A Clinical Study of Fluctuating Asymmetry and Leg Length Inequality

Introduction

The practices of chiropractic, orthopedics, osteopathy, allopathic medicine, and physical therapy often work under the assumption that the human musculoskeletal system is symmetrical across the median sagittal plane. This assumption is consistent with developmental theory as proposed by a variety of different authors. The consequence of this assumption results in clinical methods that attempt to establish symmetry of the skeletal system. Such methods would include the manipulations, braces, prescription of orthotic shoe inserts and heel lifts to balance the pelvis and spine along the median sagittal plane, as well as the use of spinal bracing and surgery to reduce scoliotic curvatures.

The reasoning behind clinical approaches to restore symmetry appears to be intuitively obvious: if the human frame is symmetrical in design, clinicians should attempt to restore that symmetry in its absence. There is no shortage, however, of asymmetries in the human body that appear to have a directional preference.

Asymmetries may have been selected by evolutionary processes because they represent some survival advantage to the organism. The human heart for example, with few exceptions is located to the left of the mid sagittal plane and the right and left lungs have different numbers of lobes. This is directional asymmetry with a distribution where the mean asymmetry is less than or greater than zero. (Figure 1A)

Other asymmetries occur in species with bimodal distribution where the mean equals zero. Some species of crab have asymmetrically sized claws. While this may also represent an evolutionary process or survival advantage for the crab, the asymmetry of the claws occur equally right to left. The large claw is found as often on the right as the left, or the small claw is found as often on the right or left. This is anti-symmetry with a bimodal distribution where the mean equals zero. (Figure 1B)

It is not known if many of the skeletal asymmetries that are observed clinically are directional asymmetries, anti-symmetries or whether their presence represents random fluctuations about a mean of zero or fluctuating asymmetry. (Figure 1C)

Leg length inequalities are an example of these skeletal asymmetries. They have not been studied in regards to their classification as directional, or anti-symmetries or fluctuating
asymmetries. The discovery of what classification of asymmetry is represented by leg length inequalities may have an important bearing on the application of some clinical interventions such as manipulations, braces, prescription of orthotic shoe inserts and heel lifts described earlier.

For the purposes of this study, leg length inequality refers to differences in the height of the femur heads as viewed on radiographs taken with the patient in a weight bearing position as described below, as opposed to the, “so-called functional short-leg, or more accurately, unloaded leg-length alignment asymmetry.”\textsuperscript{13}

The objective of the study is to attempt to discern if leg length inequality is a directional asymmetry, anti-symmetry or fluctuating asymmetry as determined by accepted and reliable radiographic clinical methods. The result most consistent with the clinical assumption that the skeletal system is intended to be symmetrical would be that leg length inequality is a result of fluctuating asymmetry.

Methods

Study Design

This study is a retrospective review of adult patients who were seen in clinical practice by the principal investigator for back pain or back and back related lower extremity pain.

Subjects

Back pain patients were included if they were 18 years or older with a diagnostic quality anteroposterior lumbopelvic radiograph that had been obtained using the modified Friberg anteroposterior lumbopelvic x-ray view/protocol.\textsuperscript{10} Patients were excluded if they were younger than 18 years of age; their clinic records did not contain a diagnostic quality anteroposterior lumbopelvic radiograph, or patients whose radiograph was not obtained using the modified Friberg anteroposterior lumbopelvic view. Patients with hip or knee prosthesis, patients with a prior history of lower extremity fracture, hip, knee or ankle dislocation were also excluded from the study population.

Four hundred and fourteen subjects met the inclusion criteria and were included in the study. (Tables 1 & 2)

Data Extraction

Data extracted from the patient files included: date of first presentation, gender, age, height, weight, and measures of leg length as determined from the radiographs.

X-ray Equipment Alignment & Positioning Protocol

Leg length inequality can be assessed most reliably with the use of x-ray examination.\textsuperscript{10, 15, 18} This of course requires great attention to patient positioning and alignment of x-ray equipment.

