DISCUSSION PAPER

LEG LENGTH INEQUALITY

MPC **use specific condition code for disability causing inequality or produced by inequality**

ICD-9

PLEASE NOTE: Entitlement should not be claimed for LLI alone. Entitlement, for VAC purposes, should be claimed for the disability causing LLI or resulting from LLI.

INTRODUCTION

A bilateral asymmetry in lower limb length is called anisomelia or leg length inequality, (LLI).

The topic of asymmetry of lower limb length has been the subject of controversy, particularly in the areas of incidence, classification, and clinical significance.

Historically, the Medical Guidelines of Veterans Affairs Canada (VAC) have considered LLI on the basis of both actual shortening of the long bone of the leg (anatomic) and functional shortening (which may be caused by a fixed flexion deformity of the hip or knee joint). They have been, however, inconsistent in the area of measurement of clinical significance.

Further, the guidelines have considered that the degenerative process in any joint of the shortened limb is not influenced by the presence of a shorter leg, but that the longer limb may be affected.

The guidelines have also concluded that, as a general rule, an altered gait in the absence of actual or functional shortening does not contribute in a significant way to degenerative changes of the joints of either limb.

The purpose of this paper is to achieve some resolution on the following issues:
1) What are the causes of LLI?
2) What LLI is of clinical significance for VAC purposes on pension application?
3) What are the biomechanical effects of clinical significance associated with LLI for VAC purposes on pension application?

As it is not anticipated that a disability will arise from a corrected LLI, inequality should be uncorrected and involve a limb in daily use. Treatment or correction of inequality may consist of the following:

1) shoe lift or prosthetic conversion
2) epiphysiodesis of long leg
3) shortening of long leg (in those too old for epiphysiodesis)
4) lengthening of short leg

CAUSES and CLASSIFICATION OF LEG LENGTH INEQUALITY

There are various medical diseases which cause leg lengthening and leg shortening. These will be discussed in the section entitled "PENSION CONSIDERATIONS".

1) **Structural Asymmetry**

In cases of Structural Asymmetry, there can be actual lengthening or shortening of the leg. When it involves limb shortening, this type of inequality is also known as "anatomic short leg". An actual shortening or lengthening of the skeletal system occurs between the head of the femur and the ankle joint mortise, which may have a congenital or acquired cause.

2) **Functional Inequality**

When factors other than actual bone shortening or lengthening make one leg shorter or longer than the other, a functional inequality occurs. When the limb is shortened, this type of inequality is also known as "functional short leg".

LLI may arise during normal growth without apparent reason. Even where LLI is 1 cm and greater, the cause is unknown in the vast majority of cases.

LLI has been classified according to the magnitude of the inequality, generally expressed in cm or mm, and described as mild, moderate, or severe. McCaw and Bates (1991) report the following classification:

- **Mild** less than 3 cm
- **Moderate** 3-6 cm
- **Severe** more than 6 cm

Conclusion:

There are many causes of LLI, as above-noted.

For the purposes of VAC, and in accordance with the spirit and intent of the *Pension Act,* the following classification of LLI will be adopted:

- **Mild** 1.5 cm and less
- **Moderate** 1.5 cm to 5.0 cm
- **Severe** 5.0 cm and greater

MEASUREMENT OF LEG LENGTH INEQUALITY OF CLINICAL SIGNIFICANCE

To make a diagnosis of LLI, the following factors must be determined:

1) Is there an LLI present, and to which side of the body is it located?
2) What is the amount of the LLI?

Once the presence of LLI is determined, the amount can be quantified by several methods. Many studies have been performed to assess the reliability and validity of the various measurement procedures. Radiographic measures have been recognized as the most reliable measure, particularly of anatomic LLI.

Gofton (1985) found that when LLI was measured clinically and radiologically in the same individuals, the radiographic method agreed with the clinical method that a disparity existed, but the amount of the difference detected by radiography was frequently lower than that found clinically.

