# Biomechanical Intelligence

Here's a novel method to simplify biomechanics.

BY KEVIN B. ROSENBLOOM, C.PED

As any doctor knows, medicine is both art and science. For some conditions there are precise tests that lead to a definitive diagnosis, but for many other ailments, it is a combination of multiple tests, coupled with the doctor's past experiences and intuition that ultimately lead to diagnosis and identification of the etiology. In podiatry, the latter occurs more often than the former. Patients often have visited multiple medical providers and physical therapists, and tried over-the-counter relief before ultimately receiving a targeted treatment plan that addresses the functional etiology and successfully treats the pathology.

In 1971, Merton Root et al published the seminal "Clinical Examination of the Foot, Volume 1" and in 1977 published "Clinical Biomechanics, Volume II, Normal and Abnormal Function of the Foot". These works established podiatry as a validated clinical field within the medical community with millions of patients treated successfully using Root Theories.

Over recent years, the focus of podiatry education has changed from biomechanics to surgical treatment. While educators still claim that understanding biomechanics is the foundation for understanding the "why" of surgical procedures, there is a shortage of podiatrists who are confident and capable of assessing patients' biomechanics whether normal and efficient, or pathological and inefficient. Surveys and discussions have confirmed a significant lack of education in biomechanics and a similar lack of understanding of the related subjects of physics and engineering among podiatrists.

For two years, I shadowed and assisted the revered Lowell Weil Sr., DPM in clinic and surgery. I carefully observed the surgical procedures and conservative therapies provided to patients and the latest literature in various journals. It was evident that the biomechanical underpinnings behind conservative therapy, which had a stronghold during the 1970's-1990's, were largely overlooked by new fellows and podiatry residents who were focused on the latest surgical techniques, not the underlying biomechanical roots of pathology. Considering the growing hole I observed in biomechanical competency and understanding by new and young podiatric physicians, I shifted my career path from surgical treatments to conservative treatments, believing there was a place for functional orthopedics and biomechanics to rise again, and began focusing on developing technology that could help physicians treat patients better.

Limited internal hip rotation
left side

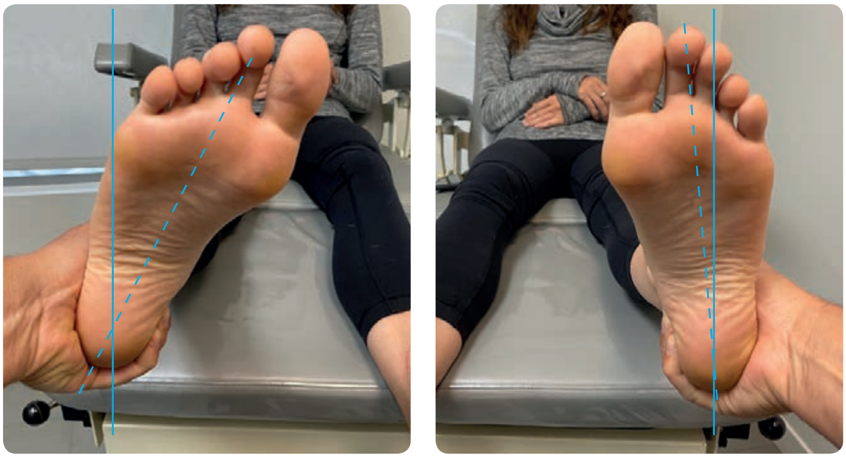

Figure 1: Limited internal hip rotation

For the past 15 years, I've worked on creating the Biomechanical Intelligence Quotient™ (BIQ™) as a Root 2.0 so to speak, a new way of evaluating patients to help doctors more effectively and efficiently identify many podiatric and biomechanical conditions by honing in on the etiologic biomechanical issues underlying the pathology. A wise podiatrist once said, "nearly every surgery I do has an underlying biomechanical imbalance."

The utility of BIQ is well-demonstrated with most pathologies presented in our clinics from toe deformities to rearfoot pathology to knee, hip and back pathology. For example, plantar fasciitis, By doing a thorough BIQ exam, the clinician may discover that a limitation of internal rotation at one hip is creating an imbalance resulting in overuse of a kinetic chain that ultimately involves the plantar fascia tissue on the bottom of the foot. (Figure 1) The diagnosis of plantar fasciitis was made using physical examination. The root

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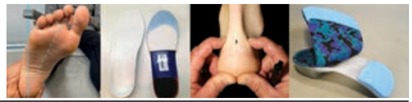

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cause of plantar fasciitis (limited internal rotation of the hip resulting in equinus, and ultimately plantar fasciitis) is discovered with a thorough BIQ exam. Addressing and treating the symptoms and pain of plantar fasciitis with calf stretches, ice water soaks, anti-inflammatory medication and orthotics does help, but failure to identify and resolve the root cause limits the patient's ability to find permanent relief. Using BIQ allows treatment aimed at the underlying biomechanical imbalance rather than the symptom alone, and tends to produce more definitive, long-lasting results and reveals to the patient a clear explanation of why they suffer from plantar fasciitis. In this case, modifying patient gait and precise orthotic therapy provides mechanical neutrality from the hip to the foot and the foot to the hip. It's important to understand that mechanics work in both directions, from hip to foot and foot to hip (sometimes fondly referred to as a "a top down—bottom up" approach.)" (Figure 2)

Plantar plate or metatarsalgia is another common pathology that is often treated by orthotics and sometimes surgery. Very often pathology is easy to diagnose but not easy to explain *why?* A longer second metatarsal or equinus can often be blamed but upon BIQ discovery, a mechanical imbalance in the tissue structures can reveal a much clearer reason why a patient has the forefoot pathology. BIQ will perhaps reveal a tight range of motion in the midfoot joints or a hip ROM/retroversion forcing longer compression and shear force on the tissues of the forefoot.

