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FRONTAL PLANE PELVIC POSTURAL ASYMMETRY

PART II

“as the twig is bent”

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ABSTRACT

CONTEXT: Despite 80 years of study, questions of how leg length differences relate to recurrent pain and somatic dysfunction remain controversial.

OBJECTIVES: Our hypothesis is that a correlation does exist between leg length inequality and back pain, and that if the common compensatory patterns described in classical osteopathic literature exist, they should interact with the pelvic postural asymmetry patterns of Lloyd and Eimerbrink in a predictable and most probably congruent fashion. In Part II these patterns are correlated with age, scoliosis, standing and seated hemipelvis measurements. A secondary hypothesis is that the seated hemipelvis measurements will correlate with Leg length and scoliosis measurements in a useful way. Both hypotheses were formed before and during the data collection.

DESIGN: The prevalence of the six types of pelvic postural asymmetry on standing lumbar x-rays in a consecutive case series of 421 patients with low back pain over a three year period are presented.

METHODS: All films were shot with a tube to film distance of 40 inches and the central ray focused at the level of the sacral base in the manner of Denslow. Evaluation for leg length inequality (Δ LLI), scoliosis, standing and seated hemiplevis are described.

RESULTS: In this consecutive case study of 421 persons with low back pain, a substantial majority have a significant leg length difference, and a majority of these have a short leg on their dominant hand side. Amongst the group with Equal leg length, a majority have scoliosis. A significant minority of those with equal leg length have a short seated hemipelvis, and this minority increases with increasing leg length difference cutoff. The ratio of C to S shaped scoliosis remains stable at about ten to one. The

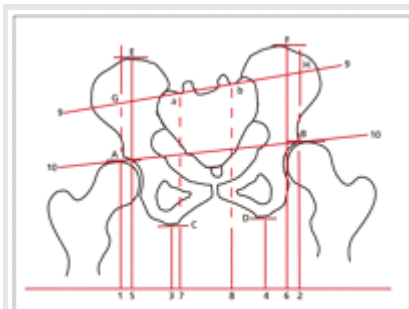
frequency of S shaped scoliosis does not increase with age or increased Δ LLI. The overall frequency of scoliosis does increase with increasing Δ LLI and in the oldest age groupings. Seated hemipelvis correlates strongly with sacral base unleveling and to a lesser degree with ipsilateral scoliosis.

Conclusions: Establishment of the frequencies of these pelvic and lumbar asymmetry patterns is a necessary first step in creating an evidence-based foundation for the further elucidation of postural compensatory patterns. The ubiquity of this asymmetry assures that diagnosis of somatic dysfunction without regard for these patterns will be largely intuitional. The seated hemipelvis measurement may prove useful in identifying the etiology of low back pain in as many as one in ten persons presenting with that symptom.

Key words: short leg syndrome, leg length inequality, seated hemipelvis, standing hemipelvis

INTRODUCTION

Asymmetry within the pelvic structures can lead to a cascade of postural compensations throughout the axial spine predisposing a person to recurrent somatic dysfunction and decreased functionality. In Part I¹ the historical context for the discussion of leg length asymmetry and its relation to low back pain was reviewed. The system for measurement (Figure I) and the frequencies of the seven different pelvic types (Table I) are reproduced from there to facilitate correlation with the new data in Part II.



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Figure 1. *Measurements for postural x-ray film.*

Step 1. Erect lines 1 and 2 perpendicular to the base through the highest point of each femoral head. (The base is technically the bottom edge of the film, mounted in a perfectly square light box. The film was shot perpendicular to the x-ray source and parallel and perpendicular to the floor, with patient placement as described in the "Methods" section. As the film is mounted perpendicular to the viewing light box and the measurements are relative, the bottom of the light box is typically used as the reference base. With practice and a transparent T-square, all measurements and calculations can comfortably be done in 3 minutes.);

Step 2. Measure the relative heights of points A, B, C, D, E and F from the base.

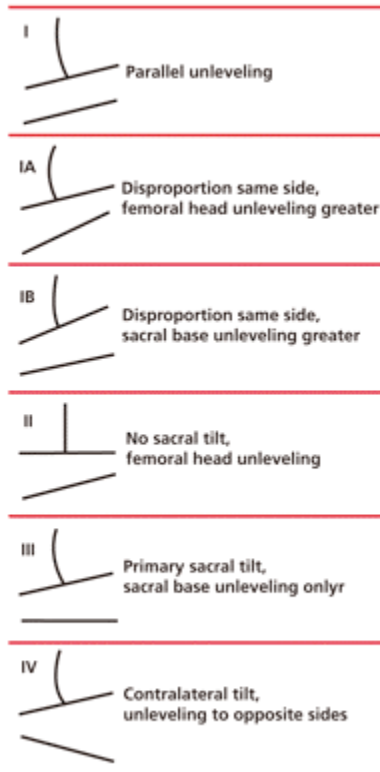
Step 3. Draw line 9 parallel to the sacral base through the two points labeled "a" and "b," which represent the convergence of the sacral ala and the articular pillars, as described in the "Methods" section. Measure the relative heights of points G and H from the base. Line 9 represents the sacral base unleveling (SBU). Line 10 represents the femoral head unleveling (FHU), and may or may not be drawn for clarity. Points C and D represent the relative heights of the ischial tuberosities (IC), while points E and F represent the relative heights of the iliac crests (IC).

Step 4. $FHU=B-A$; $SBU=H-G$; $IC=F-E$; $STHp=(a-A)-(b-B)$; and $SEHp=(a-C)-(b-D)$.

