ALAN ARAGON'S RESEARCH REVIEW

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EDITOR'S CUT

Pelvic torsion or pelvic imbalance with a functional leg length discrepancy: a sports performance perspective.

By Tom Vachét, BSN, CRRN, CPT

Editor's note: Tom Vachet is a long-time friend and colleague of mine. The vast majority of professional athletes I've counseled are a direct result of his referral. I've always known that Tom was a great practitioner, but just this past month I was surprised to find out that he has a keen ability to translate his analytical approach to training into the written word. Enjoy the article.

Pelvic Torsion, Pelvic Obliquity, Leg Length Inequality (LLI), Leg length Discrepancy (LLD), Functional Leg Length Discrepancy (FLLD), and Anatomical Leg Length Discrepancy (ALLD), are some of the terms commonly used in describing a complex combination of interrelated anatomical and biomechanical dysfunctions. I became acutely familiar with these in the Summer of 2005.

A Case Study

At that time, I had been approached by a veteran athlete, and professional basketball player, whom I'll refer to as Andre in order to protect his identity. Andre was referred to me as a consultant who could help him improve his conditioning and performance. My educational background is that of a Registered Nurse with a clinical rehabilitation specialty. I had also received training, and had developed an expertise in athletic conditioning. As a result of my education and experience, my work with a client was holistic, focusing on all their body's systems, and multidisciplinary, incorporating all the perspectives that impact health and wellness as a foundation for athletic performance.

History taking is part of an initial interview process I undertake with each new client. During this, Andre explained his pertinent history was related to two, successive stress fractures of his power-side, right foot, both requiring surgical intervention. He said these injuries were unrelated to a single event; jumping, turning, contact with another player or object. However, he related they had left him with deficits that were a major limiting factor in his ability to perform in his sport; reduced first step quickness, inability to go to the rim, etc. He also suffered with intermittent patellar tendonitis,

The fact is, Andre was beginning to realize his career was coming to a close unless he could find a way to turn things around. If I was going to help him improve, or to reduce his injury risk, it was very important to determine the cause of these two injuries.

Andre's health history did not indicate the presence of any diagnosed pre-existing condition; other related or unrelated prior injury, congenital deformity, metabolic disorder, nutritional deficit, etc., that would have pre-disposed him to his injuries. In fact, he was an obviously healthy, exceptionally fit, professional athlete in his early 30's, who it seemed had no predisposing factors that would have created an injury risk.

So, I wondered, why did this otherwise healthy athlete suffer these injuries? Was there a less obvious factor not previously considered? It seemed likely he had been excessively loading the injured foot. If so, was there an issue related to his biomechanics? The answer could be revealed in the second step in my new client intake process, which is to evaluate posture, balance, symmetry, core strength and movement, using a functional assessment. I felt this would likely provide us information useful to determining the basis for Andre's injuries.

The initial portion of my assessment process is to evaluate a client in simple standing, in order to assess his posture and symmetry. In anterior, or frontal view, my eyes went to the fact the waistline of Andre's gym shorts appeared unlevel, higher on the right than the left. As I looked a bit closer, I placed my fingers on the top of his pelvic bone, or Iliac Crest, on both sides, and compared their relative height. He appeared to have an obliquity, or unlevel orientation, of the hips from right to left, with the right-side Iliac Crest higher than the left. My first thought was to wonder if this was because he had an abnormally long leg on the right side.

In order to pursue this line of thinking, I asked Andre to lie on his back, in a supine position, on the floor. With his legs in straight alignment, I compared the positions of the right and left Medial Malleolus, the bony prominence on the inside of the ankle. The right side appeared lower than the left, and in fact his right heel appeared to be at least one inch lower than the left.
While he was still lying on his back, I then compared the position of the right and left Anterior Superior Iliac Spine (ASIS), another set of bony landmarks located on the front of each Ilium, or hip bone. Andre's right-side ASIS was also definitely lower than the left, and toward the feet end of his body. So, I considered that the right side of Andre's pelvis must somehow be rotated down.

