Simulated Leg-Length Discrepancy: Its Effect on Mean Center-of-Pressure Position and Postural Sway

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ABSTRACT. Mahar RK, Kirby RL, MacLeod DA: Simulated leg-length discrepancy: its effect on mean center-of-pressure positions and postural sway. Arch Phys Med Rehabil 66:822–824, 1985.
• We hypothesized that leg-length discrepancies of as little as 1cm would induce a significant postural shift and increase the extent of postural sway. We had 14 normal volunteers stand on a force platform with their feet in a standard position. Center-of-pressure data were recorded at 100Hz for 20 seconds while the subjects stood barefoot with no lifts or (in random order) with lifts of 1, 2, 3, and 4cm under their left and right feet. From these data we derived the mean center-of-pressure position and the extent of postural sway. Lifts of as little as 1cm shifted the mean center-of-pressure toward the longer leg to a statistically significant extent ($p<0.001$), the mean difference compared with the barefoot condition being 6.1% of the distance between the feet; increasing the discrepancy did not proportionately increase the effect. The postural sway (total travel of the center-of-pressure) in a mediolateral direction increased significantly with a 1cm discrepancy ($p<0.01$), and continued to increase in proportion to the magnitude of the discrepancy. There were no effects on anteroposterior position or sway and no influence of left-right dominance. These results support our hypothesis that a leg-length discrepancy of as little as 1cm may be biomechanically important.

KEY WORDS: Biomechanics; Leg-length inequality; Posture

A leg-length discrepancy may affect posture and lead to the development of problems in the knee, hip, and lumbar spine.[1,4,6] Gofton and Trueman[6] found an association between leg-length discrepancy of 1.27 to 2.54cm (1/2 to 1in) and superolateral osteoarthritis of the hip on the longer side. Nichols[16] found a leg-length discrepancy of ≥1.27cm 1(½in) in 22% of 180 airmen complaining of low-back pain; a similar discrepancy was found in only 7% of 1,007 airmen who were without pain. Friberg[2] found that 798 patients with unilateral low-back or hip symptoms had significantly more leg-length inequality than did 359 controls. Others have asserted that differences of as little as 6mm (which are common[17]) require correction, particularly in persons whose legs are subjected to repetitive loading, as during jogging.[18]

However, Gross[7] found that otherwise well young adults with <2cm of leg-length discrepancy perceived no functional effect. Gross[8] also evaluated 35 marathon runners and found seven with a leg-length discrepancy of ≥1cm who subjectively reported no effects on their performance. Grundy and Roberts[9] compared 70 patients who had chronic low back pain with 70 age- and sex-matched controls and found no significant difference in the incidence of leg-length asymmetry. Similarly, Hult[14] found no difference between the incidence of leg-length discrepancy among Swedish factory workers complaining of low-back pain and that among the rest of the work force at the plant. Gibson's group[3] found no symptoms or degenerative changes radiologically in 15 subjects evaluated 10 years after femoral fractures that resulted in shortening of ≥1.5cm.

Recognizing that the case-control studies to date had produced conflicting results, we wondered whether the sensitive instrumentation now widely used to study posture and balance[11] might provide new insight. If a leg-length discrepancy does produce joint problems, presumably it does so by altering body posture and mechanics.[5]

We therefore hypothesized that simulated leg-length discrepancies of as little as 1cm would induce a significant postural shift and would increase postural sway.

METHODS

Subjects

We assessed 14 volunteers, eight men and six women, with a mean (1 SD) age of 28.3 (8.4) years, height of 168.7 (8.6)cm and weight of 63.4 (10.0)kg. Eleven of the subjects were right-handed. None had a leg-length discrepancy on the basis of interview and examination.[20]

Procedure

We asked each subject to stand comfortably on a force platform[a] with the knees extended and shoes removed and to look ahead at a fixed object in a well lit, quiet room. The foot angle was 12° from the sagittal plane and the base width at the heels was 10cm.[15]

Center-of-pressure data from the force platform were sampled[b] at 100Hz for 20 seconds, and stored on a computer.[c] From these data we derived the mean center-of-pressure position (expressed as the percentage of the distance from heel to toe and from the midline of the right foot to that of the left)

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Table 1: Position of Center-of-Pressure with Simulated Discrepancies

