ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
www.aott.org.tr

Research Article

An investigation into the frequency and risk factors of low back pain following surgical treatment of isolated calcaneal fractures

Dilek Bayraktar[1], Cengizhan Özgürbüz[2], Anıl Murat Öztürk[3], Salih Kemal Aktuğlu[3], Nadir Özkayın[3]

[1]*Department of Orthopaedic Surgery, Orthopaedic Physiotherapy, Ege University, Faculty of Medicine, Izmir, Turkey*
[2]*Department of Sports Medicine, Ege University, Faculty of Medicine, Izmir, Turkey*
[3]*Department of Orthopaedic Surgery, Ege University, Faculty of Medicine, Izmir, Turkey*

ARTICLE INFO

Article history:
Submitted February 8, 2023
Received in revised form May 13, 2023
Last revision received form November 14, 2023
Accepted December 11, 2023
Publication Date February 5, 2024

Keywords:
Calcaneus Fracture
Pedobarographic Measurement
Kinetic Chain
Low Back Pain
Quality of Life

ORCID iDs of the authors:
D.B. 0000-0002-3200-7456;
C.Ö. 0000-0003-0728-4555;
A.M.Ö. 0000-0001-8674-8877;
S.K.A. 0000-0001-8058-0364;
N.Ö. 0000-0001-8767-6238.

ABSTRACT

Objective: This study aimed to determine the frequency of low back pain after calcaneal fractures treated with open reduction internal fixation (ORIF) and the risk factors that cause this condition.

Methods: Thirty-one patients (27 males and 4 females) who underwent surgery for a unilateral calcaneal fracture between 2016 and 2020 and had no complaints of low back pain before fracture surgery were included in the study. The patients were divided into 2 groups: those who developed low back pain after the operation and those who did not. Patients were evaluated with the Life Quality Short Form SF-36, the Oswestry Disability Index (ODI), and American Orthopedic Foot-Ankle Association Score (AOFAS). Sanders' fracture type, joint range of motion (ROM) measurements of injured and uninjured limbs, maximal isometric muscle strength measurements, balance on 1 leg with pedobarographic measurements, and walking time were evaluated. The obtained data were compared among the 2 groups.

Results: Low back pain was observed in 71% of the patients and was detected after an average of 6 months from the operation. In ODI, 59.1% of the patients reported that low back pain limited their lives slightly. Patients with low back pain have lower AOFAS scores and worse SF-36 physical functionality than those without low back pain ($P < .001$, $P = .016$). Balance time on 1 foot in pedobarographic measurements, foot in ROM, ankle in ankle active, passive plantar flexion, inversion, active hip, passive internal, external rotation, muscle is the foot eversion force. In these measurements, the values of the injured side are intact. It was statistically significantly lower than the other side (interaction $P < .1$).

Conclusion: Low back pain may occur after unilateral calcaneal fractures treated by ORIF. This may be caused by decreased angles of ankle dorsi and plantar flexion, foot inversion, hip abduction, and internal and external rotation. In the rehabilitation program, not only the ankle region but also the hip joint of the affected side should be included, and the kinetic chain that describes the interaction mechanism of the human body should not be forgotten.

Level of Evidence: Level IV, Prognostic Study.

Introduction

While calcaneal fractures consist of 2% of all fractures in the body, they constitute 4% of the fractures in the foot and ankle region. Displaced intra-articular fractures of the calcaneus form 60%-70% of all calcaneal fractures. Surgical restoration of joint congruity and stability are important in the treatment of this type of fractures. However, patient dissatisfaction and complaints are still common after surgery, regardless of the treatment method and the skill of the surgeon. Even in patients who underwent successful open reduction internal fixation (ORIF) surgery for calcaneal fracture, the time loss at work varies between 35 and 69 weeks.[1,2] As the largest of the tarsal bones, the calcaneus carries the entire body weight and plays an important role in forming the medial longitudinal arch and the subtalar joint. Following calcaneal fractures, the relationship between the structures forming the subtalar joint, which has an important place in foot biomechanics, is disrupted. In addition, the peri-calcaneal tendons, which help to protect the calcaneal stabilization, are damaged during fracture.[3] When the patients return to their daily life, these structures are exposed to higher stress than they were before the fracture occurred.[4]

Although the body and feet are seen as isolated parts of the body, they are functionally interconnected through the kinetic chain.[5] All of these may affect the patient's balance and mobility during gait due to both foot pain and arthritis of the subtalar joints of the affected foot, which may occur independently of the treatment. It is difficult to reach the pre-fracture level in the quality of life of patients after operated calcaneal fractures. Moreover, the lack of a standard treatment guide for the rehabilitation of calcaneal fractures may contribute to this situation, thus prolonging the complete recovery period and causing complaints continue for a long time. Severe pain, edema, decrease in walking distance, difficulties in walking on rough surfaces, and balance problems while standing on the affected foot are frequently encountered in these fractures. Seay et al[6] mentioned in their study that alteration of lower extremity mechanics and/or neuromuscular control leads to changes in the kinetic chain between the foot and the

Corresponding author:
Anıl Murat Öztürk
amuratozturk@yahoo.com

Cite this article as: *Bayraktar D, Özgürbüz C, Öztürk AM, Aktuğlu SK, Özkayın N. An investigation into the frequency and risk factors of low back pain following surgical treatment of isolated calcaneal fractures. Acta Orthop Traumatol Turc., 2024; 10.5152/j.aott.2024.23031 [Epub Ahead of Print].*

DOI: 10.5152/j.aott.2024.23031

lumbar region, especially spinopelvic area, related with the compensation mechanisms in the kinematic chain.

In our clinical experience, we noticed that patients who underwent surgery for unilateral calcaneal fractures complained of low back pain in the follow-ups after the treatment of the calcaneal fracture. In the detailed inquiries for the low back pain made during the follow-up of the patients, they stated that they did not have any complaints of low back pain before, and their complaints of low back pain began after the treatment of the calcaneal fracture. Impairment of foot-ankle mechanics or weakness in the affected lower extremity muscles may limit the degree of planar motion of the lower extremity after a unilateral calcaneal fracture. Considering the compensation mechanisms along the kinetic chain, we hypothesized that, due to the problems such as range of motion (ROM) limitations in joints and the decrease in muscle strength of affected lower extremity occurring in the patients after unilateral calcaneal fracture, would cause low back pain in patients who did not have any low back pain problem before.

In our literature review, we could not come across any research on the frequency and causes of low back pain seen as a result of impaired foot biomechanics in operated calcaneal fractures. In our study, our aim is to determine the frequency of low back pain that may occur after calcaneal fractures treated with ORIF and the risk factors that may cause this.

Materials and methods

Study design

Our study is a cross-sectional study. It was formed on patients who were operated due to unilateral calcaneal fracture in Ege University Orthopedics and Traumatology Department since the approval date of the Medical Research Ethics Committee (Approval No: 21-9T/17). The patients were first contacted by phone. The determination of the presence of low back pain was confirmed by a telephone call. During this telephone interview, patients were asked whether they had complaints of low back pain prior to the calcaneal fracture. In these interviews, the patients' complaints of low back pain, conditions such as herniated nucleus pulposus or spondylolisthesis, chronic diseases that could cause low back pain, the presence of any radiological examination that could explain the low back pain, and their visit to the doctor with this complaint before the calcaneal fracture were questioned in detail. Patients who declared these conditions before injury were excluded from the study. Patients who suffered from low back pain before fracture treatment were excluded from the study to avoid bias. They were divided into 2 groups: those who developed low back pain after the operation and those who did not. The data obtained were compared among the 2 groups.

HIGHLIGHTS

- Low back pain may occur after unilateral calcaneal fractures treated by ORIF. This study aimed to investigate the frequency and risk factors for low back pain after calcaneal fractures treated with open reduction and internal fixation.
- The results showed that 71% of patients who underwent surgical treatment for a unilateral calcaneal fracture had low back pain. Moreover, loss of joint range of motion and muscle weakness in the lower extremity operated on calcaneus fractures are factors for the development of low back pain in post-fracture patients.
- The results indicate appropriate physiotherapy treatment approaches should be planned to protect low back pain after calcaneal fracture. The rehabilitation program should not only include the ankle region but also the hip joint of the affected side to minimize low back pain in these patients.

Patient characteristics and clinical assessments

Thirty-one (27 males and 4 females, who had no complaints of low back pain before fracture) patients with unilateral calcaneal fractures operated between 2016 and 2020 were included in the study. The informed consent of the participants was obtained before research procedures started.

Inclusion and exclusion criteria from the study are shown in Table 1.

In calculating the sample size of our study, the number of calcaneus fractures admitted to our hospital in the last 5 years was taken into account. As a result of the archive search, 52 patients who met the inclusion criteria were reached. Contact information of 10 patients could not be obtained. Five patients stated that they had low back pain before the fracture. 5 patients refused to participate in the study. One patient had an infection in the operation area. Our sample size was limited since our exclusion criteria were aimed at distinguishing isolated unilateral calcaneal fractures.

