SIGNIFICANCE OF MINOR LEG LENGTH DISCREPANCY

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INTRODUCTION

Inequality of leg length and more specifically the pathogenesis of the disorder is a controversial topic. At first glance, this deformity may seem fairly simple to diagnose and treat. However, proper investigation into the etiology and the associated compensatory mechanisms requires more than a simple ruler or block test. Minor leg length discrepancy (LLD) is generally defined as less than 2 cm of difference. One study suggested that 40-70% of the population has at least some degree of LLD (1). LLD of greater than 2 cm occurs in at least 1 in every 1,000 individuals (2). It is generally accepted that congenital or developmental causes of minor LLD are not pathogenic because there are multiple compensatory mechanisms to prevent injury. However, authors and investigators vary widely on the significance of LLD and its relationship to pathological processes. This paper presents a review of LLD including etiology, classification, and the various measurement methods. It will also attempt to address the controversies concerning the significance of LLD in biomechanics and pathologies such as chronic low back pain (LBP), scoliosis, and arthritis of the hip, spine, and knee, as well as predisposition to stress fractures.

CLASSIFICATION

There are two general types of LLD. Structural or true LLD describes bony deficiency of the skeletal components of the lower extremity (Figure 1). Etiologies of this type of LLD include congenital, idiopathic development, neoplasm, and trauma. The second type is functional LLD caused by joint contracture or foot positional deformity and results in an apparent inequality in lower limb length without true osseous deficiency (Figure 2). A third type of LLD has been described as environmentally produced LLD. The classic etiology of this type of LLD is running on a crowned road. The limb closer to the side of the road functions in a shortened condition while the "up-hill" leg functions as the longer limb. Fracture walker boots can also cause an environmental LLD. This iatrogenically induced LLD

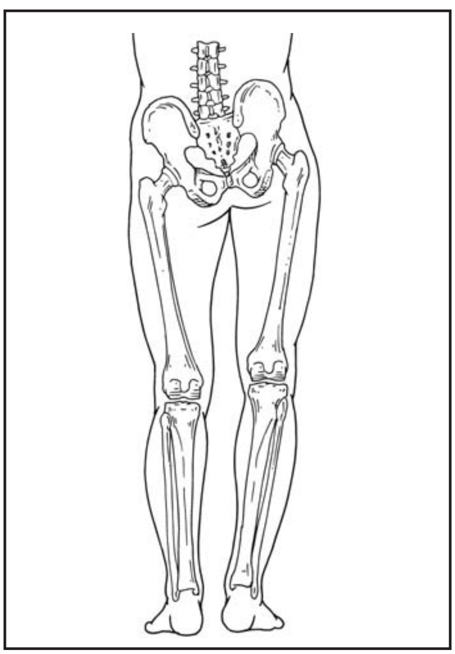

Figure 1. Structural leg length discrepancy is seen when a difference in length of the bones of the lower extremity exists. In this drawing the tibia and fibula are shorter on the left side resulting in pelvic tilt toward the shorter side.

Figure 2. Functional leg length discrepancy occurs when joints are contracted such as in this depiction of a knee contracture.

results when patients ambulate in a thick-soled boot or shoe on one side and a normal shoe on the ipsilateral extremity. The degree of LLD varies significantly depending on the brace or shoe utilized. This form of LLD results in a sudden onset of functional deformity that has been associated with higher rates of complication (3). The use weight-bearing braces such as fracture boots has increased significantly since their first introduction in the mid 1980s. Therefore, this may be one of the most common causes of LLD complication seen in the orthopedic-oriented medical practice (Figure 3).

METHODS OF LIMB LENGTH MEASUREMENT

Clinical examination of the patient with LLD should be done with the patient without shoes in relaxed standing position and then while walking. The pelvis is palpated and any asymmetry is noted. Knee position is determined on both sagittal and frontal planes. Unilateral knee flexion, varus, or valgus may indicate either structural or functional etiology of LLD. Hindfoot pronation or supination is recorded for each limb. Multi-segmental deformities may exist and must be ruled out as either cause or effect of the LLD.

