LITERATURE REVIEW

Leg Length Discrepancy

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ABSTRACT

Leg length discrepancy (LLD) is a condition of length differences in the lower extremity, caused by variety of factors, both congenital and acquired. Measurement using measuring tape, block test, and supine-to-sitting test based on bony landmarks is considered less accurate than imaging techniques. Measuring LLD can be difficult in certain cases such as obesity, leg deformities, and post arthroplasty. Individuals will develop biomechanical strategies to compensate inequality of leg when standing, walking, and running on their feet, ankles, knees, hip, and or pelvis to minimize energy consumption. It can causes several complications, including osteoarthritis, functional scoliosis, intervertebral disc degeneration, stress fractures, cardiovascular and neuromuscular problems. Management varies from wearing a shoe lift, relieve muscle and joint contracture, and surgical procedures. This paper was written to review measurement technique, biomechanical compensation strategies, complication, and management of LLD from Physical Medicine and Rehabilitation point of view.

Keyword: biomechanical compensation strategies, leg length discrepancy, lower extremity, management, measurement

ABSTRAK

Leg length discrepancy (LLD) adalah suatu kondisi perbedaan panjang ekstremitas bawah. Hal ini dapat disebabkan oleh berbagai faktor, baik kongenital maupun didapat. Pengukuran LLD dengan pita ukur, papan balok, dan tes *supine-to-sitting* berpatokan pada *bony landmark* dinilai kurang akurat dibandingkan dengan metode radiologi. Beberapa kasus tertentu seperti obesitas, deformitas kaki, dan pasca artroplasti sendi dapat menyulitkan pemeriksaan dan pengukuran. Individu dengan LLD akan melakukan strategi kompensasi biomekanik pada kaki, pergelangan kaki, lutut, dan atau panggul saat berdiri, berjalan, dan berlari guna mengurangi konsumsi energi. LLD dapat menimbulkan beberapa komplikasi, diantaranya osteoartritis, skoliosis fungsional, degenerasi diskus intervertebral, *stress fracture*, permasalahan sistem kardiovaskular dan neuromuskular. Tatalaksana bervariasi mulai dari pemakaian shoe lift, peregangan otot dan sendi, hingga prosedur operatif. Tujuan penulisan artikel ini adalah untuk meninjau Teknik pengukuran, strategi kompensasi biomekanik, komplikasi, dan tatalaksana LLD dari perspektif kedokteran fisik dan rehabilitasi.

Kata kunci: ekstremitas bawah, *Leg length Discrepancy*, pengukuran, strategi kompensasi biomekanik, tatalaksana.

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INTRODUCTION

Leg length discrepancy (LLD) is a condition of length inequality in the lower extremity. It caused by a variety of factors, both congenital and acquired. It can occur in individuals with joint contractures, scoliosis, or as well as complications of orthopedic procedure in the lower extremity such as arthroplasty, internal fixation or arthrodesis. Prevalence LLD with magnitude less than 10mm reached 90% of population, even though mostly asymptomatic.[1,2]

Based on etiology, it categorized into two types, structural and functional LLD. The severity level of LLD divided into; mild (<3cm), moderate (3-6cm), severe (>6cm). Structural or commonly known as true LLD occurs when differences in limb length are caused by bone components in the lower extremities, from femoral head to calcaneus. Functional LLD (apparent LLD) caused by soft tissue origin, as a result of weakness or muscle contracture, such as hip muscle abduction and adduction contracture, knee hyperextension due to quadriceps muscle weakness, and scoliosis vertebrae.[3] Environmental LLD is rare, often associated with repeated and prolonged limb exposure to the ground, mostly found in athletes who run on sloping surfaces in one direction.[3] Tabel 1 describes possibility combination between true and apparent LLD.