The patients who agreed to participate in the study were examined in the following order;

Fracture classification and measuring the outcome of treatment/ low back pain

Sanders' classification was used to determine the fracture type. The American Orthopedic Foot-Ankle Association Score (AOFAS) was used to evaluate pain, function, and posterior foot alignment. The Short form SF-36 life quality questionnaire was used to evaluate the quality of life. The Oswestry Disability Index (ODI) was used to evaluate the degree of functional loss in low back pain.[7-10]

Pedobarographic evaluation

Both the static and dynamic pedobarographic measurements of the patient and the balance measurements on 1 foot were made with the "Materialise Motion Footscan® v9 scientific, 1m EL system" pedobarographic measurement system. When the balance was measured on 1 foot, the patient was asked to stand on his or her foot which he or she preferred for 30 seconds, starting the timer when he or she was ready. In the event of touching his or her foot next to the supporting foot on the ground, the test was terminated and the time until that moment was recorded. Later, all measurements were repeated for the other foot. In the static measurement, the patient was asked to count with both feet on the platform while looking straight ahead, ensuring the usual width between both feet was formed. Afterwards, the patient was asked to stand still, and the measurement was recorded. With this measurement, the percentages of body weight carried by both feet while standing were measured. As for the walking speed in the dynamic measurement, the patient was asked to walk at the speed (as he or she felt comfortable) in his or her daily life, without looking at the ground. Measurements were recorded making the patient walk until his or her both feet were seen on the screen exactly for 3 times. The time spent in both feet during this walking cycle was measured in terms of msn. Thanks to this, the asymmetrical full weight bearing of the patient was detected during walking (Figure 1).

Evaluation of the lower extremity range of motion

Lower extremity ROM measurements were measured actively and passively with Halo brand Dynamic Angle Measure. Ankle dorsi and plantar flexion, foot inversion and eversion, knee flexion and extension, hip flexion, extension, abduction, adduction, internal and external rotations were recorded.[11-12]

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Reaching the contact information	Not reaching the contact information
A minimum of 1 and a maximum of 5 years have passed since the date of surgery.	Less than a year has passed since the date of surgery
Being over 18 years old	Being less than 18 years old
Experiencing no head trauma accompanying unilateral calcaneal fracture, no other fractures of the lower extremity, and no low-back fracture	Having head trauma, having bilateral calcaneal fractures, having other fractures of the lower extremity, and having low-back fracture
No complaint of low back pain before fracture	Having low back pain before fracture
Being literate	Not being literate
Volunteering to participate in the study.	Not volunteering to participate in the study.

Evaluation of the lower extremity muscle strength

Maximal isometric muscle strength measurements of the lower extremities were performed with the Lafayette Hand-held Dynamometer device. The strengths of ankle dorsi and plantar flexors, foot inverters and evertors, knee flexors and extensors, hip flexors, extensors, abductors, adductors, and internal and external rotators were determined. The extremity's exposure to gravity was minimized during the measurement. A digital hand dynamometer was placed on the patient's limb during the measurement and the patient was asked to apply with his strongest resistance as he could in the desired direction. It was ensured that the patient did not compensate during the measurement. Before starting the measurement, the patient was ensured to learn the movement by making several trials without applying resistance. The maximum isometric muscle strength that could be produced for 5 seconds was measured in each measurement. Three measurements were made, with thirty-second rest intervals between measurements. The mean of 3 measurements was accepted as the final value.[13]

Surgery and the postoperative period

All patients were operated on with an extended lateral approach under tourniquet to apply ORIF with a plate. In 2 weeks postoperatively, the wound was checked, and the sutures were removed. We replaced the long leg splint with a short leg cast for the patient who was not allowed to step on the long leg splint. Range of motion exercises to the ankle and foot began. At the fourth week, the cast was removed and was replaced with a Controlled Ankle Movement (CAM) boot without weight bearing. Range of motion exercises to the ankle and foot began. At 10 weeks, advanced weightbearing status in the CAM boot and rehabilitation began. During the first year after the operation, to evaluate the condition of the reduction, the implant placement, and the fracture healing, the patient was monitored in the second week, fourth week, third month, sixth month, and in the first year. After the first year, patients were observed every 6 months. All patients got the same rehabilitation program, supervised by a therapist.

Statistical Analysis

The frequencies and percentages were given for categorical variables; mean, SD, median, range (minimum-maximum) values were given for numerical variables as descriptive statistics. Association between the 2 categorical variables was analyzed with the Fisher's exact test. Group comparisons for numerical variables were performed with the Mann–Whitney *U*–test. Time to low back pain was estimated by Kaplan–Meier analysis. The 95% confidence interval (CI) of low back pain percentage was calculated according to the Wilson method. The main question was to investigate whether the injured and non-injured foot asymmetries in ROM, muscle strength, and pedobarographic measurements were the same for with and without low back pain patients. To answer this question, the significance of interaction, group, and time effects were evaluated in the nonparametric 2-way repeated-measures analysis of variance, which is called the Brunner–Langer model. The "injured–uninjured" effect represents repeated measurements in the analysis, because all measurements were taken from each foot of the patients. Also, the "group" effect represents 2 different patient groups who have low back pain and who do not. The "interaction" effect represents the interaction between the "injured–uninjured" and "group" effects, and it replies to the main question of the study: Do patients with low back pain have worse injured–uninjured foot asymmetry in ROM, muscle strength, and pedobarographic measurements? If the interaction effect is significant, the other 2 effects are not interpretable, but sub-group analyses were not performed following a significant interaction.

Statistical significance was assessed as $P < .05$ (with exception of interaction, it was assessed at a 0.1 significance level) and all statistical analyses were performed using R software (R software, version 4.0.5, packages: arsenal-nparLD-ggplot2, R Foundation for Statistical Computing, Vienna, Austria; http://r project.org).

Results

The demographic and clinical characteristics of the patients are presented in Table 2. The mean age of the 31 patients was 49.3 ± 12.2, of which 27 were men and 4 were women. There were no statistically significant differences observed between patients with and without low back pain concerning age, gender, body mass index, dominance of the injured foot/side, and the side of the injured foot.

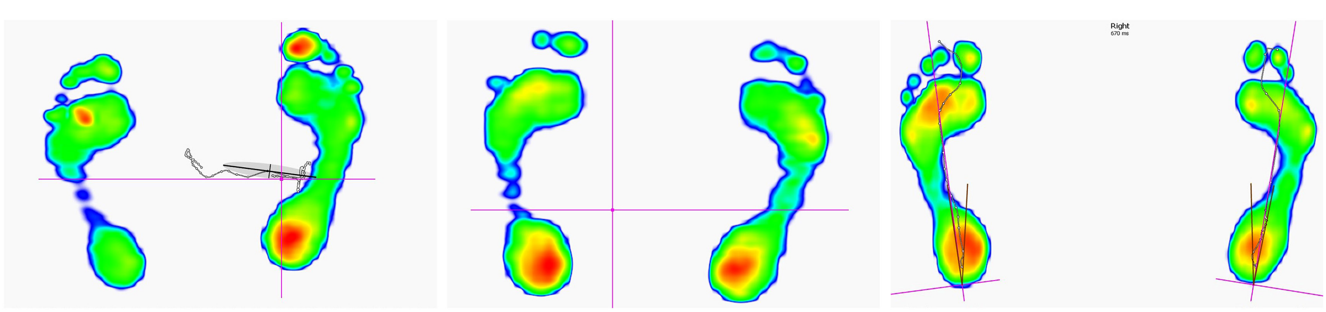

Figure 1. Pedobarographic measurements. One-foot balance measurement in injured foot (a), static measurement (b), dynamic measurement (c).