One other nugget to chew on is something I call cultural gait. Cultural gait is a distinctive mode of locomotion associated with a particular geographic locality or social class. For example, I live in Santa Monica and when I fly to New York, I find myself walking through JFK with a bit more speed and intention, my trunk is slightly pitched forward—I'm moving like a New Yorker! My brain quickly adjusts my gait to fit into local society. If I walk across a crosswalk in Santa Monica with the same intention and intensity that I walk the street in NYC, people will say "whoa, what's wrong with that guy?" In Los Angeles gait seems to be relaxed, shoulders back, cell phone in hand, and one walks very very slowly in a crosswalk to make sure everyone waiting for you knows that you are more important than everyone else. We can find examples of cultural gait dialects throughout different groups, social cliques in schools, professional/labor groups and sport standards. Michael Johnson is an olympic runner who defied cultural running form by keeping a stiff upright body and making shorter steps rather than the accepted conventional wisdom of lifting knees high to gain speed. Cultural gait and the brain's ability to adjust body movements to fit into society or activity

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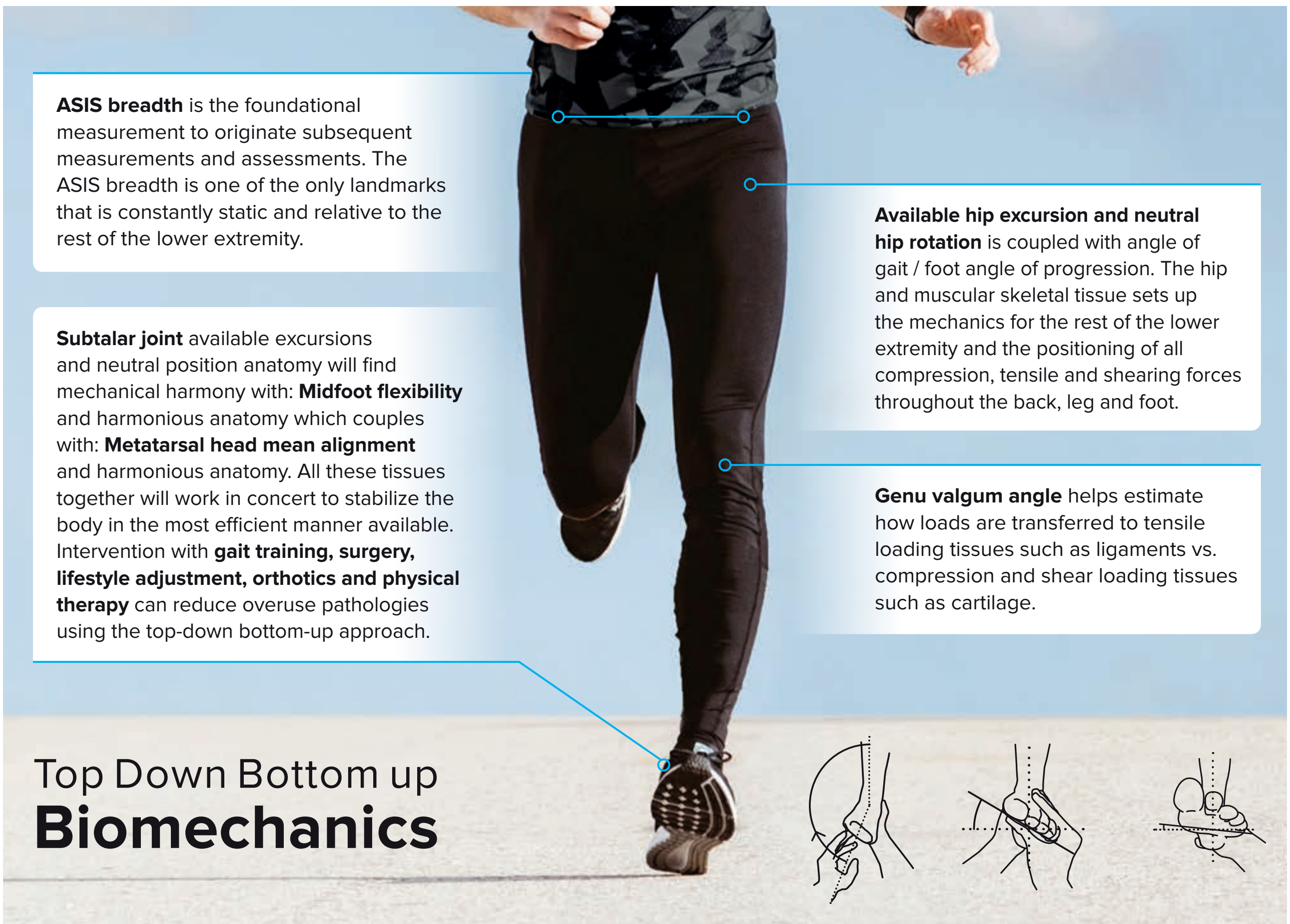
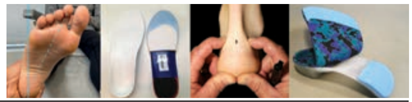



Figure 2: Top down bottom up



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is worthy of a future article. (Figure 3)

The Biomechanical Intelligence Quotient (BIQ) was born from my desire to help doctors better relieve their patient's pain. And hopefully help patients understand what the heck their doctors were saying. This tool and process allows identification, segment by segment, of the tissue structures and biomechanical features underlying and causing the patient's pain. When clinicians have a clear understanding of why and how the root function caused the pathology, the tailored treatment facilitates restoration of a more optimal alignment using things like gait training, shoe recommendations, orthotics, physical therapy and surgery. Ultimately this improves the patient's home life and work life and therefore drives more patients to your clinic—you'll be the most popular person in town!