Unequal leg length has impact on posture when static (standing) and dynamic (walking and running). It also affects many medical conditions such as premature skeletal muscle fatique, lower back pain, nerve paralysis, muscle and ligament injuries, and stress fractures.[1-3]

LLD is one of the problems that often found in the physical medicine and rehabilitation practice. A good understanding of LLD, especially the effects of leg length inequality, body biomechanical strategies to compensate for the difference in leg length, and ideal measurement techniques will greatly help physical medicine and rehabilitation specialists in developing therapeutic medical rehabilitation strategies for LLD patients.

ASSESSMENT

Initial anamnesis was taken regarding the complaints, including subjective sensation about the differences in limb length, asymmetrical pelvic, or posture anomaly when standing and walking. Sometimes patients complaint about recurrent musculoskeletal pain. History of vertebral and congenital deformity, poliomyelitis, or spine surgery, may have associations with LLD. Subjective assessment is the best screening method, especially post Total Hip Arthroplasty (THA) patients.[4,5]

Table 1. Combination True Leg Length (TLL) and Apparent Leg Length (ALL)[4]

Combination	Description
TLL and ALL equal	Limb length is equal, pelvis is balanced
TLL and ALL unequal same amount	Limb length is unequal, pelvis is balanced
TLL equal and ALL unequal	Pelvic obliquity exists
TLL unequal and ALL equal	Limb length inequality and compensatory pelvic obliquity are present

The physical examination include posture assessment, angulation abnormality, spine curve, as well as range of motion and muscle strength. Clinicians are also must assess functional conditions of individuals in activity daily life and determine the risks that will arise with such functional activities. Two individuals with same degree of LLD will have different effects when they have different levels of physical activity, especially those who use the lower limbs more often, like runners, soldiers or field workers.[4]

Direct method

Direct measurement is performed using tape, comparing the results both right and left leg. ALL is distance between umbilicus to medial malleolus, while TLL is based on distance between anterior superior iliac spine to medial malleolus. Measurement is performed in supine position. The contribution of foot height can be assessed based on distance between the floor and the medial malleolus performed in standing position. Measurement can also be done in prone position, although different position may affect pelvic tilt.[3,4,6]

Indirect method

The measurement is done using block test. Examiner evaluates the alignment of pelvis before and after block board placement. Measurement is performed in standing position, both knees are fully extended with the distance between legs approximately 10cm, and the body weight must distributed equally on both legs. The examiner place hands on both bilateral anatomical structures; superior posterior iliac spine, superior anterior iliac spine, or iliac crest, then assessed if there any asymmetry of the structure.

If there was visually different, a 0.5cm wooden board was placed under the short leg. More wooden boards are added until pelvis visually symmetrical. The thickness of the board is the value of the LLD.[3,4] Block test method are very helpful to determine fixed or flexible pelvic. The examiner can inspect and palpate curves of spine and pelvic tilt. If the pelvic tilt can be corrected using board placed under the foot, the pelvic tilt is still flexible. Otherwise, when it is fixed means pelvic is no longer able to compensate the inequality of leg. Total boards needed to make patient feel the both limbs are already balanced indicates the amount of difference that must corrected, regardless the pelvic slope is flexible or fixed.[4]

Supine to Sitting Test

Patient supine with extremities in extended position. The examiner sees and ensures both medial malleolus, patient is instructed to do sit up and examiner inspect if any of the limbs are advancing forward further and faster than other leg. If found there is leg inequality during supine and sit up, or a difference in the speed of movement of each limb, this can be caused by functional LLD as a result of pelvic dysfunction resulting from torque or pelvic rotation.[7]

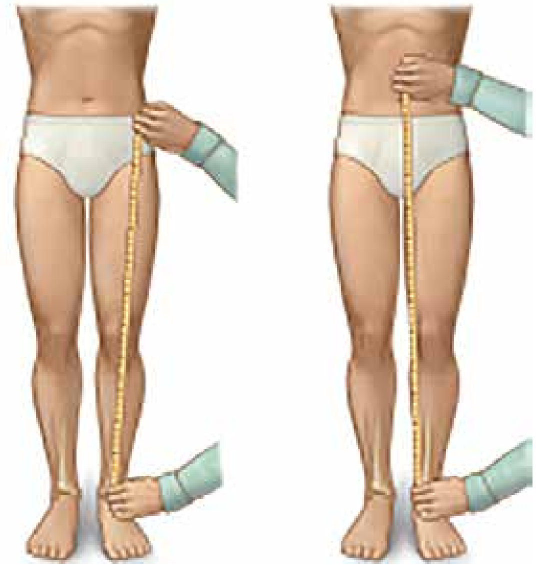

Figure 1. (Left) TLL and (Right) ALL measurements with tape[4]

Although using tape can be done easily, this method is less reliable compared to radiological methods. Controversy arising because of the high variability of the result due to measurement inaccuracy between examiners. Measurement in nonweight bearing position also has limitation because there are biomechanical changes occur between foot and pelvis when person is standing. For those reasons, it also suggest LLD measurements are also performed in standing position. Measurements with bony landmark palpation potentially make errors due to mistake in determining the bony landmark. Condition such as obesity, leg deformity, and elderly can also make it difficult for examiners.[3]

The block test method is more accurate than using a tape measure. Sabharwal[8] mentioned that indirect method have superiority in terms of validity, interobserver reliability, and specificity compared to direct method. To improve accuracy, it is recommended that measurement is done more than once.[8]

Other method also was developed to measure LLD in a standing position, namely palpation meter (PALM). PALM is a tool actually used to assess the obliquity of the pelvis as well as LLD. The accuracy level is better when assessing pelvic level than other method. This tool provides easy and proprioceptive advantages in inspection through palpation with inklinometer and term features on PALM.[9]

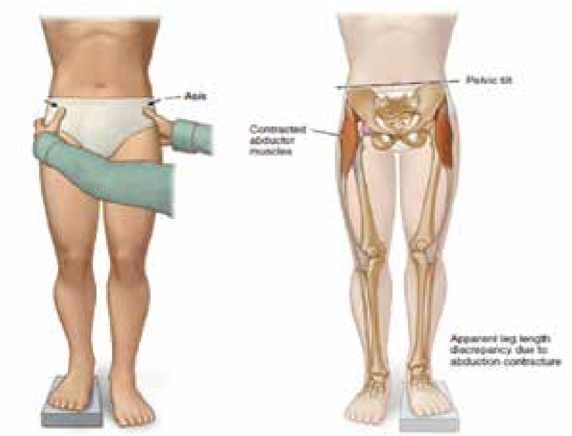

Figure 2. (Left) Block test; (Right) example of functional limb length abnormality due to abductor muscle contracture[4]

The Weber-Barstow maneuver is a new clinical method available. The examination is carried out in a supine position, examiner visually compared the inside edge of both malleoli. Subjects were asked to raise the pelvis in a "bridging" position (figure 4), maintain this position for 10 second and slowly lowered pelvis. Examiner then stretched the lower limbs to visualise again the level of the inside edge of both malleoli.[10]

Imaging technique

Radiographic examination is gold standard for assessing LLD. There are many radiological imaging techniques for evaluating limb length inequality, but standing telemetry is often used in practice. Woolson's technique is also often used in determine LLD after THA.[3,10]

COMPENSATION STRATEGY

Healthy individuals require very little activation of skeletal muscles to maintain stability of the body while doing quite standing. Muscle contractions only occur intermittently to counter if any external forces. Systematic review by Azizan[11] concluded that compensatory mechanism due to LLD could affect stability, kinetic and kinematic deviation during standing and walking.[11]

At the short limbs, LLD can reduce contact between the acetabulum and head of femur, increases tone at hip abductor muscle due to increased distance between the origin and muscle insertions. Changes in the kinematics of standing and walking will also result in higher muscle work, increasing heart rate and energy consumption.