Table 2. Demographic and clinical characteristics of patients

		Low back pain			
		No (N=9)	Yes (N=22)	Total (N=31)	*P*
Gender					.295[1]
	Male	9 (100.0%)	18 (81.8%)	27 (87.1%)	
	Female	0 (0.0%)	4 (18.2%)	4 (12.9%)	
Age					.276[2]
	Mean (SD)	47.4 (9.4)	50.0 (13.3)	49.3 (12.2)	
	Median	44.0	51.5	51.0	
	Range	37.0-61.0	22.0-66.0	22.0-66.0	
BMI (kg/m²)					.296[2]
	Mean (SD)	25.8 (3.4)	27.3 (3.5)	26.8 (3.5)	
	Median	25.4	27.4	27.3	
	Range	20.0-30.0	19.0-33.1	19.0-33.1	
Dominance of injured foot					1.000[1]
	No	5 (55.6%)	11 (50.0%)	16 (51.6%)	
	Yes	4 (44.4%)	11 (50.0%)	15 (48.4%)	
The injured side					1.000[1]
	Left	6 (66.7%)	13 (59.1%)	19 (61.3%)	
	Right	3 (33.3%)	9 (40.9%)	12 (38.7%)	
Type of injury					.027[1]
	Stucking between an object	5 (55.6%)	3 (13.6%)	8 (25.8%)	
	Falling from a height	4 (44.4%)	19 (86.4%)	23 (74.2%)	
Height (m)					.016[2]
	Mean (SD)	1.1 (1.3)	2.5 (1.3)	2.1 (1.4)	
	Median	0.0	2.8	2.5	
	Range	0.0-3.0	0.0-4.5	0.0-4.5	
AOFAS					<.001[1]
	Mean (SD)	80.6 (4.3)	64.0 (11.8)	68.8 (12.7)	
	Median	82.0	64.5	72.0	
	Range	75.0-86.0	35.0-84.0	35.0-86.0	
Oswestry disability index					
	Mean (SD)	0	32.5 (15.4)	23.1 (19.8)	
	Median	0	28.0	24.0	
	Range	0-0	14.0-70.0	0.0-70.0	
SF36-1					.016[1]
	Mean (SD)	75.7 (16.5)	59.3 (18.1)	64.1 (18.9)	
	Median	85.0	60.0	65.0	
	Range	45.0-90.0	25.0-85.0	25.0-90.0	
SF36-2					.063[1]
	Mean (SD)	76.7 (30.7)	48.4 (36.8)	56.6 (37.0)	
	Median	90.0	50.0	75.0	
	Range	0.0-100.0	0.0-100.0	0.0-100.0	
SF36-3					.659[1]
	Mean (SD)	48.1 (36.4)	41.4 (36.5)	43.4 (36.0)	
	Median	39.0	36.5	39.0	
	Range	0.0-97.0	0.0-100.0	0.0-100.0	
SF36-4					.213[1]
	Mean (SD)	56.1 (28.5)	46.7 (19.0)	49.4 (22.1)	
	Median	65.0	45.0	50.0	
	Range	5.0-100.0	15.0-100.0	5.0-100.0	
SF36-5					.913[1]
	Mean (SD)	63.9 (17.3)	64.3 (14.9)	64.2 (15.3)	
	Median	60.0	69.0	68.0	
	Range	40.0-88.0	28.0-84.0	28.0-88.0	
SF36-6					.190[1]
	Mean (SD)	75.4 (21.1)	62.1 (26.7)	66.0 (25.6)	
	Median	75.0	70.0	75.0	
	Range	22.5-91.7	0.0-91.7	0.0-91.7	
SF36-7					.147[1]
	Mean (SD)	58.0 (28.4)	49.8 (19.2)	52.2 (22.1)	
	Median	76.0	45.0	56.5	
	Range	0.0-77.5	0.0-81.0	0.0-81.0	
SF36-8					.050[1]

(*Continued*)

Table 2. Demographic and clinical characteristics of patients (*Continued*)

		Low back pain			
		No (N=9)	Yes (N=22)	Total (N=31)	*P*
	Mean (SD)	62.0 (18.4)	48.9 (17.7)	52.7 (18.6)	
	Median	73.0	50.0	55.0	
	Range	20.0-75.0	15.0-80.0	15.0-80.0	
Sanders' classification					.433[1]
	IIa	6 (66.7%)	9 (40.9%)	15 (48.4%)	
	IIb	0 (0.0%)	2 (9.1%)	2 (6.5%)	
	IIIab	1 (11.1%)	7 (31.8%)	8 (25.8%)	
	IIIac	1 (11.1%)	3 (13.6%)	4 (12.9%)	
	IIIbc	1 (11.1%)	0 (0.0%)	1 (3.2%)	
	IV	0 (0.0%)	1 (4.5%)	1 (3.2%)	
Oswestry classification					
	Mild disability	9 (100.0%)	4 (18.2%)	13 (41.9%)	
	Moderate disability	0 (0.0%)	13 (59.1%)	13 (41.9%)	
	Severe disability	0 (0.0%)	3 (13.6%)	3 (9.7%)	
	Completely disability	0 (0.0%)	2 (9.1%)	2 (6.5%)	

AOFAS, The American Orthopedic Foot and Ankle Score; BMI, body mass index; SF36-1, physical functioning; SF36-2, role-physical, SF36-3, bodily pain; SF36-4, general health perceptions; SF36-5, vitality; SF36-6, social functioning; SF36-7, role-emotional, SF36-8, mental health.[1]Fisher's exact test.[2]Mann–Whitney *U*-test.

Over a median period of 6 months (95% CI: 5.6-6.4), 71% (95% CI: 53.4-83.9) of patients with calcaneal fractures developed low back pain. The incidence of low back pain after calcaneal fracture did not differ according to gender (*P*=.295). The mean age of patients with low back pain was 50 ± 13.3, while it was 47.4 ± 9.4 for those without (*P*=.276). Although the calcaneal fracture occurred on the dominant side in approximately half of the patients (n=15, 48.4%), it was not associated with the development of low back pain (*P*=1.000). Low back pain was found to be higher in patients with calcaneal fractures due to falling from a height (*P*=.027). About 86.4% of the patients with low back pain had a calcaneal fracture after falling from a mean height of 2.5 ± 1.32.5 ± 1.3 m, and 44.4% of the patients without low back pain had a calcaneal fracture after falling from an average height of 1.1 ± 1.31.1 ± 1.3 m (*P*=.016) (Table 2).

The mean AOFAS score was found to be lower in patients who developed low back pain following calcaneal fracture (*P* < .001).

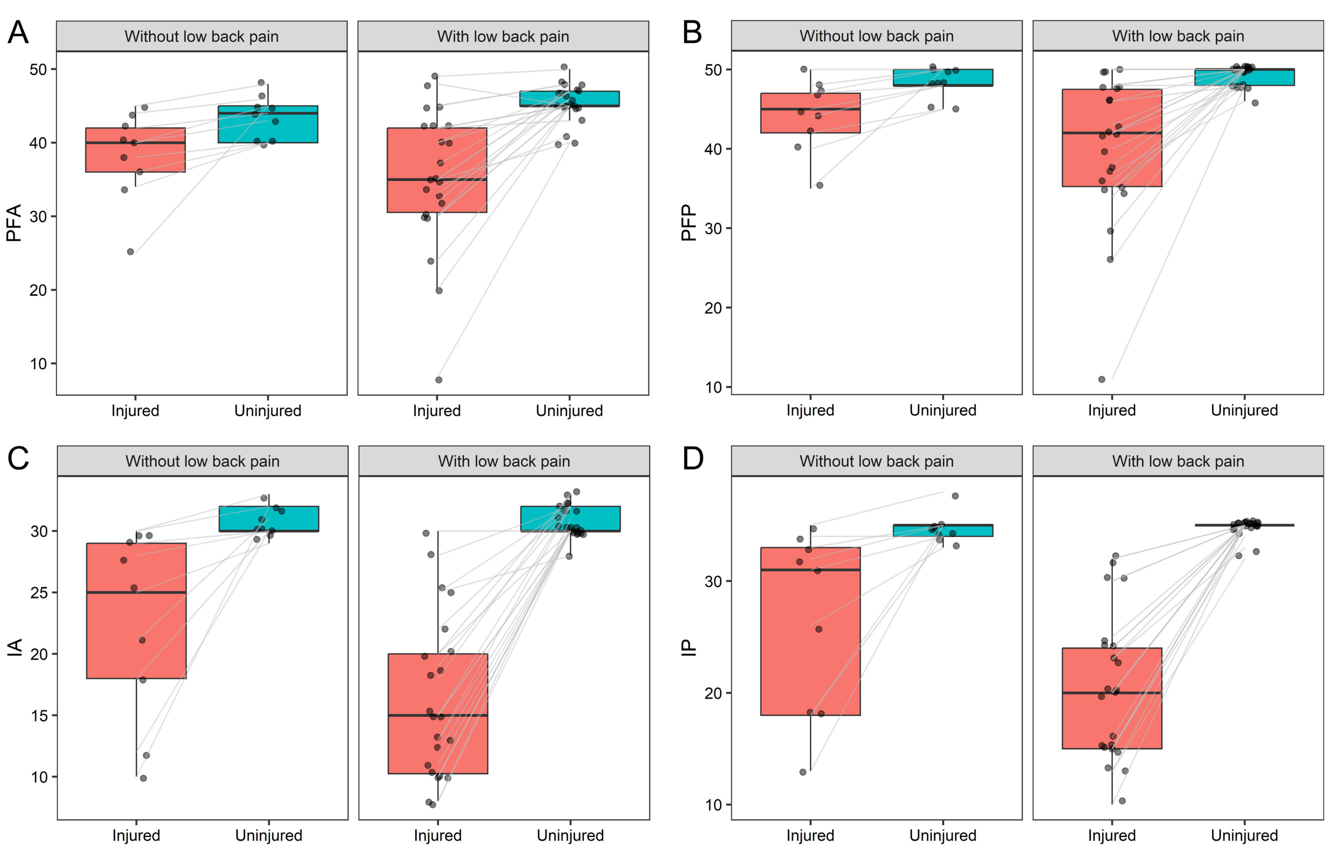

Figure 2. The lower extremity range of motion assessments associated with low back pain. Box plots were used for graphical representations. In the boxplots, the horizontal lines of the rectangles from bottom to top show the first quartile, the second quartile (median), and the third quartile, respectively. The vertical lines extend from the boxplot as 1.5 times the interquartile range. Dots on the box plots show the measurement values of each patient on that foot. The gray lines connecting the points between the 2 feet show the asymmetry between the foot measurements of the same patient. The graphs show that asymmetries between the injured and uninjured feet are more pronounced in the group with low back pain. PFA (A), PFP (B), IA (C), and IP (D).

Table 3. Evaluation of asymmetry between injured and non-injured foot in the presence of low back pain in foot and ankle, knee, hip range of motion measurements

		Low back pain, no (N=9)		Low back pain, yes (N=22)		
		Foot		Foot		*P*
		Injured	Uninjured	Injured	Uninjured	
DFA						
	Mean (SD)	18.0 (3.7)	20.8 (1.6)	15.8 (3.3)	19.0 (1.7)	Interaction: .785
	Median	20.0	20.0	16.0	19.5	Injured–uninjured: < .001
	Range	11.0-21.0	18.0-23.0	8.0-22.0	15.0-23.0	Group: .008
DFP						
	Mean (SD)	22.2 (3.3)	24.8 (1.9)	19.9 (3.0)	22.5 (1.6)	Interaction: .888
	Median	24.0	25.0	20.0	22.0	Injured–uninjured: < .001
	Range	16.0-25.0	22.0-28.0	13.0-25.0	20.0-25.0	Group: < .001
PFA						
	Mean (SD)	38.2 (6.1)	43.4 (2.9)	35.3 (9.6)	45.4 (2.6)	Interaction: .034
	Median	40.0	44.0	35.0	45.0	Injured–uninjured: < .001
	Range	25.0-45.0	40.0-48.0	8.0-49.0	40.0-50.0	Group: .436
PFP						
	Mean (SD)	44.2 (4.6)	48.2 (2.0)	39.9 (9.4)	49.3 (1.2)	Interaction: .068
	Median	45.0	48.0	42.0	50.0	Injured–uninjured: < .001
	Range	35.0-50.0	45.0-50.0	11.0-50.0	46.0-50.0	Group: .735
IA						
	Mean (SD)	22.6 (7.7)	30.8 (1.3)	16.2 (6.6)	30.8 (1.3)	Interaction: .067
	Median	25.0	30.0	15.0	30.0	Injured–uninjured: < .001
	Range	10.0-30.0	29.0-33.0	8.0-30.0	28.0-33.0	Group: .181
IP						
	Mean (SD)	26.7 (8.3)	34.8 (1.4)	20.5 (6.5)	34.7 (0.8)	Interaction: .013
	Median	31.0	35.0	20.0	35.0	Injured–uninjured: < .001
	Range	13.0-35.0	33.0-38.0	10.0-32.0	32.0-35.0	Group: .319
EA						
	Mean (SD)	9.4 (3.0)	15.3 (1.7)	7.9 (3.4)	14.7 (1.9)	Interaction: .714
	Median	10.0	15.0	8.5	15.0	Injured–uninjured: < .001
	Range	5.0-15.0	13.0-18.0	2.0-13.0	12.0-20.0	Group: .107
EP						
	Mean (SD)	13.0 (2.5)	18.3 (1.0)	11.8 (3.2)	18.0 (1.7)	Interaction: .847
	Median	13.0	18.0	12.0	18.0	Injured–uninjured: < .001
	Range	9.0-18.0	17.0-20.0	5.0-16.0	15.0-22.0	Group: .212
KFA						
	Mean (SD)	130.8 (1.7)	131.3 (2.2)	129.3 (5.2)	131.1 (3.3)	Interaction: .467
	Median	130.0	131.0	130.0	130.0	Injured–uninjured: .013
	Range	130.0-135.0	128.0-135.0	113.0-136.0	125.0-138.0	Group: .423
KFP						
	Mean (SD)	136.8 (2.1)	137.2 (2.3)	134.5 (4.8)	135.7 (3.1)	Interaction: .624
	Median	136.0	137.0	135.0	135.0	Injured–uninjured: .197
	Range	135.0-140.0	135.0-140.0	120.0-140.0	130.0-140.0	Group: .076
KEA						
	Mean (SD)	4.3 (0.7)	4.4 (0.7)	3.9 (1.2)	3.8 (1.3)	Interaction: .521
	Median	4.0	5.0	4.0	4.0	Injured–uninjured: .756
	Range	3.0-5.0	3.0-5.0	2.0-6.0	2.0-5.0	Group: .174
KEP						
	Mean (SD)	6.8 (1.1)	6.8 (1.1)	6.6 (1.5)	7.0 (1.8)	Interaction: .505
	Median	7.0	7.0	7.0	7.0	Injured–uninjured: .505
	Range	5.0-8.0	5.0-8.0	5.0-10.0	5.0-10.0	Group: .815
HFA						
	Mean (SD)	88.1 (4.9)	86.6 (9.3)	76.6 (11.8)	80.1 (8.7)	Interaction: .367
	Median	87.0	90.0	75.5	80.0	Injured–uninjured: .588
	Range	80.0-95.0	69.0-95.0	58.0-103.0	66.0-95.0	Group: < .001
HFP						
	Mean (SD)	94.7 (5.1)	93.0 (9.0)	84.1 (11.4)	86.6 (9.7)	Interaction: .587
	Median	94.0	96.0	82.0	88.0	Injured–uninjured: .562
	Range	88.0-105.0	75.0-100.0	66.0-110.0	71.0-104.0	Group: .002
HEA						
	Mean (SD)	13.2 (1.9)	13.3 (1.7)	12.2 (2.2)	12.8 (2.0)	Interaction: .283
	Median	13.0	14.0	12.0	12.5	Injured–uninjured: .107
	Range	10.0-15.0	10.0-15.0	9.0-18.0	10.0-17.0	Group: .197

(*Continued*)

Table 3. Evaluation of asymmetry between injured and non-injured foot in the presence of low back pain in foot and ankle, knee, hip range of motion measurements (*Continued*)

		Low back pain, no (N=9)		Low back pain, yes (N=22)		
		Foot		Foot		*P*
		Injured	Uninjured	Injured	Uninjured	
HEP						
	Mean (SD)	17.8 (1.9)	18.2 (1.9)	16.3 (2.1)	17.1 (2.3)	Interaction: .294
	Median	18.0	19.0	15.0	16.5	Injured–uninjured: .006
	Range	15.0-20.0	15.0-20.0	13.0-20.0	13.0-20.0	Group: .067
HADDA						
	Mean (SD)	20.2 (3.8)	20.2 (3.2)	20.1 (2.6)	20.8 (2.5)	Interaction: .509
	Median	20.0	19.0	20.0	20.0	Injured–uninjured: .160
	Range	17.0-30.0	18.0-28.0	15.0-28.0	18.0-28.0	Group: .433
HADDP						
	Mean (SD)	24.6 (3.0)	25.0 (2.9)	24.8 (2.2)	25.5 (2.2)	Interaction: .721
	Median	24.0	24.0	25.0	25.0	Injured–uninjured: .004
	Range	22.0-32.0	22.0-32.0	21.0-30.0	23.0-30.0	Group: .311
HABDA						
	Mean (SD)	36.4 (4.2)	37.2 (4.1)	33.3 (3.4)	34.4 (3.8)	Interaction: .412
	Median	36.0	37.0	32.5	35.0	Injured–uninjured: .007
	Range	28.0-42.0	30.0-44.0	30.0-40.0	30.0-42.0	Group: .046
HABDP						
	Mean (SD)	42.1 (5.1)	42.2 (5.0)	38.9 (5.3)	40.3 (3.8)	Interaction: .025
	Median	42.0	42.0	39.0	40.0	Injured–uninjured: .002
	Range	32.0-49.0	32.0-49.0	23.0-47.0	35.0-48.0	Group: .150
HIRA						
	Mean (SD)	34.9 (4.2)	36.6 (4.6)	24.4 (6.3)	35.5 (4.1)	Interaction: <.001
	Median	36.0	36.0	25.0	36.5	Injured–uninjured: <.001
	Range	28.0-40.0	30.0-43.0	12.0-36.0	23.0-40.0	Group: .015
HIRP						
	Mean (SD)	40.9 (5.0)	41.7 (5.0)	29.5 (6.4)	41.3 (4.0)	Interaction: <.001
	Median	42.0	42.0	30.0	42.0	Injured–uninjured: < .001
	Range	32.0-46.0	34.0-48.0	16.0-41.0	30.0-47.0	Group: .009
HERA						
	Mean (SD)	33.2 (2.9)	34.6 (2.7)	24.0 (4.0)	31.5 (3.7)	Interaction: < 0.001
	Median	35.0	35.0	25.0	32.0	Injured–uninjured: < 0.001
	Range	29.0 - 37.0	30.0 - 37.0	15.0 - 30.0	20.0 - 37.0	Group: < 0.001
HERP						
	Mean (SD)	38.0 (2.3)	38.9 (1.8)	30.0 (4.5)	37.2 (3.8)	Interaction: < 0.001
	Median	39.0	40.0	30.0	37.0	Injured–uninjured: < 0.001
	Range	35.0-40.0	35.0-41.0	20.0-38.0	25.0-43.0	Group: < .001