Heilig² attributed the development of the most coherent classification system for the

evaluation of frontal plane pelvic postural asymmetry and leg length difference to Lloyd and Eimerbrink, and that system is again reproduced to facilitate understanding of the text (Figure 2).

Figure 2. *Types of unleveling, based on the classification of Lloyd and Eimerbrink. (Reprinted from Heilig D. Principles of lift therapy. J Am Osteopath Assoc. 1978;77:466-472.*



In the standing position, weight transfers from the lumbar spine through the sacrum and the ilium to the femoral heads, while in the seated position weight transfers from the lumbar spine through the sacrum to the ilium, and finally to the ischial tuberosities. The Standing and Seated Hemipelvis measurements introduced in Part I are attempts to capture these weight bearing differences quantitatively.

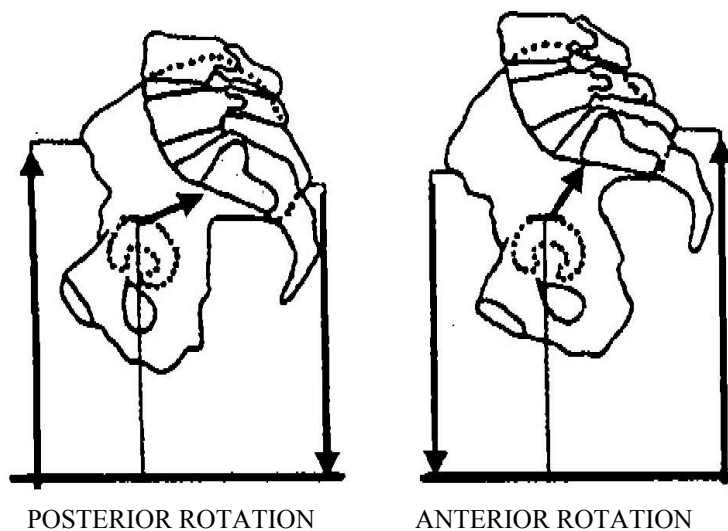
The development of the Standing and Seated Hemipelvis measurements is based on the work of Janet Travell and Richard DonTigny. In a chapter on perpetuating factors

of myofascial pain syndromes, Travell³ identifies a small hemipelvis as a contributing factor to chronic muscle strain and pain that is more neglected than a short leg as a source of spinal distortion. She quotes Lowman⁴, who found that 20-30% of patients in an orthopaedic practice had a small hemipelvis. Although less well known than Travell, DonTigny's devotion over a 40 year career to the understanding of the sacro-iliac joint is notable. In a review of sacroiliac joint pathology, DonTigny⁵ describes how rotation of the innominate on the acetabula changes the height of the ipsilateral sacro-iliac joint altering the apparent leg length on physical exam .

Figure 3

CHANGE IN APPARENT LEG LENGTH

With anterior rotation the relationship between the sacroiliac joints and the acetabula change, making the leg(s) to appear to be longer when the patient is standing. This also causes the longer leg to appear to shorten in the long-sitting position.



Note how the SIJ rises relative to the acetabula altering the apparent leg length and making them appear longer than normal

Furthermore, during anterior nutation there is some caudad translation of the sacral base, and during posterior nutation a cephalad translation⁶. The Standing Hemipelvis measurement directly captures these pelvic postural asymmetries as they relate to the standing position.

In similar fashion, The Seated Hemipelvis measurement attempts to capture the effect of innominate asymmetry and nutation on sacral base unleveling in the seated position. In FIGURE 3, the distance from the ischial tuberosity to the sacral base varies with innominate rotation. Further sources of asymmetry in the seated position can include primary sacral base unleveling, and intraosseous asymmetry of the innominates.

In a culture where a significant proportion of the workforce spends most of their workday in a seated position, postural evaluation should routinely include testing for the seated position. In 1993 the Seated Hemipelvis measurement was derived from the logic of the anatomy to try to address this issue. As a secondary hypothesis we are expecting to find that seated hemipelvis measurements correlate with leg length difference and scoliosis findings to support its use in the seated postural evaluation.

Scoliosis

Scoliosis is typically defined in the orthopaedic literature by the presence of a Cobb angle greater than 10 degrees on a standing lumbar A-P film, and has a reported prevalence within the general population of 2-3%⁷. The osteopathic literature has tended to define scoliosis as a less dichotomous and more continuous variable. Scoliosis is often described as “C” or “S” shaped. This refers to the shape of the spinal curve in the coronal plane that has been captured by the film used. Usually this is a lumbar A-P film; so an S-shaped lumbar curve means that the period of the sinusoidal or S-shaped curve occurs within or is implied within the frame of the film. Realistically, many if not all C-shaped lumbar curves have an “S” continuation off the film. That having been said, the reported

frequency of S-shaped curves varies from 20% in Beckwith's '39 study of 855 grammar school children⁸ to 2.3% in Denslow's '62 study of asymptomatic medical school students⁹.

A historical review of the short leg problem by Beal in 1950¹⁰ included a limited comparison of prior studies that specified a number of cases greater than 100 and who measured a leg length difference and lumbar convexity. Of 350 comparable cases, 311 had a short leg, and 251 (or 72%) had scoliosis. 187/251 or 75% had convexity to the short leg side. Our primary hypothesis is that we will expect to find similar correlations between leg length asymmetry and scoliosis in our data.

In 1991, Irvin¹¹ published a study of 51 persons with sacral base unleveling and lateral scoliosis less than 19 degrees convex to the short leg side. Serial increases in heel lifts to level the sacral base in combination with osteopathic manipulative treatment resulted in reduction of scolioses by one-third, as well as sustained improved symptomatology in this group of chronic pain patients.

