

# Plantar Pressure Distribution During Walking: Comparison of Subjects with and without Chronic Low Back Pain

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**Abstract.** [Purpose] The purpose of this study was to investigate changes during walking in plantar pressure distribution on both the affected and unaffected sides of patients with chronic low back pain (LBP). [Subjects] Sixty subjects were included in this study, including 30 patients with chronic low back pain and 30 healthy individuals as the control group. [Methods] The plantar foot pressure and the trajectory of the center of pressure (COP) of both groups were measured using the F-scan System while they walked at a comfortable speed. The F-scan system was used to determine the plantar pressures of both feet with data captured during three strides. [Results] Plantar pressure distribution differences between the left and right sides of the back pain group showed greater increases in anteroposterior (AP) displacement of COP than the control group. [Conclusion] Patients with chronic low back pain walked with a shorter AP displacement of COP, perhaps due to a compensatory action in trying to avoid pain. The foot pressure distributions in the back pain group provide evidence of alterations of the gait pattern in patients with chronic low back pain.

**Key words:** Plantar foot pressure, Walking, Low back pain

(This article was submitted Jun. 13, 2011, and was accepted Aug. 2, 2011)

## INTRODUCTION

Walking is accomplished through the forward movement of the body and cyclically repeated movements of the upper and lower extremities while the stability of the stance phase is maintained by the opposite limb. This movement is one of the most basic movements of the human body and results from interactions between the musculoskeletal system and the nervous system<sup>1)</sup>. In the case of patients with low back pain (LBP), the nature or quantities of proprioceptive input from muscle spindles, the Golgi tendon organ, joints and cutaneous receptors may be altered, resulting in the provision of improper information on the position of the body<sup>2)</sup>. Consequently, patients with low back pain may show abnormal postural reaction patterns, delayed reaction times and disorders in stability<sup>3)</sup>. In walking, they may exhibit a tendency toward decreased walking speeds, stride length, number of steps per minute and unilateral support time due to pain and reduced sensation. As a result, asymmetric gait patterns may appear in these patients<sup>4)</sup>.

Plantar foot pressure can be used to quantify static and dynamic pressure on the foot during walking. It is also widely used as an examination tool to check for necrosis in diabetes<sup>5)</sup>. Representative plantar foot pressure measuring methods include force plate, platform pressure and shoe

insert-type methods. The force plate and platform pressure methods have limitations in measuring specific pressures in different areas of the foot and in providing diverse pieces of information on plantar foot pressure; however, the shoe insert-type is useful for acquiring information on changes in plantar foot pressure<sup>6)</sup>. Currently, F-scan systems, Pedar systems and Parotec systems allow measurements by this method.

Attention to foot health has heightened recently, and plantar foot pressure measurement has been studied in individuals with diabetes, arthritis, rheumatoid arthritis, cerebral palsy, hemiplegia and lower extremity amputation<sup>7-11)</sup>. Although plantar foot pressure has been studied in relation to many diseases thus far, studies of changes in plantar foot pressure related to low back pain are currently insufficient.

Since different distributions of plantar foot pressure may occur in the gait of patients with low back pain compared to the gait of healthy persons, this study examined the plantar pressure distribution of patients with chronic low back pain during walking, using tools that can measure the plantar foot pressure on both sides.

**Table 1.** Demographic features of both groups with values expressed as mean  $\pm$  standard deviation

	Sex (male/female)	Age (yr)	Height (cm)	Weight (kg)
LBP group (n=30)	8/ 22	48.1 $\pm$ 5.8	163.0 $\pm$ 9.1	60.5 $\pm$ 11.1
Control group (n=30)	9/ 21	48.8 $\pm$ 5.3	163.4 $\pm$ 7.8	61.7 $\pm$ 8.8

Mean  $\pm$  SD. LBP group: Low back pain group.

## SUBJECTS AND METHODS

Sixty subjects were included in this study. Thirty patients were recruited who had been diagnosed with chronic low back pain by a university hospital and thirty healthy individuals were recruited as volunteer subjects for the study. Plantar pressures of the 30 patients with chronic low back pain were compared with those of the 30 healthy person control group. Before the experiment, each person was informed of the purpose and detailed procedure of the test, and each signed a consent form. Participants in the low back pain group were included if they could independently walk a distance of 10 m, had no history of major injuries such as fracture or surgery to their back or lower extremity, and had experienced low back pain for at least three months. Subjects were excluded if they had a leg-length discrepancy of 1 centimeter or longer, foot deformities such as flatfoot, congenital deformities of the pelvis, or had pain due to a degenerative disease in the lower extremity. The general characteristics of the subjects with LBP and healthy subjects are described in Table 1.