In short, the BIQ is an effective tool to assess the root cause of a wide range of conditions, including most complaints seen in podiatry offices.

The Biomechanical Intelligence Quotient (BIQ) collects data about the patient's lower extremities with the goal of providing comfortable ambulation and positive outcomes. The information collected includes the most crucial measurements of the bones, tendons, ligaments, and muscles comprising each joint, as well as the key measurements of the range and fluidity of each joint's motility. When all measurements are completed, this data is then used to decide on an individual treatment plan.

While The American Board of Podiatric Medicine does provide a standard biomechanical exam template, there is no standardization for the values or ranges the examining clinician should use—or at least some consistency used in the real world. As a result, there are no normative values, nor is there a way that responses can be collectively grouped together to produce data sets for research or artificial intelligence (AI) learning algorithms. With the data produced from BIQ, doctors will eventually be able to use AI to assist even further in diagnostic assessment. BIQ is designed to be a new standard to collect biomechanical data using a universal protocol.

The need for an updated standard protocol for biomechanical evaluation is evident considering the lack of standardized data collection. Other examination modalities (X-ray, CT, MRI, NCV lab tests) allow universal methods of data collection, organization, and analysis which have been adopted for AI. On the other hand, biomechanical data (bone shape, available joint excursions, quality of range of motion/flexibility) collection lacks standards, making high quality scientific analysis impossible.


Figure 3: Cultural Gait

BIQ incorporates established scientific ideas from the biomechanical literature along with clinical experience, ideas and practice. By normalizing data collection, BIQ will facilitate large-scale data analyses that may allow new correlations and patterns to emerge.

As more data is obtained, the analyses using BIQ data will become more reliable and validated, thus aiding our understanding of biomechanics and contributing to improved diagnosis, treatments, and outcomes—*extraordinary outcomes.*

**The New Way-BIQ**

BIQ is not a theory, hypothesis or a presumption. It uses the laws of physics, geometry, and engineering to reveal how tissue stress is applied throughout the body. Remember physics and geometry from high school? If you need a polishing up, there are some really fun videos on youtube. Search for things like Newton's three laws, tensile forces, compression forces, shearing forces. Or go to Kevin Kirby's facebook page and watch all his videos on tissue stress theory—he has a gift for communicating biomechanics with utmost clarity. Sometimes I have to replay what Kirby says to make sure I'm getting it right.

BIQ rolls all this science into one simple process that is fun for the clinician and the patient. Further, it facilitates identification of actionable changes that can be accomplished through lifestyle modifications, therapies, surgeries and environmental adaptations such as shoes and orthoses.

Prior to development of BIQ, patients were at the mercy of a wise physician, relying solely on a trained eye to evaluate a physical exam without widely adopted standards. BIQ measures and analyses the phenotypic uniqueness of the human body. BIQ identifies the particular variables that affect loads and forces, helping to explain individual musculoskeletal pathology such as overuse or underuse conditions. BIQ allows doctors to then target solutions at the root cause, not simply the symptoms.

*"Using BIQ has made prescribing orthotics easy and has helped me better explain to my patients their pathology,"* said James Judge, DPM. *"It also serves as great documentation for follow-up and sharing notes with referring physicians."*

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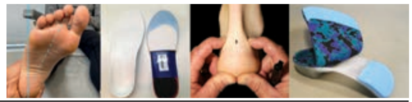

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**The Exam**

The BIQ Exam is not only designed to create universal standards, but to also take into account the realities of running a profitable practice. The current American Board of Podiatric Medicine biomechanical exam requires about thirty minutes for a doctor to administer. The new BIQ Exam can be conducted in five to seven minutes. Additionally, a clinician can take that data along with scans or a cast of a foot and send it without a formal order form to an orthotics lab, allowing the lab to help make decisions on orthosis design and construction based on the biomechanical and demographic data provided, saving the doctor even more time. We won't have time or space to go through things in full detail here but will give you an idea and hopefully spark an interest to participate in the community of clinicians adopting the BIQ standard. Online courses are being developed to provide a fun and stimulating learning environment

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## Biomechanical Intelligence Table of Key Measurements