	0 cm	1 cm	2 cm	3 cm	4 cm
Left lift		54.7 (5.1)*	56.9 (5.0)*	52.1 (10.6)	55.7 (10.7)‡
	47.4 (5.3)				
Right lift		42.5 (4.8)†	42.9 (7.5)‡	40.5 (6.6)§	40.5 (8.8)‡

Mean (1 SD) values, expressed as a percentage of the distance (from right toward left) between the midlines of the feet.
Level of significance from matched-pairs t-tests between no discrepancy (0 cm) and each of the simulated leg-length discrepancies: *$p<0.0001$; †$p<0.001$; ‡$p<0.05$; §$p<0.01$.

and the extent of anteroposterior and mediolateral postural sway (expressed as total travel in centimeters).[15] The reproducibility of postural sway data has been well documented.[12,19]

Each subject initially was tested with no lift and, to determine whether an artifact was being introduced by merely making the subject artificially taller, with 2cm lifts under both feet. We then simulated, in random order, leg-length discrepancies of 1, 2, 3, and 4cm under each foot, using cork lifts that were similar in shape and size to the subject's foot.

Matched-pairs t-tests were used to compare conditions and two-sample t-tests were used to compare right- and left-handed subjects.

RESULTS

A simulated leg-length discrepancy of 1cm produced a statistically significant shift in the mediolateral position of the center-of-pressure toward the longer leg. Increasing the discrepancy did not produce a proportionately greater shift (table 1, fig 1). All discrepancies produced a statistically significant increase in mediolateral postural sway, one that was proportionately greater as the magnitude of the discrepancy increased (table 2, fig 2).

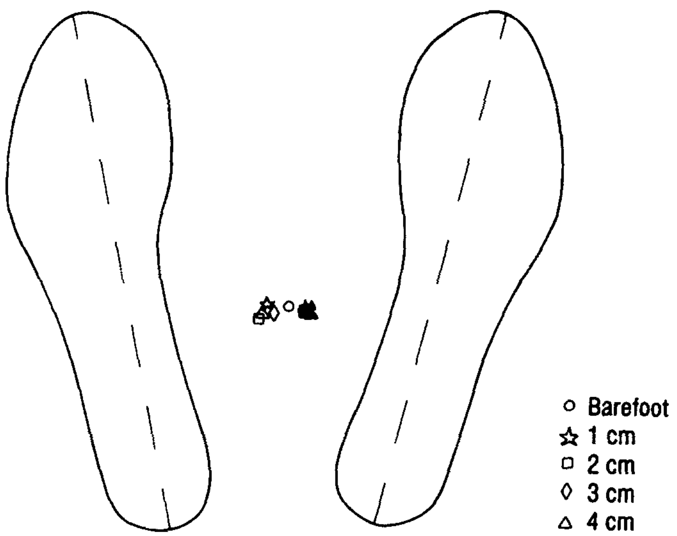

Fig 1—Effect of simulated leg-length discrepancies on the mean center-of-pressure position. Each point represents the mean mediolateral and anteroposterior position of 14 normal subjects. The open symbols indicate lifts under the left foot, the closed symbols indicate lifts under the right foot, and the open circle indicates the findings with no lift.

In the anteroposterior direction we found no consistent and significant relationship between the simulated discrepancies and either the mean center-of-pressure position or the extent of postural sway.

Comparisons between right- and left-handed subjects to determine the influence of dominance did not reveal any significant differences, nor could we find any consistent and significant difference between the effects of lifts under the left and right legs.

There were no significant differences between the data recorded with no lifts and while the subject stood with 2cm under both feet.

DISCUSSION

The data from this study show that a simulated leg-length discrepancy shifts the center-of-pressure toward the longer leg and that a discrepancy of as little as 1cm produces a shift in mediolateral position of similar magnitude to that seen with greater discrepancies. The amount of postural sway in a mediolateral direction increased with the magnitude of the leg-length discrepancy. Both findings support the argument that minor leg-length discrepancies may be biomechanically significant.

