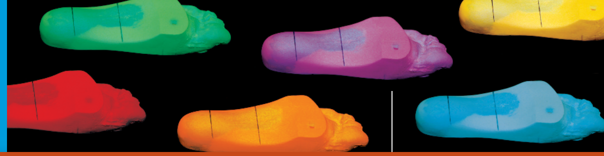

The Shortcomings of Gait Cycle Parameters in Patient Treatment

To understand gait we must consider "east-west" movement and oblique walking.

BY JAY SEGEL, DPM AND SALLY CRAWFORD MS, BIOMED. ENG.

The classically described gait cycle breaks down how we should walk when moving in a forward manner but not how we function throughout daily life. Biomechanics is the study of the way we function, how we do what we do. It is based on when events happen, how long they happen, the force and direction of what is happening and the order of said events. When performing a gait analysis we make observations and collect data, then compare those value judgments to established "norms". But do those "norms" really apply to the patient in question?

Empirically, we know now that the world is round but we didn't always know that. In the same way, we have our accepted gait "norms", develop preferred data for biomechanical events, and often spout platitudes in a vacuum based on the classic or traditional forward walking model. Time moves forward, we observe and learn, while thoughts and ideas around classical concepts evolve. More and more practitioners are beginning to note that we spend significant time functioning outside the parameters of the classic gait cycle yet how much consideration do we place on non-classic walking patterns when we diagnose, prescribe a custom orthotic or opine on patient prognosis? What parameters do we use and just what are the "norms" when climbing stairs or when we move from side to side, repetitively? The truth is, we don't know! By that I mean that we have not quantified the full extent of alternative gait patterns or identified their associated pathological parameters, nor do we have a user-friendly reference table with normal ranges for discussion amongst ourselves and with our patients, as is the case in standard gait charts. The purpose of this piece is to present biomechanics-oriented thoughts that provoke a focused discussion on the initiation of, and predominate events of lateral or oblique directed gait sometimes known as "east-west", oblique, or lateral walking, break down its mechanics, and their effects on the musculoskeletal system, then suggest ways to combat their deleterious effects.

The Problem with the Paradigm

The standard disciplined way to observe lower limb biomechanics is through analysis of the classical gait cycle where we would observe heel strike, followed by pre-midstance, midstance, toe off and swing phase. We would watch foot position, foot motion, swing phase, single and double support, open and closed chain kinetics and range of motion, as we've been taught. There are established ranges,

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New Concepts and Studies

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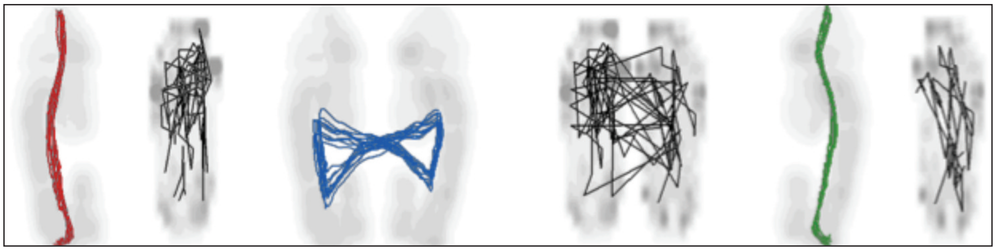

Figure 1: Measurements of Center of Pressure movement during stance and single support for classic, forwards, gait (red blue and green) and oblique gait (black). Are we rolling heel to toe for the majority of our days?

benchmarks and normal limits for these gait features, such as: at 55% of gait cycle the heel should be lifting off the support surface. When an event such as that occurs sooner than expected we may consider a diagnosis of Equinus and when we see delayed heel lift we might expect to see great overall plantar pressures and use terms like apropulsive gait. Our suppositions may be valid, but have we thought about the patients' real gait cycle, how he or she moves through the day?

