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A Footscan Plantar Pressure System for End-Stage Osteonecrosis of the Femoral Head in Patients and Healthy Subjects

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Abstract

The progressive condition known as osteonecrosis of the femoral head (ONFH) lacks a known pathogenesis and has a complicated etiology. Gait analysis can objectively assess the foot's functional behavior, revealing important aspects and influencing factors of gait abnormalities. The differences in symmetry indices, static and dynamic plantar pressure parameters, and spatiotemporal parameters between ONFH patients and healthy people were the primary focus of this study. Materials and Methods: The study population consisted of 31 ONFH patients and 31 healthy volunteers. The plantar pressure analysis system was used to calculate the gait parameters of the ONFH and healthy groups. The symmetry index was calculated using the percentages of the restricted contact area, regional impulse, and static and dynamic plantar pressure distributions. Results: Compared to healthy controls, ONFH patients walked more slowly, had shorter steps and strides, and spent more time in stride, stance, and stance percentage. On the affected side, ONFH patients had lower plantar static pressure while standing than controls, whereas controls had higher plantar static pressure. Walking peak pressures in the toe 1 and metatarsal 3 regions of ONFH patients were lower than those of controls in healthy individuals. This held true for each and every side area that was affected. Compared to the control group, ONFH patients had a higher percentage of contact area and regional impulse in the heels of both limbs. Compared to controls with decreased symmetry, ONFH patients had significantly higher symmetry indexes for stride time, stance time, step length, maximum force, impulse, and contacted area. Conclusions: Symptoms of femoral head osteonecrosis include alterations in the distribution of plantar pressure. Patients with ONFH may interpret these adjustments as an effort to alleviate the limb's burden. An objective quantitative indicator for evaluating subsequent treatment outcomes and assisting in the diagnosis of ONFH can be obtained through plantar pressure analysis.

Keywords: Plantar pressure system; Plantar pressure distribution; Symmetry index

Introduction

The progressive condition known as osteonecrosis of the femoral head (ONFH) has a complicated etiology and no known cause. It is characterized by a disruption in the blood supply, subchondral bone necrosis, and femoral head collapse [**1**]. Younger patients typically have severe hip pain and difficulty walking. Total hip arthroplasty (THA) is typically used to treat end-stage ONFH to reduce pain and improve walking quality. Despite the fact that THA has emerged as the most efficient treatment option for patients with end-stage ONFH, the outcomes are frequently subpar in young adults and the active population who undergo one or more revisions due to prosthesis loosening, excessive wear on the polyethylene prosthesis, and periprosthetic. In order to slow its progression and improve patients' quality of life, ONFH must be detected and treated promptly [**2-5**].

Tools that provide reliable and repeatable measurements can be used in the diagnosis and developmental monitoring of a variety of illnesses to identify minute differences that differentiate healthy patterns from abnormal patterns and highlight specific treatment responses. By examining walking patterns with physical means, gait analysis can objectively evaluate the foot's functional behavior and reveal important aspects of gait abnormalities and influencing factors. Consequently, it is regarded as a useful addition to clinical and imaging evaluations. In addition, the Chinese guidelines for the clinical diagnosis and treatment of osteonecrosis of the femoral head recommend gait analysis in order to objectively evaluate the efficacy of ONFH treatment. As part of the gait analysis system, the plantar pressure system examines the foot's response to ground forces during everyday activities [**6**]. The assessment of plantar pressure reveals the relationship between the first point of the leg's kinematic chain and the plantar region, as well as how the plantar region is subjected to forces from the ground. Additionally, it serves as a foundation for abnormal plantar pressure distribution analysis and gait measurement, both of which are necessary for the etiological, diagnostic, functional, and therapeutic evaluation of walking disorders. Numerous studies have examined the effects of obesity, knee osteoarthritis, flat feet, diabetic foot, vena cava foot, stroke, and spinal cord injury on foot pressure. Measurements of static and dynamic plantar pressure distribution can also help identify the characteristics of plantar pressure distribution in particular populations and help identify potential causes by comparing pathological and normal gait. Plantar pressure distribution, symmetry, and spatiotemporal parameters have not been compared between patients with femoral head necrosis and healthy controls. Our goal was to use the plantar pressure system to describe and show these changes in order to see if it could be a good way to show problems with ONFH patients' foot pressure and weight bearing. At the conclusion of our study, we also attempted to obtain plantar pressure results for ONFH patients who had never previously been studied [**7,8**].

Materials and Method

Obtaining Data on the Walking Pattern

A plantar scanning pressure system manufactured by RSscan

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International in Olen, Belgium, consists of 16384 resistive sensors arranged in a 256 x 64 matrix with a data acquisition frequency of: Areas of stress: 125 Hz, 0–200 N/cm^2), which was connected to a computer via the supplied cable. The platform was level, on a safe flat surface, and centered on a 10-meter-long rubber walkway. To prevent the subject from being scared while walking on the scanning plate, a very thin, non-elastic cloth was applied to its surface. The examination room was lit evenly to prevent the subject's test results from being affected by too much light. The test system was calibrated in accordance with the manufacturer's instructions prior to each measurement [**9**].

Participants were informed of the examination's purpose and asked to wear loose clothing that did not restrict lower limb movement prior to the test. The participants' height and body mass were accurately measured prior to the gait test. After that, the participants' basic information, such as their name, gender, age, height, and body mass, were fed into the Footscan test system [**10**]. The participants' natural standing on the scanning platform was the first step in collecting static plantar pressure parameters. Each participant was required to walk the track five to ten times in order to acclimate and ensure a natural and realistic gait through the test area prior to the collection of dynamic data.

Discussion

Because they can be used to objectively assess the foot's functional behavior and assist in resolving kinematic and kinetic biases, plantar pressure measurements are regarded as a useful complement to clinical and imaging assessments. Plantar pressure and spatiotemporal parameters in ONFH patients and healthy individuals were the focus of this study. We measured a number of spatiotemporal and plantar pressure parameters in both groups of subjects with the footscan plantar pressure system. ONFH patients had slower walking speeds, shorter step lengths and strides, and increased stride time, stance time, and percentage of stance, according to the study's findings. On the affected side, ONFH patients had lower plantar static pressure while standing than controls, whereas controls had higher plantar static pressure. Walking peak pressures in the toe 1 and metatarsal 3 regions of ONFH patients were lower than those of controls in healthy individuals. This held true for each and every side area that was affected. