Association Between Leg Length Discrepancy and Posterior Tibial Tendon Dysfunction

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〈 Clinical Research 〉

Association Between Leg Length Discrepancy and Posterior Tibial Tendon Dysfunction

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Abstract: Background. *Leg length discrepancy (LLD) is associated with a variety of orthopaedic disorders and biomechanical gait changes that involve possible overload of the posterior tibial tendon (PTT). In view of the biomechanical disturbances induced by LLD, an association may exist between LLD and PTT dysfunction (PTTD).* Purpose. *To compare the frequency and magnitude of LLD between subjects with and without PTTD and ascertain whether associations exist between clinical features and presence of dysfunction.* *Study Design. Case–control study.* Methods. *A total of 118 patients with a diagnosis of PTTD were seen between January 2009 and September 2012 and compared with 118 gender-matched and race-matched volunteers. The frequency of LLD, the mean absolute LLD, and the mean relative LLD were measured by conventional (radiographic) or computed tomography scanography and compared between cases and controls.* Results. *The prevalence of LLD and mean absolute and relative LLD values were significantly greater in the case group (94.9%, 5.64 mm and 7.36%, respectively) than in the control group (79.7%, 3.28 mm and 4.18%, respectively) (*P < *.001).* Conclusion. *The findings of this study demonstrate a relationship between LLD and PTTD. In light of the major biomechanical changes it induces, LLD may be a predisposing factor for development of PTTD.*

Level of Evidence: *Prognostic, Level III: Case–control series, retrospective*

Keywords: leg length discrepancy; posterior tibial tendon; tendon dysfunction; inequality

The key clinical findings for diagnosis of PTTD were first described approximately 3 decades ago, and the main risk factors for this condition are still unclear. Mann and Holmes assessed 67 patients with PTTD in a search for potential predisposing factors and found that 60% of patients with the condition had one of the following clinical findings:

> "Posterior tibial tendon dysfunction (PTTD) is considered the leading cause of adult-acquired flatfoot and is estimated to affect 5 million individuals in the United States alone."

Posterior tibial tendon dysfunction (PTTD) is considered the leading cause of adult-acquired flatfoot and is estimated to affect 5 million individuals in the United States alone.[1,2] Kohls-Gatzoulis et al reported a prevalence rate of 3.3% in a sample of 1000 Englishwomen over the age of 40.[3] hypertension, obesity, diabetes mellitus, history of trauma or surgery to the medial ankle, or corticosteroid exposure. Furthermore, 52% of subjects had hypertension, diabetes mellitus, or obesity. The strongest correlation was observed between PTTD and obesity.[4] Although Prado et al[5] did not identify

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any areas of reduced vascular density in 40 cadaveric *posterior tibial tendon* pairs, some studies have demonstrated the presence of areas of hypovascularization, approximately 14 mm in length, located 4 cm from the insertion at the navicular bone.[5-8] Godoy-Santos et al[9] observed a significant difference in allele T presence of the enzyme MMP-8 between individuals with PTTD and controls, and considered it a genetic marker for this tendinopathy.[9,10] Despite the systemic or bilateral effect of most of these potential risk factors, bilateral PTTD is quite rare, occurring in roughly 10% of cases.[11-14]

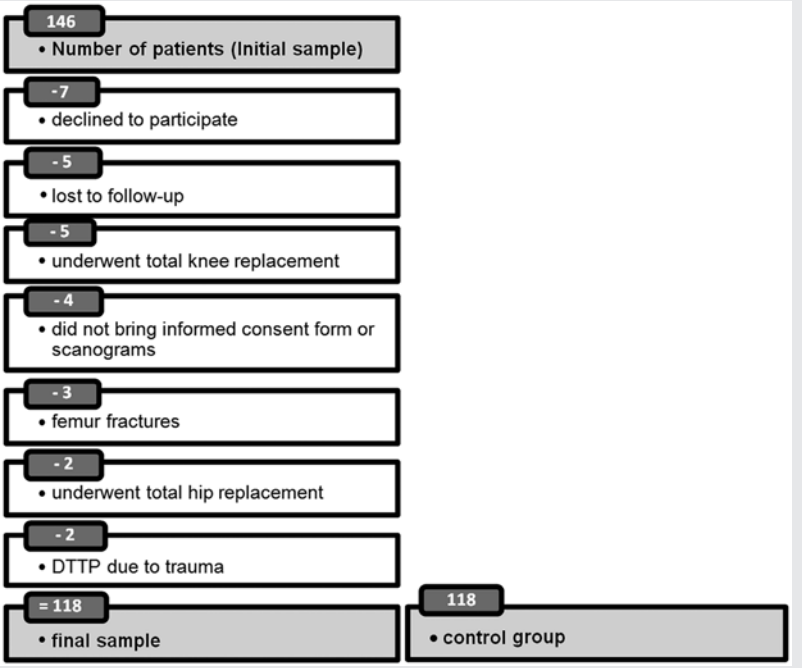
Leg length discrepancy (LLD) induces compensatory changes that have an impact on the biomechanics of the spine, pelvis, and joints of the lower extremity. Although the point where LLD becomes clinically relevant has yet to be established, persons with LLD may exhibit such changes as compensatory lumbar scoliosis, increased hip abduction, external leg rotation, hyperpronation, increased oxygen consumption during walking, and impaired quality of life.[15-23] Several orthopaedic disorders have also been associated with LLD, including low back pain, iliotibial band syndrome, hip osteoarthritis, intervertebral disc disease, and stress fractures of the femur, tibia, fibula, and metatarsal bones.[16-19,24-37]