Raising one side of a rigid object shifts the center-of-pressure to the low side. Since the opposite occurred in our subjects, one can infer that compensations must have taken place. A similar tendency has been reported by Hasselkus and Shambes[10] when evaluating the effect of leaning forward—the mean center-of-pressure of their subjects moved posteriorly. Hellebrandt and associates[13] found that wearing an army pack on the back led to a forward shift of the center-of-pressure. It is unclear whether this tendency to overcorrect, in our subjects and in the other two studies described, is an overcompensation or a precaution against falling.

There are some limitations to a study of this type. The simulated leg-length discrepancies in our study were of brief duration, with little time for adaptation. However, we reasoned that most subjects were probably accustomed to discrepancies of this magnitude, such as might be encountered when standing on inclines or on uneven ground. Even if the effects of such short-term discrepancies do disappear with time, the results of this study may have relevance to those clinical situations when leg length is suddenly changed—as in the application or removal of a plaster cast, or the correction of a leg-length discrepancy by adding a shoe lift or lengthening a prosthesis.

Caution also must be exercised in drawing from our results

Table 2: Postural Sway in a Mediolateral Direction with Simulated Discrepancies

	0 cm	1 cm	2 cm	3 cm	4 cm
Left lift		34.1 (2.0)*	35.2 (3.7)*	35.3 (4.7)§	37.3 (2.7)‡
	31.8 (3.2)				
Right lift		34.7 (3.4)†	35.8 (3.1)‡	36.4 (3.7)‡	37.8 (3.9)‡

Mean (1 SD) values, expressed as cm of travel of the center-of-pressure in 20s.
Level of significance from matched = pairs t-tests between no discrepancy (0 cm) and each of the simulated leg-length discrepancies: *$p<0.01$; †$p<0.001$; ‡$p<0.0001$; §$p<0.05$.

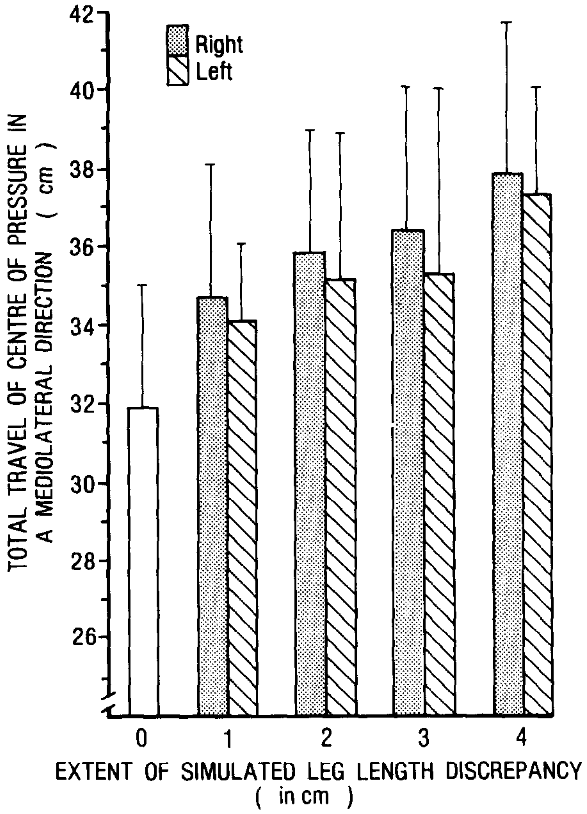

Fig 2—Effect of simulated leg-length discrepancies on the mediolateral postural sway (total travel of the center-of-pressure over 20s). The mean (+1SD) values of 14 normal subjects are shown.

any conclusions about the long-range effects of a leg-length discrepancy and about the effects of such discrepancies on dynamic activities, such as walking and running. Nor can one generalize with confidence about persons with actual leg-length discrepancies based on this study of normal subjects.

Yet, the results of this study support our hypothesis that a simulated leg length discrepancy of as little as 1 cm results in a significant shift of the mean center-of-pressure position (to the longer leg side) and an increase in postural sway.

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Suppliers

a. Force platform (model 9281B). Kistler Instruments AG, CH-8408 Winterthur, Switzerland

b. Analogue to digital converter (model 6942A multi-programmer). Hewlett-Packard, 3404 East Harmony Road, Fort Collins, CO 80525

c. Computer (model 9826). Hewlett-Packard, 3404 East Harmony Road, Fort Collins, CO 80525

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