Here's the problem with this whole paradigm: there is little place in the aforementioned analysis for consideration of oblique, side to side motion or "east-west" walking contained in the dominant paradigm for gait analysis that we call gait cycle. Yet that might be the dominant influence in a patients' foot pathology. During much of our day, and for many people, most of our day, we engage in non-classic gait. Think of all we do at work, in the bathroom, bedroom or the kitchen. These are smaller environments, where we are looking in one direction and often moving in another, from task to task, like the preparation of a meal or our daily rituals when we wake up or head to bed. Now, when we add these deleterious effects to a person who works on their feet for extended hours like a chef, salesperson, cashier, wait staff, or tradesman, to name but a few, we have a prescription for degenerative disorders that trained professionals can address and minimize with thoughtful observation. It also bears noting that oblique, inefficient, or non-classic gait patterns increase as we age or become infirmed. And so, just like the beginning of the journey away from the flat earth mindset that started with "contact", so does our intuitive brain and trained eye begin to look at the contact phase in alternate gait patterns.

If one accepts that there is a significant amount of "east-west" walking that needs to be considered during patient evaluation and creation of a treatment plan, let's look at what is going on with foot position and motion beginning with contact. If one starts with the fact that, in the prevailing paradigm of gait cycle, in order to get the swinging limb under the body during single support, the foot needs to pass through in a dorsiflexed and supinated position, otherwise we would be tripping over our toes. In that case, heel strike happens with the calcaneus inverted, compensatory pronation ensues and absorbs some of the generated ground force reaction.

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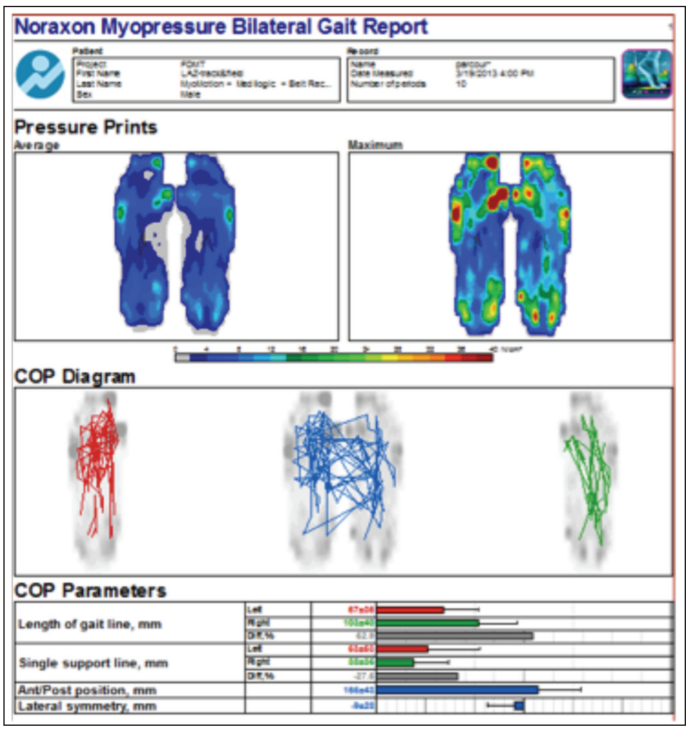

Figure 2: Measurement report page showing average and maximum pressure distribution readings, Center of Pressure traces, and parameters compiled from the oblique movement study.

East-West Walking

In "east-west" walking we instead, more often then not, find less deviation from frontal plane neutral, as there is no swinging limb that passes underneath an erect, forward-directed central body frame, with decreased forward momentum, decreased pronatory ground force reaction and, therefore, more shock in the paradigm to jar the foot and wreak havoc up the kinetic chain.

In addition, transverse plane motion increases along with midstance, while the heel strike, propulsive and swing phases all diminish and often occur out of order when compared to the classically described gait cycle. Because of the shortened motion as well as the frequent stops and

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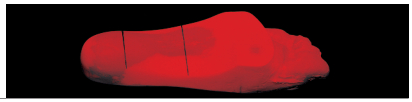

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starts in this alternative gait style, it is important to concentrate on the initiation of motion from a static position. Also, Newton's laws of motion apply here in that more energy will be required to overcome the foot being a mass at rest.