The presence of LLD was associated with relative hyperpronation of the foot on the shorter limb, as well as a shortening of the contact phase and prolongation of the propulsive phase of the gait cycle, increasing functional demands on the PTT.[15,23] Conversely, in the longer leg, there is excessive eversion of the hindfoot during the stance phase, which may increase stress on the PTT.[38] By means of these 2 mechanisms, LLD may be associated with overloading of the PTT in the longer and shorter limbs alike, perhaps leading to early wear. Therefore, we have raised the hypothesis that an association may exist between LLD and PTTD. However, a literature search found no studies on this potential correlation.

The objective of this study was to compare the frequency and severity of LLD in a sample of patients with PTTD and in a control group of subjects without PTTD, so as to evaluate the potential association between LLD and PTTD. To evaluate the dysfunction more broadly, we also attempted to correlate clinical features with the presence of disease.

Figure 1.

Study flowchart.



Materials and Methods

The present study used a case–control design and was approved by the research ethics committee of the facility where it was carried out, a public, university-affiliated hospital. Patients with a diagnosis of PTTD and healthy controls were recruited from the outpatient orthopaedic surgery service of the hospital and from an orthopaedic surgery clinic between January 2009 and September 2012. All subjects in the case and control groups provided written informed consent for study participation. The case group only included patients with a diagnosis of PTTD of unknown origin; those with a history of recent trauma that might have triggered their symptoms and those with a history of orthopaedic surgery of the lower extremity that might affect femoral and/or tibial length were excluded. Overall, 146 patients were eligible for the study and 118 met all criteria for inclusion in the case group. Twenty-eight patients were excluded: 5 due to total knee replacement, 2 due to total hip replacement, 3 due to femoral fractures treated with surgical fixation, 2 with a history of trauma that was clearly the causal factor of PTTD, 7 who ultimately declined to take part in the study, 4 who did not provide written informed consent or did not bring their scanograms, and 5 who were lost to follow-up. The control group comprised 118 skeletally mature subjects matched by race and gender to the control group and with no history of orthopaedic interventions that might affect lower limb length (Figure 1).

PTTD was diagnosed clinically on the basis of a history of pain and at least one of the following findings: (*a*) enlargement of the medial retromalleolar region or over the posterior tibial tendon insertion at the navicular, (*b*) fallen medial

longitudinal arch with forefoot abduction, and (*c*) difficulty lifting one or both feet. Weight-bearing radiographs of the feet and ankles were obtained from all patients to assess the severity of deformity and detect any secondary disorders, such as osteoarthritis. All subjects in the case group also underwent ultrasonography or magnetic resonance imaging (MRI) for structural assessment of the PTT. At least one of the following findings was detected: longitudinal intrasubstance tears, PTT diameter measure ≥2.5-fold the diameter of the flexor digitorum longus tendon, and fluid buildup within the PTT sheath.[39-45]

LLD was treated as a continuous variable, measured in millimeters on conventional (radiographic) or computed tomography (CT) scanograms, and the assessing investigator was blinded to patient diagnosis and study objective. Both absolute LLD (the difference in mm between the lengths of the lower limbs) and relative LLD (the percent difference between the shorter and longer limb) were measured. On comparison of its prevalence among groups, LLD was considered a categorical variable.