In 1994, Hoffman¹² published a smaller confirmatory study that found significantly improved relief from low-back pain when sacral base leveling was added to osteopathic and nonsteroidal anti-inflammatory medical treatment.

METHODS

Subjects

Clinicians evaluated 421 consecutive lumbosacral, anteriorposterior (A-P) x-ray films deemed clinically appropriate. Films were taken between 1994 and 1996 for persons seen at an osteopathic manipulative practice with symptoms related to the low

back. Of 421 patients, 57% were female and 43% were male. Patient's ages ranged from 13 to 93 years, with a mean age of 47 years.

The osteopathic manipulative practice of this study is located in a major metropolitan area and operates on a fee-for-service format. Although the patient base does not reflect the incidence or prevalence of pelvic postural asymmetry patterns in the general population, the base does represent the prevalence of these patterns in a population that is more clinically useful to the practicing primary care physician.

Equipment

The equipment and procedures used are described explicitly in Part I¹³. Magnification of the femoral heads was found to vary from 12% to 20%, depending on the patient's pelvic AP diameter in conformity with the findings of Denslow¹⁴. Larger relative distortion occurred in the measurements of ileac crest height.

Procedures

The system used for measuring pelvic asymmetry is essentially that presented in Foundations for Osteopathic Medicine¹⁵, with some modifications. This figure is reproduced to aid in understanding the subsequent data (FIGURE 1).

For purposes of clarity, Leg Length Inequality (LLI) will be used to refer to Femoral Head Unleveling (FHU) or Sacral Base Unleveling (SBU), or both FHU and SBU collectively. This designation will allow extraction of the group with equal leg lengths (Equal group) for separate analysis. For this consecutive case series study, "Equal" is defined as both FHU and SBU less than X (where X is 4mm, 10 mm, or 15 mm as measured on the AP lumbosacral radiograph), according to Denslow¹⁶. Delta (Δ) will be used as a prefix to indicate the relative quantitative difference on the short or low

side. Thus, Δ FHU right indicates a significantly short right leg, and Δ SBU left indicates that the sacral base is significantly low on the patient's left side. Iliac Crest will be abbreviated as (IC).

In addition to these absolute measurements, two other relative measurements were calculated. The Standing Hemipelvis (STHp) was calculated by subtracting the femoral head height from the relative height of point "a" or "b" for each side. The Seated Hemipelvis (SEHp) was calculated by subtracting the lowest point of the ischial tuberosity from the height of point "a" or "b" for each side (FIGURE 1).

Using Excel language, researchers entered a series of formulas into a Microsoft Excel program (version 7.0) that sorted cases into appropriate categories using cutoffs of 4 mm, 10 mm and 15 mm for FHU and SBU (TABLE 1). All other comparisons used 4 mm as a cutoff for significant difference.

Visual assessment was made as to whether lumbar scoliosis was present and its degree ("very mild", "mild", "moderate", "severe"), whether the scoliosis was convex to the right or left, and whether the scoliosis appeared to be "C-" or "S-shaped" within the frame of the film. The presence of lumbar facet angulation or asymmetry was not recorded, nor was the relative position of the pubic symphysis, with regard to the cranial center of gravity or the midheel line absolute reference points.

The cutoff for significance of 4 mm was chosen after careful review of 75 years of research. It may be that as the cutoff moves down to zero, the transformation of group patterns will not be smooth and some quantum change of significance in pattern frequency will occur. Despite five years of effort, this hypothesis can still not be refuted.

RESULTS

TABLE I: Consecutive Lumbosacral Radiographs (n=421) Sorted by Type using Three Cutoffs for Significance: Greater Than or Equal to 4,10, and 15 Millimeters; Group with Equal Leg Lengths Separated for Comparison of Relative Frequency of Leg Length Inequality						
Type	#	Δ 4-mm % Total	#	Δ 10-mm % Total	#	Δ 15-mm % Total
Equal	79	18.8%	238	56.5%	346	82.2%
Unequal	342	81.2%	183	43.5%	75	17.8%
RELATIVE FREQUENCY OF LLI						
II	43	12.6%	7	3.8%	0	
IA	22	6.4%	18	9.8%	7	9.3%
I	117	34.2%	49	26.8%	14	18.7%
IB	76	22.2%	72	39.3%	44	58.7%
III	66	19.3%	28	15.3%	8	10.7%
IV	18	5.3%	9	4.9%	2	2.7%
Total	342	100%	183	100%	75	100%

