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Leg Length Discrepancy: Assessment and Secondary Effects

***Ahmed A Khalifa**

Orthopaedic Surgery Department, South valley university, Egypt

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***Corresponding author:** Ahmed A Khalifa, Assistant lecturer orthopaedic surgery Department, faculty of medicine, South Valley University, Qena, Egypt, Tel: 00201224466151, Email: ahmed_adel0391@med.svu.edu.eg

Abstract

Leg length discrepancy can be noticed commonly in the general population occurring naturally without any secondary side effects it also can be noticed in some patient after surgical treatment of fractures or joint replacement surgery. The presence of this discrepancy can be assessed clinically and can be precisely measured using imaging techniques. LLD can badly affect the lower back, pelvis, hips, knees as well as the gait.

Keywords: Leg length; discrepancy; Assessment; Effects

Introduction

70% of the population had LLD [5]. Mannello remarked that the clinical significance of LLD was perhaps dependent on several factors, including the degree of inequality, the ability of the pelvis and spine to compensate for the inequality and associated conditions or problems [6]. A lot of controversy regarding the effect of mild LLD exists where some authors propose that postural adjustments compensate for the asymmetry and consider the biomechanical disruption caused by mild LLD to be in consequential, however several authors agreed that mild LLD may have a great impact if an individual participates regularly in repetitive mechanical loading tasks [7].

In the surgical treatment point of view, most surgeons have recommended that LLD of less than 20 mm is clinically insignificant, as no surgery is indicated [3]. Others suggest that LLD of just over 6mm is sufficient to cause chronic repetitive overuse trauma and should be treated [3]. Several studies attribute LLD to be associated with many lower limb and lumbar biomechanical conditions including: foot pronation; low back pain; scoliosis and osteoarthritis in the knee and hip joints [3]. Individuals with LLD can compensate by modifying their movement patterns to functionally minimize the inequality, i.e., increasing knee flexion or hip adduction of the longer limb, on the short limb side may include increasing knee extension, forward tilt of the pelvis, toe walking, hind foot supination alone or in combination [1,8]. On the other hand, these compensatory mechanisms may amplify forces across a smaller joint contact area, thus acting as a biomechanical precursor to lower extremity [2].

Classification

A differentiation must be made between the anatomical (structurally) short leg, and the functional short leg [7].

a) Functional short leg (apparent) occurs secondary to a rotated pelvis caused by joint contractures and/or axial malalignments, including a fixed spinal deformity (lumbosacral scoliosis), contractures of peri articular hip and knee muscles [7,9].

b) An anatomical short leg (structural) occurs when there is an actual length difference in the bony components of the lower limb between the levels of the femur head to the calcaneus [3].

c) A third type is often described as an environmental LLD and is common in runners who run on a sloping surface in one direction and for long periods of time [3].

d) LLD can also be classified into 3 categories according to the magnitude of the discrepancy: mild (differences < 3cm), moderate (differences, 3 and - 6cm), and severe (differences > 6cm) [7].

How To Assess LLD

Clinical Assessment

The apparent leg length can be measured from the umbilicus to the medial malleolus while the true leg length is measured from the anterior superior iliac spine to the medial malleolus [4]. Contribution of foot height to limb-length discrepancy can be assessed clinically by measuring the distance from the floor to the medial malleolus with the patient standing [1].

Clinical Techniques used for Assessing LLD

a) **Tape measure:** Referred to as the "direct" clinical method to measure LLD, using a tape and measure the distance between the ASIS to the medial maleollus and compare on both side

b) **Blocks method:** placing blocks of known height under the short limb to level the pelvis of the standing patient, this is referred to as the ''indirect'' clinical method to measure LLD [1,10].

Although the tape method is easy, safe and non-invasiveit is less reliable when compared to the radiographic methods due to fallacies in determining the bony landmarks, while using the blocks method seems to be more accurate than the tape method [1,8,10]. Accuracy of both methods can be increased while using in a clinical situation by measuring twice and averaging the result [8].