DFA, dorsi flexion active; DFP, dorsi flexion passive; EA, eversion active; EP, eversion passive; HABDA, hip abduction active; HABDP, hip abduction passive; HADDA, hip adduction active; HADDP, hip adduction passive; HEA, hip extension active; HEP, hip extension passive; HERA, hip external rotation active; HERP, hip external rotation passive; HFA, hip flexion active; HFP, hip flexion passive; HİRA, hip internal rotation active; HİRP, hip internal rotation passive; IEA, inversion active; IEP, inversion passive; KEA, knee extension active; KEP, knee extension passive; KFA, knee flexion active; KFP, knee flexion passive; PFA, plantar flexion active; PFP, plantar flexion passive.

According to ODI, low back pain did not cause a significant problem in 4 patients, limited life slightly in 13 patients, severely in 3 patients, and completely in 2 patients. Among the sub-dimensions of SF-36, only physical functionality was found to be statistically significant between with and without low back pain patients ($P = .016$). There was no association between Sanders' score and low back pain ($P = .433$) (Table 2).

Lower extremity range of motion outcomes

The foot and ankle ROM findings revealed that the injured–uninjured foot asymmetry was present independent of low back pain in the measurements of the dorsi flexion active (DFA), dorsi flexion passive (DFP), extension active (EA), and extension passive (EP) (interaction: $P > .1$ and injured–uninjured: $P < .001$). However, the injured–uninjured foot asymmetry in Plantar Flexion Active (PFA), Plantar Flexion Passive (PFP), Inversion Active (IA) and Inversion Passive (IP) ROM measurements was worse in patients with low back pain compared to those without (interaction: $P = .034$, $P = .068$, $P = .067$, and $P = .013$, respectively) (Figure 2). Interestingly, the DFA and DFP ROM measurements were found to be more restricted in both the healthy and affected foot in patients with low back pain (interaction: $P > .1$ for all and group: $P = .008$ and $P < .001$, respectively) (Table 3).

The only statistically significant knee ROM restriction was observed in Knee Flexion Active (KFA) between the injured and uninjured extremity, regardless of the presence of low back pain (interaction: $P = .467$ and injured–uninjured: $P = .013$). Besides this, calcaneal fractures did not significantly impact knee joint ROM in the patient cohort [interaction: $P > .1$ and injured–uninjured: $P > .05$ for knee flexion passive (KFP), knee extension active (KEA), and knee extension passive (KEP)] (Table 3).

The lower extremity hip ROMs were more restricted in the injured foot than in the uninjured foot for the hip extension passive (HEP), hip adduction passive (HADDP), and hip abduction active (HABDA), regardless of the presence of low back pain (interaction $P > .1$ for all and injured–uninjured: $P = .006$, $P = .004$, and $P = .007$, respectively). On the other hand, the asymmetry between the 2 feet in hip adduction passive (HABDP), hip internal rotation active (HIRA), hip internal rotation passive (HIRP), hip external rotation active (HERA), and hip external rotation passive (HERP) ROM measurements was found to be statistically significant between those with low back pain and those without (interaction: P=.025, P < .001, P < .001, P < .001, and P < .001, respectively) (Figure 3A-E). Noteworthily, it was observed that hip flexion active (HFA), hip flexion passive (HFP), and HABDA ROM measurements of the foot and ankle were more limited in patients with low back pain on both feet compared to the other group of patients (interaction: P > .1 for all and Group P < .001, P=.002, and P=.046, respectively) (Table 3).

Lower Extremity Muscle Strength Outcomes

The analysis of foot and ankle muscle strength measurements showed that the patients with low back pain had worse injured–uninjured asymmetry in eversion strength than patients without low back pain (interaction: P=.085) (Figure 3f). The asymmetries between the 2 feet in dorsi flexion strength, plantar flexion strength, inversion strength foot and ankle strength measurements were found to be statistically significant, regardless of low back pain (interaction: P > .1 and injured–uninjured: P < .001 for all). Similarly, when the results were examined for the knee and hip, significant injured–uninjured foot asymmetry was observed in the knee extension strength, hip extension strength, and hip internal rotation strength, independent of low back pain (interaction: P > .1 for all and injured–uninjured: P < .001, P=.002, and P=.002, respectively) (Table 4).

Pedobarographic Outcomes

The injured–uninjured foot asymmetry of static bearing and balance measurements was found significant, regardless of the presence

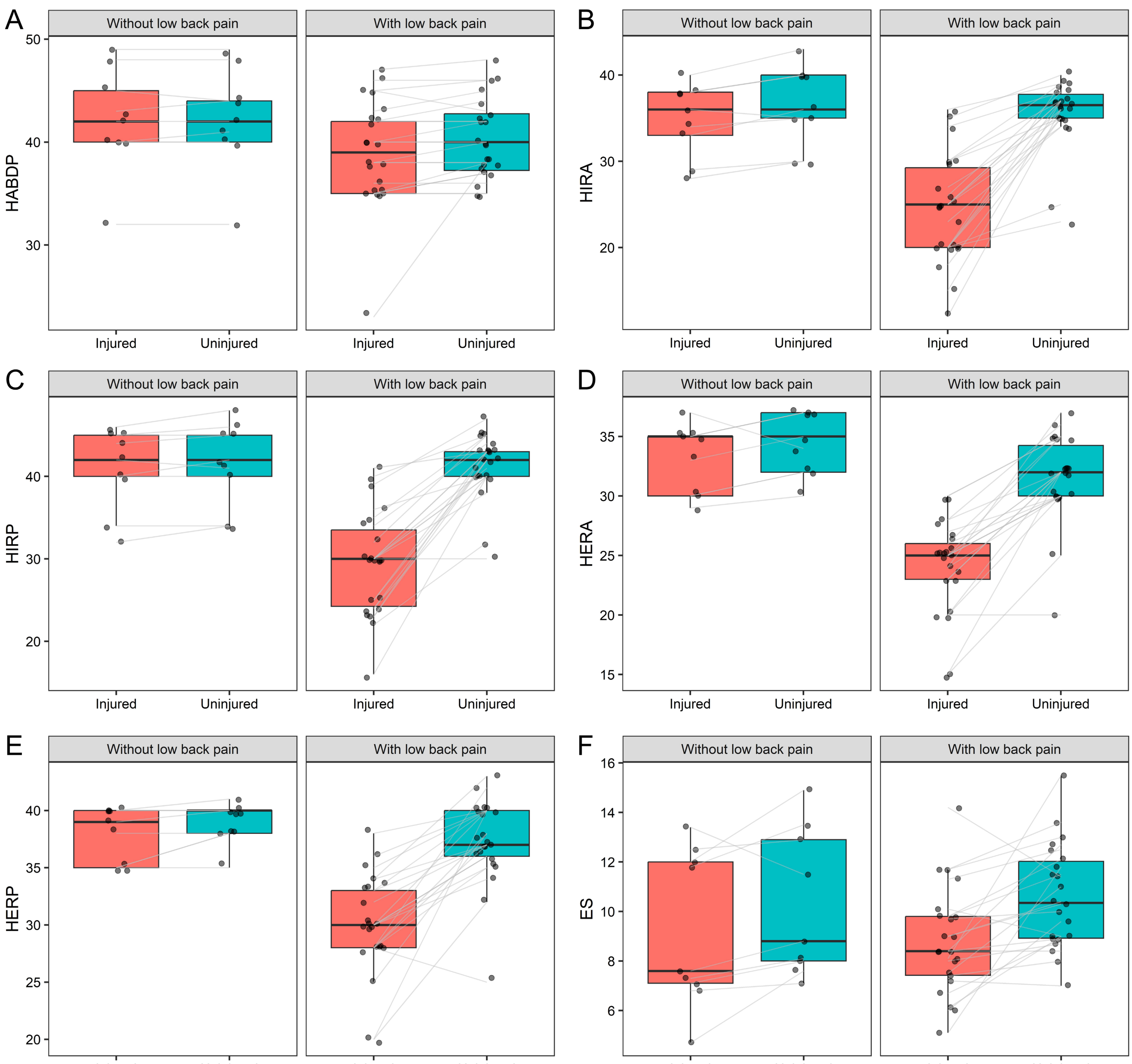

Figure 3. Some lower extremity muscle strength assessments associated with low back pain. Box plots were used for graphical representations. In the boxplots, the horizontal lines of the rectangles from bottom to top show the first quartile, the second quartile (median), and the third quartile, respectively. The vertical lines extend from the boxplot as 1.5 times the interquartile range. Dots on the box plots show the measurement values of each patient on that foot. The gray lines connecting the points between the 2 feet show the asymmetry between the foot measurements of the same patient. The graphs show that asymmetries between the injured and uninjured feet are more pronounced in the group with low back pain. HABDP (A), HIRA (B), HIRP (C), HERA (D), HERP (E), and ES (F).