Table IIA-D: Correlation of Δ FHU to other measured parameters

II-A Δ SBU to same side as Δ FHU												
Type	Δ 4-mm n = 263				Δ 10-mm n = 155				Δ 15-mm n = 68			
	S	O	E	NA	S	O	E	NA	S	O	E	NA
I	104				49				14			
IA	22				18				7			
IB	76				72				44			
II				43				7				
IV		18				9				3		
	202	18		43	139	9		7	65	3		
%	77%	7%		16%	90%	6%		4%	96%	4%		
II-B IC to same side as Δ FHU												
Type	Δ 4-mm n = 263				Δ 10-mm n = 152				Δ 15-mm n = 67			
	S	O	E	NA	S	O	E	NA	S	O	E	NA
I	87	3	13	1	45	1	2	1	13	1		
IA	22				18				7			
IB	63	1	10	2	61	1	8	2	43			1
II	32		11		7							
IV	11	1	6		5		4		2		1	
	215	5	40		136	2	14		65	1	1	
%	83%	2%	15%		89%	1%	9%		97%	1.5%	1.5%	
II-C Δ STHP to same side as Δ FHU												
Type	Δ 4-mm n = 263				Δ 10-mm n = 155				Δ 15-mm n = 68			
	S	O	E	NA	S	O	E	NA	S	O	E	NA
I	1	78	25			48	1			14		
IA		22				18				7		
IB	2	24	50		2	24	46		2	21	21	
II		43				7						
IV		17	1			8	1			3		
	3	184	76		2	105	48		2	45	21	
%	1%	70%	29%		1%	68%	31%		3%	62%	31%	
II-D Δ SEHP to same side as Δ FHU												
Type	Δ 4-mm n = 263				Δ 10-mm n = 155				Δ 15-mm n = 68			
	S	O	E	NA	S	O	E	NA	S	O	E	NA
I	17	8	78	1	16	2	31		6	3	5	
IA	1	8	13			7	11			2	5	
IB	29	3	44		28	2	42		19	1	24	
II		13	30			1	6					
IV	2	12	4		2	6	1		1	2		
	49	44	169		46	18	91		26	8	34	
%	19%	17%	64%		30%	12%	58%		38%	12%	50%	

TABLE III SCOLIOTIC CONVEXITY CORRELATED WITH Δ LLI

Convexity	Δ FHU	Δ SBU	Δ LLI
All Scoliosis n = 285			
Same Side * (188)	148 52%	173 61%	176 62%
Opposite Side (59)	54 19%	45 16%	56 20%
N/A (38)	(E & III) 83 29%	(E & II) 67 23%	(E & IV) 53 18%
C-Shaped Scoliosis n= 248			
Same Side (175)	139 56%	162 65%	162 65%
Opposite Side (46)	42 17%	34 14%	44 18%
N/A (27)	(E & III) 67 27%	(E & II) 52 21%	(E & IV) 42 17%
S-Shaped Scoliosis n = 37			
Same Side* (13)	9 24%	11 30%	12 32%
Opposite Side (13)	12 32%	11 30%	12 32%
N/A (11)	(E & III) 16 43%	(E & II) 15 40%	(E & IV) 13 35%

N/A means Scoliosis Present, No Δ LLI

*The lower part of the S-Shaped Curve is convex to the same side as the Δ LLI

TABLE IV SEATED HEMIPELVIS CORRELATED WITH SCOLIOSIS & Δ SBU

Δ SEHp	SEHp x scoliosis		NA	Δ SEHp x Δ SBU
	Same	Opposite		
Equal	10	2	7	(no SBU)
Type I	26	10/26=38%	7	16/26=61%
Type IA	9	1/9=11%	6	1/9 = 11%
Type II	13	6/13=46%	5	(no SBU)
Type IB	32	26/32=81%	1	29/32=90%
Type III	25	16/25=64%	3	22/25=88%
Type IV	15	6/15=40%	5	9/15=60%
	130	67	28	35
				77/107=72%

NA means Seated Hemipelvis present, no scoliosis.

TABLE V-A: FREQUENCY OF SCOLIOSIS BY AGE AND TYPE - 4-mm CUTOFF

		TYPE																	
Age	E: n=79		I: n=117		II: n=43		IA: n=22		IB: n=76		III: n=66		IV: n=18		Sub-Totals		No		
	Scoliosis		Scoliosis		Scoliosis		Scoliosis		Scoliosis		Scoliosis		Scoliosis		Scoliosis		Scoliosis		
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S			
13 - 22 (n = 9)			1		3				1		1		1		7		78%	2	
			1		3				1		1		1		7				
23 - 32 (n = 67)	4		11		3		3		14		7				42		63%	25	
	4		10	1	2	1	3		14		5	2			38	4	11%		
33 - 42 (n = 117)	9		25		9		5		16		9		3		76		65%	41	
	6	3	22	3	8	1	4	1	16		9		2	1	67	9	12%		
43 - 52 (n = 81)	14		14		3		3		8		12		6		60		74%	21	
	8	6	14		2	1	3		6	2	12		5	1	50	10	17%		
53 - 62 (n = 62)	5		12		3		2		9		5				36		58%	26	
	4	1	10	2	3		2		7	2	4	1			30	6	17%		
63 - 72 (n = 54)	4		11		5		2		8		8		1		39		72%	15	
	4		9	2	5		2		8		7	1	1		36	3	8%		
73 - 82 (n = 25)	3		5		3		3		3		3		1		21		84%	4	
	2	1	4	1	2	1	3		2	1	3		1		17	4	19%		
83 - 93 (n = 6)			1						2		1		2		6		100%		
			1						2			1	2		5	1	17%		
13 - 93 (n = 421) %	39 (49%)		80 (68%)		29 (67%)		18 (82%)		61 (80%)		46 (70%)		14 (78%)		287 (68%)			134	
	C	S																	
	28	11															28%		
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S			
	71	9	25	4	17	1	56	5	41	5	12	2	222	26					
		11%		14%		6%		8%		11%		14%		10%					