Subjects in both the chronic LBP and control group wore their own indoor shoes which were fitted with the portable equipment and the pressure-sensitive insoles described below. The cuff unit was attached to the lower leg using a velcro strap. The F-scan system® (Tekscan, USA) was used to measure plantar foot pressure. The pressure was recorded at 50 Hz with a pressure sensitive insole consisting of a 0.15 mm-thick sensor with an embedded matrix of 960 pressure-sensing cells, evenly distributed at 0.5 cm (0.2 in) intervals. Before use, the disposable insole was trimmed to fit into the shoes. A 9.25 m cable was connected to the sensor and the sensor was set to collect data at 50 Hz for 4 seconds. Because temperature changes of the insole might alter the data, temperature equilibration was essential. This was ensured by a pretrial 5-minute period during which the foot was in the shoe with the sensor in place after which the system was calibrated. Using their indoor shoes bilaterally, the subjects performed 3 walks of approximately 3 strides each. Plantar pressure was recorded for 3 strides in the middle of the test walk and the mean pressure value was calculated. After the pressure was read and recorded, data were processed with custom-made software, F-Scan version 4.19F.

To assess the plantar pressure distribution difference during gait between the left and right sides of the two groups and between the affected and unaffected sides of the LBP group, both feet were divided into three regions, forefoot (FF), midfoot (MF) and hindfoot (HF), using 40%, 30% and 30% of the total foot length, respectively<sup>12,13</sup>. The

**Table 2.** Onset/diagnostic characteristics of LBP subjects

Variable	Division	Male	Female
Diagnosis	HNP	4	14
	Sprain	2	8
	Stenosis	1	
	Degenerative spondylitis	1	
Spine surgery	Yes	0	1
	No	8	21
Pain area	Left/ Right foot	5/3	11/11
Number of months since pain onset (mean $\pm$ SD)		11.53 $\pm$ 3.7	12.89 $\pm$ 4.8

parameters of contact area (CA), peak pressure (PP), relative impulse (RI) and trajectory of COP (TCOP) were calculated and averaged for each foot region as the stance phase of gait progressed from heel-strike to toe-off. Plantar pressure distributions of both the affected and unaffected sides were included in the data analysis.

Data were analyzed using the SPSS package (version 14.0). Demographic features were compared between the two groups using the independent t-test for continuous data. The independent sample t-test was performed to detect the plantar pressure distribution difference between the left and right sides of the two groups. Differences in plantar pressure distribution between the affected and unaffected sides of the LBP group were analyzed with the paired sample t-test. The alpha level for significance was chosen as 0.05.

## RESULTS

The low back pain group (n=30; 8 males and 22 females) averaged 48.1 years in age, 163.1 cm in height and 60.5 kg in weight; the control group (n=30; 9 males and 21 females) averaged 48.8 years in age, 163.4 cm in height and 61.7 kg in weight (Table 1). There were no significant differences in these average measures between the groups, indicating that the two groups were homogeneous. Table 2 shows the onset and diagnostic characteristics of the LBP patient group. Independent t-test analysis of the COP trajectory between the two groups revealed significant right-left value differences in AP displacements of the LBP group, indicating less weight bearing on the affected leg (right or left side), in comparison to differences in AP displacement of trajectory COP between the two sides of the control group ( $P < 0.05$ ) (Table 3). There were no statistically significant differences in CA, PP, RI and TCOP (Table 3)

**Table 3.** Characteristics of plantar pressure measurements: differences between the left and right sides of the two groups

		LBP group	Control group
CA (cm <sup>2</sup> )	FF	2.93 ± 2.06	2.32 ± 1.42
	MF	2.93 ± 1.98	3.09 ± 2.43
	HF	2.19 ± 2.08	1.96 ± 1.43
PP (kPa)	FF	55.1 ± 46.96	73.93 ± 70.81
	MF	33.80 ± 30.73	27.40 ± 24.24
	HF	57.56 ± 46.01	50.93 ± 30.17
RI (kPa)	FF	68.26 ± 51.92	82.03 ± 78.24
	MF	33.10 ± 30.33	36.16 ± 23.15
	HF	72.46 ± 68.18	54.90 ± 35.88
TCOP (cm)	ML displacement	0.26 ± 0.28	0.26 ± 0.17
	AP displacement*	0.70 ± 0.53	0.41 ± 0.29