Table 4. Evaluation of asymmetry between injured and non-injured foot in the presence of low back pain in foot and ankle, knee, and hip muscle strength measurements

	Low back pain, no (N=9)		Low back pain, yes (N=22)		
	Foot		Foot		*P*
	Injured	Uninjured	Injured	Uninjured	
DFS					
Mean (SD)	10.6 (3.4)	11.6 (3.5)	11.8 (3.9)	13.6 (3.0)	Interaction: .121
Median	9.7	10.2	11.9	14.1	Injured–uninjured: < .001
Range	5.3-16.4	7.9-18.0	4.2-21.2	7.4-22.0	Group: .233
PFS					
Mean (SD)	10.7 (4.6)	12.0 (3.7)	11.8 (4.3)	13.8 (2.9)	Interaction: .341
Median	10.8	9.4	12.5	14.1	Injured–uninjured: < .001
Range	4.9-19.5	9.0-19.4	1.6-19.8	6.8-18.4	Group: .273
IS					
Mean (SD)	10.1 (2.7)	11.5 (1.7)	8.9 (2.2)	10.2 (1.7)	Interaction: .674
Median	10.5	11.0	9.2	10.4	Injured–uninjured: < .001
Range	4.0-13.5	8.8-13.8	5.0-13.8	6.9-12.9	Group: .077
ES					
Mean (SD)	9.2 (3.2)	10.3 (2.9)	8.8 (2.2)	10.6 (2.1)	Interaction: .085
Median	7.6	8.8	8.4	10.4	Injured–uninjured: < .001
Range	4.7-13.4	7.1-14.9	5.1-14.2	7.0-15.5	Group: .888
KFS					
Mean (SD)	12.5 (4.4)	13.2 (4.5)	11.8 (2.8)	12.5 (3.1)	Interaction: .433
Median	12.0	12.3	11.8	11.7	Injured–uninjured: .288
Range	7.2-20.4	7.7-20.9	5.0-17.4	9.0-21.6	Group: .793
KES					
Mean (SD)	13.2 (2.9)	15.0 (2.5)	13.4 (3.4)	14.3 (3.1)	Interaction: .135
Median	13.7	15.9	13.9	14.5	Injured–uninjured: < .001
Range	7.5-18.0	10.3-17.1	6.3-20.0	7.5-20.1	Group: .851
HFS					
Mean (SD)	12.8 (2.5)	13.6 (2.9)	13.4 (2.5)	13.4 (2.2)	Interaction: .144
Median	13.6	13.5	12.6	13.8	Injured–uninjured: .141
Range	9.4-17.4	10.1-17.2	9.9-17.4	9.8-16.7	Group: .887
HES					
Mean (SD)	13.7 (2.8)	14.6 (2.5)	14.3 (2.9)	14.8 (2.9)	Interaction: .152
Median	13.4	15.0	14.1	14.6	Injured–uninjured: .002
Range	10.7-20.0	11.4-18.2	9.8-20.8	10.0-22.4	Group: .695
HADDS					
Mean (SD)	10.5 (3.1)	10.4 (0.9)	10.1 (1.6)	10.7 (1.4)	Interaction: .626
Median	9.7	10.4	10.4	10.8	Injured–uninjured: .061
Range	5.8-16.9	8.9-11.4	6.7-13.7	7.6-13.4	Group: .875
HABDS					
Mean (SD)	11.3 (2.6)	11.4 (2.0)	10.7 (2.7)	11.0 (2.4)	Interaction: .711
Median	12.5	12.0	10.4	10.5	Injured–uninjured: .397
Range	6.1-13.6	7.4-13.5	6.7-18.8	7.2-15.6	Group: .358
HIS					
Mean (SD)	9.9 (3.3)	10.7 (3.3)	9.7 (1.6)	10.2 (1.7)	Interaction: .620
Median	9.5	10.0	9.6	9.9	Injured–uninjured: .002
Range	6.6-17.3	6.4-18.0	6.4-12.9	7.0-14.1	Group: .874
HESA					
Mean (SD)	9.3 (2.2)	9.1 (1.7)	9.6 (2.0)	10.2 (2.2)	Interaction: .468
Median	9.0	9.2	9.2	9.9	Injured–uninjured
Range	7.0-13.7	7.0-11.8	6.4-14.2	7.0-15.0	Group: .420

DFS, dorsi flexion strength; ES, eversion strength; HABDS, hip abduction strength; HADDS, hip adduction strength; HES, hip external rotation strength; HFS, hip flexion strength; HIS, hip internal rotation strength; KES, knee extension strength; KFS, knee flexion strength; PFS, plantar flexion strength; IS, inversion strength.

of low back pain (interaction: $P > .1$ and injured–unjured: $P < .001$ for all). The balance measurements were worse in the group with low back pain in both feet (interaction: $P=.444$ and group $P=.035$) (Table 5).

Discussion

The human ankle and foot complex is a complicated mechanism that is fundamental in the interaction between the lower extremity and the ground during movement.[14] Changes occur in this mechanism after calcaneal fractures. The soft tissues in the posterior of the foot are also injured during the injury. The plantar surface is crushed under the compressive force. This situation leads to crushing of the fat pad around the calcaneus, primarily the plantar fascia.[7-15] The situation that the patient must deal with after calcaneus fractures is not limited to bone fracture healing. Changing biomechanical balances during the healing process makes the situation even more complicated. Disruption in the mechanism leads to changes in ground reaction force and muscle activities that occur during walking.[16,17] All these changes can cause pain in the upper parts of the body,

Table 5. Evaluation of asymmetry between injured and non-injured foot in the presence of low back pain in pedobarographic measurements

	Low back pain, no (N=9)		Low back pain, yes (N=22)		*P*
	Foot		Foot		
	Injured	Uninjured	Injured	Uninjured	
Static bearing					
Mean (SD)	47.4 (2.0)	52.6 (2.0)	47.5 (6.8)	53.0 (5.7)	Interaction: .635
Median	46.9	53.1	45.3	54.7	Injured–uninjured: < .001
Range	45.4-51.0	49.0-54.6	37.1-66.0	38.2-62.9	Group: 1.000
Walking time					
Mean (SD)	732.8 (104.9)	762.3 (86.7)	817.1 (315.6)	808.5 (106.8)	Interaction: .975
Median	750.0	730.0	760.0	812.5	Injured–uninjured: .070
Range	560.0-890.0	645.0-890.0	305.0-2080.0	685.0-1060.0	Group: .330
Balance					
Mean (SD)	12.6 (10.8)	28.7 (4.0)	8.2 (9.0)	26.0 (8.9)	Interaction: .444
Median	9.0	30.0	4.0	30.0	Injured–uninjured: < .001
Range	3.0-30.0	18.0-30.0	1.0-30.0	4.0-30.0	Group: .035

independent from the injured areas.[14] After calcaneus fractures, movement restrictions occur in both the tibiotalar and subtalar joint (STJ).[2-18] Due to the deteriorated natural pronation movement of STJ after the trauma, the rolling motion (movement) that occurs in the foot during walking shifts from the middle of the foot to the lateral of the foot.[19] As 1 of the 3-plane movements in STJ, the movement that occurs in the frontal plane on the back of the foot in subtalar pronation causes rotation in the tibia and femur in the transverse plane.[20-21] Internal rotation of the tibia and femur leads to anterior pelvic tilt and, subsequently, low back pain.[22-23]

In our study, we found that the incidence of low back pain after calcaneal fractures treated with ORIF was 71%. This complaint appeared on average starting from the 6th month. This situation shows that the possible low back pain that can be experienced after fracture healing cannot be ignored. Seay et al investigated the rate of admission to the hospital with complaints of low back pain in the first year after the injury of soldiers who had all lower extremity injuries in the US Army. The rate of low back pain development was determined to be 70%.[6] The frequency mean of low back pain in our study is very close to this value, though our sample size is limited. This means that it is not enough to focus only on only the source of the problem. Especially, the physiotherapy process should be holistic.

