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Relationship between foot posture index and plantar pressure distribution in patients with minor limb length inequality: a case series study

Relación entre el índice de postura del pie y presiones plantares en estática en pacientes con dismetrías de longitud menores de los miembros inferiores: estudio transversal de serie de casos

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Palabras clave:

Dismetría de longitud de miembros inferiores, discrepancia de longitud, heterometrías índice de postura del pie, presiones plantares, podobarografía, estática, compensaciones.

Resumen

introducción: La presencia o no de compensaciones en pacientes con asimetría de longitud de miembros inferiores (AMI) menores actualmente sigue siendo un motivo de debate. El presente estudio trató de comparar las diferencias en la posición en estática del pie y en las presiones plantares en los miembros corto y largo de pacientes con AMI menores.

Pacientes y métodos: Se estudiaron a sujetos con AMI (diagnosticados mediante telerradiografía de miembros inferiores) que acudieron a una clínica del pie en los que se valoró el índice de postura del pie (FPI) y el porcentaje de presiones plantares en estática que recibía cada pie (derecho e izquierdo). Se analizaron la presencia de diferencias en el FPI y en la distribución de las presiones plantares entre el miembro corto y largo de los sujetos.

Resultados: Se incluyeron un total de 19 sujetos con AMI anatómica en el estudio. No se encontraron diferencias en el FPI entre el miembro corto y largo de pacientes con AMI ni en la distribución del porcentaje de presiones plantares que recibe cada miembro en estática.

Conclusión: Estos datos no apoyan la idea de patrones de compensación generados en pacientes con AMI por los que se modifica la posición del pie en estática o se aumenta o disminuyen las presiones plantares en el miembro largo o corto en estática. Las características especiales de la muestra utilizada (pacientes con dolor o molestias en el pie o miembro inferior) y la potencia baja del estudio podría haber influido en la ausencia de resultados estadísticamente significativos.

Keywords:

Limb length discrepancy, leg discrepancy, leg length inequality, foot posture index, plantar pressures, podobarography, static, compensations.

Abstract

Introduction: The presence of compensations in patients with limb length inequality (LLI) is still an issue of debate. The present study compared differences in the static position and in the plantar pressure distribution during standing of both feet of patients with LLI.

Patients and methods: The study included patients with LLI (diagnosed with full limb x-rays) who went to a foot office by different reasons. The foot posture index (FPI) and the percentage of plantar pressure distribution between the left and right feet during static standing were measured in both feet. Differences in the FPI and plantar pressure distribution of the long and short limbs were analyzed.

Results: A total of 19 subjects were included in the study. No differences were found in the FPI neither the plantar pressure distribution in standing static between the short and long limbs of patients with LLI.

Conclusion: Data of the present study do not support the idea of compensation patterns in LLI patients in which foot position or plantar pressure distribution between the short and long limbs in static position are changed. However, singular characteristics of the sample of the study (patients with pain or ailments in the foot or lower limb) and the small power of the study could have influenced in the absence of statistical significant results.

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INTRODUCTION

Inequality of the lower limbs or limb length discrepancy (LLD) and its clinical significance has been a controversial issue in the medical literature for decades, and barely any conclusion has been satisfactorily stablished. Historically, LLD has been divided in two main groups: anatomic and functional[1]. Anatomic (or real) LLD is defined as a structural deformity originated by a real difference in the length of the osseous segments from the femoral head to distal tibia. Functional LLD is defined as a difference in the length between both limbs that is not related to a inequality of the length of the osseous segments but because a mechanic problem such us muscle contractures, mechanical alignment or the lower limb (static or dynamic) in any of the three planes, or by muscular weakness or shortening[2]. Regardless of its origin, different studies have pointed out a possible relationship between the presence of LLD and scoliosis[3], pain in the lower spine (lumbalgia, sacroileitis and lumbosacral pain)[4] vertebral arthritis[5,6], hip and knee osteoarthrosis[7,8], stress fractures[9], stress fractures in runners[10,11], patelofemoral pain syndrome[12], adult adquired flatfoot[13], Achilles tendinopathy[14] and plantar fasciopathy[15].

A central point regarding the concept of LLD is the compensation stablished in the lower limbs, pelvis and spine in these patients when they have an anatomic or real LLD. It is widely accepted that the presence of LLD has postural compensations in the individual[16]. Much of these postural compensations are associated with LLD usually bigger than 3-4 cm and related to polio, equinovarus feet or other ailments present in a small amount of population. However, minor LLD (smaller than 2 cm) are present in a large percentage of population[17,18] and it is not clear which are the compensation mechanisms in these cases of small or minor LLD and which is its clinical significance and its contribution to musculoexqueletal ailments.