Concern has been expressed regarding radiation exposure from radiological measurement and, therefore, other measurement devices have been developed as an alternative. These methods are classified as indirect and direct, with indirect seen as superior (Baylis, 1988; ten Brinke, 1999). The indirect method involves reduction of the pelvic tilt and levelling of the sacral base by means of placing a material of known thickness under the short leg while the person is standing. The direct method involves measuring the distance between two points, usually the anterior superior iliac crest and the medial malleolus.

Problems associated with direct measurement include difficulty in locating bone landmarks with obese people, poor quality and inaccuracy of the tape measure, discomfort of the patient during the exam, and incorrect positioning of the patient by the examiner.

Conclusion:

While it appears that radiographical measurement is the most precise method, particularly for structural as opposed to functional inequality, the direct method is believed to offer convenience and acceptable reproducibility for the purposes of the pension program at VAC. Therefore, a clinical examination is considered sufficiently reliable if conducted in the following manner:

- in supine position with both knees as fully extended as possible
- lower limbs in neutral position
- measure from anterior superior iliac supine (ASIS) to medial malleolus on each lower limb
- measurement is taken and recorded as the average of 3 measurements.

Modification may have to be made in certain cases, particularly in cases of functional inequality (e.g. hip ankylosis in abduction or an ankle in fixed plantar flexion).

MEASUREMENT OF BIOMECHANICAL SIGNIFICANCE

It will be noted that measurement may be stated in accordance with the metric or imperial system, as follows:

- 0.5 in = 1.27 cm
- 1.0 in = 2.54 cm

There is disagreement in the literature as to what degree of LLI is of clinical significance.

One of the major problems in determining the value of the data is the accuracy of different measurement methods. There are also certain factors which may influence the effects of LLI include:

- actual length of discrepancy
- age of person, as a child with inherent flexibility may tolerate leg length discrepancy better than an adult
- duration of LLI, e.g. adult onset versus childhood onset
- other medical problems, including but not limited to arthritis, joint fusion, joint replacement, and malalignment

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.

Conclusion:
There is no universal acceptance of a specific measurement of clinical significance. When considered in accordance with the generous provisions of the *Pension Act*, a measurement of clinical significance may be as broadly stated as one that promotes permanent adverse functional effects.

However, for VAC purposes, a discrepancy of 1.5 cm may be considered to be a measurement of biomechanical significance. If the inequality is less than 1.5 cm, biomechanical effects are not considered to be caused by the LLI.

BIOMECHANICAL EFFECTS OF LEG LENGTH INEQUALITY

A number of factors may impact on determination of clinical importance of the biomechanical effects. These include:

- a lack of awareness of LLI by physician or patient
- the degree of inequality
- whether the LLI is structural or functional
- the ability of the pelvis and spine to compensate
- other medical conditions affecting the patient

Compensation mechanisms for LLI may produce effects which are sometimes considered to be a direct result of LLI. Some of the most commonly documented compensation mechanisms associated with LLI include:

- various patterns of sacral and pelvic tilt, spinal curvature, pelvic shift and/or pelvic rotation
- foot pronation on the long leg side

Lateral imbalance in the erect posture, caused by LLI, and the associated pelvic tilt are compensated by functional scoliosis with lumbar convexity toward the short leg side. This curvature produced by the spinal musculature will resolve when lying or sitting. In contrast to functional scoliosis, structural scoliosis is more rigid and cannot be corrected by muscle force or by recumbent position. Some researchers have

suggested that functional scoliosis may become structural over time.

There are various types of gait abnormality with various causes. A short leg may produce a gait abnormality. An early heel off may be seen on the short side. The long side will have a shortened swing phase while the short side will have a longer swing phase of gait. The long side will have a longer stance phase while the short side will have a shorter stance phase.

This paper is concerned with gait abnormality from a short leg only.

Various studies have identified diverse medical symptoms felt to be caused by LLI. One of the most widely researched areas is that of low back pain.