In our study, we found that in the evaluation of balance on 1 foot, the duration of balancing on the injured foot was shorter than that on the non-injured foot. This loss in balance was found to be statistically associated with low back pain. In their study, Hirschmüller et al determined a shortening in standing time on the injured foot in single-foot balance measurements. They mentioned that the loss of mechanoreceptors providing sensory input in the afferent side of the sensorimotor system is more important than muscle strength.[19] The feet and soles are the areas where mechanoreceptors are abundant. The abundance and quality of the afferent information transferred from here affects many movements that require balance, especially walking balance. Neuromuscular losses may occur due to reflex inhibition caused by pain and edema occurring during the formation of the fracture in the soft tissue and due to traumas occurring during the operation, and delayed start of walking with full-weight bearing. We think that this is the main reason behind the loss of balance.

An asymmetrical walking cycle occurs after calcaneus fractures. We found that the duration of the "single support" period of walking was statistically shorter in the injured foot than in the non-injured foot. In their study, the findings of Schepers et al are in line with our findings.[23] We think that the presence of pain and the lack of balance cause this situation.

In our study, the decreases in plantarflexion and inversion angles as ROM measurements of the ankle and foot were statistically found to be associated with low back pain. Also, we found that the ROM values of the other injured foot were statistically significantly lower than the non-injured ones.

In the studies, a limitation in ROM in both planes was found in parallel with our study.[2-19] Even though the calcaneus restricts movement in the frontal plane due to its existence in the STJ structure, it also has an effect on the range of motion in the sagittal plane with the joint it makes with the talus. Pronation, which occurs at the beginning of the "pose" phase of walking, flattens the arches of the feet, increases the movement of the forefoot, helps to absorb the shock from the ground reaction forces, and helps the foot adapt to the ground. The supination that occurs toward the end of the "pose" phase causes the arch to rise, therefore decreasing the current motion of the forefoot, providing stability, and facilitate the effective pushing phase mechanics.[24] Dysfunction occurring in STJ disrupts this entire system. This also influences the behavior of the plantar fascia during walking. This situation leads to inefficiencies in the absorption of ground reaction forces in the late pose phase of walking.[25]

Insufficient shock absorption may not only increase the pain in the foot but also may cause joint and muscle damage in the upper segments. In addition, these rotation deficiencies must be compensated for by higher segments.

In our study, we found a decrease only in active knee flexion angle measurements in knee ROM measurements. In the study of Bozkurt et al[2] while a decrease was found in knee flexion, an increase was determined in knee extension angle. In this study, measurements were made while walking. In our literature searches, we saw that goniometric measurements were only for the foot and ankle in studies performed after heel fractures. We could not find any literature information about the measurements of the upper segments.[3-18] Rotational motion deficiencies in the foot may not have a dramatic effect on the knee, because, as far as we think, the hinge structure of the knee joint can protect itself from these rotational effects at the maximum level.

In our study, the decrease in active and passive internal and external rotation angles of hip ROM was found to be statistically associated with low back pain. We also determined a decrease in active and passive hip flexion, passive hip extension, passive adduction, active and passive abduction forces. In their study on healthy individuals, Duval et al,[27] came up with a hypothesis that the alignment of the lower extremity up to the pelvic girdle may change due to the forces acting on the foot, and that the interaction between the foot and the pelvis occurs as a kinematic chain reaction. However, at the end of their study, they were not able to prove the effect of pronation or supination of the foot on the pelvis statistically. This study consists of a one-time and instant measurement of the reflection of different angles on the upper segments in healthy individuals. However, a person who has impaired foot biomechanics is exposed to these situations many times in his/her daily life. Moreover, we found the duration of low back pain to occur in our patients at the sixth month following the fracture date. In other words, following the patient's starting to walk with full-weight bearing, this situation emerged from the 3rd month on average. Therefore, the length and frequency of exposure may cause pathologies in the upper segments. In their study, Shum et al[16] reported that there was a statistically significant decrease in hip flexion on the painful side in the straight leg raising test and this was also observed in the extension, adduction, and internal rotation of the ipsilateral hip. These findings are in line with what we have found in our study. In addition to all these, we think that the decrease in the degree of external rotation that we found may be due to muscle imbalances or pain.

In the measurement of muscle strength, the loss of strength in the foot evertors was associated with low back pain. Moreover, when compared to the non-injured side, weakness of the injured side was statistically significant in the values of the injured side in DFF (dorsi flexion force), PFC, HR, EF (eversion force), KEF (knee extension force), HEF (hip extension force), and HIRF (hip internal rotation force). Hirschmüller et al[19] isokinetically measured the joint muscle strength of the tibiotalar joint in the non-injured and injured foot after operated calcaneal fractures. They found a statistically significant decrease in the strength of the plantar flexors. In follow-up studies with many different types of ankle injuries (distortion, functional instability, malleolus fractures), the plantar flexors were shown to be the first to be affected.[26-28]

Klöpfer-Krämer et al[29] stated that the long-term immobilization of the gastrosoleus complex and the reduction in the length of the Achilles tendon, which provides the force transmission from the plantar flexors to the calcaneus, were the causes of plantar flexor strength loss after calcaneus fractures. In their study, searching for the balance on 1 leg in calcaneal fractures, Nilsson et al,[30] found a statistically significant decrease in the strength of both plantar and dorsi flexors. They related the decrease in muscle strength and loss of balance to age.

In our study, we found a decrease in strength in these muscle groups in younger patients as well. We think that delayed full weight-bearing walking and decreased ROM are important in muscle weakness. We think that decreased ROM causes a dysfunction in the Achilles tendon as well and a decrease in the response to mechanical weight-bearing. There may also be a decrease in the cortical and subcortical motor representation of the extremities in the central nervous system after prolonged immobilization of the leg.

Bozkurt et al[2] determined a decrease in knee flexion and extension strength during walking. They said this was caused by an imbalance between the quadriceps and gastrocnemius muscles, pain, and ankle and knee contractures. We could not measure muscle strength during walking, yet we think that the decrease in knee extension strength may be due to the limitation of movement in the foot and ankle and the strength loss in the triceps surae complex.

Barwick et al[31] conducted a review in which they examined the relationship between foot movements and the lumbo-pelvic region and hip. In their study, they mentioned that the increased pronation movement in the foot created power imbalances in the iliopsoas, piriformis, and gluteal muscles. They mentioned the decrease in gluteus medius muscle strength was evident. This situation may cause decreased force output in external and internal rotations of the hip. Also, internal rotation force at the hip with increased pronation in the foot during the single-support period of walking may also cause a decrease in the tensor facia lata strength. These situations may explain the loss of strength in hip rotators that we found in our study.

Tomesen et al[32] found AOFAS 84.1 and SF-36 76.4 in their study with patients who underwent closed reduction surgery for Sanders II-III type fractures. Yeap et al[33] compared the results of ORIF and another surgical technique. The mean AOFAS score was found to be 86.2 points in patients in the ORIF group. The SF-36 physical functionality average was 58.3 and the mental functionality average was 45 points. Driessen et al[34] and Yeap et al [33] found AOFAS as 76 and SF-36 as 63 in ORIF patients in their evaluation in similar treatment groups. In both 2 studies, Sander's type II and III fractures were examined again. All the values we found in our study are close when we compare them with these studies. Low AOFAS may not only increase the incidence of low back pain but also affect physical and mental functionality negatively. Croft et al[35] reported the relationship between low back pain, depression, and anxiety in their study. In our study, the low score level in mental functionality may be due to long-term exposure to pain whose treatment has not been fully resolved. Clearly, reductions in psychological well-being can negatively affect pain, and pain can negatively affect psychological well-being.

Some limitations could be noted in this study. It was a cross-sectional study. Our patient sample was low, and a larger patient population is needed to further assess. Although patients who did not suffer from low back pain throughout their lives were included in our study, it was difficult to distinguish LBP that develops after fracture in the patients included in our study from LBP that also occurs in the normal population. Post-op computed tomography examination could not be performed. In terms of incidence, calcaneal fractures are not the most common fractures of the lower extremities. In this study, the incidence and risk factors of low back pain with other types of lower extremity fractures were not compared to the incidence and risk factors of low back pain with calcaneus fractures.

In conclusion, low back pain may occur after unilateral calcaneal fractures treated by ORIF. This may be caused by decreased angles of ankle dorsi and plantar flexion, foot inversion, and hip abduction, internal and external rotation on the affected lower extremity after treatment of calcaneus fracture. Although the aim of rehabilitation after these fractures is to minimize foot and ankle stiffness, to prevent reflex sympathetic dystrophy, and to provide early ambulation, it should be kept in mind that low back pain may occur in these patients. Therefore, in the rehabilitation program, not only the ankle region but also the hip joint of the affected side should be included, and the kinetic chain that describes the interaction mechanism of the human body should not be forgotten.

Ethics Committee Approval: This study was approved by Ethics committee of Ege University (Approval No: 21-9T/17, Date: September 9, 2021).