Simple, accurate and reproducible methods of measuring leg length have proven to be elusive. All methods have been described as having a fairly significant degree of imprecision. In clinical situations, tape measure techniques or block tests are generally used. Tape measure methods are considered direct methods and block test are indirect methods of determining the amount of LLD. Both methods require accurate determination of bony landmarks such as the anterior superior iliac spine (ASIS) and the medial malleolus. Radiographic techniques, while more accurate are more expensive, require radiation exposure, and are more time consuming. More recently magnetic resonance imaging (MRI) and ultrasonic techniques have been introduced.

Tape Measure Techniques

Tape measure techniques to quantify the discrepancy are done with the patient in the supine position. The ASIS is identified with palpation as is the medial malleolus. A tape measure is used to determine the distance between the two points for each extremity (Figure 4). Measuring each extremity twice and averaging the result has been shown to improve the accuracy of the technique (4). It should be noted that foot position or deformity is ignored in this method of measurement. Patients with extreme pronation or osseous collapse such as in an unreduced calcaneal compression fracture will have deficiency of the limb not measured (Figure 5). Supination of the hindfoot would add length to the extremity.

Indirect methods of measurement utilizing blocks to level the pelvis appear to be more accurate than direct tape measurement techniques. Block testing compensates for both structural and functional LLD and includes foot deformity or position in the determination (Figure 6). This indirect method of measurement utilizes material of known

Figure 3. The patient depicted here required a fracture boot to treat a partial achilles tendon tear. She developed severe hip pain while in the boot while working on her feet for 8 hours a day. Her spouse fabricated a shoe lift in form of wood screwed to the bottom of her shoe to level the LLD. This can be considered an environmental or iatrogenic LLD.

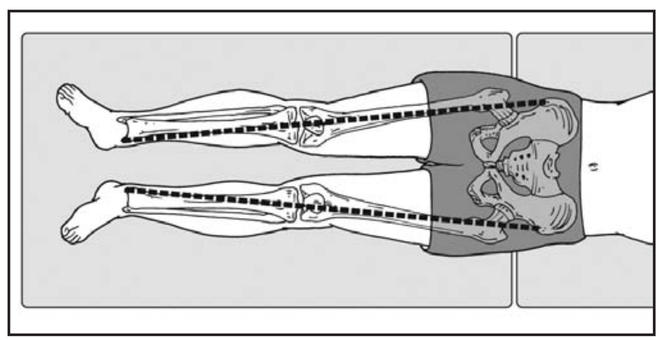

Figure 4A. Measurement of structural leg length with a tape measure technique is shown. The anterior superior iliac spine is palpated and used as the proximal reference point. The distal tip of the medial malleolus is used as the distal reference point.

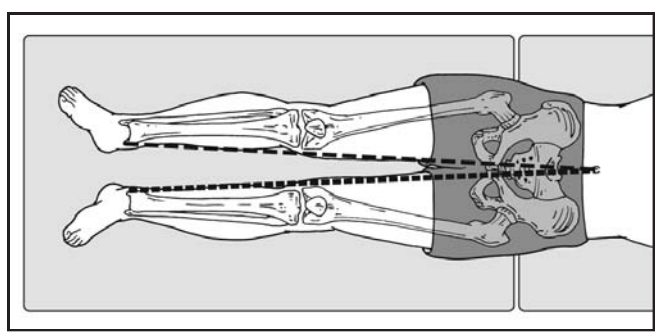

Figure 4B. To determine if a functional leg length discrepancy exists measurement from the umbilicus to the medial malleolus is done for each leg. This helps to reveal pelvic tilt, hip or knee contracture as the etilology of the discrepancy.

thickness placed under the standing patient's short limb to level the pelvis. To determine which segment is causing the discrepancy a carpenter's level is used across the seated patient's knees while their feet are flat on the floor. If the knees are level while seated the femoral segment is indicated as the cause of the discrepancy. If the knees are not level, the structures below the knee including the foot are the likely etiology.

Radiographic techniques

Clinical methods are sufficient in most circumstances. However, if accuracy is critical, imaging techniques must be used. These techniques include orthoroentgenogram, which is a single radiologic exposure but has problems with distortion. Scanograms utilize a 3-exposure technique of the hip, knee, and ankle. This is more technically difficult and increases the radiation exposure of the patient. Computerized digital radiographs lessen the radiation exposure and improve the accuracy of the measurement. Computed tomography, ultrasonic, and MRI techniques have also been described and have been reported to be accurate but are more expensive than the methods above.