It is not the purpose of this paper to go into a detailed discussion of equipment alignment. Suffice it to say, the most important aspects of equipment alignment are: (a) that the focal spot of the x-ray tube produces a central ray that strikes the grid cabinet at the vertical center of the grid cabinet (i.e. at a point along the median sagittal plane of the grid cabinet), (b) that the x-ray tube is perpendicular to the grid cabinet at all possible focal film distances (FFD), and (c) the grid cabinet is level and the film is securely placed against the bottom of the cassette.

If these conditions are not met, equal magnification of skeletal structures on opposite halves of the body cannot possibly occur and radiographic measures that rely on true vertical or horizontal alignment of the edges of the film will produce spurious information.

By simply illuminating the collimator, sliding the tube back and forth between the focal film distances (FFD) of 40 and 72 inches while observing the position of the collimator cross hairs on the grid cabinet, one may get a rough idea if the rails the x-ray tube travels are perpendicular to the grid cabinet. If the tube’s travel rails are perpendicular to the grid cabinet, the vertical cross hair of the collimator will remain on the vertical center line of the grid cabinet as the tube is moved back and forth. If the tube’s rails are not perpendicular to the grid cabinet, the vertical cross hair of the collimator will appear to move in lateral deviation left or right of the vertical center line of the grid cabinet as the tube is moved between the FFD’s.

To test the focal spot, the x-ray tube is centered on the center of the grid cabinet. Hildebrandt\textsuperscript{17} suggests placing a small metal washer over the exact center of the tube aperture. The hole in the center of the washer should be ½ inch in diameter. Next a round lead ball ¼ inch in diameter is placed in the exact center of the film. Exposures made at various FFD’s should all project with the lead ball in the center of the metal washer if the focal spot is aligned with the center of the grid cabinet.

The equipment used to obtain the radiographs for this study was subjected to this analysis and the x-ray tube and grid cabinet were aligned to meet these requirements.

Also crucial in determining leg length inequality via x-ray examination are the height of the x-ray tube in relation to the top of the patient’s femur heads and patient placement between the x-ray tube and grid cabinet.

In a standard anteroposterior sectional view of the lumbar spine and pelvis, the femur heads are below the level of the central ray of the x-ray tube. This creates a situation where axial rotation malposition of the patient in front of the tube may produce a false image of an anatomical short leg (pseudo short leg).

Friberg\textsuperscript{15} and others\textsuperscript{14,16-19} suggest that the best manner in which to determine leg length inequality, and to control for the problem of the pseudo short leg secondary to image distortion, is to take a special view of the pelvis with the height of the level central ray of the x-ray tube aimed across the top of the femur heads.
The modified Friberg projection is taken with the patient’s feet placed six inches apart and the patient’s mid-ankle point below the mid-point of the grid cabinet, and below the median sagittal plane of the x-ray film and cassette. The positioning should be as exact as possible for each point. In addition, the patient is placed in such a manner so that the median sagittal plane of the pelvis is exactly centered with the median sagittal plane of the grid cabinet. The grid cabinet is first set at the height used for taking the lateral lumbopelvic view (i.e. the superior-inferior center of the grid cabinet at the height of the patient’s iliac crests). The x-ray tube is level and the central ray is aimed at the center of the grid cabinet. The tube is collimated to fit the 14” X 17” film size. (Figure 2)

Next, the x-ray tube is lowered to the height of the patient’s femur heads. This may be determined by palpating the cephalic edge of the patient’s greater trochanter. The tube height is then lowered to one inch above the top of the greater trochanter. (Figure 3B) With the collimator opened to the 14” X 17” setting, the tube is then angled cephalically to match the grid cabinet. (Figure 4)

Finally, the patient is placed with the feet as described above and the median sagittal plane of the patient’s pelvis is centered to the vertical primary rays of the x-ray tube. This is accomplished by making sure the sacral tubercles are in the center of the grid cabinet and the patient is not rotated around their vertical axis (i.e. Y-axis) away from the midline. (Figure 4)

Figure 5 is a radiograph of the modified Friberg projection. The film clearly depicts the lumbar vertebrae, pelvis, hip joints, and proximal femora. This view provides a complete look at the lumbar spine and pelvis and controls for the variable (i.e. height of the tube) that can cause the appearance of the “pseudo short leg.”