A. LOW BACK PAIN

The literature demonstrates a discrepancy as to whether LLI produces chronic mechanical low back pain (as defined in the Entitlement Eligibility Guideline for Mechanical Low Back Pain), or influences degenerative changes of the lumbar spine.

(i) Literature Supporting An Association between LLI and Chronic Low Back Conditions

Giles and Taylor (1981) reviewed the medical literature on LLI and found on average large studies using radiographic measures show 7% (range 4-8%) of the adult population with no history of back pain have an LLI of 1 cm or more. They also note that in groups of patients with severe or chronic back pain the incidence of leg length inequality ranges from 13-22%, although one study only found 6% in keeping with the symptom free control group. When the smaller differences in leg length (5mm or greater) are included, the prevalence of LLI in the general population rises to 44% and is significantly increased to 75% in patients with low back pain.

Friberg (1983) studied 653 patients with chronic low back pain symptoms and compared them with 359 symptom-free Finnish army conscripts. Chronic pain was defined as lasting for at least 3 months or having at least three previous periods of low back pain. In patients with low back pain, the incidence of LLI of 5 mm or more was 1.7 times that of a symptom-free control. The incidence of LLI of 15 mm or more was 5.3 times that of a symptom-free control. However, the control group had less than 5 mm of radiologically measured LLI in 56% of the group, and 5 mm or more of shortening in 44%. LLI of 5 mm or more occurred in 75% of patients with low back pain and only 44% of control subjects. This indicated that patients can have LLI without any symptoms of low back pain. This was found to be statistically significant. However, the control group was younger and it was not known whether some of these symptom-free people in the

control group would later develop low back pain.

Giles and Taylor (1981) studied 1,186 patients presenting with chronic low back pain, as well as 50 control subjects. Chronic low back pain was not defined, although it is clear the authors differentiated between acute and chronic pain. Of control subjects, 8% had 1 cm or more of x-ray shortening while 18% of patients with chronic low back pain had 1 cm or more of shortening. These results are in keeping with Friberg's study, and show that the prevalence of LLI of 10 mm or more appears to be more common in patients suffering from low back pain (LBP) than in the normal population.

Similar results were found by Gofton (1985) in a small retrospective study of 10 patients (LLI ranging from 10-16 mm) and their response to correction of LLI. The patients had an unexplained back problem not clearly related to a diagnosis of trauma, intervertebral disc disease, fibrositis or sacroiliitis. Gofton describes back pain associated with LLI as characteristically occurring on standing and relieved by sitting, with no pain on bending; straight leg raising tests were negative, and there was no sciatica. A clinical method was used to estimate LLI. A corrective lift was used. In all instances pain relief was major or complete. Gofton suggests it is rare to see back pain associated with an LLI of less than 9 mm (3/8").

Biering **-** Sorensen (1984) examined the relationship of LLI and low back pain in 30 to 60 year old inhabitants of a suburb of Copenhagen. LLI was measured clinically as the difference in iliac crest heights and the amount of lift under the short leg which would correct the inequality. Of the entire group of 922 participants, 30% had an LLI of 1 cm or greater difference. A significant association between LLI and a history of low back pain before the onset of the study was found, although LLI was not found to be associated with first-time episodes of low back pain. Of the patients, 46% had unequal leg lengths, higher than the 29% seen in the population in general.

(ii) Literature Disputing An Association between LLI and Chronic Low Back Conditions

In contrast to the studies supporting an association of LLI and chronic low back conditions, there are other studies and reviews of literature with differing conclusions.

Rothenberg (1988) reports on a small cross-sectional study by Gibson (1983) who examined 15 patients with LLI due to a femoral fracture. The LLI was neutralized and the patients were examined a minimum of 10 years after the fracture. X-rays demonstrated that 10 of the 15 patients had "residual changes" of the lumbar spine. There were no complaints of discomfort attributable to the LLI and associated lumbar scoliosis.