The gait abnormality caused by LLD ≥2 cm will increase work rates of the lower extremities skeletal muscles, increase heart rate and total oxygen consumption. Other study explain that simulated LLD, as low as 5mm, causes biomechanical changes in the lower limbs during gait revealed in both kinematics and dinamic leg length, suggesting that LLD, as small as 5–10mm, should not be ignored. Renkawitz[12] even stated that discrepancies just larger than 5mm relate to unphysiological gait kinematics within the first year after THA.[3,12-14]

Increased pelvic tilt moves the body's center of gravity, resulting in compensation for the skeletal muscle activity and also increased load on the joint. The general strategy is change pelvic tilt (sagittal plane). Tilting the pelvis is known can compensate LLD up to 2.2cm. In severe cases, pelvic tilt also folowed by hip, knee flexion and ankle plantarflexion on the long leg.

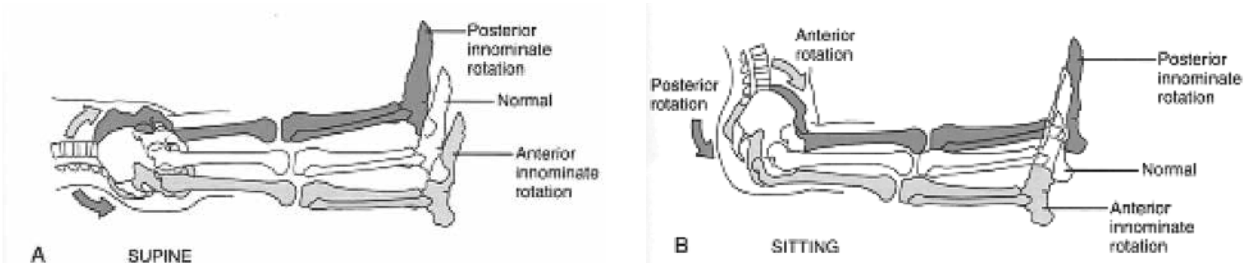

Figure 3. Supine to sitting test[7]

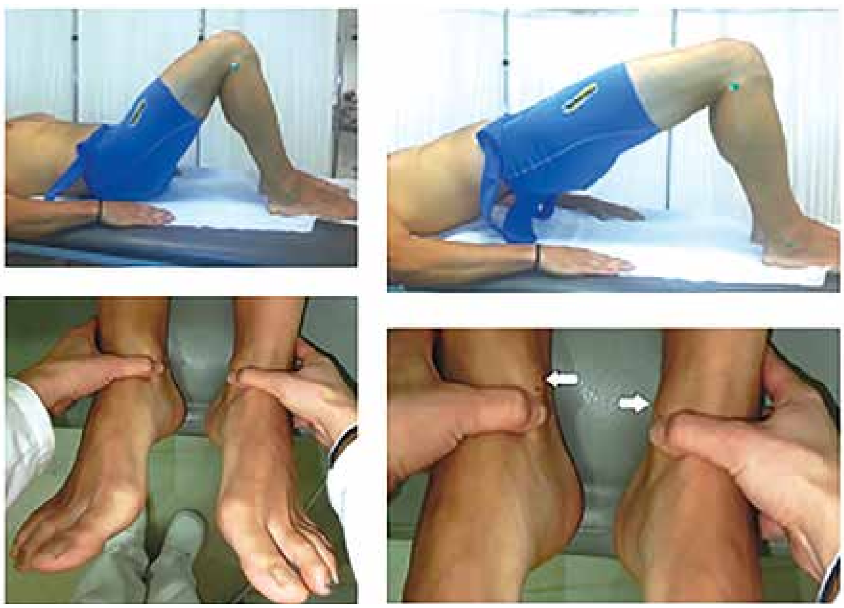

Figure 4. The Weber-Barstow Maneuver10

The degree of compensation varies greatly causing no expert agreement on which strategy is more likely occur to counter LLD. The greater the degree of deviation in leg length, the more compensational strategies needed to balance the legs. Other studies show that compensation begins from the distal part towards proximal of body.[15]