The traditional Friberg view is the ideal projection for structural and postural measurement in this study and valuable in daily clinical practice. Some practitioners add a standard anteroposterior lumbopelvic view to a study using a modified Friberg view. This may not be necessary as the modified Friberg view suffices and additional ionizing radiation and expense can be avoided.

**Data Analysis**

After data collection, descriptive statistics were calculated and multiple regression analyses were used to determine the degree of relationship between the various demographics as related to leg length asymmetry. In addition, methods described elsewhere were used to determine the type of asymmetries that exist in the patient population. (http://www2.biology.ualberta.ca/palmer/palmer.html)

**Results**

Measurement of the Friberg films showed 296 (71.5%) of the subjects had leg length inequality while 118 (28.5%) of the subjects did not. Those having leg length inequality were divided into two groups, subjects with left leg length inequality and subjects with right leg length inequality. Subjects with left leg length inequality (146) represented 49.3% of the subjects with leg length inequality while subjects with right leg length inequality (150) represented 50.7% of the subjects with leg length inequality. (Table 3)

When plotted, the subjects with leg length inequality showed a distribution about a mean of zero or a graphic representation consistent with fluctuating asymmetry (Figure 6). Left leg length inequality occurrence was statistically equal to right leg length inequality indicating skeletal symmetry in regard to leg length is the desired state.

**Discussion**

Three types of asymmetries: directional asymmetry, anti-symmetry and fluctuating asymmetry have been studied. Fluctuating asymmetry has been studied extensively in many species in relationship to environmental adaptation, evolution, function, health, mating habits and other factors. In general, these studies have demonstrated that populations of organisms and individuals within populations with greater indices of symmetry tend to have better overall health (resistance to parasitic disease, etc) in relation to their less symmetrical counterparts. These observations by others has led to our interest to investigate whether or not leg length inequality is a manifestation of fluctuating asymmetry, directional asymmetry, or antisymmetry.

In a review by Knutson data were retrieved from six separate studies for a combined population of 272 that reported left versus right leg length inequality. The studies demonstrated a greater tendency for the right leg to be short versus the left leg. The data would suggest leg length inequality to be a directional asymmetry, and consequently, that finding would suggest that no clinical intervention would be appropriate, since a directional asymmetry would suggest some evolutionary choice towards that prevalence.

We questioned this overall finding (greater tendency towards right leg length inequality) and suggest that the combined data may be shifted towards the right leg due to minor, but perhaps significant differences, in the manner in which those different studies were carried out. To test this hypothesis, we performed our study with a greater overall population with the
exact same protocol of assessment on each subject. Our findings, although similar to those presented in combined form by Knutson, contradict the idea that the right leg is more often shorter versus the left leg in humans.

Our study focused on leg length inequality in the human skeletal system with the intent to determine if the clinically observed phenomenon of leg length asymmetry is a result of fluctuating asymmetry. As discussed previously, this is an important determination as symmetry and balance of the skeletal system have long been the basis of many chiropractic, osteopathic, allopathic and physical therapy clinical assessments.

Some would argue that small asymmetries exist in all populations and many are not of clinical significance. This assertion may be true. But, are the asymmetries evolutionary (directional or anti-symmetry) or are they random (fluctuating asymmetry)? If the asymmetry is fluctuating, as this study suggests, the implication is that symmetry should be restored for the optimal health of the individual. This is consistent with the long-standing clinical theories of various healthcare systems.

Our study, though small, is a significant step toward further defining and understanding asymmetries of the human frame.