Rothenberg observes that this and other studies contained small numbers and that it is possible that a subgroup with LLI and low back pain was missed. He points out that the patients were young adults and that subsequent structural or degenerative changes of the spine and/or low back pain might occur with the passage of time.

Rothenberg also notes that postural adjustments (pelvic tilt and pelvic torsion) which occur in response to LLI are associated with low back pain. These changes place chronic stress on the ligaments and other soft tissue structures of the lower back. Pelvic tilt also produces a compensatory scoliosis which resolves in young individuals with correction of LLI, but may not resolve in older individuals.

Frymoyer (1991) states there is no convincing evidence that equalizing subtle differences in leg lengths favourably impacts on the natural history of acute or chronic back pain. Frymoyer points out the difficulties in determining the value of the leg length data due to imprecision of measurement**.** He also concludes that normal postural variations, including minor degrees of scoliosis, have no impact on the occurrence or progression of low back pain, but acknowledges that there is controversy in this area.

In the Soukka (1991) study of 247 men and women aged 35 to 40 years where LLI was measured by x-ray, a wide range of leg length discrepancy (up to 20 mm) provided data for studying a possible association between LLI and low back pain. No increases in adjusted relative risks of having low back pain or disability were found due to LLI. A mild LLI of 5 mm or less as a factor contributing to low back pain was not supported. Unlike Giles and Taylor, the Soukka results provide no support for the hypothesis that the risk of low back pain substantially increases with an LLI of 10-20 mm. In Giles and Taylor only 4 persons of 50 symptom-free controls (8%), had a leg length asymmetry of 10 mm or more. In the symptom-free group in the Soukka study, 18.9% had an LLI of 10 mm or more. In the series of 1186 chronic low back pain patients within the larger study of Giles and Taylor, 217 patients or 18.3% had an LLI of 10 mm or more. The corresponding percentage in the Soukka study was 16.7%.

The Soukka study notes that in previous studies potential confounders were not taken into consideration in the statistical analysis. They conclude that the association of mild LLI with low back pain is questionable, that a relationship between inequalities of more than 20 mm and low back pain is not considered conclusive, and that before a radiologically observed LLI be considered a cause of low back pain, an erect posture radiograph of the whole pelvis and lumbar spine is essential to assess existing pelvic tilt and scoliosis.

Hoikka (1989) also concluded that there was a questionable association between LLI and low back pain. One hundred young or middle-aged adult men and women suffering from chronic low back pain were measured for LLI and its hypothetical consequences of

pelvic tilt and lumbar scoliosis. The mean length of LLI was only 5mm (range 2-8mm). LLI was found to have a good correlation with pelvic tilt assessed from the iliac crests, a moderate correlation with the sacral tilt, and a poor correlation with lumbar scoliosis. Only when sacral tilt is great enough does it lead to a compensatory lumbar scoliosis on the side of the shorter leg, proportional to the magnitude of the pelvic tilt. There was a gradually decreasing correlation between the posture parameters when moving from the hips up to the lumbar spine. Even the patients with LLI over 10mm showed poor correlation with the lumbar scoliosis.

McCaw and Bates (1991) did a select review of the literature relating mild LLI (less than 3 cm) to low back pain. They concluded that while the literature supports the hypothesis that LLI imposes a structural malalignment on the lower back, it does not conclusively link LLI and back pain. The authors explain that a pelvic tilt common to LLI may invoke a functional or transient scoliosis, concave to the side of the longer limb, and that the degree of scoliosis is related to the magnitude of the LLI. This LLI-induced scoliosis has been hypothesized as a possible causal factor in the development of non-specific low back pain and sciatica. The authors conclude that more research investigating the link between LLI and low back pain is warranted.