Imaging Methods of Assessment

There is general agreement that radiographs are more accurate and reliable than clinical methods for assessing LLD [10]. Although various imaging techniques have been used to evaluate leg-length inequality, plain Radiography remains the gold standard [11].

Plain Radiography Assessment: four different imaging methods have been used for determination of LLD: orthoroentgenography, scanogram, teleroentgenography and computed Radiography [3,10].

a.Orthoroentogenogram: using three distinct exposures centred over the hip, knee, and ankle minimize measurement error secondary to magnification [10].

b.Scan gram: both lower limbs similarly positioned with both patellae pointing up and a radio-opaque ruler taped to the table between the limbs. Three separate AP images are obtained centred over the hip, knee, and ankle joints, using three separate cassettes [11].

c.Teleoroentgenogram: single radiographic exposure in a standing position with patella facing forward to get an AP view of both lower limbs with the x-ray beam cantered at the knee from a distance of approximately6 feet (180 cm) [11].

d.Computed Radiography: A latent image is produced that is stored on a photo stimulatable phosphor receptor contained in a standard radiographic cassette. The images are recorded on a computed radiography long-length imaging system utilizing a vertical cassette holder with three individual 35 9 43-cm CR storage phosphor cassettes. The three images are then stitched at the CR reader console, using customized software [11].

Ultrasound: The ultrasound transducer eases the identification of the bony land mark at the hip, knee and ankle [10].

a. CT Scanogram: Typically, an anteroposterior (AP) scout view of the bilateral femurs and tibias are obtained, the images had not shown advantage over the plain radiographs except in patient with significant knee flexion contracture, but it had been shown that it entails considerably less amount of radiation exposure than the conventional radiographs [1].

b. MRI Scan: using the T1 weighted sequence and select the best coronal images have been used to determine the length of the femur by measuring after defining the classic bony landmark (femoral head and medial femoral condyle) [10-13].

Secondary Effects of LLD

Spine(Low back pain)

The data relating to the possibility that limb-length discrepancy causes low back pain in adults are contradictory [1]. Results have been unequivocal, Grundy, Roberts and Botte reported no link between the presence of LLD and low back pain, while Friberg, Matheson et al., Giles and Taylor reported that low back pain was prevalent among those with LLD [7]. In a study done by Giles and Taylor using 1,309 subjects with chronic low back pain (and 50 volunteers without) found that 18.3% of chronic low back pain patients had LLD of 10 mm or more compared to 8% of controls [3] a further study done by the same above authors reported that subjects who had LLD of greater than 9 mm suffer from altered lumbo sacral facet joint angles which may contribute to low back pain while subjects with less than 3 mm difference did not [3]. Frieberg also reported 211 patients with low back pain treated conservatively with shoe lifts, after 18 months and 157 were symptom free [8,14].

Other compensatory effects to LLD have been demonstrated by Giles et al. which may include alterations and asymmetry of lumbosacral facet joint angles, postural scoliosis, concavities in the vertebral body end-plates, wedging of the 5th lumbar vertebra and traction spurs, however, no relationship of these findings to symptoms was claimed [6]. In a prospective study of 257 college athletes, Nadler et al found that low back pain was not associated with LLD [8].

Effect on alignment

Functional scoliosis can occur as a compensation to achieve erect trunk when a subject with LLD bear weight equally on both lower limbs [1]. According to the literature, however, the

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convexity of the curve may be variable; mostly it is concave to the side of the longer limb [1]. Severity of LLD will determine the degree of scoliosis; the literature is unequivocal as to whether transient functional scoliosis will become structural over time [7]. More than half of individuals with LLD of 6 mm or more noted to have scoliosis and abnormal lumbar lord sis in a retrospective study done to analyse the radiographs of 106 chiropractic patients which may indicate abnormal weight bearing in the joints of the lumbar spine [3]. A notable increase in the electromyography activity of the erector spinae muscles was noted in a study by Vink and Huson only when the leg-length discrepancy was above 3 cm [4].