The Acetabulum, the socket where the head of the Femur, or thigh bone, attaches, is part of the Ilium. If Andre's right Ilium was rotated down toward the ground, the Acetabulum would also move in that same direction, as would the attached Femur. This would result in the entire right leg moving to a lower position relative to the left, and when Andre was lying down, it would definitely give the appearance of being longer. Then, when Andre stood up, his right hip would be forced up, appearing to be higher than the left.

As one last check, I took a tape measure, placing one end on the Greater Trochanter, a bony knob on the proximal, or the head, end of the Femur. From this landmark I ran the tape down to the Lateral Malelolus, the bony prominence on the outside of the ankle at the distal, or foot end, of the Tibia, or leg bone. To get an accurate measurement of leg length, you would have to take a standing X-ray of the legs, or perform an MRI. However, my simple measurements on both legs appeared equal, a reasonable indication the leg bones on both sides were anatomically equal.

What I was seeing, for the first time, in my career as a clinician, was what is called a Functional Leg Length Discrepancy (FLLD) or Functional Leg Length Inequality (FLLI). Through later research I learned that it is thought 90% of the human population is born with an Anatomical Leg Length Discrepancy (ALLD), an actual measurable difference in total leg length from right to left. FLLD is different, in that it is not structural, but caused by soft tissue anomalies.

However, no matter the cause, most researchers seem to feel that an inequality of greater than 1.27cm, or .5” can have serious consequences, including scoliosis of the spine, as well as causing other injuries.

Twenty years previously, I had worked to create postural positioning solutions for spinal cord injured patients who would sit for hours in a sling-seated wheelchair. By the forces of gravity, these patients would assume a position where one hip would center at the bottom of the sling, and the other up and to the side, creating a seated pelvic obliquity. As a consequence, these patients suffered with a myriad of postural and biomechanical consequences. I began to consider there were many similarities between their posture and Andre’s, with some serious potential implications to his health and performance.

Anatomical Impact

As I continued my survey, there was a pattern of interconnected asymmetries and compensations that began to emerge:

- In standing, again looking at Andre from the front, his right shoulder appeared lower than the opposite side, and was rotated slightly forward.
- When putting his arms over his head, he had limited range of motion in his right shoulder, with a resulting longer reach on the left side.
- On the same, right side as the high hip, Andre stood with his knee slightly flexed, with his foot pronated, or falling in, and the arch of his foot was collapsed, or flattened.
- On his left side, he stood with his left knee slightly hyper-extended into a position called genu-recurvatem.
- From the back, I again noticed the unequal height of the left and right Iliac Crest. I also noticed Andre had a slight, left convex spinal scoliosis, or abnormal curvature. This compensation resulted from an attempt to keep his gaze level to the horizon, and maintain a perpendicular orientation to the ground.
- On the upper back, the inside or medial edge of both Andre’s shoulder blades were tilted up. However, his right shoulder blade was also positioned higher than the left, and rotated, or protracted, outward, in coordination with the shoulder, which I had previously noted was rotated forward.
- From the side, I noticed a general anterior, or forward, tilt of the pelvis, creating an accentuated curve, or lordosis, in his low back. He then had a slight reciprocal, forward tilt or kyphosis of the upper back, just below the shoulders.

All in all, I was amazed, but also confounded, with all the anatomical anomalies I was seeing in this high-functioning athlete. I began to consider all the biomechanical consequences of what I was observing, but needed to confirm my concerns through some functional testing.