CONCLUSIONS REGARDING LOW BACK PAIN:

All authors selected patients on the basis of low back pain, and did not differentiate between the existence of low back pain prior to or after the development of an LLI, or between the causes of low back pain (e.g. whether that be soft tissue pathology or osteoarthritis). As outlined in the Entitlement Eligibility Guidelines on *Cumulative Joint Trauma in the Development of Osteoarthritis of the Lumbar Spine, Hips, Knees and Ankles*, a period of time is required before degenerative changes in an otherwise normal back appear. This period of time is longer than that required for the appearance of soft tissue symptomatology, such as in lumbosacral strain.

As LLI, which involves the weight-bearing limbs**,** is permanent and continuous throughout the daily life of an individual, it is concluded that it produces greater repetitive loading than that considered to be associated with cumulative joint trauma as discussed in the Entitlement Eligibility Guideline.

An LLI of 1.5 cm and greater may cause or aggravate ligamentous or muscular diseases in the lumbar spine if LLI is present for several months prior to development of the diseases.

An LLI of 1.5 to 3.0 cm may cause Degenerative Disc Disease or Osteoarthritis if LLI is present for a minimum period of 10 years prior to onset of Degenerative Disc Disease or Osteoarthritis.

An LLI of 3.0 cm and greater may cause Degenerative Disc Disease or Osteoarthritis if LLI is present for a minimum period of 5 years prior to onset of Degenerative Disc Disease or Osteoarthritis.

An LLI of 1.5 cm and greater may aggravate Degenerative Disc Disease or Osteoarthritis if LLI is present for a period of several months prior to onset of Degenerative Disc Disease or Osteoarthritis.

B. MEDICAL CONDITIONS OTHER THAN LOW BACK PAIN CAUSED AND/OR INFLUENCED BY LLI

In the 1992 article "*Leg length inequality. Implications for running injury prevention*", McCaw concluded that further research is required to quantify the biomechanical effects of LLI as they interact with other factors related to running injury. The author reviewed research findings over time regarding musculoskeletal effects of LLI and the relationship between LLI and sports injuries. Inequality was considered to be a plausible etiological factor in the development of a variety of overuse injuries because it alters the distribution and magnitude of mechanical stress within the body. It was observed that LLI has been linked with lower extremity stress fractures, low back pain, hip pain, and vertebral disc problems of runners and that there are a variety of musculoskeletal imbalances related to LLI noted, including pelvic tilt, scoliosis, hip and knee malalignment and excessive foot pronation. No unequivocal relationship between LLI and increased risk of sport injury was found; however, it was felt that additional study is required, recognizing the following:

- the interplay between extrinsic (e.g. footwear) and intrinsic (e.g. physiological condition) factors in injury,
- the need to develop more appropriate guidelines respecting treatment of LLI, and
- that the symptoms and effects of LLI may not become evident for an extended period.

Gofton (1985) noted the occurrence of cartilage degeneration in the medial compartment of the knee of the longer leg, in particular with "gross" leg length discrepancy. The definition of "gross" was not given. He observed that patients with small disparities in leg length discrepancy have occasionally had knee pain, improved by correcting the discrepancy, and medial cartilage degeneration. He noted that pain of the greater trochanter and a form of OA of the hip are often associated with discrepancy on the longer side. Distorted biomechanics and stresses throughout the body by virtue of "trivial asymmetry" deserve, in Gofton's opinion, more investigation.

In reviewing the literature relating mild LLI (less than 3cm) to osteoarthritis, McCaw and Bates (1991) have recognized the need for an increased understanding of the

biomechanical implications of LLI. They acknowledge that the pelvic tilt imposed by LLI may impose bilaterally unequal stresses in the hip and knee joints during upright posture. The two effects of pelvic tilt, i.e. increase of magnitude of internal joint force and reduction of contacting area of articulating joint surfaces, are thought to represent a possible biomechanical precursor to osteoarthritis. They note there is no conclusive evidence of a relationship.