The increase of load in any of the lower limbs could be a critical factor to explain the presence of musculoexqueletal problems showed en LLD patients. However, this point has not been clarified in the literature[2]. On one hand, there are studies that suggest an increase of load in the longer limb in patients with LLD. Perttunen et al. found an increase in load in the longer limb in patients with LLD[19]. Song et al.[20] also found an increase in the mechanical work of the longer lower limb in patients with anatomical LLD and Mahmood et al.[15] found an association between the presence of plantar fasciopathy in the longer limb of patients with LLD which would suggest an increase of load in that limb. On the other hand, White et al.[21] found an increase of loads in the short limb in patients with LLD during walking and Swaminathan et al.[22] found an increase in load in the short limb in static conditions in normal patients in which LLD was simulated with the use of raised blocks.

Because all of this, it is necessary a better understanding of the compensations stablished in minor LLD and the effect that LLD has on the mechanical behavior of foot and lower extremity. The present work studied the relationship between the short and long limbs and the position of the foot during static standing in patients with minor anatomic LLD and also with the plantar pressures of each foot during static standing. To fulfill these objectives three main questions were formulated: 1) Are there any differences in the static position of the foot during static standing between the short and long limbs of patients with minor LLD?; 2) Are there any differences in the global plantar pressures of the short and long limbs of patients with minor anatomic LLD during static standing? This question tries to answer if some differences exist in the load the short or long limb support during standing; 3) Is there any association between the pressure in each limb and its position in static standing in patients with minor anatomic LLD? With that question, it was tried to evaluate if load and position of the foot could be related and this could explain some of the compensation mechanism occurred in LLD.

PATIENTS Y METHODS

The design of the present study is a case series cross-sectional study carried out prospectively and for the reporting of the present manuscript the STROBE (Strengthning of Reporting Observational Studies in Epidemiology) statement was followed[23].

Study population

All patients diagnosed of LLD in Clinica del Pie Embajadores (Madrid, Spain) between May 2013 and December 2015 that fulfill the following inclusion criteria were included in the study: Patients older than 18 years old with presence of anatomical LLD diagnosed with full limb radiography made in weightbearing condition bigger than 5 mm and lower than 20 mm. Exclusion criteria were those subjects with history of foot or lower extremity surgery, congenital escoliosis, severe malformations in the lower extremity that can cause LLD such us polio, equinovarus foot, etc. All the participants gave informed consent prior to participation in the study. The present study was carried out following the international recommendations for clinical investigations of the WHO held in the Helsinky declaration[24].

Study Variables

Limb length discrepancy was measured using the full limb x-ray of each patient made in weightbearing conditions. For the measurement, the reference points used were the most proximal point of the femoral head and the most distal tibia in the center of the articular ankle joint in each limb. In cases in which x-rays were not in its actual size, measurement was made in the same manner and the values were transformed adjusting to the scale in which the x-ray had been printed.

Foot Posture Index (FPI – 6 version)[25] was carried out in all patients to assess clinical foot position of the left and right

foot of all subject of the study. The assessment of the FPI was made by the same investigator (C.A.L.) which is the second author of the paper and has more than 9 years of professional experience as a podiatrist.

Plantar pressures in static conditions were measured in all subjects to evaluate the amount of load supported by the shorter and longer limbs of subjects with LLD. Subjects stood in static condition in a pressure platform (Podoprint Namrol®, Barcelona, España) that was embedded in the floor. The software of the pressure platform calculates the percentage of pressures that has each feet (right and left) is supported in static position and that was the value that was used for the measurements of the plantar pressures (Figure 1). Two measurements of plantar pressures were taken to each subject. One measurement was taken with the subject looking at front (Figure 2) and the other with the subject looking backwards (rotated 180° from the first measurement) (Figure 3). Order of measurements (front or back) was randomized to avoid a sequence effect in the measurement of the plantar pressures. For the first measurement the subject was order to stood quietly for 1 minute and then the measurement was taken. That measurement catches the percentage of plantar pressures from the total body weight that is loaded in each foot at that instant moment. During the plantar pressures measurement, two investigators were looking at the subject and following the evolution of the plantar pressures in each feet during that time to avoid intentional pitfalls in the measurement. After that, the second measurement was taken following the same protocol. The mean of the two percentages measurements was taken as the final value for each subject. Subjects with only one measurement were discarded from the study.

Statistical Analysis

A descriptive analysis of data was made using mean ± standard deviation for age, FPI of the right and left foot and the difference in length between both limbs. Simple percentage was used for sex and laterality of the short and long limbs. A null hypothesis significant test was performed by means of non-parametric Wilcoxon rank sum test for paired samples to assess the differences in FPI between the short and long limbs and between the percentage of plantar pressures in static condition in the short and long limbs. Finally, a Pearson's linear correlation was carried out to assess the difference of FPI and the difference of plantar pressures between the right and left limbs. Data was analyzed using SPSS software, version 22 (IBM Corp, Armonk, USA).