Functional Impact

Functionally, Andre had as many deficits as I had observed anatomical abnormalities:

- His core endurance in both prone and side-lying plank, a yoga-like position widely used to develop core strength and endurance, was poor. He was only able to maintain the prone position for two minutes, and the side plank for approximately one-minute on each side.
- Andre’s Gluteus Medius, the muscle located on the outside the hip, was markedly weaker on right than left strength performing side-lying hip abduction and extension, with a downward force exerted on the distal leg.
- His Gluteus Maximus, the large muscle at the center of each buttock, was markedly weaker on left than on right, when performing a prone, or face down, hip extension with resistance against pressure on the distal thigh.
- Additionally, he demonstrated over-activation and recruitment of the Biceps Femoris, or hamstrings, and the Paraspinals, or superficial low-back extensors, with inhibition of the ipsilateral, or same-side, deep extensors, the Multifidus.
- In performing a single-leg, sit-to-stand exercise. Andre’s balance and stability was poor. He could not stand upright, starting from a from a 90º/90º seated position, without assistance. He had markedly greater difficulty performing this exercise on his right leg, with his knee collapsing immediately into genu-valgum, or to the centerline of the body, on both sides, worse right than left.
- Andre’s overhead squat was limited to 120 degrees of knee flexion, with a probable mechanical restriction in the right ankle and foot, but also demonstrating a likely limitation in his core strength.
- His stability in a lateral push-off was poor, and he was markedly less stable pushing off from the right leg to move to his left.
- His single leg vertical leap was limited, more on right than left.

All these findings were significant, both from the clinical and functional standpoint. Andre was limited in his ability to reach overhead, jump, explode laterally or diagonally, or decelerate. It was painfully obvious this highly-compensated, professional athlete was functionally impaired in ways that dramatically affected his ability to perform his job.

I was trying to wrap my head around the biomechanical health and performance implications of the observations I had made, and how all these were likely tied together in a way that not only impaired performance, but set up Andre for his pattern of injuries. I had already assumed the repeat stress fractures were the end result of chronic overloading. I just had not pieced together the mechanics of how they occurred.

Connecting the Dots

In the mid-80's I had taken a physical therapy course, the NDT Hemiplegia Course. One of the gems I pulled from that course revolved around the instructor telling us that "proximal stability provides distal mobility". She was talking about the 'core' long before the concept became in vogue in the fitness industry.
I later incorporated that concept, rephrasing it to for my athlete clients to say, "core stability allows you to express power efficiently". As I began to assess the impact of a pelvic torsion on Andre's ability to activate this core, and the increased risk for injury it created, I also began to look at core deficiencies more from the standpoint of injury prevention. I also began to appreciate the role of the skeletal system as an underlying component of the core.

Although it was complicated, it all made sense. My supposition was the problem began with the pelvic bones becoming twisted. This is actually easier to occur than it sounds. The pelvis is generally made up of a right and left Hip Bone. Each hip bone has three areas or parts:

- Ilium – the large flat area that includes the landmarks, Anterior Superior Iliac Spine and Posterior Superior Iliac Spine
- Ischium – the lower portion that includes the sit bone or Ischial Tuberosity
- Pubis – the bone that is in the front, at center

The two hip bones are joined on the backside to the flat end of the spine, or sacrum, at the two, Sacro-Iliac or SI Joints. At the front, center, the right and left Pubic bones come together to form another joint at a cartilage disk called the Symphysis Pubis. These three joints are bound together by a number of ligaments.
Activities of daily living, and also with the performance of sport require sequential muscle firing, or activation. The difference is that most ground-based sports, such as football, soccer, basketball, volleyball, and hockey, etc., require explosive lateral or diagonal movement, as well as jumping, and therefore generate more force. That force is generated across attachment points to bone.

Attached to the pelvis, at the top and bottom, on both right and left sides, are many of the most powerful muscles in the body:

Upper Body

- Internal oblique
- External oblique
- Transverse abdominus
- Erector spinae
- Quadratus lumborum
- Latissimus dorsi

Lower Body

- Gluteus minimus
- Gluteus maximus
- Gluteus medius
- Adductor longus
- Biceps femoris
- Rectus femoris

Muscle tissue on the lower end of the body is connected, continuously, to tissue at the contra-lateral, or opposite side, and opposite end. In regard to the upper body, this is commonly referred to by Strength and Conditioning Trainers as the "Serape Effect". In the clinical world of Physical Therapy and Osteopathic Medicine, or with Soft Tissue Practitioners, there is a similar viewpoint, expressed as the "Anatomy Trains" theory.
Muscle force, necessary to the performance of activities of daily living, but with a higher intensity with sports, is then generated in a diagonal fashion across the body, with the pelvis serving as a central juncture. Remembering that the pelvis is a three-part structure, held together by ligaments, it becomes easy to visualize one part pulled one direction, and another being pulled in exactly the opposite way.

In sport, with increasingly stronger, faster athletes, enough moment force is exerted, or enough reoccurring force or cumulative stress is placed on these ligamentous connections, to create "sprains", similar to a sprained ankle. When the pelvis is twisted, or placed in "torsion", through explosive or repetitious activation of opposing muscle groups, one side often rotates forward and down, and the other rotates up and to the rear. However, the fact is the pelvis can move in multiple dimensions simultaneously, meaning the final position of the different bones after the sprain resulting from an applied force, is unpredictable and can be different from person to person. What is predictable, are the ripple effect implications through the kinetic chain in both directions:

Down the chain –

- As one side of the pelvis rotates forward, structures such as the hamstrings, attached to the bottom surface at the rear are placed on a stretch, creating the opportunity for pulls and strains.
- As the opposite side is rotated to the rear, structures such as the adductor muscle are also placed on a stretch, creating the opportunity for sports strains or groin pulls.
- On the long leg side, the Gluteus Medius is inhibited, placing it in a poor mechanical position to deliver stability to the hip, knee and ankle. As a result the Tensor Fasciae Latae, (TFL) including the Iliotibial Band (ITB), a fibrous layer of tissue covering the outside of the thigh, becomes hypertonic, or overactive, working harder to stabilize the lateral hip, creating ITB syndrome.
- Hip flexors, particularly the Rectus Femoris, become dominant and overactive, contributing to a tight IT Band and patellar tendonitis.
- In addition, on that same leg side, the foot will pronate, or cave in at the arch. This creates the risk of plantar fasciitis, as well as a chronic abnormal loading condition of several bones in the foot contributing to stress fractures.
- The lower leg follows the foot, rotating inward. The thigh is pulled into the same rotation. As it does this, the knee caves into midline. This rotation creates a torque force through the knee joint, stressing the MCL, ACL and PCL ligaments, creating the opportunity for strains and tears. In addition, the patellar tendon and ligament are pulled

laterally, creating patellar tendonitis, as well as the potential for a patellar dislocation. The unequal loading across the knee joint results in the lateral meniscus being ground between the Femur and Tibia, setting up meniscus tears and ultimately chondral defects requiring microfracture or allograft surgical repair.

Up the chain –

- The Quadratus Lumborum, a deep extensor muscle located in the low back, is inhibited by the pelvic instability. As a result, the smaller, less powerful muscles of the low back, the Erectors, which have less endurance, become overactive on the contralateral side. As they fatigue, they are likely to spasm.
- In an effort to overcome the unlevel pelvis, or obliquity, associated with the leg length inequality, and to keep the torso perpendicular to the ground, the lumbar and thoracic spine curves away from the long leg side, creating a scoliosis.
- This scoliosis, often has a rotational component to it, rotating forward and down in the direction of the long leg. The rotation of vertebrae in the mid-back often results in adjacent muscle tenderness or spasms. The resulting shoulder position creates the opportunity for restricted movement and nerve impingements.

The Fix

So, the next logical question, in regard to Andre, was this correctable? If so, how does that work? For that, I relied on the clinician who I had turned to for the treatment of every one of my elite and professional athlete clients, Bob Patterson, PT, CAE. Bob is an outcome-driven manual physical therapist, whose approach combines hard therapeutic osteopathic and soft tissue skills. He is also a three-dimensional thinker and puzzle-solver, which I believe is a requisite talent in order to assess and treat all the connected body parts.

My contribution to Bob's treatment of Andre, was only to describe my observations his anatomical and biomechanical pathology, his performance limitations and injury history, and my theory on how I thought this might all be tied together.

Bob did confirm the two components of the Pelvic Torsion that my limited assessment did not reveal. First, Andre's sacrum was in fact rotated, with all the connecting ligaments either lengthened or shortened relative to what should be expected. Also, his Symphysis Pubis, the bony juncture of the two Pubic Bones, was actually displaced downward in relation to the other.
Since I cannot begin to describe the complex treatment rendered to Andre, I can only say the result of Bob's good work was that my client was restored to a state of biomechanical balance, including a symmetrical pelvis and equal leg length from right to left. It was an incredibly interesting process; part anatomy lesson, part human biomechanics symposium, and all-round impressive.

Astoundingly, Andre experienced immediate relief of symptoms as soon as the pelvis was reduced, and while still on the treatment table. This same experience has been shared by nearly every other athlete I have referred to Bob for treatment of Pelvic Torsion. From the discomfort of patellar tendonitis, to the deep nagging pain associated with an apparent groin strain, the discomfort vanished. In addition, things like deep squat, gait, overhead reach, all also improved while still in the clinic. I recognized immediately the incredible significance of treating this problem as it relates to an athlete.
Bob's treatment of Andre ultimately provided me opportunities, through my strength and conditioning work, to restore his normal muscle activation, recreate proper firing sequences, and access a level of functional strength he had never before experienced. There were dramatic improvements in his core strength and endurance, balance and stability. He also enjoyed a remarkable improvement in his aerobic endurance, I'm certain the result of enhanced biomechanical efficiency.

Although there were, unfortunately, reoccurrences of Andre's pelvic torsion, over time we accepted this problem would likely recur as a consequence of the demands of his sport, and would therefore require continuing maintenance throughout his career. Preventative physical therapy became a lynchpin component of Andre's year-round wellness program through the balance of our relationship.

I believe this integrated approach to the management of performance translated directly to the court, and as a result, after a successful treatment intervention, this athlete enjoyed three back-to-back-to-back statistical best years of his career.

Retrospective

Prior to meeting Andre, I had worked with 14 professional athlete clients. Nearly half of these clients were NHL hockey players, many of whom had suffered a litany of injuries, including abdominal strains or tears. I regretfully consider many of these injuries likely resulted from a pelvic torsion, and were therefore very treatable.

Unfortunately, no university class I've taken, no nursing or physical therapy continuing education course, and no health and fitness seminar has ever addressed or even mentioned this issue. As a result I lacked awareness, and therefore did not assess any of these clients for pelvic torsion. Like most other trainers and therapists, I took a simplistic, cookie-cutter approach, and was evaluating and then addressing the typical deficits I had come to expect, and that were associated with a weak core.

Since Andre, I have worked with 32 athletes, 25 of which were collegiate or professional basketball players. I have referred 27 of these, or 85%, for physical therapy assessment and treatment of an identified pelvic torsion with associated LLD. Each of those referred was symptomatic at the time of the evaluation with chronic recurring tendonitis on the long-leg side. Many others had active acute injuries, were recovering from surgery to correct major injuries, and/or had major injury histories. Some had all three.

The injury histories of this athletes included 1 adductor strain, 1 degenerative hip, 4 herniated lumbar discs requiring decompression, 1 degenerative lumbar disc requiring dynamic stabilization, 3 chondral defects, 2 of which required microfracture and 1 allograft, 4 meniscus tears, 3 ACL repairs, 2 complete ankle reconstructions, and 3 shoulder impingements.

Despite the injuries and the complicated compensations that accompanied them, every athlete was able to be successfully treated, with a restoration of pelvic symmetry and an elimination of the LLD, often on the first appointment.

Implications

The widely accepted fact is 60-70% of the injuries to the knee and ankle in the NCAA and NBA are non-contact related. My experience has raised my awareness and created a concern that Pelvic Torsion and LLD dysfunction may potentially be the single most likely contributor to a list of crippling injuries involving the low back, hip, knee and ankle.

Although ½ inch, or 1.27 cm, of LLD is considered clinically significant, and even provides an entitlement to a claim of disability under the Medical Guidelines Veterans Affairs Canada, many researchers believe an even smaller discrepancy may have a significant link to injuries in a more active population.