Biomechanical changes can occur in the hips, knees, ankles, as well as pelvic and assessed from frontal and sagittal view. Changes also seen at length of postural sway during quite standing.[11,15]

Type of gait abnormalities found in person with functional LLD are circumduction, hip hiking, steppage and vaulting. Circumduction is a movement of the limbs with a circular pattern. Foot contact with the ground at swing phase (long limb) can be avoided with the circular swing pattern of the limbs, form an arch. Swing phases on short limb are usually normal.[17]

Hip hiking occur through increasing of one side pelvic upward at swing phase (long limb). It emerges from contraction of spinal and lateral abdominal muscles. It includes pelvic obliquity at anteroposterior of the axis, the rotation of pelvis with vertical axis, and aided by the posterior bending vertebra on at the start of the swing phase.[17]

Steppage is a simplest compensation on gait at swing phase, consisting of a combination of hip and knee flexion higher than usual to lift legs in order to increase ground clearance on the long leg. Vaulting occurred at short limb in stance phase. Ground clearance of long limb at swing phase occur if individuals do tiptoe at short limb at stance phase. This will cause increase in vertical movement of the trunk, causing higher energy consumption.[17]

COMPLICATIONS

Complications occur as a result of abnormal mechanical linkages cause by LLD. It may occurs over a long period of time, depending on the duration and severity of the LLD. Complications may also worsen in patients with a previous premorbid history such as osteoarthritis and elderly patient.[18]

Limbs length difference causes one limbs will receive larger load than other. It means larger pressure to legs, knees, hips, sacroiliac, and vertebral facet joints. Although still controversial, it suggest that mild LLD contribute accelerating degeneration process at the joints. This condition also related to musculoskeletal impairment due to overuse; patellar chondromalacia; greater trochanteric bursitis; iliotibial strain; anterior tibial shin splint; synovitis of the medial ankle; posterior tibial tendonitis; medial plantar fascitis. Osteoarthritis knee and hip associated with LLD in both the longer and shorter limbs (the longer being more frequent).[19]

Another complication resulting from changes in pelvic tilt is lumbal rotation resulting in functional scoliosis. Changing the pelvis is strategy to maintain the mediolateral center of gravity line with the base of support. Scoliosis usually present on the short side of the leg convexity, as an indirect compensation. If not treated optimally, functional scoliosis in LLD will become permanent scoliosis.[20]

Table 2. Common kinematic gait deviations of the foot, ankle, knee, hip and pelvis due to LLD16

Short limb (stance phase)	Increased degree foot supination and ankle plantarflexion, short or absence of First Rocker, foot flat or forefoot initial contact Decreased degree hip and knee flexion Increased degree hip abduction and pelvic obliquity (short side lower)
Short limb (swing phase)	Decreased degree ankle dorsiflexion Increased degree hip abduction and pelvic obliquity (short side lower)
Long limb (stance phase)	Increased degree foot pronation, hip and knee flexion, hip adduction and pelvic obliquity (long side higher) Prolonged ankle dorsiflexion time
Long limb (swing phase)	Decreased degree ankle dorsiflexion Increased degree hip and knee flexion, hip abduction and pelvic obliquity (long side higher)