TABLE V-B: FREQUENCY OF SCOLIOSIS BY AGE AND TYPE-10-mm CUTOFF

Age	TYPE																Sub-Totals	No Scoliosis
	E: n=238		I: n=49		II: n=7		IA: n=18		IB: n=72		III: n=28		IV: n=9		Scoliosis			
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S		
13 – 22 (n = 9)	5								1				1		7 (78%)		2	
	5		1						1				1		7			
23 – 32 (n = 67)	17		5				3		14		3				42 (63%)		25	
	15	2	4	1			3		14		2	1			38	4		
																10%		
33 – 42 (n = 117)	37		9		1		4		16		6		2		75 (64%)		42	
	29	8	9		1		3	1	16		6		2		66	9		
																12%		
43 – 52 (n = 81)	33		7		1		2		7		7		4		61 (75%)		20	
	25	8	7		1		2		5	2	7		3	1	50	11		
																18%		
53 – 62 (n = 62)	17		12				2		8		2				36 (58%)		26	
	13	4	10	2			2		7	1	2				30	6		
																17%		
63 – 72 (n = 54)	24		7		1		2		7		1		1		39 (72%)		15	
	21	3	6	1	1		2		7		1		1		36	3		
																8%		
73 – 82 (n = 25)	10		3		1		1		3		2				21 (84%)		4	
	8	2	3		1		1		2	1	2				17	4		
																19%		
83 – 93 (n = 6)	3		1						2						6 (100%)			
	2	1	1						2						5	1		
																17%		
13 – 93 (n = 421) %	146 (61%)		36 (73%)		4 (57%)		14 (78%)		58 (80%)		21 (75%)		8 (89%)		287 (68%)		134	
	C	S																
	118	28 19%																
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S		
	33	3 8%	4	0	13	1	54	4	20	1	7	1	131	10				
				0%		7%		7%		5%		13%		7%				

In Tables IIA-D, correlations are explored between Femoral Head Unleveling (FHU) and the other measured parameters. To the left of each row, the cases with Δ FHU are further subclassified by Type. In Table II-A, the correlation of Δ FHU to the same side as Δ SBU is presented. It is essentially a reprise of the Lloyd and Eimerbrink scheme, but it is useful to recall that the pelvic types are based on this differential. The Type III pattern is excluded (because there is no Δ FHU), and the Type II pattern is classified as N/A (because there is no Δ SBU). In the rest of the types the Δ SBU follows the Δ FHU with the exception of the oppositional Type IV pattern which diminishes across the three significance groupings.

In Table II-B, the correlation of the Δ FHU to the Low Iliac Crest (Δ IC) is presented. The Δ IC falls to the same side as the Δ FHU in a large percentage of cases. A small minority remain opposite, and in a significant minority the ICs remain level, despite a significant Δ FHU. Dott et.al.¹⁷ found a poor correlation between iliac crest heights and sacral base unleveling in a radiological study of over 350 cases. It appears that the sacrum, which acts as a gear box between the bipedal mechanics of the lower half of the body and the unimodal torso, apparently does not follow the gravitational effect of the Δ FHU with the same regularity as the iliac crest. Perhaps the clearest explanation of the incongruity of Table II-B and Dott et.al. is, that while the Δ IC is a relatively poor guide of Δ SBU, it tends to follow the Δ FHU by the simple force of gravity. The innominate tends to follow the short leg (Δ FHU) even when the sacrum is contrary as in Type IV, supporting the contention by Gracovestsky¹⁸ and others that the leg begins at the SI junction.

In Table II-C, the correlation of the Δ FHU to the smaller Standing Hemipelvis

(Δ STHp) is presented. The measurement of Δ STHp is an attempt to capture the pelvic compensation for a short leg in the standing position. The innominate does not simply rotate about a transverse axis or along a sagittal plane. The STHp acts as a dependent variable with regard to Δ FHU; a long STHp accompanies a short leg except where primary sacral dysfunction jams the mechanism. This can be appreciated by the Type IB Group at ≥ 15 mm in Table II-C where “equal” STHp occur almost half of the time. Conversely in Types II and IA, where presumably the compensatory mechanism (to level the sacrum) is at its best, 100% of long STHp are ipsilateral to the short leg in the four, ten and fifteen mm cutoff groupings. Because the Δ STHp is so often proportional to the Δ FHU, it can be used to confirm the Δ FHU where the film is difficult to read, or where there is some question about whether the patient was positioned properly for the film.

In Table II-D, the correlation of the Δ FHU to the smaller Seated Hemipelvis (Δ SEHp) is presented. Unlike the clear grouping of STHp around the compensatory pattern initiated by a short leg, the Δ SEHp occurs with greater frequency to the same side as the short leg in the Type I and Type IB Groups while occurring to the opposite side in the Type II and IA groups. Fully one third of all cases with Δ FHU at the 4-mm cutoff have significantly short SEHp; these are split evenly ipsi and contralateral, to the short leg side. This increases from 40% to 50% in the 10 and 15-mm cutoff groupings, and is one statistical argument against considering SEHp a truly independent variable. Further evidence that SEHp acts as a variable independent of Δ FHU can be seen by looking at the frequency of significantly short SEHp in the group with equal leg length using 4-mm cutoff. Fourteen percent of the Equal Group have significant differences in SEHp (data not shown). Finally, in the 4-mm cutoff grouping, 30% of the Type II Group

have a significant SEHp. It remains to be seen whether either of these situations would be distinguishable from a Type III pattern based on physical exam. The asymmetric grouping of SEHp measurements with the different pelvic types does not suggest a random association, and supports our secondary hypothesis.

In two case studies where a significant Seated Hemipelvis difference was found on standing lumbar A-P film, after informed consent, a *seated* A-P film of the pelvis confirmed that the Δ SEHp measurement on the standing film did correlate with the extent and direction of sacral base unleveling in the seated position. (Data not shown) More case studies would be expected to confirm that basic correlation.

Clinically, use of a butt lift under the ischeal tuberosity on the short Δ SEHp side has produced mixed results. Presumably, some of the same compensatory mechanisms that come into play in the standing position operate in the seated position.