The list of related injuries includes disc degeneration and herniations, degenerative hip disorder, ACL, MCL and PCL strains and ruptures, Meniscus tears, chondral defects, patellar dislocations, ankle sprains, stress fractures, plantar fasciitis, and peroneus longus strains.

In addition, the 2009-2010 NBA season has seen a remarkable number of non-contact patellar fractures. We know anterior pelvic tilt, with or without pelvic torsion, elongates the hamstrings, potentially slowing their response times, while conversely shortening the hip flexors, resulting quadriceps dominance. The strong eccentric contraction of the rectus femoris during the landing phase of a jump, places an inordinate load across the patellar tendon, and is a recognized mechanism in this injury.

In summary, I believe that based on my own experience, until a relationship between this dysfunction and injuries in athletes is properly researched and can be ruled out, consideration for the existence of Pelvic Torsion and its associated FLLD should be incorporated into the new client or patient evaluation process. This assessment is particularly important when a client or patient reports an active injury, or injury history.

Obstacles To Treatment

I made a decision to add this final section after having received the feedback of a number of physicians, clinicians and former clients, who I either spoke with in advance, or asked to review my article after it was written. All felt, for different reasons, that convincing clinicians as well as athletes that treatment of Pelvic Torsion and FLLD would be appropriate or beneficial would be difficult. Much of what was said reiterated my own intuition. Considering what is at stake, I think it is worth placing these things on the table for consideration and discussion.

First, as the attached listing of research and professional articles demonstrates, there is considerable awareness of Pelvic Torsion and LLD. Unfortunately, interest in this problem has been limited primarily to the Osteopathic, Chiropractic Podiatric and Physical Therapy realms. As I stated in the main article, this is an issue that is not addressed in any classroom, seminar or course venue.

Even though the science is out there, very few clinicians have put it all together into a meaningful and effective assessment and treatment algorithm. Therefore, one of my primary objectives in undertaking this article was to connect pieces of somewhat disparate research together in a thoughtful way, illuminating the process from identification of the problem through assessment, through understanding its implications, and finally appreciating there are effective treatment modalities available.

Add to that, when an athlete presents to a therapist with an injury, restricting treatment to the site of the injury itself is commonplace. There is minimal consideration given to assessing or ascertaining the underlying cause. This is to some degree due to the fact treatment time is limited by reimbursement practices. The unfortunate result is clinicians often fail to conduct a thorough biomechanical assessment, necessary to reveal a Pelvic Torsion.

Physicians as a group tend to focus on the treatment of injured patients, not the promotion of wellness, and certainly not biomechanical wellness. As they generally view PT as hot packs, ultrasound and massage – arbitrary and ineffective, they also often, but not always, lack appreciation for the sophistication of biomechanical intervention, and therefore tend to dismiss the contribution of therapy or manipulative medicine as useful or effective treatment modalities.

In addition, I have observed these same physicians, who service collegiate and professional sports teams, often feel pressured or compelled to provide simple solutions which accelerate an athlete's return to sport following an injury. Understanding and treating the performance and injury implications of pelvic torsion and FLLD requires a level of patience and understanding in short supply in the team training room.

For example, we all can agree that a Marcaine and Cortisone injection may provide relief from the pain and inflammation of an acute injury. We also know that Bone Growth Stimulation (BGS) is a beneficial adjunct in healing a fracture. However, to inject an injured athlete between quarters of a game, ace wrap and tape him, and send him back out to play, isn't necessarily in the best interests an athlete's long-term health or career. In addition, to apply a technology that is intended to be used in situations where other more conservative efforts have failed, just to accelerate a return to sport, might be considered unethical.

Team athletic trainers undoubtedly have the greatest access to the athletes, and also the greatest responsibility to positively influence their medical care. Unfortunately, and to some extent for reasons outside of their control, they generally operate from a reactive, fire-fighting posture, meaning assessing athletes for musculoskeletal health as a preventative measure is not likely to exist in their repertoire.