RESULTS

The sample was initially formed by 22 subjects and 3 of them were discarded because of missing data from the clinical tests performed (2 cases) or because the LLD was fewer than 5 mm (1 case). So, the final analysis was performed in

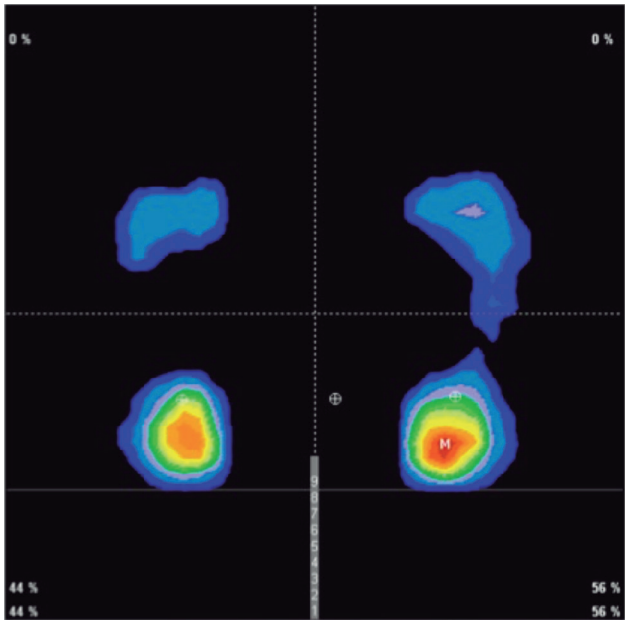

Figure 1. Plantar pressures captured in static condition. Note the total percentage of plantar pressures in each feet.

Figure 2. Measurement took with the subject in position 1.

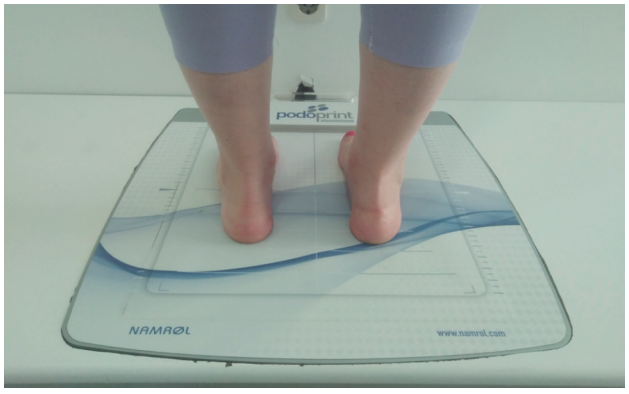

Figure 3. Measurement took with the subject in position 2.

19 subjects. Table I shows the descriptive data of the subjects of the study including age, sex, laterality of short/long limb and amount of LLD of the subjects.

Table II shows the Wilcoxon rank sum test results for paired data with the differences in FPI values in the short and long limbs of the subjects of the study and the difference in the percentage of plantar pressures in static condition between the short and long limbs of the subjects of the study. No significant differences were found in the FPI values between the short and long limbs. No significant differences were neither found in the percentage of plantar pressures between the short and long limbs in static condition of the subjects of the study.

Finally, it was tested the association between the difference in FPI between both feet with the difference in percentage of plantar pressures in static condition by means of Pearson linear correlation. Correlation showed a positive direction (the bigger the difference between the plantar pressures, the bigger the difference in the FPI of both feet) but correlation coefficient was weak and non statistical significance was found ($r = 0,155$; $p = 0,527$).

DISCUSSION

The presence of compensations in the lower extremities of patients with minor LLD has been a topic of debate for decades. Those compensations could include asymmetric pronation of supination of the foot, unilateral genu valgus or genu varus, joint unilateral degeneration of the knee and hip, altered position of the pelvis and walking disturbances[26]. However, literature about LLD is non-conclusive and there is a lack of evidence regarding the compensations that can be found in these patients. Moreover, it is not clear which is the minimal amount of LLD that can be considered clinically relevant. While some works pointed that LLD bigger than 5 mm can produce ailments in the musculoexqueletal system[14] or compensatory mechanisms in the column[4] and the lower extremity[20,27], others do not appreciate significant alterations that should be treated in LLD cases till 25 mm[28,29]. The use of methods with very low validity or non reliable to quantify the amount of shortening is a major problem in most of the literature regarding LLD which questions much of the results obtained in the studies. This aspect is one of the reasons that could explain the confounding results about the clinical significance of minor LLD in the literature. The present study looked for differences in the static position of the feet and in the plantar pressures supported in each feet in static conditions in cases of minor LLD using full limb and pelvis x-rays in weigthbearing for the diagnosis of LLD, which is an objective method to detect anatomic LLD reducing the risk of bias of the patients included in the study.