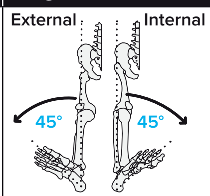
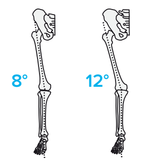
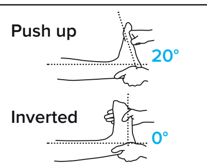
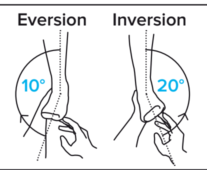
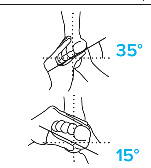
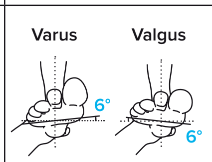
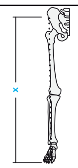
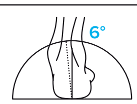
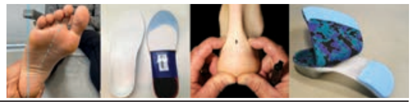
| Assessment | What it Measures | Diagram RT side | Normal Value | Significance | Effect of Deviation |
|---|---|---|---|---|---|
| Hip Excursion | Foot Progression Angle relative to hip rotation excursions |  | 45° External<br>45° Internal | • High Significance<br>• Joint system comprised of largest muscles and largest bone<br>• Effects all tissue loads distal and proximal to hips | **More external** = increased medial foot plantar pressure<br><br>**More internal** = increased lateral foot plantar pressure |
| Genu Valgum/varum | Q angle – angle of imaginary line from ASIS to center of knee joint and a line from center of knee joint to achilles insertion |  | 8-12° for men<br>12-17° for women<br>8-17° for they | • Moderate Significance<br>• Relative to breadth of ASIS | Larger Q angle more load on tensile bearing tissue and more efficient lateral propulsion Smaller Q angle more load on compression bearing tissue and more efficient propulsion |
| Foot Dorsiflexion Excursion | Dorsiflex available excursion angle from the tibia line to the line from the plantar heel to plantar metatarsal heads. Inverted - to the 5 metatarsal. |  | Push up 20°<br>Inverted 0-2° | • High significance<br>• Tensile and compression loading tissues of the foot and lower leg are affected | Larger temporal tensile and compression loads while the body passes over the foot may lead to overuse pathologies |
| Subtalar Joint Excursion | Available range of motion of the calcaneus relative to lower leg |  | Eversion 10-25°<br>Inversion 20-35° | • Moderate significance<br>• Significance increases when midtarsal joints are abnormal | Limited eversion and inversion increase articulation responsibility to midtarsal joints and mid and forefoot bone geometry to stabilize the body against the ground |
| Midfoot Flexibility | Angle of the mean line of plantar metatarsal heads articulated and the AAA line. |  | 35° (inversion)<br>15° Reverse (eversion) | • High significance<br>• The ability of the foot to be in mechanical concert and stabilize the body against the ground | **Limited flexibility** (ROM) will pass mechanical responsibility to the available excursion of the STJ<br>**Excessive flexibility** will pass mechanical responsibility to the tensile loading tissues such as the PTT |
| Metatarsal Head Mean Alignment | The angle of the mean plantar met heads relative to the AAA line while the heel is held in AAA and the tensile structures of the foot are in equilibrium. |  | 2-4° varus | • Moderate<br>• High significance once the varus or valgus angle is 20° or more | A larger angle will limit the efficiency of the foot and rely on tensile loading tissues (muscle and tendon) to stabilize the body. A smaller angle will stabilize the body relying on osseous tissue. Position of the met heads and ability to stabilize the body are mechanically coupled with the mid and hind foot mechanics. |
| Functional Limb Length Discrepancy | Comparative Length of ASIS to Distal Hallux of one side vs the other side |  | Equal lengths bilateral | • Low significance<br>• Moderate significance above 2cm difference<br>• High significance above 3cm difference | Compensatory strategies to normalize the work performed by the lower extremities such as stride length and foot angle of progression |
| Kevin's Angle | Angle of bisection of plantar calcaneus line drawn to most deviated bisection point of the achilles tendon. |  | 4° - 6° | • Moderate significance<br>• High significance above 12° | This is a sign used to help determine the rear mid and forefoot compensatory strategies when anatomy is less efficient for normal gait |

Figure 4: All BIQ 10 measurements.



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from your bathroom or home office—on your time. (Figure 4)

Prior to conducting the BIQ exam, clinicians record the patient's height, weight, past and current pathological tissue.

The clinical BIQ Exam has the doctor perform assessments that determine the structural morphology and available range of motion of a patient's lower extremities.

The test can be performed sitting or standing in a standard exam room, and requires nothing more than a protractor, a non-gravitational goniometer, a measuring tape and, if available, a caliper. The acquisition of biomechanical data must be rigorous, with strict adherence to the established protocols. It is only with universal application that this growing data source can be used to establish normative data, and to recognize patterns and correlations. That said, *application* of this data can, and should, be modified based on clinician experience and judgment.

**ASIS-Achilles Alignment (AAA)**

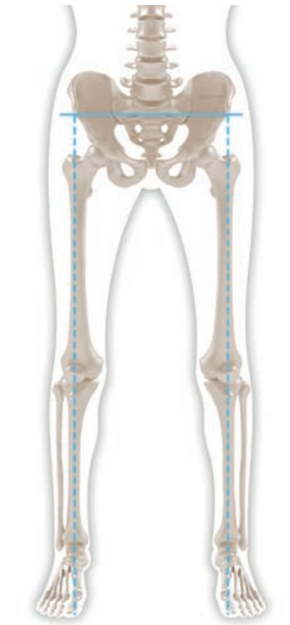

Figure 5: BIQ reference AAA, ASIS—Achilles—Alignment

**Assessment Elements of the BIQ Exam**

***ASIS breadth and the AAA***

The anterior superior iliac spine (ASIS) is the central point of reference for the BIQ. ASIS width demonstrates how the core of the body resets on the locomotive lower extremities and sets the biomechanical foundation for an individual's lower extremities by defining the origination of all ipsilateral downstream bones and muscles. ASIS width is analogous to the axle width of an automobile, demonstrating how the chassis of the vehicle sits on the wheels. Just as the axle and chassis width sets the foundation for the mechanical character of the vehicle, the ASIS width sets the foundation for the mechanical character of the person.