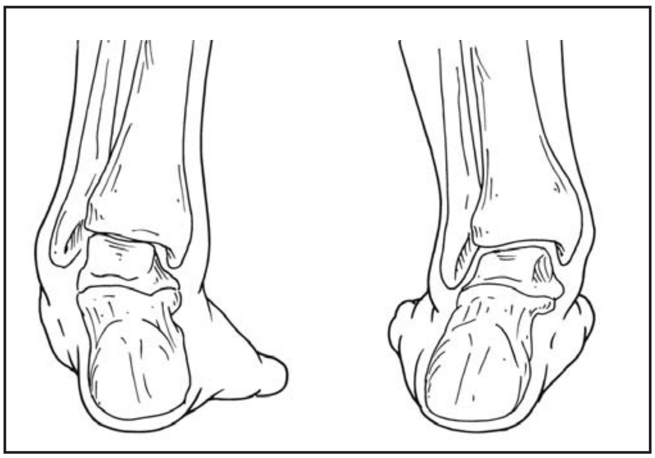

Figure 5A. Note the difference in height of the tibiotalar articulation in this depiction of a supinated foot position on the left versus a pronated hindfoot position.

Figure 5B. This post-polio patient shows a typical appearance of pronation of the longer limb and supination of the shorter limb to compensate for the LLD. Note the foot on the left is also smaller than the right. Patients with significant shoe size difference should raise the clinicians suspicion for LLD.

SIGNS AND SYMPTOMS OF LLD

Examination of an individual with a suspected LLD should systematically evaluate the various segments of the body to determine if a short lower limb exists. Subtle clues such as shoe size variation, head tilt, shoulder dip, or asymmetric foot deformities should increase suspicion for LLD. Symptoms that have been associated with LLD include hip, back, knee pain. Ankle pain due to various forms of tendonitis may exist relative to the position the hindfoot takes during compensation.

COMPLICATIONS OF LLD

Numerous studies have indicated that functioning with LLD can be a pathologic process, however, the degree of LLD necessary to produce complication varies widely between investigators. Generally, individuals that have jobs that require significant periods of walking or weight bearing will have less tolerance for small degrees of LLD than individuals that are more sedentary. Athletes or individuals with high functioning levels of weight-bearing stress may poorly tolerate even minor LLD. Younger patients appear

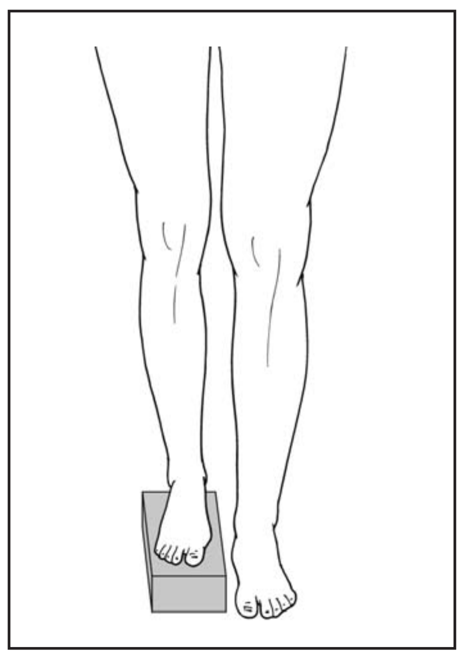

Figure 6 A block test utilizies known thicknesses of material that can be placed under the shorter limb until the hips and pelvis are leveled.

to compensate easier for LLD than do older patients. Gurney found that LLD as little as 3 cm could cause significant quadriceps fatigue in older adults and differences as small as 2 cm caused difficulty with walking in patients with significant cardiac, neuromuscular, or pulmonary disease (5).

The effects of LLD on balance appear to be significant for individuals with artificially induced LLD (6) while patients with true LLD have been shown to have no significant difference between control subjects and afflicted individuals (7).