New focuses like "lead leg mechanics" in "east-west" walking demonstrate the biomechanical event differential as evidenced by the observation that initial ground force reaction is mitigated at the level of the lateral forefoot and midfoot, whereas, in classic gait, these forces are processed first at the heel. In fact, in standard gait cycle, motion and phases of gait are headed in the same direction, proximal to distal. The change in the order of phasic biomechanical events, i.e., primary contact occurring distal to normal heel strike, followed by retrograde motion back onto the heel, create a biomechanical nightmare called shear stress. Shear is described in this case as a force created when two adjacent objects interact while moving in parallel opposition, and is often a stress associated with the plantar foot, but here it is seen in oblique walking at the ankle joint as well. So in the instance stated above, the initial lead leg contact occurs about the level of the mid to forefoot followed by heel set. Foot center of pressure at that moment in time can be shown to track anterior to posterior, or distal to proximal when displayed over a pressure graph, yet momentum and leg movement is lateral and forward on that same graph. These divergent forces carry the increased possibility of joint and tissue distortion and deformation through repetitive microtrauma, resulting from the shearing stress.

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The Study

In a recent study of 25 subjects beginning at a standing start on a large format pressure distribution platform coupled with 2D video kinematics, we see that, as the lead leg initiates lateral movement it engages in abduction and external rotation at the hip, knee flexion, ankle plantar flexion, and the foot supinates. The

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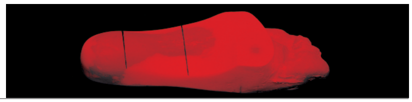

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lead leg goes through a short swing phase and the trunk rotates in sync with the motion while the planted contralateral, trailing limb pronates at the knee joint to compensate for the limb length discrepancy caused by the change in transverse plane position and lateral movement of the lead leg. These pronatory forces place added strain on the hip abductors and at the pes anserinus extra forces can lead to medial knee pain and soft tissue compensatory pathologies such as pes anserine bursitis. At this moment, the base of gait is widened to provide stability while the lead leg lands. To complete that movement cycle, the contralateral limb pivots and propels from the medial forefoot into a medial guided swing phase. The deleterious effects of pronation on the first metatarso-phalangeal joint (MPJ) are well known, but in the "east-west" model of motion described herein, this oblique motion taxes that joint at a much higher level. As the direction

Figure 3: Set-up of the Noraxon SEMG direct transmission system used in the investigation of medial and lateral calf components. MyoVideo analysis tools display how the contralateral limb pivots and absorbs the compensations needed, due to the transverse plane position caused by lead limb.

of lateral motion is at a more disadvantageous angle to the motion desired by the hinge joint styled first MPJ, so increases the wear, deformity and trauma to the forefoot.

There are additional soft tissue elements to consider, including ligamentous laxity/tauntness and its effects on range of motion, imbalances created by agonist/anatagonist muscular relationships, changes in direction of force and times of engagement of muscular groups. If we divide the lower limb into four main muscular groups for evaluation purposes—the dorsiflexors, the tibialis contingent, the peroneals and the gastroc-soleus complex with its Achillies tendon—we can begin to note the differences in behavior between the forward going gait cycle and the oblique model being highlighted.

During standard gait, the dorsiflexors are responsible for the sagittal plane control of the foot as a unit. They reduce foot slap during loading response and, in initial swing phase, they contract concentrically to prevent foot drop and continue through midswing. But as discussed earlier, swing phase is radically different in oblique walking and occurs in an altered sequence and with a different set of time parameters than we have relied upon in classic gait. So, as the events, forces, timing, and directions change during initial swing phase of oblique walking, we might expect to see a change in dorsiflexor activity and thus, all linked components in the kinetic chain.

Looking at the ankle plantarflexors during gait, the onset of biarticular gastocnemius begins say, 20-30%[1] of the standard cycle, with the soleus starting usually just after the former. Given that these muscles are oriented longitudinally, one would fairly even bundle activity from medial to lateral in forward walking. Now adjusting for lateral primary motion, the ankle plantarflexors governing the lead limb will begin earlier and show asymmetric wave patterns reducing the usual stabilizing effect of this group during midstance. The