Rothenberg (1988) noted that discrepancies of leg length are associated with gradual development of degenerative arthritis in the hip joint on the side of the longer leg. The longer leg is typically held in adduction under a tilted pelvis, resulting in decreased acetabular covering of the femoral head, thereby placing higher stress per square centimetre on the weight-bearing area. Support for this is outlined in several studies he reviewed.

Rothenberg (1988) also concluded there is an increased incidence of sciatica, in persons with LLI of greater than 10 mm on the side of the longer leg. Trochanteric bursitis and tensor *fascia lata* pain were found to be more common in the shorter leg.

Finally, McCaw and Bates' (1991) review supports a relationship between mild LLI and stress fractures insofar as it is possible for LLI to contribute to muscle weakness and repetitive muscle pull on bone that exceeds the threshold stress. They note a study by Friberg of 130 military recruits which found that the majority of stress fractures in the weight-bearing bones (tibia and femur) occurred in the long limb. This is explained on the basis that persons with LLI tend to shift weight-bearing towards the longer limb. It is noted that the effect of strenuous movement on weight distribution is unclear. McCaw and Bates conclude that skeletal compensation to LLI may be associated with stress fractures of the lower extremity, but that a better understanding of the compensatory skeletal realignment from LLI and its effect on bilateral loading of the limbs is required.

CONCLUSIONS FOR MEDICAL CONDITIONS OTHER THAN LOW BACK PAIN CAUSED AND/OR INFLUENCED BY LLI:

To cause a disability, the inequality must remain uncorrected and involve a limb in daily use.

An LLI of 1.5 to 3 cm may cause Osteoarthritis of the Hip of the long leg if LLI is present for a minimum period of 10 years prior to onset of the Osteoarthritis.

An LLI of 3 cm and greater may cause Osteoarthritis of the Hip of the long leg if LLI is present for a minimum period of 5 years prior to onset of the Osteoarthritis.

An LLI of 1.5 cm and greater may aggravate Osteoarthritis of the Hip of the long leg if LLI is present for several months prior to aggravation of the Osteoarthritis.

An LLI of 1.5 to 3 cm may cause Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for a minimum period of 10 years prior to onset of the Osteoarthritis.

An LLI of 3 cm and greater may cause Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for a minimum period of 5 years prior to onset of the Osteoarthritis.

An LLI of 1.5 cm and greater may aggravate Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for several months prior to aggravation of the Osteoarthritis.

An LLI of 3.0 cm and greater may cause and aggravate Sciatica of the long leg if LLI is present for several months prior to onset or aggravation of the Sciatica.

An LLI of 1.5 cm and greater may cause and aggravate Trochanteric Bursitis of the short leg if LLI is present for several months prior to onset or aggravation of the Bursitis.

An LLI of 1.5 cm and greater may cause Stress Fractures of the Tibia and Femur, the weight-bearing bones, of the long leg if LLI is present prior to onset of the fracture.

SUMMARY

The issues of what degree of LLI is of clinical significance and the nature of the impacts are complex and cannot be answered with certainty.

There is some consensus in the literature that a clinically significant LLI can influence adversely the lumbar spine, the hip, and the long lower extremity.

The disability from LLI is generally associated with the long leg, but may be associated with the short leg depending on individual circumstances.

The disability from LLI may be associated with resultant compensation mechanisms for LLI, such as pelvic tilt and scoliosis.

While there is some support for LLI as a factor in overuse injuries of the legs and low back from sports, this support is sufficiently equivocal at this time so as to preclude a recommendation for acceptance even with the generous provisions of the legislation. However, this should not cause automatic rejection of a biomechanical relationship

between LLI and overuse injury. The relationship is also complex, with overuse injury involving the interaction of multiple extrinsic and intrinsic etiological factors. Any combination of factors that causes a person to exceed the threshold factor of safety for that individual will result in injury.

If there is disagreement as to the presence of LLI, an erect posture x-ray will provide the most precise measurement.

The existence of LLI may be overlooked on medical examinations.

