degs and external rotator ms Strength in a short position. If all 3 tests +ve → manip + ex's.

If -ve move to next test.

Knee hyperextension → If hypo or excessive → ?? full knee assessment.

TEST in PRONE

Hip close packing → If hypo or painful → full hip assessment → ? capsular pattern
? labral pathology