Degenerative effects

Kakushima et al. by induced a 3-cmLLD in healthy participants using a heel-raising orthotic device and they found that there is an increase in lateral bending of the thoracic and lumbar spinal segments during walking compared with participants with no heel lift, they concluded that increased lateral bending stresses may lead to development of spinal degenerative disorders in LLD individuals [5].

Pelvis

Mechanically, in the standing position, the weight of the body in the pelvis induces a force vector through the hip joints and towards the feet, with asymmetry of the leg-lengths, the pelvis, being pushed down on the femoral heads, must compensate by rotation [6]. These compensations can lead to postural consequences which are atorsion change in pelvic posture in both the sagittal and/or frontal planes with posterior rotation of the ilium on the longer leg side and anterior rotation of the ilium on the short leg side in both anatomical and artificially induced LLD [3,6]. Walsh et al found that compensation for LLD was commonly achieved by change in pelvic obliquity when the difference was up to 22 mm, with increase in the difference, subjects begin to compensate by flexion of the knee in the long leg [6].

Pelvic tilt or torsion resulting from LLD shifts the centre of gravity, resulting in compensatory muscle activity, which may increase the magnitude of internal joint load in combination with placing unequal stresses on the foot, ankle, knee, hip, sacro-iliac, and lumbar spinal joints in the upright posture [3,7]. In studies of pelvic rotation imposed by foot lifts, there was an approximately linear relationship in pelvic torsion as the leg was lengthened from 1/4 to 7/8" [6]. Obliquity resulting from LLD leads to abnormal mechanical alignment of the SIJ of both sides which subsequently increase the loads passing through the joint that eventually leads to SIJ dysfunction with subsequent contribution to low back pain [12]. LLD increases the joint load on both short and long leg sides; however, this increase was higher on the longer side, as little as 1 cm of LLD can increase the load across SIJ to almost 5 times that of intact (shorter) side, this increase can reach almost 12 times of intact at 3 cm discrepancy [12].

Hips

LLD with subsequent altered weight bearing of the hip joint is a potential contributing factor to OA in the hip [3]. Pelvic tilt occurring as compensation to LLD may reduce the contact area of articular cartilage within the joint due to a disruption of normal skeletal alignment and increase in joint loading forces, these two effects may translate to increased pressure on the cartilage and the underlying bone which may lead to the development of osteoarthritis [3]. Krakovits calculated the decrease in the weight-bearing area of the femoral head with a mathematical model, based on his formula, one centimeter LLD would result in 5% reduction in weight bearing area on the femoral head on the long leg side and theoretically, a 25% reduction would result from a 5 cm LLD [8]. Controversy exists however, concerning which hip is subjected to greater forces of the short limb or of the longer limb, and some previous research in clinical samples has indicated that hip OA may be more common in the longer limb than the shorter limb [2].

Tallroth et al, in a study of 100 consecutive patients undergoing hip arthroplasty, reported that radiographic hip OA occurred more frequently in the longer limb (84%) [2]. In another study over runners with self-reported LLD, complained of hip pain twice as often as runners without LLD, Friberg reported that of 254 patients with LLD complaining of hip pain, 226 had pain on the longer extremity [8]. In contrast, some other studies have suggested that the shorter limb may sustain greater forces through the hip compared to the longer limb, Brand and Yack reported decreased forces through the hip of the longer limb when subjects were given an artificial LLD [2,8].

Knees

It is known that cartilage loss and joint space narrowing occurring in osteoarthritis of the knee anatomically shortens the leg [5]. On the other hand, TKA anatomically lengthens the limb as shown in one study where TKA procedure was found to lengthen the leg in 76% of patients by about 5 mm [5]. Harvey et al radiographically measured the anatomic leg lengths of 3026 individuals at high risk for knee osteoarthritis, they found a strong correlation between LLD of 1 cm or more and both symptomatic and radiologic knee osteoarthritis in the shorter leg, These findings support the theory that knee osteoarthritis pain occur more frequently in the apparently shorter leg in elderly population [5].