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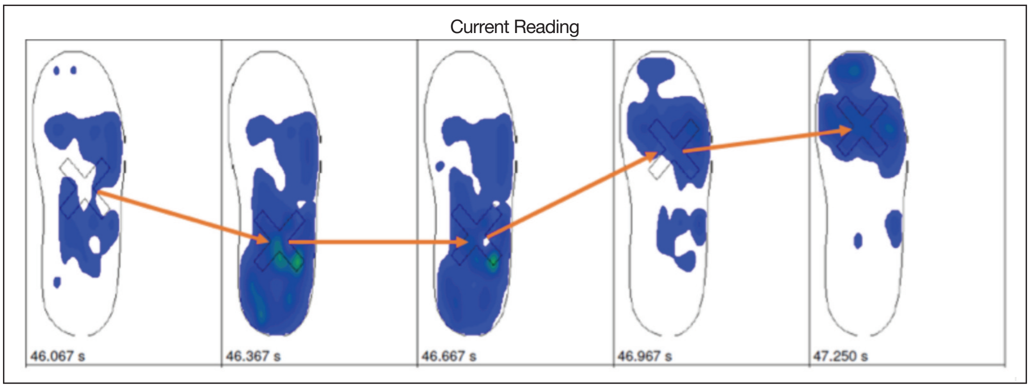


Figure 4: In-shoe pressure time graphics of trailing limb showing Center of Pressure shift, and directions of force change due to the compensations from lead limb. Shifts graphically display the un-benchmarked patterns in movement initiation.

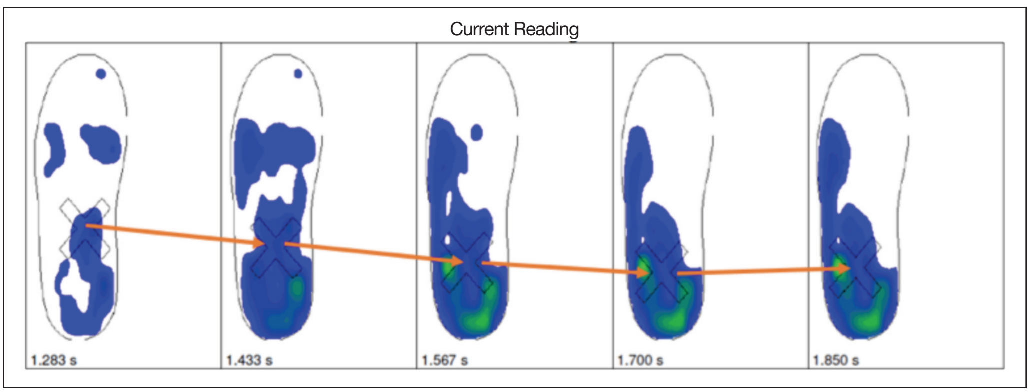
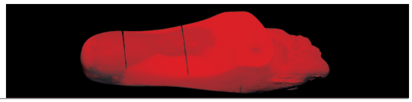


Figure 5: Further oblique movement study step showing lead limb Center of Pressure shift, first distal to almost normal heel strike. During oblique walking, the direction of momentum changes substantially, thus encouraging increased shear stress.



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anterior and posterior tibialis muscles are strong supinators of the foot and relied to provide stability and prepare the foot for the terminal phase of gait. From heel strike through the first 10% of gait cycle they resist the forces of pronation stemming from our gravitation center, foot position and a subtalar joint designed anatomically to perform about a 42 degrees axis of motion. If we observe the trailing limb at single support through to double support, with a laterally moving lead limb, the foot tends to be in a relatively more pronounced pronated position, placing a greater strain on the tibiali as a group and the spring ligament as well. This scenario can lead to conditions like Posterior Tibial Dysfunction, ligamentous laxity and even rocker bottom foot.

The antagonist muscle group to the aforementioned foot supinators are peroneus brevis and longus. This group contracts at contact to support the plantar ligaments, pronating the foot to absorb shock as ground force reaction in forward gait. In our initiation and continuation of oblique walking, the direction of momentum has changed substantially. As the momentum turns more lateral in the lead limb, the peroneals will have to work harder to stabilize the foot and off-load shock as this requires motion in the direction of subtalar joint neutral. When you consider the changes in momentum, planes of motion, initiation of activity, asymmetry and gravity, one can look at all of the muscles involved in foot function and apply this logic to many more soft tissue structures and find the potential root of other biomechanically based pathologies.