Variables may influence the outcome of any case. These include, but are not limited to, the following:

- degree of inequality
- accuracy of measurement
- impact of other medical conditions, including ability of pelvis and spine to compensate
- duration of inequality
- age of person

PENSION CONSIDERATIONS

Classification of LLI for VAC purposes is as follows:

- **Mild** 1.5cm and less
- **Moderate** 1.5 - 5.0 cm
- **Severe** 5.0cm and greater

An LLI is to be measured in the following manner:

- in supine position with both knees as fully extended as possible
- lower limbs in neutral position
- measure from anterior superior iliac supine (ASIS) to medial malleolus on each lower limb
- measurement is taken and recorded as the average of 3 measurements.

No entitlement will be given for LLI alone.

Entitlement for pension purposes should be claimed for the disability causing an LLI of 1.5 cm or greater, or produced by an LLI of 1.5 cm or greater.

A. CAUSES OF LLI

There are multiple causes of LLI. The causes listed below must involve the lower limbs. The following list is prepared for pension purposes, and is not exhaustive.

1. ANATOMICAL

Various bone disorders of the lower extremities may cause LLI. Those anatomical conditions which may cause LLI include, but are not limited to, the following:

a) Non-reducible hip dislocation

b) Legg-Perthe's disease (Osteocondrosis of the capital epiphyses)
- this can result in the arrest of the growth plate with shortening of the lower limb.

c) Congenital limb shortening
- femoral abnormalities
- congenital coxa vara/valga
- congenital pseudarthrosis of tibia

d) Congenital limb lengthening
- unequal development
- vascular malformation/ hemangiomata - Lengthening results from increased blood supply to growth plate.

e) Multiple exostoses

f) Fixed flexion contracture of 15 degrees or greater of hip or knee
- This results in a functional LLI. A fixed flexion contracture can be caused by burns, immobility, strokes, improper casting, etc. Fifteen degrees is felt to be clinically significant, due to the body's ability to compensate for minor degrees of flexion contracture. For example, a 15 degree flexion contracture of the knee in a person of average height would result in a 15 mm leg length shortening.

g) Asymmetric genu varum or valgus
- The amount of inequality depends on the severity of the genu varum or valgus. A fifteen degree asymmetric genu valgum (knock-knee) could result in a 16 mm inequality in a person whose knee to ankle measurement is 20 inches.

2. NEUROMUSCULAR

Some medical conditions will result in asymmetrical muscle atrophy and/or weakness. A period of several months would be required to produce an LLI of 1.5 cm or greater. These medical conditions include, but are not limited to, the following:

a) Poliomyelitis
b) Sciatic palsy
   - This can occur from hip arthroplasty resulting in a greater than 2.5cm leg lengthening, as well as other causes.
c) Myelodysplasia
   - This is felt to be the result of increased blood supply.
d) Cerebral palsy
e) Muscle paralysis

3. INFECTIOUS

Infection can increase the blood supply or affect the growth plate in the epiphyseal or metaphyseal regions, resulting in limb lengthening or shortening. A period of several months would be required to produce an LLI of 1.5 cm or greater. Infection can be caused by, but not limited to, the following:

a) Osteomyelitis
b) Septic arthritis
c) Epiphyseal injury prior to maturity

4. TUMOURS

Tumoural conditions can increase the blood supply or affect the growth plate in the epiphyseal or metaphyseal regions, resulting in limb lengthening or shortening. A period of several months would be required to produce an LLI of 1.5 cm or greater. Tumoural conditions include, but are not limited to, the following:

a) Fibrous dysplasia
b) Malignant tumours
c) Epiphyseal injury prior to maturity

5. RADIATION

Radiation used by a radiation oncology unit can increase the blood supply or affect the growth plate in the epiphyseal or metaphyseal regions, resulting in limb lengthening or shortening. Radiation therapy may affect bone growth, cause osteonecrosis, and induce neoplasia.

