DOES EVERYONE HAVE AN ANATOMICAL SHORT LEG?
... and what to do about it!

The numerous research studies cited below conclude that between 70% - 80% of all individuals have an Anatomical Short Leg (ASL)! Not everyone with an ASL will have associated biomechanical symptoms, but amounts above 5mm of inequality is when biomechanical problems are most predictible. Other studies indicate that even smaller deficiencies can cause problems. Therefore each individual must be evaluated independently. Furthermore any practitioner who implements treatment protocols to correct/balance posture (and objectively document the change), must address an ASL because all balanced structures must start with a level foundation.

The prevalence of ASL has been well researched and documented over the years. Today, the presence of a short leg "... is so common that it is considered a normal variant." (1)

Rush and Steiner (2) reported the following results of 100 general duty soldiers, randomly selected, verified by x-ray. 71% exhibited ASL, 38% at between 0-5 millimeters, 29% between 6-10 mm, and 4% between 11-20 millimeters. Reynolds and Hooton (3) reported that an x-ray study of randomly selected college personnel revealed that 79% had ASL. Lawrence's study (4) of asymptomatic freshman students at National College demonstrated that 84% had ASL.

Beal (5) reported that eight different x-ray studies of 3,252 individuals with either low back pain or some related postural abnormality revealed an ASL prevalence at an average of 74.5%.

Friberg (1) measured 798 patients with chronic low back and/or unilateral hip symptoms and 359 symptom free subjects. ASL of 5mm or more was found in 75.4% of the symptomatic patients and 43.5% of the asymptomatic controls.

The majority of the literature does implicate leg length inequality as a possible cause of low back, sacroiliac, hip, knee, ankle and/or foot pain. Controversy exists as to what height an ASL effects biomechanical function. Common sense tells us that there is a point where asymmetry leads to stress and strain. Perhaps the determining factor lies with the activity level of the individual or with the genetic and/or nutritional integrity of the individual's soft tissues.

Subotnick (6) states that minor ASL would cause little difficulty in the non-athlete but can cause significant symptoms in the active athlete. Klein (7) stated that a study of 300 post operative knee injury cases, revealed that 79.6% were injured on the ASL short leg side!

Some authors maintain that even a few millimeters of ASL may be the primary or contributing cause of various symptoms (5,6,8,9,13). 5-7 millimeters of ASL has been indicated as the amount of inequality most often associated with biomechanical compensation problems (1,10,2,11,12).

Functional vs. Anatomical

Lawrence (38,39) questions the use of the term "Functional Leg Length Inequality" as being appropriate. This is because, in general, the measurement of that entity (the functional leg length) is used to describe changes in pelvic mechanics and not actual changes in limb length (38,39), and does not apply (to the leg length) when the individual becomes weight bearing. <u>We recognize the importance of the "Functional" short leg in many chiropractic techniques, but feel that it needs to be distinctly defined and distinguished from the "Anatomical" short leg.</u>

To eliminate confusion let's define the pertinent terms:

1. <u>Anatomical Leg Length</u> - the measurement from the top of the femur to the bottom of the heel.
2. <u>Anatomical Short Leg</u> - verified by weight bearing xray (central ray at the level of the femur heads with feet placed directly under the femur heads), comparing measurements from the top of each femur to the bottom of the film (14,15,16) or verified visually on a weight bearing subject using iliac crest heights (20) and anatomical landmarks within the square and plumb SAM frame (21). If leg length inequality is discovered, further evaluation is required on the short leg to rule out a True Functional Short Leg (unilateral fallen arch, unilateral knee valgus).
3. <u>True Functional Short Leg</u> - can only be caused by the difference in alignment of the supporting structures within the leg itself (ie. unilateral fallen arch, unilateral knee valgus). A true functional short leg can only be caused by the difference in alignment of the supporting structures within the leg itself. If a leg measures 36" (top of the femur to bottom of the heel), it will always measure 36" unless something within that 36" changes. For all practical purposes, the true functional short leg is caused by only two conditions; a unilateral fallen arch (28) and/or unilateral knee valgus. Beal and Grant (28) found that there was a low talus in 52 out of 100 cases of short leg syndrome. Nineteen of these cases exhibited the low talus on the short leg side, thirty three exhibited the low talus on the long leg side. 80% of these low talus cases exhibited foot pronation. The goal of treating each of these conditions would be to restore symmetry (with orthotics) with or without utilizing a heel lift. Based on the conclusions of Beal and Grant (28) and others (29,30), the high incidence for a unilateral fallen arch needs to be evaluated, and if indicated, treated with orthotics.
4. <u>Prone Leg Length</u> - comparing leg lengths (at the heels) of a prone individual.
5. <u>Apparent Functional Short Leg</u> - determined in the prone individual, caused by soft tissue/joint imbalances that deviate the non-weight bearing spine, pelvis and finally displayed as a leg length imbalance. This same individual (if he/she has equal anatomical leg lengths), if observed weight bearing, will not exhibit changes in femur height (31,32,17,33,34,35). In other words the anatomical length of the legs did not change (35,36,37). An Apparent Functionsl Short Leg (no matter how much it affects the prone leg lengths) will have no effect on the weight bearing leg length. We discount <u>any</u> arguement that a spinal and /or pelvic distortion can significantly effect weight bearing leg lengths. Gofton and Trueman (40) using a skeleton, showed that with the xray tube at the same level of the femoral heads, pelvic rotation of 18 degrees resulted in no error. Remember the heels are planted on the ground, a spinal/pelvic distortion does not lift one leg/heel off the ground so any change in femoral height would have to come from rotational forward or backward movement (of the SI joint). **A unilateral pelvic distortion great enough to cause a difference in weight bearing femor heights would require a sacroiliac dislocation!**

By definition an Apparent Functional Short Leg will have no effect on the leg lengths and thus the structures above the legs (when an individual assumes a weight bearing posture). In contrast an Anatomical Short Leg will effect the structures above because if the foundation is not level the structures above it won't be either.

If a practitioner is to use posture and/or prone leg checks in both evaluating and treating patients it is vital that each individuals' anatomical leg lengths be established! From a postural standpoint, the AP posture will never correct if an anatomical leg length deficiency is not corrected! From an evaluation standpoint (if the practitioner uses prone leg length checks) how can the evaluation be objective if an anatomical short leg exists, and has not been verified and/or quantified? Perhaps the most compelling reason to verify anatomical leg lengths (on individuals with spinal problems) is that research concludes that the anatomical short leg is prevelent in 80% of all individuals!

Measuring for ASL

First of all, leg length is defined as the actual distance between the bottom of the heel and the top of the femur. Leg length determination has involved numerous methods over the years including x-ray measurements, visual comparisons using iliac crest heights, and tape measurement comparisons using anatomical landmarks.

Weight bearing x-ray measurement techniques (14,15,16) have been determined to be the most accurate studies for ASL determination. The typical x-ray method relies on a weight bearing AP pelvic view measuring from the top of the femur heads to the bottom of the film (assuming that the floor is level). The patient's feet must be directly under the femoral heads and the central ray must be at the height of the femoral heads, with a focal film distance of 40 inches.

In the absense of an xray evaluation a visual evaluation has shown to be very reliable, especially so when used in conjunction with a square grid such as that provided in a SAM machine.
Bailey and Beckwith (20) reported a direct relation between a low iliac crest and a short leg on the same side in 88% of subjects. Caillet (21) correlates three anatomical indicators; including the iliac crest heights, the sacroiliac dimples, and the vertical position of the lumbar spine related to the base of the sacrum.

Tape measure comparisons using anatomical landmarks have shown to be the least reliable due to asymmetry and inaccurate locations of bony landmarks (17,18.19).

Using SAM to Identify and Treat ASL

The SAM evaluation allows you to quickly evaluate for an Anatomical Short Leg (ASL) plus the entire spinal effect of an ASL. The SAM ASL evaluation also allows you to incorporate frequent progress evaluations sparing the individual from x-ray exposure and added expense. The plumb & square frame of the SAM unit provides a consistent objective starting point. The SAM ASL evaluation protocol incorporates iliac crest height (20,21) (with sacroiliac dimples & the vertical position of the lumbar spine), body shift or mean center of gravity shift (22,23) and bilateral weight measurement (4,24,25).