Additionally, when placed under the considerable pressure of college administrators, team owners, management and coaches to keep athletes off the injury list, trainers may feel compelled, similarly to the team physicians, to employ those modalities which provide simple and quick, if not long-term, solutions. Also, acting out of a sense of accountability, the trainers exert tight control over the athlete's medical care, and are generally resistant to collaborative treatment arrangements with providers outside the accepted team system who might have a better understanding or competence in the recognition and treatment of pelvic torsion and FLLD.

Finally, athletes are conditioned from an early age to hide, minimize and play through injuries. They realize early on that there are small degrees of separation between athletes who get a job on a team and those who do not. When they do find themselves injured, they are as uninformed about health care as any member of the general public. They are both dependent on the team's health care recommendations, and susceptible to the team's pressure to follow those recommendations.

It is often not until an athlete has suffered recurring injuries, or increasingly serious injuries, that they begin to question their medical care. Unfortunately, by that time they are already beginning to experience the serious health and performance consequences of the inappropriate or inadequate care of their injuries.

At the end of the day, the process of healing an injury requires a combination of smart medicine and patience. Unfortunately, as I stated previously, patience is one of the rarest commodities in the locker and training rooms of collegiate and professional sports.

Research, Reference Articles, & Related Literature

There is considerable literature on the subject of Pelvic Torsion and Leg Length Discrepancy, some of it dating back many years. However, despite the volume of articles and research, there is no consensus on many aspects of this dysfunction. Here are a few selections that are noteworthy:

From: Veterans Affairs of Canada
Discussion Paper Leg Length Inequality
http://www.vac-acc.gc.ca/clients/sub.cfm?source=dispen/elguide/leglen

"In 1994, the American Academy of Orthopaedic Surgeons documented a study where a discrepancy of 1.2 cm was acknowledged as capable of influencing the direction of the scoliosis curve. Gofton (1985) found that a leg length difference of approximately 1.27 cm could lead to a compensatory scoliosis of the lumbar spine. A compensatory scoliosis is reversible, and does not represent a fixed deformity of the spine."

"Frymoyer (1991) observes that a leg length discrepancy of "greater than 0.5 inches" (1.27 cm) may cause back pain (see also Bloedel et al (1995))".

"Harries (2000) states that discrepancies of less than 1.3 cm are cosmetic in most persons, but that a discrepancy of more than 0.5 to 1.0 cm may be symptomatic and require treatment in certain instances, e.g. in top level athletes. He also suggests there is no conclusive evidence that a permanent disability results from LLI less than 1.3 cm."

From: Podiatry Today
Detecting And Treating Leg Length Discrepancies
Volume: 15 Publication Date: Dec 01 2002
Issue Number: 12
Author(s): By Mark A. Caselli, DPM, and Edward C. Rzonca, DPM

"The spine, pelvis and lower extremity are all involved in the compensation of leg length asymmetry. Leg length asymmetry causes the center of gravity to be shifted to the short leg side. Most commonly, the compensations associated with limb length asymmetry include pelvic tilt (to the short side), lumbar scoliosis (convex to the short side), knee flexion (increased on the long side), genu recurvatum (on the short side), subtalar joint pronation (on the long side), and ankle plantar flexion and foot supination (on the short side)."

"The most common symptom associated with LLD is backache. Other symptoms affecting the lower extremity with a structural discrepancy usually appear first on the long leg side and include flank pain, arthritis of the knee, psoasitis, arthritis of the hip, patellar tendinitis, patellofemoral pain syndrome, plantar fasciitis, medial tibial stress syndrome and metatarsalgia. Symptoms affecting the short extremity include iliotibial band syndrome with lateral knee pain, trochanteric bursitis, sacroiliac discomfort, Achilles tendinitis and cuboid syndrome."

From: Podiatry Today
How To Evaluate For Leg Length Discrepancy
Volume: 17 Publication Date: Jun 01 2004
Issue Number: 6
Author(s): By David Levine, DPM, CPed

"Asymmetry is often the first clue that the patient has a LLD. Understanding the prevalence of LLD and how these differences can contribute to pathomechanics will yield important clues in helping you provide successful treatment outcomes for your patient's biomechanical problems."