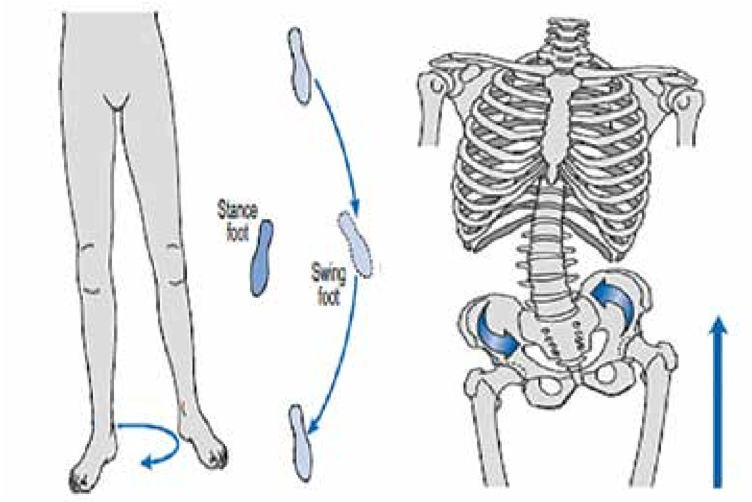

Figure 5. Circumduction (Left) and Hip Hiking (Right)[17]

Association between mild LLD and degenerative joint disease has been researched by Murray[19], which found that LLD might be correlated with the incidence of degenerative joint disease at hip and lumbar spine.[21] The mechanism of degenerative damage to intervertebral discs in relation with LLD is not well understood. Continuous and asymmetrical loading of the joint that is not followed by period of relaxation, causing diffusion failure of nutrients, causing nucleus pulposus become fibrotic, shrinked disc, and degenerative processes may occur. It has investigated that there is an increased degree of lateral bending in the thoracic and lumbar segments during walking in LLD patients compared to normal. The increase in the degree of deflection of this bone segment increases the rate of degenerative processes in the disc. Abnormal joint loading due to LLD also occurs at facet joints, resulting osteoarthritis of this joint. All of these problems may cause low back pain, decrease function and quality of life.[11,20]

The incidence of stress fractures has been reported to be increased in individuals with LLD. It also related closely to certain activity such as runner athletes and soldiers. The increased incidence of stress fractures in the short limbs corresponds to the greater force of the short side of the leg compared to long leg.[22]

However, LLD severity required to cause, or contribute to any musculoskeletal disorder remains controversial. Some authors stated that LLD of ≤20mm is clinically insignificant, but others said otherwise.[19]

MANAGEMENT

Management varies from conservative treatment including shoe lift, relieve muscle and joint contracture, to surgical procedures, including leg lengthening of short leg and shortening of long leg, and epiphysiodesis. There is no clear consensus available to determine when and how manage LLD adequately. Best treatment choice based on amount of difference in leg length, severity of symptoms, and vocational status. Prediction of bone maturity is an important requirement in the correction of leg length in children. The treatment plan can be based on the accuracy in predicting bone maturity, especially for children who will be corrected surgically.[23]

It suggest that LLD must be managed if the length unequal >1cm, despite other said the treatment begin at ≥2cm discrepancies. It is not necessary to make leg length equal completely. It must corrected to 1cm and 2cm residual inequality in children and after skeletal maturity, respectively.

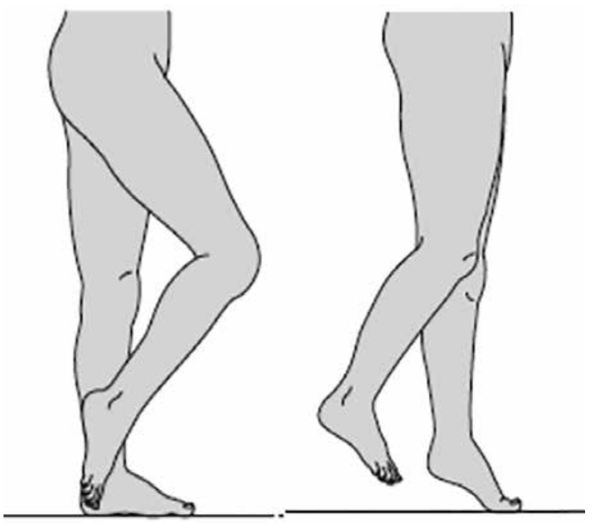

Figure 6. Steppage (Left) and Vaulting (Right)[17]

