LEG LENGTH INEQUALITY

AN OPPORTUNITY FOR PREVENTION

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At the end of WWII, two American military radiologists measured the lengths of the lower extremity (leg) in 1000 male veterans who complained of low back pain, using erect radiography. Using this technique they could measure the difference in leg lengths to within 1 mm. This population of subjects was unselected – they presented consecutively.

For comparison, the leg lengths of 100 asymptomatic male veterans were measured in a similar fashion. Table 1 shows the results for the first, symptomatic group.

TABLE I

MEASUREMENTS OF LOWER EXTREMITY LENGTHS

(1000 cases)

Lower Extremity Lengths	Millimetre Difference	Total Millimetre Difference	Number of Cases	Average Millimetre Difference
Equal	None	None	230	None
Right shorter than left	0 – 5	665	199	3.34
	6 – 10	963	119	8.09
	11 – 20	1128	78	14.47
	21 over	278	10	27.80
TOTAL		3034	406	7.47
Left shorter than right	0 – 5	604	196	3.08
	6 – 10	836	106	7.88
	11 – 20	739	55	13.43
	21 over	188	7	26.71
TOTAL		2367	364	6.5
Total Cases			1000	

Table IV shows the results for the second, asymptomatic group.

TABLE IV

MEASUREMENTS OF LOWER EXTREMITY LENGTHS

(100 cases)

Lower Extremity Lengths	Millimetre Difference	Total Millimetre Difference	Number of Cases	Average Millimetre Difference
Equal	None	None	29	None
Right shorter than left	0 – 5	74	19	3.89
	6 – 10	151	19	6.10
	11 – 20	35	3	11.66
	21 over	0	0	0
TOTAL		260	41	6.34
Left shorter than right	0 – 5	56	19	2.94
	6 – 10	74	10	6.80
	11 – 20	11	1	11.00
	21 over	0	0	0
TOTAL		141	30	4.7
Total Cases			100	

These tables have been copied from:

W.A. Rush, H.A. Steiner. A study of lower extremity length inequality. Am. J. Roentgenol. 1946; <u>56</u>: 616-623.

Not only is this paper remarkable for the quality of the tabulated data, it is even more remarkable for the <u>complete absence</u> of statistical analysis.

QUESTIONS

Q1. Tables I and IV tabulate the data according to which leg was shorter.

Retabulate the data in grouped form and calculate the mean leg length difference for the subjects with back pain and for the asymptomatic subjects. Use the average mm difference as the 'midpoint' of the interval, for each interval.

Q2. Because of the large numbers of subjects and the care with which the measurements were made, this paper is now regarded as the best source of population parameters.

Calculate the 95% confidence intervals for the mean leg length difference for the subjects with low back pain and for the subjects without pain.

Q3. Compare the two means and their 95% confidence intervals.

On the basis of these values, is it apparent whether the two means differ to a statistically significant extent ($p<0.05$)?

Calculate the appropriate test statistic to compare the two means. Do they differ significantly?

Q4. Erect radiography is a rather arcane procedure, as the name implies. Since few physicians have access to such high technology, most measure leg lengths with cloth tape measures, if the idea ever even occurs to them. Chiropractors do it regularly.

Is the difference in the two means calculated in Q3 likely to be measurable in a repeatable fashion with a cloth tape measure?

Q5. The $64,000 question

Practitioners of the art of compensating for leg length inequalities by shoe modification, like myself, know that such therapy can often dramatically relieve back pain, flank pain, and hip pain.

From the data so carefully provided by Rush and Steiner, estimate the amount of leg length difference that a patient with symptoms must have before the symptoms can be attributed to the difference in leg lengths.

Hint: Begin by calculating the cumulative relative frequencies for the different measured differences for the 2 groups. The tables that you compiled for Q1 will help get you started. If you get stuck, go on to Q6.

Q6. Now that you have calculated a probability for the possibility that the 2 distributions of leg length differences differ on the basis of chance, comment on the probability that correcting the leg length difference will benefit a given patient.

ANSWERS

Q1.

1000 MEN WITH LOW BACK PAIN

Interval	'Midpoint'	f(no. men)	f.x	f.x^2	Cumulative Relative Freq.
0	0	230	0	0	0.230
0 – 5	(665+604)÷395=3.21	395	1267.95	4070.12	0.625
6 – 10	(963+386)÷225=8.00	225	1800.00	14400.00	0.850
11 – 20	(1125+739)÷133=14.04	133	1867.32	26217.173	0.983
21 over	(278+188)÷17=27.41	17	465.97	12772.238	1000
TOTAL		1000	5401.24	57459.531	

$$\therefore mean\ leg\ difference = \sum fx / \sum f = 5.40$$

1000 MEN WITH NO SYMPTOMS

Interval	'Midpoint'	f(no. men)	f.x	f.x^2	Cumulative Relative Freq.
0	0	29	0	0	0.29
0 – 5	(74+56)÷38=3.42	38	130	444.46	0.67
6 – 10	(151+74)÷29=7.76	29	225	1746.31	0.96
11 – 20	(35+11)÷4=11.5	4	46	529.00	1.00
21 over	0	0	0	0	
TOTAL		100	401	2719.77	

$$\therefore mean\ leg\ difference = \sum fx / \sum f = 4.01$$

Q2.