Golightly et al. [2] found in across-sectional study of 3012 individuals with osteoarthritic knee and hip pain that there was moderate association between knee pain and less strongly associated with hip pain with LLD , However, They defined LLD as being 2cm or greater as measured from ASIS to medial malleolus , but, 206 of this group had a LLD of 2 cm or greater, and pain location was not associated with either the short or the long leg, so they suggested that the extent of LLD may have different effects on knee osteoarthritis and osteoarthritic

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pain [5]. Another study done by Harvey and colleagues using radiographic LLD measurements in 3,026 subjects aged 50 to 79, concluded that LLD of 5 mm or more was associated with knee osteoarthritis progression and increase in symptoms prevalence [3]. Bhave et al reported that LLD leads to increased ground reaction forces in the longer leg [11]. With significant reduction in ground reaction force asymmetry after surgical lengthening of the shorter limb to be within 1cm of the contra lateral limb [4].

on the other hand, the ground reaction force may also increase in the shorter leg during walking as it has to come from higher level to reach the ground, White et al found that the shorter limb sustained a greater portion of the load in patients with LLD less than 30 mm, Toole et al also found that pedobarographic measurement of loading patterns were higher on the short limb [8,11]. Therefore, compared with legs of equal length, both shorter and longer legs may subject the knee to increased biomechanical loading and may increase the risk for osteoarthritis and pain of the knee [11]. In another study in which 14.5% of the participant experience leg-length in equality of 1 cm or greater they found that this difference was significantly associated with prevalent radiographic and symptomatic osteoarthritis at the baseline and predicted progression of knee osteoarthritis30 months later and the shorter legs were at high risk for radiographic progression [11].

Gait

Gait abnormalities can result from limb-length discrepancies of 2 cm or greater can lead to increase in muscle activity, heart rate, and oxygen consump¬tion [13]. Gurney et al. evaluated the effects of an artificial limb-length discrepancy on gait economy and lower extremity muscle activity in older adults, they found that with 2 to 3 cm of LLD, there was a significant increase in oxygen consumption. With 3 to 4 cm of LLD, there was a significant increase in heart rate and significant quadriceps activity in the longer limb. With over 4-cm LLD, there was a significant increase in plantar flexor activity in the shorter limb.

The authors concluded that difference of between 2 and 3 cm is the trigger point for change and effect on the physiologic parameters in older adults, however in elderly patients with pulmonary, cardiac, or neuromuscular problems they may develop difficulty in walking with a limb length discrepancy as small as 2 cm [4,5,8]. In a pilot study of 6 individuals with chronic obstructive pulmonary disorder Crosby showed that they experienced improved pulmonary function when LLD was corrected [5]. Song et al. reported increased work done by the long side with greater vertical displacement of the centre of body mass in patients with discrepancies greater than 5.5% compared with the other limb [1]. The effects of LLD on balance appear to be significant in individuals with artificially induced LLD while patients with true LLD have been shown to have no significant difference between control subjects and affected individuals [8]. In a gait analysis done by Kaufman et al they demonstrated that subjects with a LLD of less than2.0 cm had no greater gait asymmetry than the general population [1,5].

Stress Fractures

In normal stance, body-weight is evenly distributed between both lower limbs; in persons with LLI there is a tendency to shift weight-bearing towards the longer limb [7]. In a study conducted on Finnish army recruits, Friberg found that 15.4% of individuals without LLD experienced stress fractures, while at least a 10 mm LLD had a 46.2% rate of stress fracture and 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 among those, a total of 73% of the stress fractures occurred in the long leg [7,8]. Brunet found that incidence of stress fracture development in runners with LLD is twice those without LLD [8].

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