For review purposes the SAM machine utilizes 2 colors of crosswires (green, placed closest to the patients) and (red, placed closest to the practitioner). Each color contains one long vertical for evaluating body shift left or right of center, and 3 short horizontal for the evaluation of pelvic, shoulder, and head tilt. The green crosswires are used to depict normal or level. To begin an evaluation the long vertical green is placed at “0” at top of the SAM frame. Move the pelvic horizontal level pair (red and green) to the low back level, and using the measurement tapes, set the green crosswire at level (for example at 32 on each side). You can now look through the level green crosswire to the anatomical landmarks (iliac crests, sacroiliac dimples, sacral apex, and lower lumbar vertical position) to set the red crosswire. You will also now look through the long green vertical crosswire and set the red vertical (at the occipital midline) to depict any body shift, left or right of center. (Refer to the SAM owner’s manual for detailed instructions on patient placement and entire crosswire protocol)

A low iliac crest indicates a short leg on the same side. Other anatomical landmark findings will usually (but not always) confirm a low iliac crest, the sacral apex usually shifts opposite the low side, the sacroiliac dimples will be low on the low iliac crest side, and the vertical position of the lower lumbar spine will lean toward the low iliac crest side. If the deficiency is less than 6mms, body shift (away from center), will be towards the short leg side. This will almost always be confirmed by the body carrying more weight on the short leg side. With an ASL of 6mms or more, the body will carry more weight on the long leg side due to equilibrium compensation and the upper body (occipital midline) will shift to the long leg side (with larger amounts of an ASL, as the body shifts opposite the short leg side it may not cross the center line but in combination with the shoulders leaning towards the long leg side you will recognize the compensation effect). Of the three indicators, weight imbalance carries the least significance as to if an ASL exists, but is a very good piece of the puzzle in solving whether a deficiency is above or below 6mm. As Lawrence (4) has shown, individuals with an ASL of less than 6mm will bear more weight on the short leg side. However, those with a difference greater than 6mm will transfer weight to the long leg side. This is attributed to the compensatory mechanism of the hip abductors, such as the gluteus medius, when it is utilized to shift weight to the long leg side. This phenomenon was confirmed by Mahar (24).

The exact degree of deficiency is not necessarily important because our heel lift placement protocol always begins with no more than 3mm of correction. We suggest that a lift should not be placed until after an initial treatment period, in order to stretch and strengthen (26) and to allow the symptoms to stabilize (27).

SAM will allow you to instantly observe the biomechanical changes as a lift is introduced. Unless a full spine x-ray or numerous spot views are used, an x-ray evaluation won't allow you to evaluate the effect of a ASL on shoulder tilt, head tilt, and body shift. If indicated, more lift is introduced in 2mm increments after a two week adaptation period and further treatment for each increase.

As a rule, it is better to under-correct than to over-correct. An optimal lift height would level the pelvis, center the body shift, and even the bilateral weight measurements. Many studies have concluded that heel lift use is more effective in younger individuals due to the pliability of the connective tissue, but don't underestimate the body's ability to adapt. In older individuals postural change may take longer, and may not completely balance. **Always instruct the patient that if a lift makes their condition worse (after a day or so) to remove it.** If a lift is removed, re-evaluate the person’s biomechanics to verify that the lift is on the correct side. Reinsert the lift only after further stabilizing any acute condition. Sometimes the body will not accept a heel lift, so be aware that not all ASL’s will be able to be treated with a lift.

NOTE: The exact deficiency isn't vital because you always begin with no more than a 3mm correction. The hydraulic lift and depth gauge of the SAM Mark VIII model will quantify a deficiency, while the SAM Slimline model (minus the hydraulic lift and depth gauge) can give you an accurate estimate of deficiency. Since the measurement tapes on the SAM Slimline unit are a lateral distance from the individuals' femurs, an actual deficiency measured from the tapes will be multiplied. Generally, depending on the size of the patient, times 2. Therefore whatever the measured deficiency equals divide by 2. For example, a measured deficiency of 1/2" would actually be 1/4".

<u>Rules for Heel Lift Placement</u> (check our links page for heel lift suppliers)

Although the S.A.M. evaluation using the square posture frame grid and crosswires has proven to be accurate, THE NEW S.A.M. Precision Level Pelvic Analyzer provides a quicker, highly accurate, objective evaluation for ASL determination. Bailey and Beckwith (20) reported a direct relation between a low iliac crest and a short leg on the same side in 88% of subjects.

