

## Plantar Pressure Distribution during Walking after Specific Soft Tissue Heel Injury – Case Study

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**Abstract.** Calcaneal injuries are injuries, affecting the all-aged population. The abnormalities in the gait pattern after calcaneal injuries are very common many months after the injury. These abnormalities can be evaluated by different biomechanical methods. Pedobarography detects differences in plantar pressure distribution between injured (INJ) and uninjured foot (UIN) while walking. The aim of our study was to compare plantar pressure distribution and trajectory of centre of pressure (CoP) in the stance phase during walking 6 and 12 months after the heel injury in a patient after the necrotic tissue removal. This study was a case interpretation. The participant was 9-years old young girl after a car accident. The measurement was performed 6 and 12 months after the injury and after a soft necrotic tissue removal. Measurement of plantar pressure distribution and pressure values was performed while walking on the pedobarography measurement platform (EMED ®-c50/R, Novel, Munich, Germany) with the frequency of 50 Hz. The measurement was done during the stance phase while walking. For each step, loading variables and temporal variables and also trajectory of CoP were observed. The mean of 5 steps for each variable was used to compare INJ and UIN. The loading variables normalized to body mass included peak pressure, representing the maximum pressure recorded under the foot, maximum vertical force and trajectory of CoP. Peak pressure values were higher on the UIN (6 months: 10.4% and 12 months: 8.2%). At maximum vertical force, the values on the UIN were lower (6 months: 3% and 12 months 2.5%). Peak pressure values under the heel were higher on the UIN in both measurements. Six and 12 months after the injury, the trajectory of CoP on the INJ was similar. It started in the midfoot, continued in the direction to the hindfoot and then tended over the metatarsal head to the toes area. Trajectory of CoP in UIN has changed when 6 months after the injury the trajectory was similar to the healthy subjects (starting in the hindfoot and continuing through the midfoot, metatarsal heads to the big toe area) but 12 months after the injury was the trajectory of CoP more similar to the trajectory at the INJ. Plantar pressure distribution asymmetry between the INJ and UIN occurred in both measurements (6 and 12 months follow up). The trajectory of CoP on the UIN in 6 months follow up measurement was similar to the healthy subjects in previous studies but it has changed during the next 6 months. Unfortunately the correct gait stereotype on the UIN has lost and patient tended to use the wrong gait stereotype according the INJ. According to our study we recommend to use orthopaedic insoles with various heel support to eliminate the differences between the plantar pressure distribution under the injured and uninjured foot and to ensure the right gait stereotype.

## Introduction

Calcaneal injuries are complex injuries, typically affecting the middle-aged active population. The main causes include falls and landing from heights or car accidents. In most cases, soft tissues are harmed.

The results of calcaneal treatment are assessed in several ways. It is in most cases clinical examination, X-ray images or computed tomography [1]. The abnormalities in the gait pattern after calcaneal injuries are very common many months after the injury [2,3]. These abnormalities can be evaluated by different biomechanical methods. Such methods include pedobarography, which allows plantar pressure analysis at various time intervals after the injury [2-4]. With this method, differences in the plantar pressure distribution between injured and uninjured foot while walking can be detected. These abnormalities include usually decreased pressure under the injured foot, shortened stance phase and load shift from the calcaneus to the midfoot [4].

One aspect of physiological walking is symmetry in the action of the lower limbs and symmetry of the ground reaction forces [5]. High degree of loading symmetry between the left and right feet during walking in healthy subjects have been observed [6,7].

The purpose of this study was to compare the plantar pressure distribution in the stance phase during walking 6 and 12 months after the calcaneal injury in a patient after the necrotic tissue removal.

## Methods

The aim of our study was to compare plantar pressure distribution and trajectory of Centre of Pressure (CoP) during walking 6 and 12 months after the injury. It was a case study.

### *Patient*

The participant was 9-years old young girl with necrotic tissue on the calcaneus caused by a car accident (Fig. 1). The measurement was performed 6 and 12 months after the injury.



Fig. 1 Heel bone after necrotic tissue removal

Six and twelve months following operative treatment, the patient was contacted to participate in the measurement. It was performed during the period 7/2015 – 7/2016. Participant and also her parents were familiarized with the design of the measurement and parents signed an informed consent. Analysis of plantar pressure distribution while walking

was then performed. All experiments were approved by the Institutional Review Board of Technical University of Liberec and in accordance with the Declaration of Helsinki.