Informed Consent: Informed consent was obtained from the participants who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – D.B., C.Ö., A.M.Ö.; Design – D.B., C.Ö, A.M.Ö.; Supervision – A.M.Ö., D.B., K.A., N.Ö; Resources – D.B., A.M.Ö., K.A., N.Ö.; Materials – D.B., A.M.Ö.; Data Collection and/or Processing – D.B., A.M.Ö.; Analysis and/or Interpretation – D.B., A.M.Ö.; Literature Search – D.B., A.M.Ö.; Writing – D.B., A.M.Ö.; Critical Review – D.B., C.Ö., A.M.Ö., K.A., N.Ö.

Acknowledgments: We would like to thank Semiha Özgül, working in our university's Department of Biostatistics and Medical Informatics, her valuable contribution in statistical measurements.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Coughlin MJ. Calcaneal fractures in the industrial patient. *Foot Ankle Int.* 2000;21(11):896-905. [CrossRef]
2. Bozkurt M, Kentel BB, Yavuzer G, Öçgüder A, Heycan C, Tonuk E. Functional evaluation of intraarticular severely comminuted fractures of the calcaneus with gait analysis. *J Foot Ankle Surg.* 2004;43(6):374-379. [CrossRef]
3. van Hoeve S, de Vos J, Verbruggen JPAM, Willems P, Meijer K, Poeze M. Gait analysis and functional outcome after calcaneal fracture. *J Bone Joint Surg Am.* 2015;97(22):1879-1888. [CrossRef]
4. Zhang H, Lv ML, Liu Y, et al. Biomechanical analysis of minimally invasive crossing screw fixation for calcaneal fractures: implications to early weight-bearing rehabilitation. *Clin Biomech (Bristol Avon).* 2020;80:105143. [CrossRef]
5. Brantingham JW, Lee Gilbert J, Shaik J, Globe G. Sagittal plane blockage of the foot, ankle and hallux and foot alignment-prevalence and association with low back pain. *J Chiropr Med.* 2006;5(4):123-127. [CrossRef]
6. Seay JF, Shing T, Wilburn K, Westrick R, Kardouni JR. Lower-extremity injury increases risk of first-time low back pain in the US Army. *Med Sci Sports Exerc.* 2018;50(5):987-994. [CrossRef]
7. Çırpar M. Fractures of calcaneus. *TOTBİD Dergisi.* 2013;12(2):168-176. [CrossRef]
8. Analay Akbaba Y, Celik D, Ogut RT. Translation, cross-cultural adaptation, reliability, and validity of Turkish version of the American Orthopaedic Foot and Ankle Society Ankle-hindfoot Scale. *J Foot Ankle Surg.* 2016;55(6):1139-1142. [CrossRef]
9. Demiral Y, Ergor G, Unal B, et al. Normative data and discriminative properties of short form 36 (SF-36) in Turkish urban population. *BMC Public Health.* 2006;6:247. [CrossRef]
10. Yakut E, Düger T, Öksüz C, et al. Validation of the Turkish version of the Oswestry Disability Index for patients with low back pain. *Spine (Phila Pa 1976).* 2004;29(5):581-5; discussion 585. [CrossRef]
11. Muralidaran S, Wilson-smith AR, Maharaj M, et al. Validation of a Novel Digital Goniometer as a Range of Motion Assessment Tool for The Lower Extremity. *J Orthop Res Ther.* 2020;5:1-8. [CrossRef]
12. Hancock GE, Hepworth T, Wembridge K. Accuracy and reliability of knee goniometry methods. *J Exp Orthop.* 2018;5(1):46. [CrossRef]?
13. Stoll T, Huber E, Seifert B, Michel BA, Stucki G. Maximal isometric muscle strength. Normative values and gender-specific relation to age. *Clin Rheumatol.* 2000;19(2):105-113. [CrossRef]
14. Leardini A, Benedetti MG, Berti L, Bettinelli D, Nativo R, Giannini S. Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. *Gait Posture.* 2007;25(3):453-462. [CrossRef]
15. Davies MB, Betts RP, Scott IR. Optical plantar pressure analysis following internal fixation for displaced intra-articular os calcis fractures. *Foot Ankle Int.* 2003;24(11):851-856. [CrossRef]
16. Shum GLK, Crosbie J, Lee RYW. Three-dimensional kinetics of the lumbar spine and hips in low back pain patients during sit-to-stand and stand-to-sit. *Spine (Phila Pa 1976).* 2007;32(7):E211-E219. [CrossRef]
17. Hanada EY, Johnson M, Hubley-Kozey C. A comparison of trunk muscle activation amplitudes during gait in older adults with and without chronic low back pain. *PM R.* 2011;3(10):920-928. [CrossRef]
18. Allmacher DH, Galles KS, Marsh JL. Intra-articular calcaneal fractures treated nonoperatively and followed sequentially for 2 decades. *J Orthop Trauma.* 2006;20(7):464-469. [CrossRef]
19. Hirschmüller A, Konstantinidis L, Baur H, et al. Do changes in dynamic plantar pressure distribution, strength capacity and postural control after intra-articular calcaneal fracture correlate with clinical and radiological outcome? *Injury.* 2011;42(10):1135-1143. [CrossRef]
20. Pohl MB, Messenger N, Buckley JG. Forefoot, rearfoot and shank coupling: effect of variations in speed and mode of gait. *Gait Posture.* 2007;25(2):295-302. [CrossRef]
21. Pinto RZA, Souza TR, Trede RG, Kirkwood RN, Figueiredo EM, Fonseca ST. Bilateral and unilateral increases in calcaneal eversion affect pelvic alignment in standing position. *Man Ther.* 2008;13(6):513-519. [CrossRef]
22. Betsch M, Wild M, Große B, Rapp W, Horstmann T. The effect of simulating leg length inequality on spinal posture and pelvic position: a dynamic rasterstereographic analysis. *Eur Spine J.* 2012;21(4):691-697. [CrossRef]
23. Khamis S, Yizhar Z. Effect of feet hyperpronation on pelvic alignment in a standing position. *Gait Posture.* 2007;25(1):127-134. [CrossRef]
24. Kirby KA. Biomechanics of the normal and abnormal foot. *J Am Podiatr Med Assoc.* 2000;90(1):30-34. [CrossRef]
25. Erdemir A, Hamel AJ, Fauth AR, Piazza SJ, Sharkey NA. Dynamic loading of the plantar aponeurosis in walking. *J Bone Joint Surg Am.* 2004;86(3):546-552. [CrossRef]
26. Kinner BJ, Best R, Falk K, Thon KP. Is there a reliable outcome measurement for displaced intra-articular calcaneal fractures? *J Trauma.* 2002;53(6):1094-101; discussion 1102. [CrossRef]
27. Duval K, Lam T, Sanderson D. The mechanical relationship between the rearfoot, pelvis and low-back. *Gait Posture.* 2010;32(4):637-640. [CrossRef]
28. Termansen NB, Hansen H, Damholt V. Radiological and muscular status following injury to the lateral ligaments of the ankle follow-up of 144 patients treated conservatively. *Acta Orthop Scand.* 1979;50(6 Pt 1):705-708. [CrossRef]
29. Klöpfer-Krämer I, Brand A, Kröger I, et al. Development of the center of pressure velocity in the healing process after intra-articular calcaneus fractures. *Gait Posture.* 2022;95(January):135-140. [CrossRef]
30. Nilsson G, Ageberg E, Ekdahl C, Eneroth M. Balance in single-limb stance after surgically treated ankle fractures: a 14-month follow-up. *BMC Musculoskelet Disord.* 2006;7(35):35. [CrossRef]
31. Barwick A, Smith J, Chuter V. The relationship between foot motion and lumbopelvic-hip function: a review of the literature. *Foot (Edinb).* 2012;22(3):224-231. [CrossRef]
32. Tomesen T, Biert J, Frölke JPM. Treatment of displaced intra-articular calcaneal fractures with closed reduction and percutaneous screw fixation. *J Bone Joint Surg Am.* 2011;93(10):920-928. [CrossRef]
33. Yeap EJ, Rao J, Pan CH, Soelar SA, Younger ASE. Is arthroscopic assisted percutaneous screw fixation as good as open reduction and internal fixation for the treatment of displaced intra-articular calcaneal fractures? *Foot Ankle Surg.* 2016;22(3):164-169. [CrossRef]
34. Driessen MLS, Edwards MJR, Biert J, Hermans E. Long-term results of displaced intra-articular calcaneal fractures treated with minimal invasive surgery using percutaneous screw fixationNo. *Injury.* 2021;52(4):1054-1059. [CrossRef]
35. Croft PR, Papageorgiou AC, Ferry S, Thomas E, Jayson MIV, Silman AJ. Psychologic distress and low back pain: evidence from a prospective study in the general population. *Spine (Phila Pa 1976).* 1995;20(24):2731-2737. [CrossRef]