Values are expressed as mean ± standard deviation. \* Significant difference ( $p < 0.05$ ). CA: Contact area; PP: Peak pressure; RI: Relative impulse; TCOP: Trajectory of COP. ML displacement: Medial-Lateral displacement; AP displacement: Anterior-posterior displacement. FF: Forefoot; MF: Midfoot; HF: Hindfoot.

between the two groups. Analysis of the plantar pressure distribution of the foot on the both sides of the LBP group indicated that CA, PP, RI, and TCOP values were typically larger on the unaffected side ( $p > 0.05$ ) (Table 4).

## DISCUSSION

This study investigated the distribution of plantar pressures of patients with chronic low back disorders and compared them with those of a control group. To the best of our knowledge, no previous studies have compared differences of plantar pressure distribution on the affected and unaffected sides among individuals with low back pain. This study found statistically significant changes in AP displacement of COP between the left and right feet in the LBP group. Comparison of right vs. left AP displacement values during walking by the patients with chronic low back pain indicated a shorter forward movement on the affected side than on the left and right sides of the control group. It is possible that the LBP patients bear more weight on the unaffected side as a compensatory action to avoid pain during walking. In addition, low back pain leads to reduced physical activity and muscular force, with resultant balance difficulties. The findings of another study<sup>14)</sup>, which described weight distribution in a low back pain group during standing, seems to agree with the results of the present study, because the difference in the weight distribution on each foot of the back pain group showed a greater difference than that of the control group. Among patients with LBP, there were no significant differences in the plantar pressure parameters of CA, PP, RI and TCOP between the affected side and the unaffected side during walking, even though the unaffected side generally showed a tendency of increase in CA, PP, RI, and TCOP. This might be related to walking slowly with shorter step length in both feet of the LBP patients due to nonspecific chronic low back pain influencing gait. In addition, our present result is similar to the findings of a study by Elbaz et al.<sup>15)</sup> in which

**Table 4.** Characteristics of foot measurements between the affected and unaffected sides of the LBP group

		Affected side	Unaffected side
CA (cm <sup>2</sup> )	FF	62.09 ± 9.24	62.70 ± 8.40
	MF	25.07 ± 6.54	25.17 ± 6.60
	HF	35.43 ± 5.32	35.04 ± 6.23
PP (kPa)	FF	312.96 ± 78.02	337.93 ± 75.24
	MF	94.73 ± 36.62	98.66 ± 44.23
	HF	259.23 ± 81.51	273.26 ± 84.01
RI (kPa)	FF	317.10 ± 94.62	326.96 ± 83.07
	MF	108.30 ± 48.21	104.60 ± 51.87
	HF	264.83 ± 86.84	272.56 ± 7870
TCOP (cm)	ML displacement	0.99 ± 0.28	1.00 ± 0.41
	AP displacement	15.24 ± 1.07	15.80 ± 1.09

Values are expressed as mean ± standard deviation. CA: Contact area; PP: Peak pressure; RI: Relative impulse; TCOP: Trajectory of COP. ML displacement: Medial-Lateral displacement; AP displacement: Anterior-posterior displacement. FF: Forefoot; MF: Midfoot; HF: Hindfoot.

significant differences between the affected and unaffected sides in step length, normalized step length and double limb support were found in chronic low back patients. Patients with chronic low back pain show malfunctions in the muscles and ligaments due to behaviors aiming to avoid pain and as a result, the range of motion of certain joints may be reduced<sup>16)</sup>. Due to such reductions, the nature or quantity of proprioceptive input would be changed and improper information regarding body/joint position would be provided. Consequently, a patient would begin to feel unstable and strategies used in moving would have to be modified<sup>17)</sup>. Our present study provides data that may be useful to researchers studying gait patterns in patients with chronic low back pain because chronic back disorders can lead to diverse changes in the musculoskeletal system. One limitation of this study is that diverse patients with a variety of specific back disorders, including disc herniation, spinal stenosis and spondylitis, were grouped together in the chronic LBP group for this study. We recommend that future studies examine the plantar pressures in low back pain patients with specific diagnoses.

## ACKNOWLEDGEMENT

This research was supported by a Daegu University Research Grant, 2010.

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