**Conclusion**

Bilateral symmetry, the basic underlying premise that serves as the intuitive baseline by which abnormal structure is evaluated clinically, has rarely been assessed by scientific method in chiropractic, orthopedics, osteopathy or physical therapy. A specific asymmetry found by a clinician may or may not be “normal” based upon classification of human asymmetry as either a directional asymmetry or a manifestation of fluctuating asymmetry.

Those asymmetries that exist as directional asymmetries should, by definition, not be addressed as deviations from normal baseline for a population or individual, since they may represent an evolutionary advantage for that population or individual. If, however, the asymmetry under investigation is one that exists as a manifestation of random fluctuations about zero (fluctuating asymmetry), then a logical rationale may exist that indicates the clinician should intervene to attempt to reestablish symmetry in that population or individual.

Our data suggests that leg length inequality is a manifestation of fluctuating asymmetry. This indicates a potential scientific rationale exists that confirms clinical interventions aimed at achieving skeletal symmetry and balance of the lower extremities.

**Acknowledgements**

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**References**

### Table 1 Inclusion and Exclusion Criteria

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<tr>
<td>Back Pain Patients 18+ years of age or older</td>
<td>Back Pain Patients less than 18 years of age</td>
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<td>Patients with AP lumbopelvic radiograph obtained using the modified Friberg projection protocol</td>
<td>Patients with hip or knee prosthesis</td>
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<tr>
<td>Data from the patient’s file; date of first presentation, gender, age, height, weight, measurements of leg length as determined from the Friberg radiograph</td>
<td>Patients with prior hip, knee or ankle dislocation</td>
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<td>Patients with prior lower extremity fracture</td>
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### Table 2 Demographic Data

- **Gender:** 227 Females/188 Males
- **Age Range:** 18-82 years, Average Age = 49.9 years
- **Height Range:** 4’11” – 6’6”, Average Height = 5’8”
- **Weight Range:** 94lb – 330lb, Average Weight = 174lb

### Table 3 Distribution of Leg Length Inequality

- Subjects Studied: n = 414
- Subjects without leg length inequality: 119 or 28.7% of the total population
- Subjects with Leg length Inequality: 146 left/150 right or 71.5% of total population
- Subjects with leg length inequality of 1-5 mm; 132 or 31.9% of the population with leg length inequality
- Subjects with leg length inequality of 6-10mm, 118 or 28.4% of the population with leg length inequality
- Subjects with leg length inequality of 11-15mm, 36 or 8.7% of the population with leg length inequality
- Subjects with leg length inequality of 16mm or greater, 9 or 2.2% of the population with leg length inequality

### Figure 1

**A.** Graphic representation of directional asymmetry (A), antisymmetry (B), and fluctuating asymmetry (C).
Figure 2. The patient is placed for the lateral radiograph. The X-ray tube is level with the floor and the horizontal primary rays are at the top of the iliac crests.

Figure 3. With the X-ray tube arranged as in Figure 2, the patient turns to face the X-ray tube with the feet placed exactly as described in the text (A). The height of the tube is then lowered to the height of the femur heads by placing the horizontal primary rays (horizontal cross hair of the collimator) one inch above the greater trochanter.

Figure 4. The X-ray tube is then angled cephalically until the horizontal cross hair of the collimator matches the center of the grid cabinet/film. The patient is placed with the feet exactly equidistant apart with the mid-ankle point at the exact center of the grid cabinet. The pelvis is placed against the grid cabinet such that the median sagittal plane is aligned with the middle of the grid cabinet and vertical primary rays of the X-ray tube.
Figure 5. Radiograph of the modified Friberg projection. A true horizontal line is drawn across the top of the “long” leg (line segment AB). Line segment CD represents the measured leg length inequality.

Figure 6. Normal distribution of data points about a mean of zero. Left leg length deficiencies were reported as negative values and right leg length deficiencies were reported as positive values.