A period of several months would be required to produce an LLI of 1.5 cm or greater. Radiation changes are dose-related. The larger the dose, the greater the effect and the more likely that irreversible changes will result. The threshold for changes in bone is believed to be 3000 cGy with irreversible cell death at 5000 cGy.

6. INFLAMMATORY ARTHRITIS

Rheumatoid Arthritis may lead to bone loss or destruction of the cartilage of the joint depending on the severity of the disease and the number of joints involved, and may result in a lower limb inequality.

It is recognized that other inflammatory conditions, including Osteoarthritis of the hip/knee/ankle, may cause a certain degree of LLI. However, these conditions do not produce a significant LLI for pension purposes, i.e. an uncorrected LLI of 1.5 cm.

7. TRAUMA/SURGICAL

a) epiphyseal injury prior to maturity
   - fractures other than growth plate fractures can cause lengthening of the lower extremity in children when growth plates are stimulated from an increase blood supply during the fracture repair process. Fractures involving the growth plate may cause shortening.

b) fracture with shortening/overriding bone segments

c) fracture with lengthening/overstimulation of bone segments

d) post-arthroplasty
   - while leg lengths should be equal after hip arthroplasty, leg length is difficult to determine accurately in the course of surgery. Most often the limb that is operated on is lengthened. Lengthening may result from insufficient resection of bone from the femoral neck through the use of a prosthesis with a neck that is too long, or from a change in the acetabulum's centre of rotation.

B. RECOMMENDATIONS FOR CONDITIONS CAUSED BY LLI

To cause a disability, the inequality must remain uncorrected and involve a limb in daily use.

LUMBAR SPINE:

1. An LLI of 1.5 cm and greater may cause or aggravate ligamentous or muscular diseases in the lumbar spine if LLI is present for several months prior to development of the diseases.

2. An LLI of 1.5 to 3.0 cm may cause Degenerative Disc Disease or Osteoarthritis if LLI is present for a minimum period of 10 years prior to onset of Degenerative Disc Disease or Osteoarthritis.

3. An LLI of 3.0 cm and greater may cause Degenerative Disc Disease or Osteoarthritis if LLI is present for a minimum period of 5 years prior to onset of Degenerative Disc Disease or Osteoarthritis.

4. An LLI of 1.5 cm and greater may aggravate Degenerative Disc Disease or Osteoarthritis if LLI is present for a period of several months prior to onset of Degenerative Disc Disease or Osteoarthritis.

KNEE:

1. An LLI of 1.5 to 3 cm may cause Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for a minimum period of10 years prior to onset of the Osteoarthritis.

2. An LLI of 3 cm and greater may cause Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for a minimum period of 5 years prior to onset of the Osteoarthritis.

3. An LLI of 1.5 cm and greater may aggravate Osteoarthritis of the medial or lateral compartment of the Knee of the long leg if LLI is present for several months prior to aggravation of the Osteoarthritis.

HIP:

1. An LLI of 1.5 to 3 cm may cause Osteoarthritis of the Hip of the long leg if LLI is present for a minimum period of 10 years prior to onset of the Osteoarthritis.

2. An LLI of 3 cm and greater may cause Osteoarthritis of the Hip of the long leg if LLI is present for a minimum period of 5 years prior to onset of the Osteoarthritis.

3. An LLI of 1.5 cm and greater may aggravate Osteoarthritis of the Hip of the long leg if LLI is present for several months prior to aggravation of the Osteoarthritis.

OTHER:

1. An LLI of 3.0 cm and greater may cause and aggravate Sciatica of the long leg if LLI is present for several months prior to onset or aggravation of the Sciatica.

2. An LLI of 1.5 cm and greater may cause and aggravate Trochanteric Bursitis of the short leg if LLI is present for several months prior to onset or aggravation of the Bursitis.

3. An LLI of 1.5 cm and greater may cause Stress Fractures of the Tibia and Femur, the long weight-bearing bones, of the long leg if LLI is present prior to onset of the fracture.

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