### *Plantar Pressure Analysis Protocol*

Measurement of the plantar pressure distribution and pressure values was performed while walking on the pedobarography measurement platform (EMED ®-c50/R, Novel, Munich, Germany) with the frequency of 50 Hz.

The measurement was preceded by a 5-minute training walk over a measurement platform. The measurement was then initiated, aimed at analysing the plantar pressure distribution during the stance phase while walking. The participant was asked to walk barefoot at a self-selected speed that she uses in everyday life over a platform. She took at least three steps before and after the platform to ensure recording of a step in full gait. The measurement was repeated until a total of five individual steps of injured (INJ) and five individual steps of uninjured (UIN) limbs were recorded.

For each step, loading variables and temporal variables and also trajectory of CoP were observed. The mean of 5 steps for each variable was used to compare INJ and UIN. The loading variables normalized to body mass included peak pressure, representing the maximum pressure recorded under the whole foot, maximum vertical force and also the trajectory of centre of pressure (CoP).

## Results

Comparison of plantar pressure variables between the injured and uninjured limbs 6 and 12 months after the surgery is shown in Figure 2.

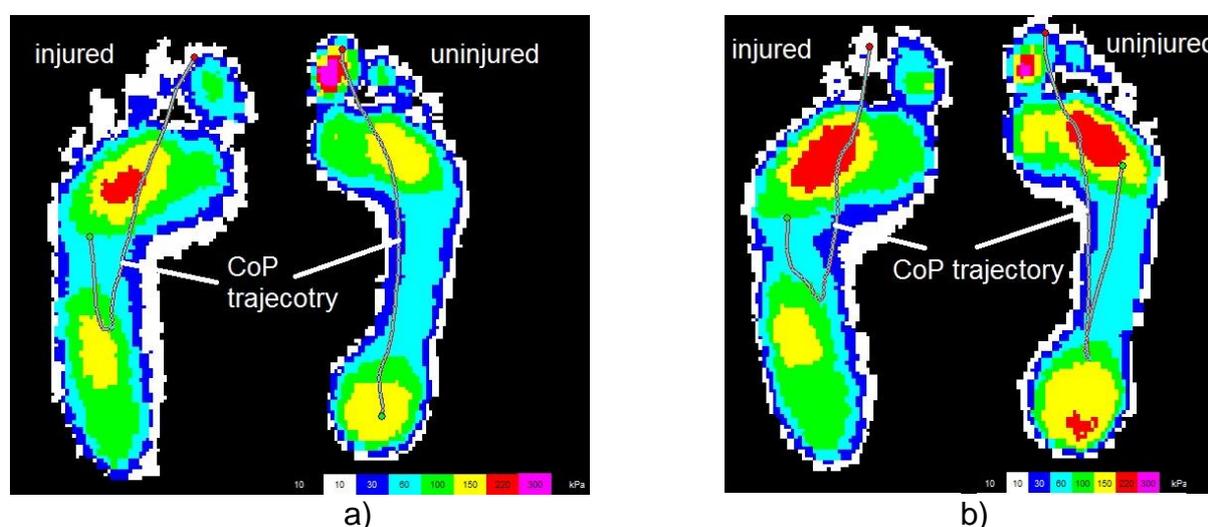


Fig. 2 Plantar pressure distribution and trajectory of CoP 6 (a) and 12 (b) months after the injury

Peak pressure values were higher for both measurements on the uninjured limb (6 months: 10.4% and 12 months: 8.2%). At maximum vertical force, the values on the injured limb were lower (6 months: 3% and 12 months 2.5%). Peak pressure values under the heel were significantly higher on the uninjured limb in both measurements.

CoP trajectory was different for both limbs in both measurements as well. Six months after the injury, the trajectory of CoP on the injured limb started in the midfoot, continues very shortly in the direction to the rearfoot and then tends over the middle metatarsal head to the toes area. Twelve months after the injury is the trajectory of CoP on the injured limb very

similar to the trajectory 6 months after the injury. The interesting change of the trajectory of CoP in uninjured limb occurred twelve months after the injury when 6 months after the injury the trajectory is as in healthy subjects (starting in the rearfoot and continuing through the midfoot, metatarsal heads to the big toe area) but 12 months after the injury is the trajectory of CoP more similar to the trajectory at the injured foot (starts under the metatarsal heads, continuous to the heel direction and then tends to the forefoot - big toe area). Unfortunately the subject lost the correct gait stereotype on the uninjured limb and tends to use the wrong gait stereotype according to the injured foot between the 6 and 12 months measurement.