SCOLIOSIS

In our 421 consecutive case study, 285 (or 68%) of cases had scoliosis. 248 of 285, or 87% were considered C-shaped and 37 or 13% were S-shaped. The C-shaped convexities followed the Δ LLI 66% of the time, but opposed a Δ SBU half as often as a Δ FHU. Another way of saying this is that the convexity of scoliosis has a higher correlation with the sacral base unleveling than it does with the short leg (TABLE III). This supports Greenman¹⁹ and Eggleston's²⁰ clinical experience that sacral base unleveling is more important in terms of spinal compensatory functions and dysfunctions than femoral head unleveling. Practically, heel lifts for persons with Type II patterns may be counterproductive.

The S-shaped curves are more evenly split between following and opposing both Δ FHU and Δ SBU. A large percentage of S-shaped curves (43%) occur in the absence of an unlevel sacrum (TABLE III).

To address the question of how and whether SEHp relate to scoliosis, we have in Table IV 130 short SEHp cases, of which 95 (or 73%) occur in the presence of scoliosis, and 67/95 or 70% occur on the side of scoliotic convexity. Surprisingly, in the Type II and IA groups, Δ SEHp correlation with scoliosis is neutral or negative. The Type IV group also shows no clear preference. In the Type IB and III groups however, Δ SEHp is found on the side of scoliosis 81% and 64% respectively; but the correlation with Δ SBU is even higher (88-90%), supporting the hypothesis that a short seated hemipelvis contributes to sacral base unleveling, and to a lesser degree, to ipsilateral scoliosis.

Taking a broader clinical view, looking at the combined total of 142 cases in the Type IB and III groups at ≥ 4 mm significance, fully 30% have a short seated hemipelvis on the side of scoliotic convexity; that is one out of ten for the entire case series of 421 patients with low back pain.

In a population that spends an increasing amount of their time sitting, clinical response to a foot lift may be masked by an uneven seated hemipelvis.

An association between Δ LLI and C or S-shaped scoliosis was attributed by Janet Travell to Judovich and Bates²¹, who reported that patients with a leg length difference of less than 10-mm were more likely to have a C-shaped scoliosis. Travell²² went on to say that in her clinical experience, leg length differences of greater than 13-mm were associated with S-shaped curves. Numerous authors^{23 24} have repeated this as fact, but without supporting data.

In TABLES V-A & V-B, a matrix is made to correlate the frequency of scoliosis with patient age and pelvic type. In Table V-A, using a 4-mm cutoff, 79 cases are classified as Equal. 39/79 or 49% had scoliosis and 11/39 or 28% were S-shaped. The frequency of S-shaped scoliosis among the other six types with Δ LLI \geq 4-mm varied from 6 to 14% for an average frequency of 26/248 or 10%.

In TABLE V-B using the 10-mm cutoff, 238 cases were classified as Equal. 146/238 or 61% had a scoliosis and 28/146 or 19% of those were S-shaped. The frequency of S-shaped scoliosis among the other six types with Δ LLI \geq 10-mm varied from 5 to 13% for an average frequency of 10/141 or 7%.

Our data does not support the contention that increasing FHU is associated with higher incidence of S-shape scoliosis. This finding was not a primary endpoint of our study, and may reflect a paucity of cases of Δ LLI \geq 15-mm.

Again, from TABLE V-B, there is an increased frequency of scoliosis in the oldest age groupings. This is consistent with a much larger study by Robin et.al.²⁵, of scoliosis in the elderly.

THE EQUAL GROUP

Using the 4-mm cutoff, 79 (18.8%) of the cases were classified as “Equal”(Table 1). Half of these cases had scoliosis, (seven of which were classified as moderate to severe), with 37% convex right and 63% convex left. 10/78 (13%) of the Equal Group had a significantly short Seated Hemipelvis. This percentage increased linearly to 19% and then 24% for the \geq 10mm and \geq 15mm cutoff groups respectively (data not shown). Only 3/38 or (8%) of the Equal Group with scoliosis had Δ SEHp; the other seven Δ SEHp occurred in the absence of scoliosis.

TYPE I GROUP

Roughly 70% of the Type I Groups at 4-mm and 10-mm cutoffs have an associated scoliosis (Table VA&B). Type I reflects the most common compensatory response to a short leg at 4-mm cutoff, but at 10-mm and 15-mm cutoffs, this Group diminishes considerably. Δ SEHp occurs in a quarter to a third of the cases at these higher cutoffs, and does not strongly associate with the convexity of scoliosis.

Type III & IB Groups

While the Type III Group can be viewed as a pure primary sacral dysfunction, the Type IB Group implies a secondary sacral dysfunction. Support for this interpretation can be found in Tables I and II-A, where the most common type at the 4-mm cutoff is Type I; as the cutoff increases to 10-mm and 15-mm, Type IB emerges as the largest group. For combined III & IB Groups, scoliosis averages 75-80% at both 4-mm and 10-mm cutoffs. From Tables I and IV, 40% of the combined IB and III Groups have a Δ SEHp, and 91% of Δ SEHp are found on the side of convexity where scoliosis is present. This is one of the strongest arguments for the utility of the SEHp measurement.

TYPE IV GROUP

In Table II-C, the *long* STHp follows the Δ FHU in the Type IV Group as often as in all the other Groups. In Table IV it can be seen that in the Type IV Group the Δ SEHp tends to occur on the side of the Δ SBU (60%) much less frequently than occurs in the Type IB and III Groups (90-88%) and much more frequently than occurs in the Type IA group (11%), suggesting a possible counterbalancing mechanism. The Type IV Group has the highest frequency of scoliosis (Tables VA & B). The frequency of Left Handed people among the Type IV group is remarkable. From the Handedness data in Part I,

scoliosis is typically convex to the side of SBU in 86% of the Type IV Group (Table 6, Part I). In Table IV, sorting first by Group IV and then by scoliosis, the correlation between Δ SEHp and scoliosis is much less robust.