Another key reference point for all BIQ measurements is the ASIS-achilles

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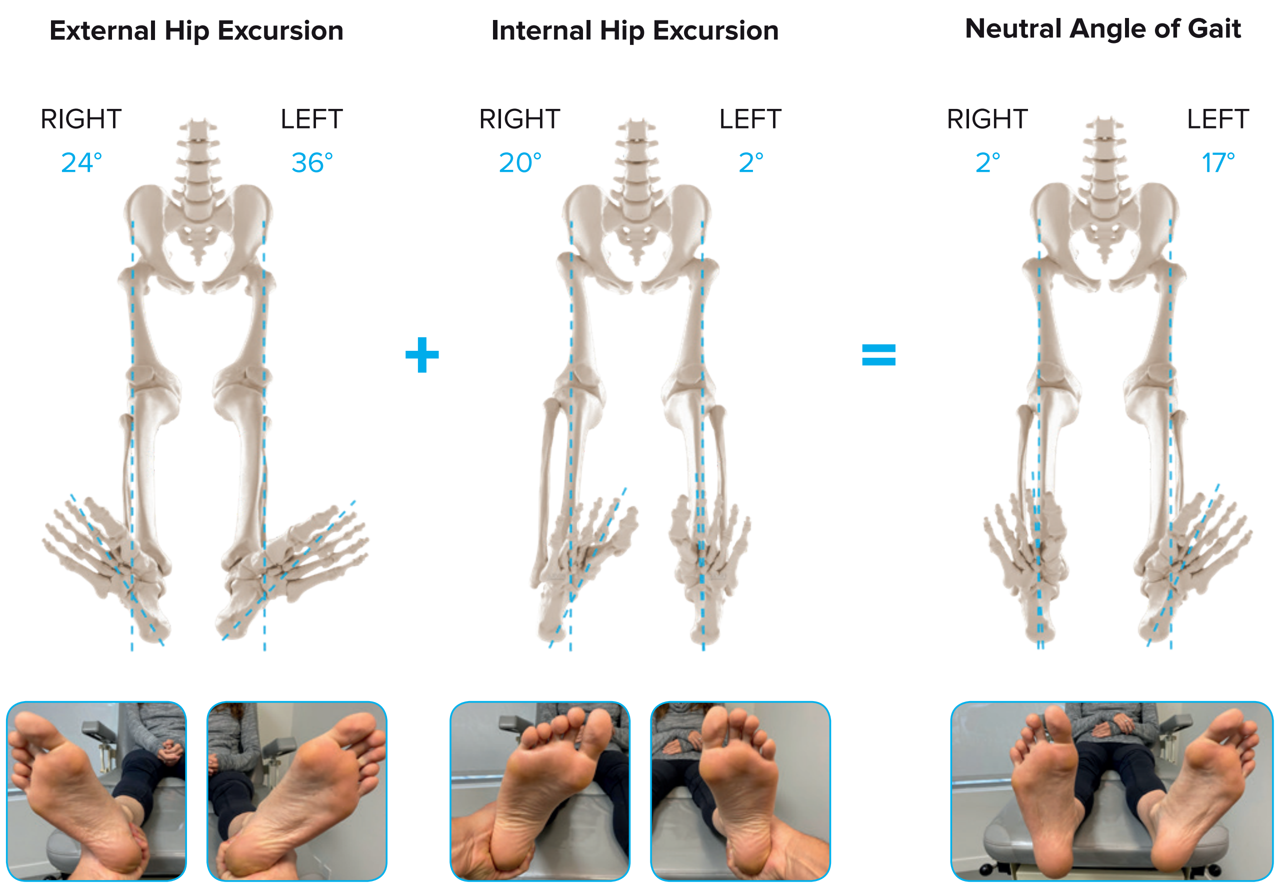
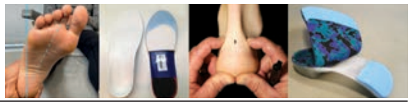



Figure 6: Hip external ROM + Hip internal ROM = Neutral



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alignment (AAA), which is a line drawn downward from the ASIS on each side, at a 90° angle to the line connecting the right and left ASIS. The AAA is uniform for all individuals, and is the reference point for many subsequent BIQ measurements. That is, BIQ measurements are measured as their angle of deviation from the AAA. (Figure 5)

***External and Internal Hip Excursion***

This is probably one of the most important and ground-breaking measurements you can observe. When there is a mechanical asymmetry in hip excursions, you will see pathology on the more deviated neutral angle of gait side. This needs to be studied further and is strictly observational from my own experience. However, take the data from the illustrations. (Figure 6) This is actually from a real patient who had a hip replacement surgery on the left side. Knowing all of the pathology and mechanical data provided a good explanation why this patient had hip pathology ultimately requiring a replacement. Hip excursion asymmetry and cultural gait is a recipe for pathology. A society that dictates accents in language, the clothes we wear and even the way we walk can mis-match with a patient's ability to align their mechanics to their culture. In short, a patient with limited internal excursion at the hip and greater than 45° external excursion at the hip will still use their hip at an end range of hip range of motion. This puts strain on the tissues from the top down—bottom up as the hip goes through extension and flexion, eventually leading to failed tissue and an over-use pathology. Adjusting your patient's angle of gait to match his/her own biomechanics in a novel idea. Most PTs and clinicians have encouraged patients to walk straight because it is considered "normal." However, I have found that encouraging a patient to walk within their own personal normal or neutral position in the hip ultimately reduces all sorts of presenting symptoms in the lower extremity. It has been one of the most powerful remedies—finding the patient's personal neutral in the hip joints and encouraging the patient to embrace asymmetry while walking rather than succumb to cultural and societal pressures to walk with feet facing forward.