## Discussion

The aim of our study was to compare plantar pressure distribution and trajectory of CoP during walking 6 and 12 months after the car accident and injury of the heel tissue.

One aspect of physiological walking is symmetry in the action of the lower limbs and symmetry of the ground reaction forces [5]. High degree of loading symmetry between the left and right feet during walking in healthy subjects have been observed [6,7]. In general, lateralization of peak pressure distribution and temporal parameters presented in our study for the injured and uninjured foot are similar with the values found in the literature for calcaneal fractures [4,6,8,9].

Six and 12 months after surgical treatment of tissue on the heel significant differences between the injured and uninjured limb in all of the observed variables (maximal pressure, vertical force, trajectory of CoP) were found. These side-to-side differences have been reported in the literature to remain for quite a long time after surgery when the calcaneal bone was injured [6,9]. Although in our study the tissue on the heel was necrotic and the replacement will be done not before 10 years, the symmetrical plantar pressure distribution can not be expected.

The time of the step on the rearfoot of the injured limb was shorter according to previous study carried out on the subjects after calcaneal fractures [10]. Thus, unlike the uninjured foot, the stance phase and heel contact of the injured foot was shortened [4].

As for dynamic parameters, the values on the injured foot were lower than those for uninjured foot regardless of the follow up duration. The peak pressure measured under the whole foot during the stance phase was different between both limbs in the 6 months follow up measurement, in which the injured foot values were 10.4% lower. In the 12 months follow up measurement, the peak pressure values in the injured foot were lower by 8.2%.

This finding points to the fact that 6 and 12 months after injury, the patient - with respect to maximum pressure under the heel - tended to step more and more cautiously on the injured heel. This overall trend of a load shift towards lateral regions of the injured limb is supported by differences in other areas. This indicates a persisting deviation of the gait pattern long after injury [6] and in this case it can occur at least until the tissue replacement will be done.

On the injured foot, plantar pressure is shifting towards the forefoot. The displacement of pressure toward the midfoot can be explained by the limited range of motion in the subtalar and tibiotalar joints [11]. Post-traumatic changes after this type of injury may lead to a breakdown of the gait stereotype and result in a flat foot [9].

In terms of time in specific zones (heel, midfoot, forefoot and toes), the CoP trajectory was significantly different in the injured and the uninjured foot in 6 months and 12 months follow up measurements. CoP trajectory in the injured foot started in the area of the midfoot, continues slightly in the posterior direction and then tends over the middle metatarsal head to the toes area. It does not reach the heel zone. This fact is likely to be related to the overall CoP shift toward the forefoot and relieving the heel due to the absent tissue in the area under the heel bone when stepping. The trajectory of CoP in the uninjured foot 6 months after the injury started in the heel zone as in the healthy subjects and then is directed more toward the

anterior part of the foot. In our study, there was a significant change in the trajectory of CoP in the uninjured foot in the 12 months follow up comparing to the 6 months follow up measurement. The trajectory tends to be like in the injured foot and the gait stereotype is changed. This fact is very undesirable from the prospective point of view when the tissue replacement will be done in the future. According to our study we recommend to use orthopaedic insoles with various heel support to eliminate the differences between the plantar pressure distribution under the injured and uninjured foot (Fig. 3) and to ensure the right gait stereotype.



Fig. 3 Formthotics insoles with heel support

Limitations of this study include the fact, that due to the low frequency and oneness of this injury, it was not possible to conduct the measurements in other patients. Generalisability of these results should be done carefully. Another limiting factor in this study is that the participant walked at her preferred speed. Because the measurement was taken at a relatively early stage of recovery, it was not possible to influence the walking speed. The study was performed not in a group of healthy subjects, but according to previous studies the human gait in healthy adults is symmetrical [5].

However, despite our appreciation of the limitations of our investigation, we believe that the results of this study could be useful for the posttraumatic therapy and the results could be used in the practice of gait stereotype.

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