TYPE II & IA GROUPS

The Type II pattern reflects ideal compensation for a short leg by leveling of the sacral base. The long STHp invariably follows the short leg in the Type IA and II Groups. In Tables II-D and IV, the Δ SEHp tends to be opposite in direction from the Δ LLI and from convexity of scoliosis, suggesting a possible counterbalancing mechanism. By similar token in Table 6 of Part I, the Type II Group does not show any preference for scoliotic convexity with regard to short leg. The 67% frequency of scoliosis for the Type II Group is the same as the Type I Group (68%) at ≥ 4 -mm cutoff, and falls only marginally to 57% at ≥ 10 -mm cutoff. This however is the lowest frequency of scoliosis for all the Groups at 10-mm cutoff, including the Equal Group (See tables V-A & B).

DISCUSSION

With regard to Leg Length Inequality, health care providers should strive to avoid the assumption that patients with a knee or hip replacement thereby have a level sacral base. Turala et al ²⁶, looked at Leg Length Inequality after total hip arthroplasty, and postulated that it might play a role in aseptic loosening of prostheses and unexplained hip pain following arthroplasty.

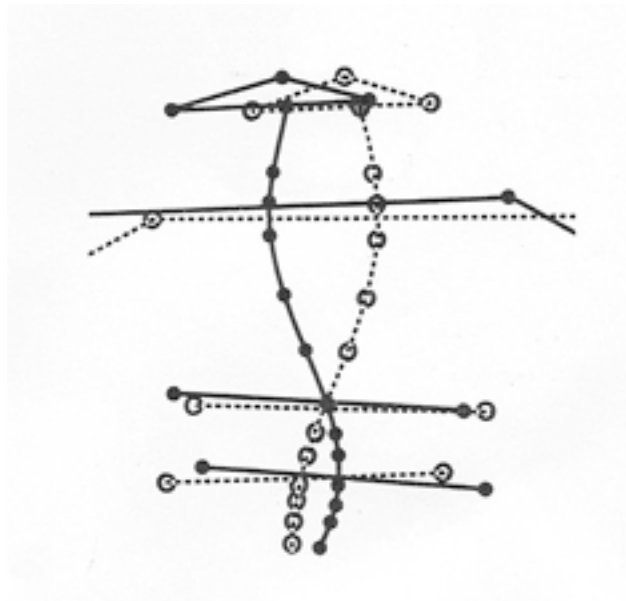
Delacerda and Wikoff ²⁷ found that a large Δ LLI caused temporal asymmetries in phases of gait. Incorporation of a shoe lift reduced asymmetry and decreased the kinetic energy requirements as measured by O₂ consumption.

With regard to scoliosis, we typically think of a static posture, or poise. It is useful to recall that the suspended, balanced still photo of the x-ray is but a snapshot of a moving oscillatory waveform in motion in the coronal plane.

With the use of Spinoscope technology developed in the 1970's and 80's, Gracovetsky²⁸ was able to capture the sinusoidal motion of the spine during one walking cycle. One of his conclusions was that S-shaped spinal curves in the coronal plane while Ambulating are normal. (Figure 4)

Figure 4

Motion of LED markers along during one walking cycle, highlighting this S-shaped motion. The spine converts the primitive lateral bend of the fish into an axial torque driving the pelvis. This is the way we walk and it is the essence of the spinal engine theory.

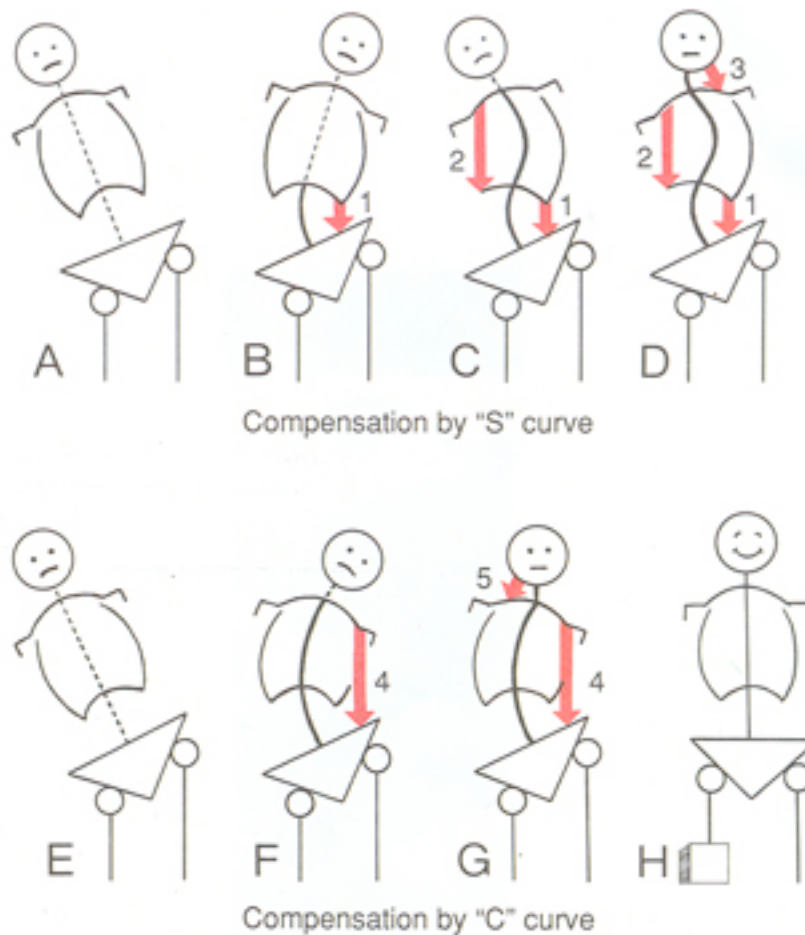


What can we say about the periodicity or the waveforms from an evidence-based perspective? Is it realistic to assume that the coupled motions of Gracovetsky's spinal engine (and of classical osteopathic theory) somehow cease below the sacral base? Would we see a higher frequency of S shaped curves in a healthier asymptomatic population?