Otherwise other stated that even LLD <10mm associated with musculosceletal pain show improvement of the symtoms when treated adequately.[24,25]

Mild LLD can be treated conventionally. Moderate cases managed conventionally and or surgical procedure in severe symptoms, balancing the potential risk and benefit for the patients. Severe LLD must be corrected through a surgical procedure. For very severe cases (>60 mm) surgical treatment is required along with other procedures, such as prosthetic fitting.[25]

Functional LLD

It suggest that functional LLD caused by postoperative procedure disappeared completely and left only 0.5% of patients within 6 months. Flexible functional LLD can be managed by comprehensive rehabilitative program such as stretching and strenghtening exercises of affected muscles. Almost all cases of LLD after THA resolve within 3-6 months follow up. It generally takes 3 months to restore pelvic tilt due to abductor muscle shortening and 1 year in more severe cases. Nakanowatari[26] said that both specific exercise and modifiable heel lift can impact functional discrepancy after THA procedure. Post isometric relaxation exercises also eliminate patient-perceived LLD.[26]

Stretching and strenghtening exercises has little benefit for those with structural LLD. Strengthening and stretching exercises also can be done with fixed functional LLD, although fixed pelvic obliquity abnormalities cannot be corrected conservatively.

Structural LLD

Common management of mild structural LLD is use of shoe lifts. Shoe lifts have many advantages, including noninvasive, low price, easy to use, and can be removed when no longer needed. There are two methods often used, by inserting the shoe (outer sole) or adding an insole to the shoe. Shoe lift modifications can be in the form of shoe wedges or heel lifts, depending on which part of the foot is to be elevated. In general, leg lengths of up to 20mm can be corrected with an insole, while above 20mm should be corrected by the outer sole of the shoe. A full correction with shoe wear is possible with LLD from 10mm.[24]

Campbell[24] has showed that shoe lift therapy for LLD greater than 20mm gives optimal results, but some experts recommend surgery although this is not completely approved. Other researchers concluded that LLD up to 20 mm did not require any correction. However, in certain conditions, a small LLD corrected by shoe lift has a positive effect in reducing pain and improving function. Individuals with high level activity such as soldiers and runner athletes are recommended to receive therapy, although in small LLDs.[24,27]

The indication for the use of shoe lifts for short-term therapy is still a matter of controversy. There is very little literature that states that the use of shoe lifts has both short and longterm protective and biomechanical effects.[24]

Definitive surgical corrective treatment can also be considered especially in severe LLD. LLD between 20-50mm in children is more often done by epiphysiodesis, which is a technique where the growth of a long limb is slowed down on the epiphyseal growth plate so that the short leg can grow and is able to catch the length of the leg by cutting the epiphyseal plate of the long leg.[23,25]

CONCLUSIONS

LLD is common often found in normal population, but has not been well evaluated. The large spectrum of LLD is so wide that it creates controversy for health practitioners in clinical decision making.

Several clinical measurements are often used by health practitioners because of cost and convenience considerations, but have a weakness in the accuracy of the results which have a large margin of error. Simple techniques using measuring tape, block test, supine to sit test can be used as the initial screening for LLD. Imaging techniques have high validity and reliability, but are rarely used in practice because of their expensive and unexpected effects of radiation on patients.

Individuals with LLD develop compensatory mechanisms which alter the kinematic patterns at the lower extremity. The amount of compensation varies depending on duration anddegree of discrepancy. Individual biomechanical changes with LLD will have secondary effects, including the incidence of low back pain, functional scoliosis, and degenerative processes, stress fractures, and persistent walking pattern abnormalities. Poor walking patterns will result in increased muscle activity, heart rate and the average individual's oxygen consumption. All of these complications will reduce the patient's activity and functional participation and the quality of life.

Treatment decision must comprehensive based on severity and symptoms occurred, also considering age, occupation and comorbid status. Treatment option include physical therapy for stretching, and strengthening soft tissue, orthotic device, and surgical procedure.

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