External and internal hip excursions measure the amount of movement available at the hip in the transverse plane. It measures the degree to which the foot can be turned out or in by the clinician. An individual's optimal hip position is defined by the midpoint between the external and internal measurements. An individual whose gait results in excursion that falls outside of his or her optimal range is at risk of strain and damage to skeletal tissue at the hip, knee, ankle, and foot.

***Genu Valgum/Varum***

When the bones of the lower extremity are stacked like well-aligned building blocks, the knee joint is in line with the AAA. In most individu-

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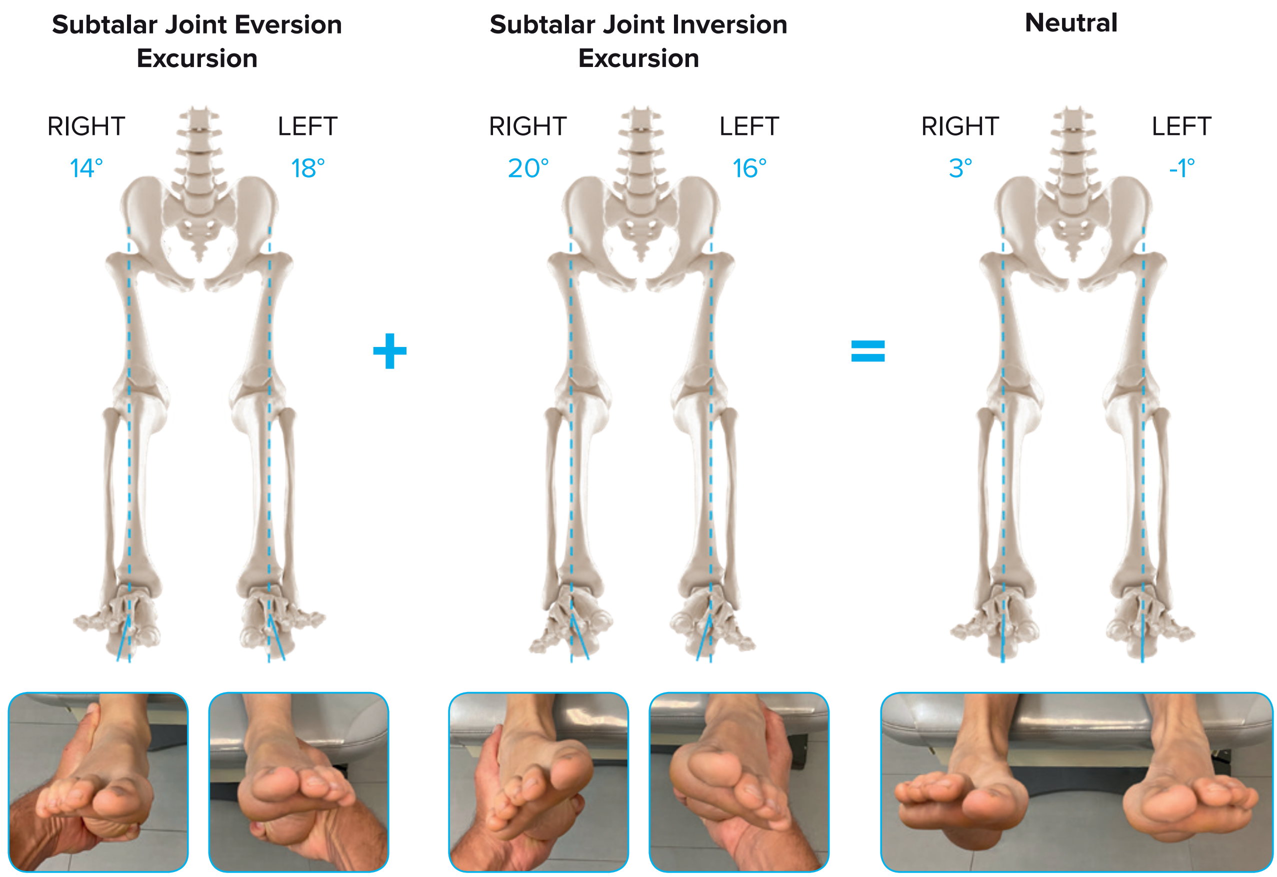


Figure 7: Subtalar Joint motion

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als, however, the bones are not perfectly aligned. Measurements of deviation from the AAA at the knee joint quantify the degree of genu valgum or genu varum in an individual. Any deviation from the AAA can indicate unstable positioning. Regaining stability requires additional work by the muscle and soft tissue to stabilize the knee and leg. When severe, this can cause excessive tensile, shearing, and compressive forces on the leg tissues (musculature, ligaments, and tendons), which may be overused and ultimately result in injury/pathology.

***Foot Dorsiflexion Excursion***

Foot dorsiflexion excursion measures the degree to which the ankle can bend upwards toward the shin when held in AAA alignment. This test quantifies the degree of dorsiflexion. Limited dorsiflexion, known as equinus, results in compensatory mechanisms such as flattening of the arch, early heel rise with walking, and increased pressure on the ball of the foot, all of which can result in foot, leg, and back pathology. Hyperflexibility, on the other hand, may also be problematic by shifting loads in a manner that the lower extremity is not optimized to handle.