Testing Results

When testing these gait concepts, during the study described above, and follow-up tests looking at the quantitative analysis of forward gait, initiation of "east-west" walking, and continuous "east-west", oblique walking, the following diagnostic computer-based analytical systems were used: Noraxon's MyoPressure—wireless Medilogic Pressure Insoles and Force Distribution Measurement Treadmill—along with the TOG Gaitscan™. Testing was performed barefoot, shod and with orthotics. For the continuous oblique walking assessment, one subject was examined moving in unplanned, yet functional directions, with movements gauged only by the task at hand: cooking dinner in a small 10ft square area. The subject was wearing Noraxon's wireless Medilogic Pressure Insoles directly transmitting to the same aforementioned MyoPressure software. The following was found:

- Direction changes and initiation of motion from a static position occur frequently. Movement is not patterned nor repeated to any substantial degree with the exception of the initiation of motion (see also Figure 1 and 2).
- Movement is not forward, and when looking in one direction and moving in another, from task to task, this concept was exaggerated.
- When the lead limb's midfoot or forefoot contacted first, deceleration was localized, and often times the center of pressure remained forward, other times it shifted laterally, and only occasionally when the movement was trending forward, it shifted back and then forward again.

Normal decelerators remained unused, and unloaded, or over-used, and super loaded in these oblique directions, depending on the phase and limb.

Increased shearing is found here, described above.

- Normal decelerators remained unused, and unloaded, or over-used, and super loaded in these oblique directions, depending on the phase and limb. This lead limb forefoot contact happened more than once, which reverses the practiced gait order of events.
- The amount of pronation and supination and the timing of these "tasks" was inconsistent for every step. There is no way now to relate to the "norms" we know, and to add to this, the balancing and supporting actions were unlike the patterns we rely on. Stability in any oblique direction is impossible to generalize as there are contributions from the en-

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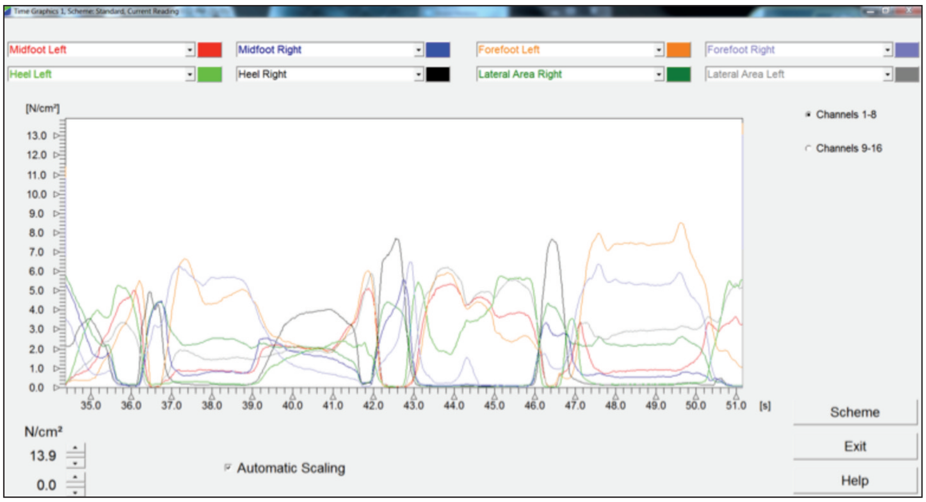

Figure 6: Noraxon's Medilogic oblique movement study pressure over time graphic for all regions of the feet, both trailing limb and lead limb. Note that loading pattern and impulses are quite literally all over the map, but the initiation phases of each movement should be stressed and become of far more importance.

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tire kinematic chain helping (or hindering) that cannot be normalized even with advanced motion capture solutions recording every action.

• Timings were inconsistent and the amount of standing increased during oblique walking.

Where does that leave the phases of gait now? Maybe we can focus on the trailing limb? Maybe the pattern is there as it is certainly not for the lead limb. From the tests the answer was clear—even the trailing limb pivoted inconsistently.

In practical conclusion, if we are considering biomechanical intervention in the form of orthotic therapy, all of these new conditions become considerations when constructing a custom prescription. The analysis of the initiation of "east-west" movement and oblique walking seems to suggest that a more controlling device might be in order. Orthotic modifications like deep seated heel cups, medial and lateral flanges found on UCBL insert shells and dynamic rear foot posting systems, may add the increase in the level biomechanical correction desired by an individual prone to oblique motions. In any case, though the world is round, our steps are flat, our feet are three-dimensional and more studies are needed to guide us along this slippery slope. **PM**

Reference

[1] Francis, Carrie. et al. The modulation of forward propulsion, vertical support, and center of pressure by the plantarflexors during human walking

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