1. A heel lift is a powerful tool, it can dramatically shift the body weight and hence the effects of gravity on the body. Sometimes the body will not accept a heel lift, so be aware that not ASL's will be able to be treated with a lift. For example, osteoarthritic spurring may cause an exacerbation or a complete relief in symptoms (when a lift is introduced due to the subsequent weight shift). Symptomotlogy, amount of distortion, and age should all be considered when deciding on heel lift use, A trial period should be monitored in all cases of heel lift use.

2. Since the unilateral fallen arch (the True Functional Short Leg, page 2 of this report, Beal and Grant (28) can be a factor in up to 52% of all ASL you must evaluate for a unilateral fallen arch. A unilateral fallen arch may/may not be responsible for the full amount of an ASL or may only be partially responsible. A quick check to evaluate for a unilateral fallen arch is to have all subjects (that reveal a low iliac crest) forcefully supinate both feet and check for a change in iliac crest height. A more detailed analysis involves placing a pen mark on each talus of the weight bearing subject. With a ruler (remember the participant is standing) measure the distance from the floor to each talus mark. If the distance is not equal bilaterally, a unilateral fall arch is present and an arch support/orthotic is indicated. Postural re-evaluation with the arch support in place will reveal if a heel lift is also indicated.

3. A lift can be placed at the onset of treatment, but is probably best incorporated after soft tissue problems have been stabilized. Once the lift is started, it must be worn at all times to be effective.

4. For convenience and compliance, provide enough lifts for each pair of shoes. Lifts should be secured in place with either double stick tape or with a staple gun.

5. As described on the previous page, a low iliac crest indicates an ASL on the same side, bilateral weight and body shift (left or right of center) are indicators of whether the amount of deficiency is 6mm or more vs. less than 6mm.

6. The exact quantity of an ASL is not essential because you always start with no more than a 3mm lift, and if indicated through subsequent progress evaluations, only increase with 2mm increments after two week adaptation periods at each new height.

7. It is better to under-correct than to over-correct.

8. An optimal lift height would level the pelvis, center the body shift, and even the bilateral weight measurements.

9. Progress evaluations should be performed with the lift in place.

10. If a lift makes the symptoms worse (after a day or so) instruct them to remove it. If a lift is removed, re-evaluate the person's biomechanics to verify that the lift is on the correct side. Reinsert the lift only after an acute condition stabilizes. The body will not always accept a heel lift, so be aware that not all ASL's will be able to be treated with a lift.