Associated factors were considered categorical variables. Dyslipidemia, hypertension, and diabetes mellitus were considered present in individuals who were receiving dietary or drug therapy for any of these conditions. Hypothyroidism, rheumatoid arthritis, hyperuricemia, and psoriasis were considered present in patients with an established diagnosis and current drug treatment. Obesity was considered present in individuals with a body mass index above 30. Smoking was defined as the habit of smoking 1 or more cigarettes per day.

All data were collected by the same investigator at the study site and entered into a specifically designed form. Forms were then collated and data entered into a Microsoft Office Excel 2010 spreadsheet by the same investigator.

Statistical Analysis

A comparison was made of the prevalence and severity of LLD and of the presence of comorbidities in the case and control groups. Student's *t* test for independent samples or the Mann–Whitney *U* test were used as appropriate for between-group comparison of continuous data. The χ^2 test was used for comparison of proportions. To control confounding factors we performed multivariate logistic regression with the inclusion of clinical variables potentially associated with PTTD (age, sex, race, body mass index, presence of diabetes mellitus, hypertension, and dyslipidemia), as well as the relative value of LLD as possible variable associated with the presence of PTTD outcome.

Quantitative variables were expressed as means and standard deviations, and categorical variables as absolute and relative frequencies. The significance level was set at 5%. All statistical analyses were carried out in the SPSS (Statistical Package for the Social Sciences) 13.0 software environment.

Table 1.

Subject Profiles in the Case and Control Groups.

	Cases	Controls	*P*
Mean age	62	49	<.001
Gender: male/female	15/103	17/101	
Skin color: white/black	114/4	114/4	
Number of cases with no LLD	6	24	
Mean absolute LLD	5.69	2.91	<.001
Mean relative LLD	2.77	1.11	<.001
Number of cases with right leg longer	51	30	
Number of cases with left leg longer	61	64	

Abbreviation: LLD, leg length discrepancy.

Results

Mean age was 62 years in the case group and 49 years in the control group. Overall, 103 patients (87.28%) in the case group were female, versus 101 (85.59%) in the control group. In both groups, most subjects were white (114 of 118 [96.61%] in the case and control groups). Six patients in the case group and 24 subjects in the control group had no discrepancy in leg lengths (LLD = 0). The mean absolute and relative LLD values were 5.64 mm and 7.36%, respectively, in the case group and 3.28 mm and 4.18%, respectively, in the control group. The right leg was longer in 51 patients in the case group and 30 subjects in the control group. The left leg was longer in 61 patients in the case group and 64 subjects in the control group (Table 1).

There was a difference between the prevalence of LLD between groups. LLD values of 0, indicating absence of LLD, were observed in 6 patients in the case group and 24 subjects in the control group. The mean absolute and relative LLD were higher in the case group compared with the control group.

Case Group

Mean absolute and relative LLD values in the case group were 5.64 mm and 7.36%, respectively. Six cases (5.08%) had no detectable LLD. Regarding

Table 2.

Characteristics of the Case Group.

	n	%
Right-sided PTTD	43	36.44
Left-sided PTTD	63	53.38
Longer leg affected	49	41.52
Shorter leg affected	51	43.22
Bilateral involvement	12	10.16

Abbreviation: PTTD, posterior tibial tendon dysfunction.

PTTD, 43 patients (36.44%) had right-sided dysfunction, 63 (53.38%) had left-sided dysfunction, and 12 (10.16%) had bilateral involvement. As shown in Table 2, the longer leg was affected in 49 cases (41.52%) and the shorter leg in 51 cases (43.22%). The remaining patients either had no LLD or had bilateral PTTD (Table 2).

Absolute LLD values were in the range of 1 to 4.9 mm in 50 patients (42.37%), in the 5 to 9.9 mm range in 47 patients (39.83%), in the 10 to 14.9 mm range in 9 patients (7.62%), and in the 15 to 20 mm range in 6 patients (5.08%; Table 3).

Control Group

Mean absolute and relative LLD values in the control group were 3.28 mm and 4.18%, respectively. Twenty-four controls (20.33%) had no detectable LLD. Sixty-four controls (54.23%) had a longer left leg and 30 (25.42%) had a longer right leg. Absolute LLD values were ≤4.9 mm in 58 controls (49.15%), in the 5 to 9.9 mm range in 31 controls (26.27%), and between 10 and 14.9 mm in 5 controls (4.23%; Table 4).

There was a significant between-group difference in the prevalence of absolute LLD ranges (Figure 2).