A short leg should increase the amplitude of spinal and pelvic oscillations, hence, those systems would be less efficient. Could somatic dysfunction be thought of as the

bodies attempt to stabilize, or reduce the inefficiency of increased spinal oscillations due to a leg length inequality?

Figure 4.19 from Travell and Simons²⁹



In viewing the periodicity of the human spine, the normal wavelength most typically runs from the sacrum thru the first thoracic vertebrae, consistent with the sinusoidal pattern described for Gracovetsky's spinal engine. In patients with Low Back Pain, the most common poise as captured on lumbosacral x-ray is C-shaped, suggesting

that the wavelength must be extended up to the occipito-atlas joint. This could provide a functional mechanism by which leg length inequality could interact with cranial patterns.

Studies attempting to maximize interexaminer reliability of palpatory examinations for diagnosis of somatic dysfunction³⁰ might well benefit by knowledge of true positives for Leg Length Inequality and Seated Hemipelvis difference. When the apparent leg length differences caused solely by somatic dysfunction can more easily be teased out, diagnostic consistency will improve.

In comparing the frequencies of the seven pelvic types in '95-97 to a later data base ('98-01) using a 10 mm cutoff for significance, there is no significant variation between the two data sets, suggesting that the groupings are stable over time (data not shown) .

Using historical data on patients with and without back pain , a person with ≥ 10 mm Δ LLI would have an increased odds ratio for reporting back pain of 2.63 based on Giles and Taylor, and 2.36 based on Friberg's studies³¹ . Assuming 20% of the general population have a Δ LLI of ≥ 10 mm and allowing for a sample size calculation with a 5% type one error rate and 80% power, another 94-125 controls (persons without back pain) should be enough to confirm the causal relationship between Δ LLI and Low Back Pain.

CONCLUSIONS

In this consecutive case study of 421 persons with low back pain, a substantial majority have a significant leg length difference and a majority of these have a short leg on their dominant hand side. Amongst the group with equal leg length and low back pain, a majority have scoliosis. A significant minority of those with equal leg length have a

short seated hemipelvis, and this minority increases with increasing leg length difference cutoff.

The ratio of C to S shaped scoliosis remains stable at about ten to one. The frequency of S shaped scoliosis does not increase with age or increased Δ LLI. The overall frequency of scoliosis does increase with increasing Δ LLI and in the oldest age groupings.

The leg begins at the Sacroiliac junction. While the convexity of lumbar scoliosis tends to follow the Sacral Base Unleveling (Δ SBU), the anterior innominate (long STHP) tends to follow the short leg (Δ FHU).

Beginning with the assumption that function and form are interdependent, the ubiquity of pelvic postural asymmetry assures that diagnosis of somatic dysfunction without regard for these patterns will be largely intuitional.

Our preliminary prevalence data supports our primary hypothesis of strong correlations between Leg Length Inequality and low back pain. We are not yet able to confirm causality, but further mapping of postural compensatory patterns of somatic dysfunction onto evidence-based coronal plane pelvic asymmetry is warranted.

In a culture where a significant proportion of the workforce spends a significant proportion of their workday sitting, postural evaluation should routinely include testing for the seated position. Although we do not have enough power to confirm that the Seated Hemipelvis measurement taken from a *standing* lumbo-sacral x-ray reflects the postural weight bearing of the *seated* position, our data supports the secondary hypothesis that this measurement can be useful in evaluation of the seated posture.

We propose that Leg Length Inequality, pelvic postural asymmetry and lumbar scoliosis are ubiquitous but not innocuous; the lesser the asymmetries, the healthier the physical condition and the younger the age of the individual, the better they will be able to compensate for the energetic inefficiency caused by the asymmetry.

Postural compensatory patterns are powered by gravity.

Based on those propositions, we make the following five predictions:

- 1) When a sufficient number of asymptomatic cases from the general population are collected using this format for comparison to our already collected symptomatic low back pain groups, a significant correlation will be found between Leg Length Inequality and Low Back Pain; and that correlation will strengthen both as the LLI increases and as the age of the population comparitors increases.
- 2) The Seated Hemipelvis measurements will prove useful in identifying the etiology for Low Back Pain in as much as one in ten persons presenting with that symptom.
- 3) Given the high frequency of lateral axial curvature as found in our broadened definition of scoliosis, it follows that Type I group somatic dysfunctions must also have a high prevalence.
- 4) Common compensatory patterns of somatic dysfunction are induced by pelvic postural asymmetry and Leg Length Inequality; and they will be more predictable and understandable when viewed in this context.

- 5) The better understanding of pelvic postural asymmetry and compensatory mechanisms will strengthen our understanding of the correlations between sacral and cranial dysfunctions.

The table is now set for the mapping of frequencies of somatic dysfunction onto an evidence-based database.

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