Bibliography

1. Friberg O: Clinical symptoms and biomechanics of lumbar spine and hip joint in leg length inequality. Spine, 1983, 6 (6):643-650.
2. Rush, WA, and Steiner HA: Study of lower extremity length inequality. Am J Roentgenol. 56:616-623, Nov. 1946.
3. Reynolds E, and Hooten EA: Relation of pelvis to effect posture; exploratory study. Am. J. Phys. Anthropol. 21:253-278. June 1936.
4. Lawrence D: Lateralization of weight in the presence of structural short leg: a preliminary study. J Manipulative Physiol Ther 1984; 7:105-8.
5. Beal MC: A review of the short leg problem. JAOA, 1950, 50 (2):190-191.
6. Subotnick S: Limb length discrepancies of the lower extremity (the short leg syndrome). J Orthop Sports Phys Ther 1981; 3:11-6.
7. Klein KK: Development asymmetries of the weightbearing skeleton and its implications in knee stress and knee injury. Athletic Training. 13:2:78-80, Summer 1978.
8. Heilig D: Principles of lift therapy. J Am Osteopath Assoc. 1978; 77:466-72.
9. Subotnick SI. The short leg syndrome. J Am Podiatr Assoc 1976; 66:720-3.
10. Ladermann JP. About inequalities of the lower extremities. Ann Swill Chiro Assoc 1976; 6:37-57.
11. Pauwels P. A correlation between disc degeneration and short leg. J Clin Chiro 1978; 2:3-11.
12. Travell JG, Simons DG. Myofascial pain and dysfunction: the trigger point manual. Baltimore: Williams & Wilkins, 1983.
13. McCaw ST, Bates BT. Biomechanical implications of mild leg length inequality. Br J SportsMed 1991. Mar; 25 (1):10-3.
14. Friberg O, Koivisto E, Wegelius C. A radiographic method for measurement of leg length inequality. Diagn Imag Clin Med. 54: 78-81 (1985).
15. Lawrence DJ, Pugh J, Tashanski C, Heinze W: Evaluation of a radiographic method of determining short leg mensuration. J Am Chiro Assn, 1984, 18:57-79.
16. Giles LGF, Taylor JR. Low back pain associated with leg length inequality. Spine 1981; 6:510-21.
17. Okun SH, Morgan JW, Burns MJ. Limb length discrepancy. J Am Podiatr Assoc 1982; 72:595-9.
18. Nichols PJR, Bailey NTS. The accuracy of measuring leg length differences. Br Med J 1955; 29:1247-8.
19. Aitken AGF, Flodmark O, Newman DE, Kilcoyne RF, Shuman WP, Mack LA. Leg length determination by CT digital radiography AJR 1985; 144 613-5.
20. Bailey HW, Beckwith CG. Short leg and spinal anomalies: their incidence and effects on spinal mechanisms. J Am Osteopath Assoc 1937; 36:319-27.
21. Caillet R. Low back pain syndrome. 3rd ed. Philadelphia, FA Davis, 1983:72-4.
22. Song KM, Halliday SE, Little DG. The effect of limb-length discrepancy on gait. J Bone Joint Surg Am 1997; 79:1690-8.
23. Bailey HW. Theoretical significance of postural imbalance. especially the "short leg." J Am Osteopath Assoc 1978; 77:452-5.
24. Mahar RK, Kirby RL, MacLeod DA. Simulated leg-length discrepancy: its effect on mean center-of-pressure position and postural sway. Arch Phys Med Rehabil 1985; 66:822-4.
25. Murray MP, Peterson RM. Weight distribution and weight shifting activity during normal standing posture. Phys Ther 1973: 53:741-8.
26. Bluestein S, DíAmico J. Limb length discrepancy. J Am Podiatr Med Assoc 1985; 75:200-6.
27. Fisk JW. A practical guide to management of the painful neck and back: diagnosis, manipulation, exercise, prevention. Springfield, IL: Charles C Thomas, 1977:56-9.
28. Beal MC, Grant JH: Standing foot x-rays. J Am Osteop A. 46:306-307. Jan 1947.
29. Judovich B, Bates W: Segmental neuralgia in painful syndromes. Ed. 2. FA Davis Co., Philadelphia, 1946.
30. Atkins CE: Pelvic imbalances as causative factors in foot disturbances. Clin Osteopathy. 34:5-9. July 1938.
31. Reid DC, Smith B. Leg length inequality: a review of etiology and management. Physiother Can 1984; 36: 177-82.
32. Leeuwenberg GNM, Vickers CNH. The short leg in practice. Bournemouth, England: Anglo-European College of Chiro, 1980-1981.
33. Eichler J. Methodological errors in documenting leg length and leg length discrepancies. In: Hungerford DS, ed. Leg length discrepancy - the injured knee. Berlin, Germany: Springer-Verlag 1977:29-39.
34. Beal MC The short leg problem. J Am Osteopath Assoc 1977; 76:745-51.
35. Winterstein JF. Lower extremity inequality: short leg syndrome. In: Lawrence DJ, ed. Fundamentals of chiropractic diagnosis and management. Baltimore: Williams & Wilkins, 1991:498-509.
36. Winterstein JF. The "Short Leg" Syndrome. Chiro Econ 1974 1974:78-82.
37. Winterstein JF. Lettel to the editor. J Manipulative Physiol Ther 1989; 12:241.
38. Lawrence D. Chiropractic concepts of the short leg: a critical review. J Manipulative Physiol Ther 1985; 8: 157-61.
39. Lawrence D. Leg length inequality. In: Cox JM, ed. Low back pain: mechanism, diagnosis, and treatment. Baltimore: Williams & Wilkins, 1990:204-1
40. Grofton JP, Trueman GE. Studies in osterarthritis of the hip. Part II. Osteoarthritis of the hip and leg-length disparity. Can Med Assoc J 1971: 104: 791-9.