In relative values, LLD corresponding to ≤5% of the length of the longer leg were detected in 35 patients (29.6%); 49 (41.5%) had a difference corresponding to 5% to 10% of the length of the longer leg, 23 (19.5%) had a discrepancy of 10% to 20%, and 5 (4.2%) had a discrepancy of 20% to 25%. Among controls, 55 (46.6%) has an LLD corresponding to ≤5% of the length of the longer leg; 28 (23.7%) had a difference of 5% to 10% and 11 (9.3%) had a discrepancy of 10% to 20% (Table 5).

Mean relative LLD was significantly greater in the case group (Mann–Whitney *U* test, $P < .001$) than among controls. There was a significant between-group difference in the prevalence of relative LLD ranges (Figure 3).

There were also significant between-group differences in the prevalence of other factors. Subjects in the case group were more likely to have dyslipidemia, hypertension, diabetes mellitus, and rheumatoid arthritis. There were no between-group differences in the prevalence of hypothyroidism or smoking. Hyperuricemia and psoriasis were only present in the case group (2 patients each; Table 6).

A multivariate logistic regression analysis, controlling for clinical characteristics such as age, race, sex, body mass index, and presence of diabetes mellitus, hypertension, and dyslipidemia, indicated that the DCMI relative was associated with the presence of PTTD (coefficient = 1, 14, standard error = 0.04, $P < .001$).

Discussion

The present study showed that LLD is more prevalent and more severe in patients with PTTD. Our findings corroborate previous evidence of a greater risk of lower limb injury in persons with LLD.

Within this context, Mahmood et al assessed 26 patients with LLD and found a greater prevalence of unilateral plantar fasciitis in the longer limb.[46] Korpelainen et al compared 31 athletes with a history of at least 3 stress fractures with a group of 15 athletes with no history of fractures and found an association between LLD and development of stress fractures.[35] Fields et al found a higher incidence of injury among runners with LLD.[47]

The changes in gait biomechanics seen in patients with LLD were detected both in the shorter leg and in the longer limb, and some of these changes may be associated with overloading of the posterior tibial tendon. Previous studies have shown that, in the longer leg, there is excessive eversion of the hindfoot,[38] the foot bears a greater load overall and more of this load is shifted to the forefoot.[48] In the shorter leg, compensatory toe walking occurs,[49] and the propulsive phase of the gait cycle is prolonged.[15,50]

Leppilahti et al investigated the potential association between LLD and Achilles tendon rupture in 100 patients undergoing tendon repair and found no significant association. The mean absolute LLD was 5 ± 4 mm; 59% of patients had a longer left leg, 31% had a longer right leg, and 10% had no detectable LLD. Among patients with LLD, 42% had experienced tendon rupture in the longer leg and 48% in the shorter leg.[51]

To the best of our knowledge, this was the first study to test for a potential association between LLD and PTTD. There were significant differences in mean absolute and relative LLD values between cases and controls, which suggest that LLD may predispose to development of PTTD. Among cases, the frequency of PTTD was similar on both sides, suggesting that the presence of an LLD may contribute to the development of PTTD in the longer and shorter leg alike. In this group, LLD was statistically more frequent and more severe than among controls ($P < .001$), which suggests that even minor degrees of LLD may not be as harmless as some authors have maintained.[52,53]

In our sample, mean BMI was higher among cases (28.58 kg/m^2) than among controls (24.87 kg/m^2), and the proportion of obese subjects was significantly greater in the case group than in the control group ($P < .001$). This corroborates the findings of Mann and

Table 3.

Stratification of Absolute LLD Values in the Case Group.

LLD (mm)	n	Left Leg Longer	Right Leg Longer	Longer Leg Affected	Shorter Leg Affected	Bilateral Involvement
0	6					
≤4.9	50	25	25	20	27	3
5-9.9	47	25	22	22	17	8
10-14.9	9	7	2	4	4	1
15-20	6	4	2	3	3	
Overall	118	61	51	49	58	12

Abbreviation: LLD, leg length discrepancy.

Table 4.