"Addressing the injured joint or chief complaint only without looking at the interrelationship between the injury and the rest of the body can allow some problems to slip by without being properly identified. The injury, ache or pain may improve with the prescribed treatment, but then may resurface if the underlying cause is a LLD that was not properly identified. This may then lead to a pattern of injuries, injuries that may perhaps affect one side of the body from the back down to the foot."

From: Gait Posture
Leg length Discrepancy
Volume: 2002 Apr;15(2):195-206.
Author(s): Gurney, B.

"The role of leg length discrepancy (LLD) both as a biomechanical impediment and a predisposing factor for associated musculoskeletal disorders has been a source of controversy for some time. LLD has been implicated in affecting gait and running mechanics and economy, standing posture, postural sway, as well as increased incidence of scoliosis, low back pain, osteoarthritis of the hip and spine, aseptic loosening of hip prosthesis, and lower extremity stress fractures."

From: Sports Med.
Leg length inequality. Implications for running injury prevention.
Volume: 1992 Dec;14(6):422-9.
Author(s): McCaw, ST.

"Leg length inequality is a relatively common musculoskeletal malalignment related to structural, postural and environmental factors. The inequality is a plausible aetiological factor in the development of a variety of overuse injuries because it alters the magnitude and distribution of mechanical stress within the body. Leg length inequality has been linked with lower extremity stress fractures, low back pain, hip pain and vertebral disk problems of runners."

From: Br J Sp Med
Biomechanical implications of mild leg length inequality
Volume: 1991; 25(1)
Authors: S. T. McCaw, BPHE, PhD, and B. T. Bates, BEng, PhD

"The pelvic tilt common to LLI may invoke a functional scoliosis, concave to the side of the longer limb. Pelvic tilting helps maintain the line of the centre of gravity mediolaterally within the base of support. The degree of scoliosis is related to the magnitude of the LLI."

"It has been hypothesized that LLI-induced scoliosismay be a causal factor in the development of non-specific low back pain and sciatica. Scoliotic subjects frequently suffer from sciatica on the concave side of the curved spine. In the scoliotic spine, the annulus of the intervertebral disc on the concave side of the spine is in compression, while that on the convex side is in tension. The compressed annulus can protrude out of the intervertebral space and impinge on the dorsal sensory nerve root."

From: Journal of Sports Science and Medicine
Lower Extremity Malignments and Anterior Cruciate Ligament History
Volume: (2004) 3**,** 220-225
Authors: Jay Hertel, Jennifer H. Dorfman, and Rebecca A. Braham

"The results of our study suggest increased ND and anterior pelvic tilt, regardless of gender, are significantly associated with a history of ACL rupture. While females demonstrated larger q-angle measures than males, this difference was independent of ACL injury history. These findings suggest that malalignments at the foot and the pelvis influence risk of ACL injury."

"Excessive pronation was found to be the factor most associated with ACL injury history. This finding is in agreement with other retrospective studies."

"It has been previously demonstrated that increased pronation is correlated to greater internal rotation in the transverse plane at the knee (Coplan, 1989). This increased rotation may place additional strain on the ACL during deceleration activities and increase the risk of rupture."
"Increased anterior pelvic tilt was also found to be significantly associated with ACL injury history. While we found that females had more anterior pelvic tilt than males, we did not find a significant interaction between gender and injury history related to this measure. In other words, increased anterior pelvic tilt was associated with ACL injury history in both males and females."

"In addition to being associated with genu recurvatum, increased anterior pelvic tilt places the hamstrings in an elongated position. Lengthening of the hamstrings may slow their neuromuscular response time (Trontelj, 1993), and thus, their capacity to serve as dynamic agonists to the ACL. Conversely, anterior tilt is associated with shortening of the hip flexors, including the rectus femoris (Lee et al., 1997). This may allow for faster neuromuscular facilitation of this muscle (Trontelj, 1993) and contribute to the phenomenon of quadriceps dominance hypothesized by Huston and Wojtys (1996)."

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