The role of LLD in gait disturbances has been more extensively researched. It is important to understand that even normal walking requires raising of the center of mass as the individual vaults over the extended extremity. This energy is not regained as the center of mass is lowered onto the flexed extremity. LLD extenuates this energy consumption. Mechanisms of compensation for LLD during gait on the short limb side include increasing knee extension, forward tilt of the pelvis, toe walking, hindfoot supination alone or in combination. The longer limb may participate in compensation by increased knee or hip flexion, hip circumduction, posterior hip tilt, or hindfoot pronation. Ground reactive force (GRF) measurement has been used to quantify work differentials between the short and long limb in LLD. Again, investigators have reported significant differences in GRF measurements. Kaufman reported that LLD more than 20 mm resulted in gait asymmetry greater than that observed in the normal population (8).

Both the long and short leg have been described has absorbing greater GRF. Bhave found that the longer leg had a greater GRF measurement that was equaled after leg length correction to within 10 mm was achieved (9). However, White et al found that the shorter limb sustained a greater portion of the load in patients with LLD less than 30 mm (10). O'Toole et al (11) also found that pedobaragraphic measurement of loading patterns were higher on the short limb.

Pertunnen et al (12) reported that moderate limb length discrepancies resulted in asymmetrical gait patterns. The duration of the stance phase was reduced in the short limb in both walking speeds. The vertical ground reaction force in the push-off phase was greater in the long limb both at normal and fast walking speed. Peak plantar pressures were higher under the big toe in the long leg and the heel-off occurred faster. Their results implied that the loading of the long limb is greater and the foot loading patterns shifted more to the forefoot in the long limb.

Low Back Pain

Low back pain has be associated with LLD by numerous investigators most of whom called for equalization of the LLD as preventive treatment for LBD. Giles and Taylor (13) treated 50 patients with low back pain with shoe lifts resulting in less working days lost, decreased symptoms, and increased range of motion. Frieberg (14) reported 211 patients with low back pain treated with shoe lifts. After 18 months, 157 were symptom free. Another study by Golightly et al (15) found that shoe lifts may reduce low back pain and improve function for patients who have chronic low back pain and LLD. Conversely, several investigators have found no significant relationship between low back pain and LLD. In a prospective study of 257 college athletes, Nadler et al (16) found that LLD was not associated with future low back pain treatments.

Hip Pain

The relationship between hip pain and LLD is less equivocal. In one study self-runners with self-reported LLD complained of hip pain twice as often as runners without LLD (17). Friberg reported that of 254 patients with LLD complaining of hip pain, 226 had pain on the longer extremity (13). Morscher found that decreased surface contact of femoral head in the acetabulum results in greater pressure on the longer leg hip joint (18). Decrease in the weight-bearing area of the femoral head was calculated by Krakovits (19) with a mathematical model. Based on his formula, one centimeter in LLD would result in 5% reduction in weight bearing area on the femoral head on the long leg side. Theoretically, a 25% reduction would result from a 5 cm LLD. Again, controversy exists however, concerning greater forces through the hip of the longer leg. Brand and Yack (20) reported decreased forces through the hip when subjects were given an artificial LLD.

Osteoarthritis

Extrapolation of many of the studies mentioned above and below would indicate that asymmetric loading of the joints of the low back and hip might result in increased joint arthritis. Incongruous or abnormal loading was proposed as cause of idiopathic osteoarthritic hip conditions by Solomon (21).

Stress Fractures

The association of LLD with increased risk of stress fractures has been reported by several investigators. Brunet (16) in the same study cited above, found that runners with LLD developed stress more than twice as often as those without

LLD. Friberg (22) found that 15.4% of individuals without LLD experienced stress fractures. Finnish conscripts used in the study with at least a 10 mm LLD had a 46.2% rate of stress fracture. Those with 15 to 20 mm of LLD had almost 67% incidence of stress fracture. The stress fractures were most commonly seen in the tibia, metatarsals, and femur. A total of 73% of the stress fractures occurred in the long leg.

CONCLUSION

The study of asymmetry of the lower extremity in the form of LLD is complicated by multiple variables. There are few subjects that would seem to give so many opposing results. However, some trends do seem to surface with exhaustive review of the literature. In general, individuals with LLD of congenital or long standing nature appear to compensate well for their deformity. Individuals with rapid onset of their deformity or condition appear to exhibit more complications of LLD. Younger individuals appear to tolerate fairly significant degrees of LLD in many cases while older individuals may exhibit significant complications from minor LLD. Simple compensation of LLD with shoe lifts appears to be a reasonable and efficient means of preventing symptoms and arthritic degeneration of the knee, hip, and back.

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