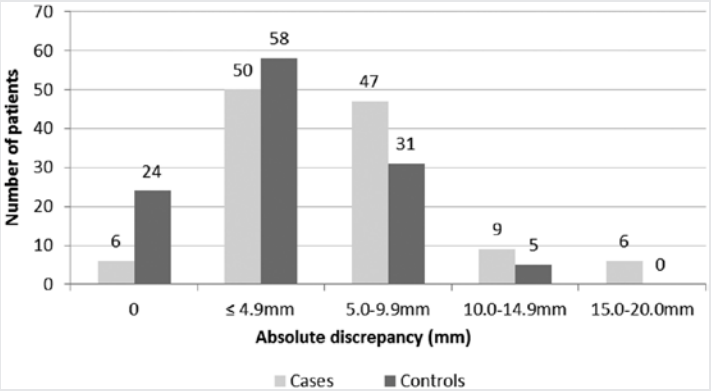
Stratification of Absolute LLD Values in the Control Group.

LLD (mm)	n	Left Leg Longer	Right Leg Longer
0	24		
≤4.9	58	36	22
5-9.9	31	24	7
10-14.9	5	4	1
15-20	0		
Overall	118	64	30

Abbreviations: LLD, leg length discrepancy

Figure 2.

Prevalence of LLD, stratified by absolute discrepancy (mm), in the case and control groups.



Holmes, who, in their analysis of potential risk factors, found that the strongest correlation was between PTTD and obesity.[4] Dyslipidemia, hypertension, diabetes mellitus, and rheumatoid arthritis were significantly more common in cases than in controls, corroborating the findings of previous studies.[4,54] Although most factors associated with development of PTTD are systemic or bilateral, previous studies have shown that dysfunction is bilateral in approximately 10% of cases, a frequency similar to that seen in our patients.

The sensitivity and the specificity of radiographic and CT scanograms are not determined, but several authors have demonstrated adequate reliability and accuracy of the methods for assessing LLD.[55-58] Limitations of this study include the relatively younger mean age of controls as compared with cases. Although LLD is not expected to change with advancing age, some controls might develop PTTD—and, therefore, cross over to the case group—over time.

Most studies of LLD use absolute values for analysis, disregarding the biomechanical importance of the severity of LLD in relation to total lower limb length. In this study, we used both absolute and relative LLD values for analysis and found that both parameters were, on average, higher among patients with PTTD than among controls, which is indicative of an association between

Table 5.

Stratification of Relative LLD Values in the Case and Control Groups.

LLD (%)	0	≤5%	5% to 10%	10% to 20%	20% to 25%
Case group	6	35	49	23	5
Control group	24	55	28	11	0

Abbreviation: LLD, leg length discrepancy.

Figure 3.

Prevalence of LLD, stratified by relative discrepancy (%), in the case and control groups.

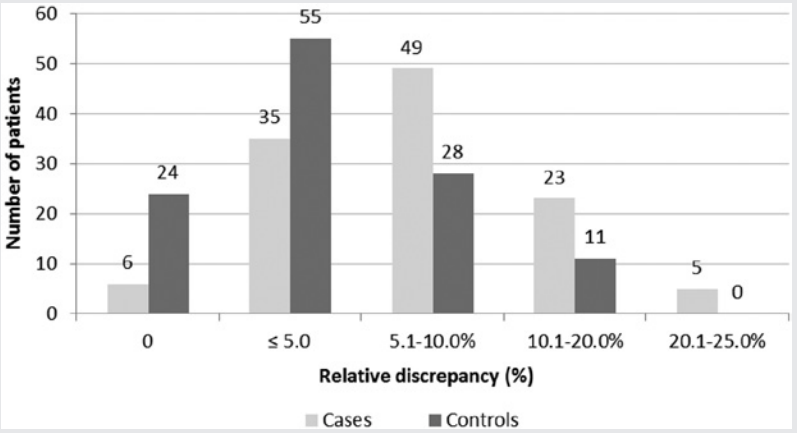


Table 6.

Prevalence of Other Factors in the Case and Control Groups.

	Cases, n (%)	Controls, n (%)	*P*
Dyslipidemia	73 (61.86)	34 (28.81)	.006
Hypertension	59 (50)	21 (17.79)	<.001
Diabetes mellitus	23 (19.49)	4 (3.38)	<.001
Obesity	35 (29.66)	11 (9.32)	<.001
Hypothyroidism	19 (16.1)	16 (13.55)	.58
Rheumatoid arthritis	8 (6.77)	1 (0.84)	.02
Smoking	9 (7.62)	10 (8.47)	.81
Hyperuricemia	2 (1.69)	0 (0)	
Psoriasis	2 (1.69)	0 (0)	

LLD and PTTD. Future studies on the utility of LLD compensation strategies in the prevention of PTT overload are encouraged.

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