In the present study no association has been found in foot position in static conditions measured by means of the FPI between the short and long limbs in patients with anatomic LLD. No association has neither found in the percentage of plantar pressures carried out by the short and long limb in static stance. So, from the data obtained in the present study it is not possible to reject the null hypothesis of no differences between the short and long limbs in the static position of the foot and in the amount of load that each limb support during static stance in patients with minor LLD. These data are opposed with some studies that have shown different types of mechanical behavior between the short and long limbs in patients with LLD[18].

Table 1. Descriptive data of the sample of the study (n = 19)

Age (years)	Sex	Foot Posture Index (FPI) Right foot	Foot Posture Index (FPI) Left Foot	Shorter Limb	Diference in length (mm)
44,07 ± 13,07	73,7 % Men 21,1 % Women	3,74 ± 3,84	4,05 ± 3,56	47,4 % Right 52,6 % Left	11,30 ± 3,39

Table 2. Comparison between FPI and percentage of pressues in the short and long limb of the sample of the study

	Median [range]	Difference (mean ± SD)	*p*-value*
FPI shorter limb	5 [-7, 9]	0,63 ± 3,09	0,458
FPI longer limb	4 [-6, 9]		
Percentage of pressures in the shorter limb	49,00 [39,50 - 60,00]	-1,52 ± 10,52	0,493
Percentage of pressures in the longer limb	51,00 [40,00 - 60,50]		

SD = standard deviation
Wilcoxon rank sum test for paired data

One of the questions that was tried to assess in the present study was if the differences in the FPI between the short and long limbs in patients with LLD could be derived from an increase in the load of the foot instead of postural compensations derived from the LLD. For that, a linear correlation was carried out between the difference of the FPI of the right and left feet and the difference in the percentage of total plantar pressures supported by each foot. Data do not support the hypothesis and the data analysis showed no correlation between the FPI of the shorter and longer limb and the difference in the percentage of the plantar pressures. One possible reason could be because of the characteristics of the sample of the study. In the present study, the sample was obtained from patients that went to a podiatric office generally complaining of pain or discomfort in the foot or lower extremity and they were mainly no normal subjects without pain in which his only alteration was the presence of minor LLD. In patients with painful disorders or ailments there exists clinical factors that can influence deviations or compensatios adquired for the patient such us antialgic positions. In this sense, it is possible that because of the unique characteristics of the sample, plantar pressure data obtained of the load of each foot could have been influenced by other painful conditions of the patient at the momento of the study and do not reflect "strictly" compensations that are stablished in the load of each foot in patients with minor LLD. At the same time, it is important to consider that the concept of compensation of LLD is a quite complex mechanism in which several factors such us load, muscular contractions, presence of pain, and proprioception can take part[26]. For all of that, it is possible that compensations seen in patients with LLD do not follow an unique pattern and could be subject specific.

There exist some limitations associated with the study and their results should be taken cautiously. One of the main limitations is referred to the sample size and the power associated with the study. Because of the limited number of participants and the variability of the FPI observed in the sample, the power of the study (its ability to detect differences when they really exist) is quite low (0.07 for the detection of differences in the FPI and 0.14 for the detection of differences in plantar pressures). It is the opinion of the authors that this is a major limitation of the present study because of absence of statistical significance could be conditioned by the low power of the study. An optimal power of 0.8 would have required a sample size bigger than 500 subjects. Another limitation of the study came from the design carried out which is a case series of patients with LLD. This design is useful to analyze characteristics of the disease and to generate hypothesis. However, the absence of a control group (group of patients without LLD) in the study do not allow to stablish comparisons of behavior between patients with LLD and patients without LLD. We do not know if the data observed regarding FPI and plantar pressures in patients with minor LLD do also occur in healthy population without LLD.

In conclusion, the present study gives data about differences in the static foot position and in the percentage of static load of each feet in cases of minor anatomic LLD. No differences have been found in the FPI between the short and long limbs in patients with LLD and no differences have neither found in the percentage of plantar pressures in static condition supported by the short and long limbs in patients with LLD. No correlation was found between the difference in FPI and the difference in plantar pressures in each subject. These data do not support the hypothesis that patterns of compensations generated in patients with minor LLD could cause a change in foot position of one limb regarding the other or in which load is increased in the shorter or longer limb. However, the characteristics of the subjects of the sample (patients with pain or discomfort in the foot or lower extremity) could have influenced the percentage of plantar pressure in each foot. At the same time, the low power of the study could have also influenced in the absence of statistical significant results. More studies are necessary with bigger samples and more homogeneous samples (subjects without pain) that could compare the relationship between foot position and plantar pressures in patients with minor LLD.

CONFLICTS OF INTERESTS
None.

FINANTIAL DISCLOSURE
None.

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