***Subtalar Joint Eversion and Inversion Excursions***

The subtalar joint in the foot is responsible for movement of the foot away from the AAA in the coronal plane. Subtalar joint eversion and inversion excursions measure this deviation outwards and inwards, respectively. Movement and rotation at the subtalar joint is essential for walking. Insufficient eversion results in inadequate untwisting of the plate—i.e., shock absorption—resulting in excessive compressive forces on the upstream tissues. Insufficient inversion—i.e., twisting the plate—results in poor coordination of the movements of the subtalar joint with upstream and downstream joints and bones, ultimately producing inefficient ambulation. On the other hand, excessive eversion or inversion, twisting or untwisting the plate requires the stabilizing muscles and tendons of the foot to work excessively, resulting in strain and overuse pathology throughout the lower extremity and back. (Figure 8)

***Midfoot and Reverse Midfoot Flexibility***

Midfoot and reverse midfoot flexibility measurements take into account movement of the talocalcaneonavicular, calcaneocuboid, naviculocuneieform, cuboideonavicular, interecuneiform, cuneocuboid, tarsometatarsal, and intermetatarsal joints. Just as under-and over-flexibilty of the subtalar joint can result in lower extremity pathology, under- and over-flexibility of the midfoot and reverse midfoot can confer similar problems. Rigidity of the midfoot or reverse midfoot results in problems twisting and untwisting the plate, whereas hyperflexibility requires that

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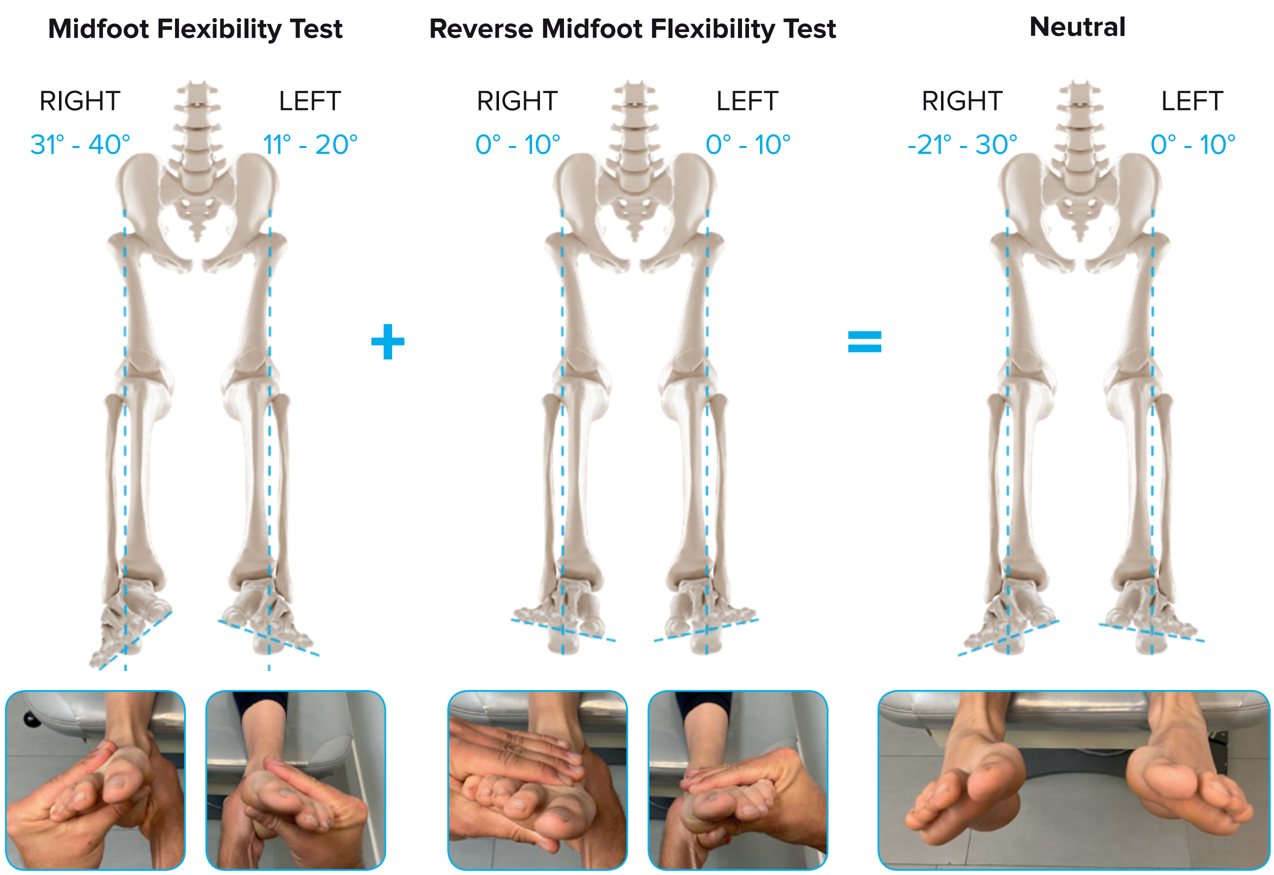
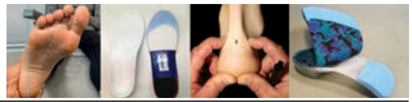



Figure 8: Midfoot flexibility /reverse flexibilbiy



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the structures stabilizing the foot need to work too hard, again resulting in strain and overuse.