(i) 1000 men with low back pain

$$SD = \sqrt{\frac{\Sigma fx^2 - \left(\Sigma fx\right)^2 / \Sigma f}{(\Sigma f) - 1}}$$

$$= \sqrt{\frac{57{,}459.531 - 29{,}173.394}{999}} = 5.32mm$$

$$\therefore\ SEM = \frac{5.32}{\sqrt{1000}} = 0.168$$

$$95\%\ \text{CI} = \bar{x} \pm (1.96 * \text{SEM})$$
$$= 5.40 \pm 0.33$$
$$= (5.07, 5.73)\ \text{mm}$$

(ii) 100 men with no symptoms

$$= \sqrt{\frac{2719.77 - 1608.01}{99}} = 3.35mm$$

$$SD \therefore SEM = \frac{3.35}{\sqrt{100}} = 0.335mm$$

95% CI = $\bar{x}$ ± (1.96 * SEM)
= 4.01 ± 0.66
= (3.35, 4.67) mm

Q3.

The 95% CIs do not overlap, so the 2 means are significantly different (p>0.05) with the symptomatic group having the larger mean leg length difference.

$$n^1 = 1000 \quad \bar{x}_1 = 5.40mm; \sigma_1^{\ 2} = (5.32)^2 = 28.30mm^2$$
$$n^2 = 100 \quad \bar{x}_2 = 4.01mm; \sigma_2^{\ 2} = (3.35)^2 = 11.22mm^2$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{\sigma_1^{\ 2}}{n_1} + \frac{\sigma_2^{\ 2}}{n_2}}} = \frac{1.39}{0.375} = 3.71 \quad \therefore \ p > 0.01$$

[Note from JH: Colin Sharpe should have said s^2 rather than σ^2]

The 2 means differ significantly; the null hypothesis of no difference can be rejected – the probability of finding a difference as extreme or more extreme than that observed is less than 0.01, if the null hypothesis were true.

Q4.

A difference of 1.39 mm in leg length will not be measurable with a tape measure.

Q5.

Inspect the column labelled ‘Cumulative Relative Frequency’ for the 100 asymptomatic men. 96% of the normal men have leg length differences less than 10 mm. 15% of the symptomatic men have leg length differences more than 10 mm. From this one gets the impression that the two distributions begin to differ fro differences more than 10mm. This impression can be verified by calculating x^2.

(i) Compare the 2 distributions of leg length difference, for differences less than 10 mm.

	Symptomatic	Asymptomatic	Row Totals
0-5 mm	625	67	692
6-10 mm	225	29	254
	850	96	
			N=946

$X^2 = 0.612$, df=1

$\therefore p>0.25$ i.e. the distributions do not differ significantly for LLD $\leq$ 10 mm

(ii)

	Symptomatic	Asymptomatic	Row Totals
0-5 mm	625	67	692
6-10 mm	225	29	254
11-20 mm	133	4	137
	983	100	
			N=1083

$X^2 = 8.13$, df=2

$\therefore 0.01 < p < 0.02$ i.e. the distributions do differ significantly, but only when LLDs >10 mm are considered as well.

Conclusion: One cannot attribute symptoms to a leg length difference of 10 mm or less, because the distributions of leg length difference for symptomatic vs asymptomatic subjects do not differ when LLD $\leq$ 10 mm.

Q6.

Just because a given patient has a LLD > 10 mm does not mean that one can conclude that his symptoms are secondary to the LLD. The only way to decide is to correct the LLD by thickening the sole of the shoe on the shorter leg – if symptoms are relieved, one may presume a relationship between symptoms and LLD.

See: C.R. Sharpe. *Leg Length Inequality*. Can. Fam. Physician; vol 29: 333-336; 1983

Postscript

Two Vancouver physicians, J.P. Gofton and G.E. Trueman have suggested that unilateral idiopathic osteoarthritis of the hip, a common crippling disorder, might be secondary LLD; CMAJ (1971) 104, 791-9. If so then it might be preventable by shoe modification before symptoms develop.

For a while I was starting to screen my patients with a view to doing a prospective study. Even people with large (2cm) LLDs often refused to consider shoe modification, for cosmetic reasons.

Then I started to think. I tracked down Dr. H.A. Steiner, the second author of the 1946 study. I suggested that we do the 40 year follow-up study on the 1100 veterans – they would be easy to track down via the Veterans' Administration: all we would need to do was get them to answer a question and get bilateral hip x-rays for each. By such a 'cohort' study, we could test Gofton and Trueman's hypothesis.

Dr. Steiner agreed and proceeded to try to locate their stored data. He discovered that it had been stored in a fireproof government building, designed to store government archives. There had been a fire – everything went up in smoke except the building.

PJR Nichols (BMJ 1960; 1 : 1863-5) was the first person to correctly interpret the significance of Rush and Steiner's data.