***Metatarsal Head Mean Alignment***

Metatarsal head mean alignment studies the relationship of the metatarsal heads to the AAA. To obtain this measurement, the practitioner determines the average protrusion of the plantar aspect of the five metatarsal heads, and compares this vector to the AAA in the coronal plane. The metatarsal heads are the distal segment in the closed chain. Normal alignment is, on average, 2 degrees of varus. An alignment that strays excessively from this norm requires compensation by muscles, tendons, and ligaments during ambulation, again resulting in extra work to stabilize the body. (Figure 9)

***Functional Limb Length Discrepancy***

The functional limb discrepancy measures right-left differences in leg and foot length. This measurement is taken from the ASIS to the hallux with the patient standing in their natural angle of gait. Most important here is the fact that the limb measurement takes into account not just the length of the leg (as would be obtained by measuring from the ASIS to the heel on the floor), but also the length of the foot. This is critical because the foot is an important lever while walking, and discrepancies in the length of the two feet (in addition to those between the two legs) may impact the forces generated on the two sides of the body and the location of the center of mass while walking.

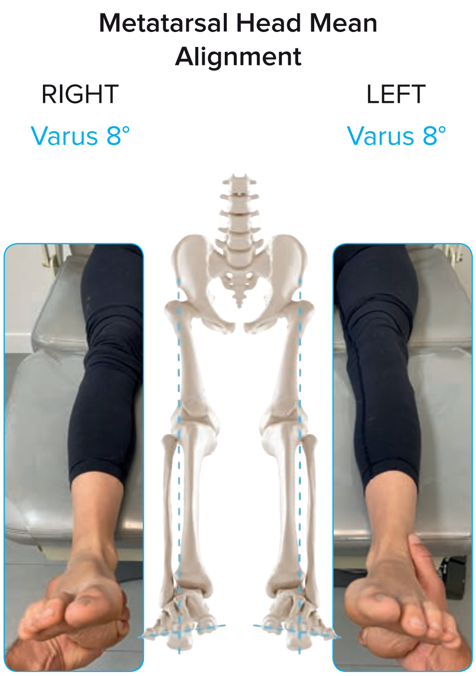


Figure 9: Forefoot mean alignment

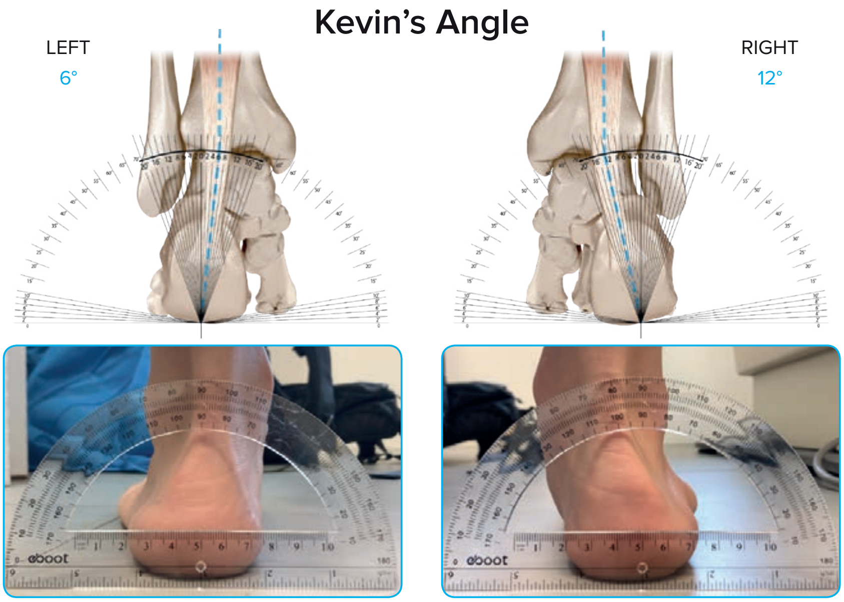


Figure 10: Kevin's Angle

***Weight-bearing Foot Anatomical Type***

The Weight-bearing Foot Anatomical Type assesses the arch of the foot. It is a qualitative appraisal of the shape of the arch: flat-footed, high arch, etc based on graphical representation of common arch shapes. The shape of the arch contributes to the overall structure of the foot and its ability to transfer loads between tissues and structures, so this assessment affects the interpretation of other metrics within the BIQ 10.

***Kevin's Angle***

Kevin's Angle is the final test in the BIQ 10 exam. It examines the efficiency of the achilles tendon by measuring the angle of the tendon from the center of the plantar aspect of the calcaneus. A tendon that is perfectly aligned with the AAA is maximally efficient, whereas deviation from this reference line results in loss of efficiency. That aside, this test allows the clinician to get close and personal with the patient's weight bearing foot and observe other tissue and mechanical features. (Figure 10)

**Conclusions**

The BIQ is a new way of collecting and documenting biomechanical data that aids in understanding patients' mechanics. And planning for treatment by helping doctors identify and treat the root cause of the pathology manifested by the patient.

The BIQ Assessment should aid clinicians in diagnosing many podiatry issues by providing a data-driven, visual model with universal standards. With the data derived from BIQ assessments, future AI tools can be developed to further help doctors with diagnostic assessments. For more information on BIQ and information on becoming a Certified BIQ provider visit www.kevinrootmedical.com or email hello@kevinrootmedical.com. **PM**

**Kevin B. Rosenbloom** is a Functional Orthopedic Biomechanist and Pedorthist practicing in Santa Monica, California. He is the creator of Biomechanical Intelligence™, Foot ID™ and is the CEO and Medical Director of KevinRoot Medical.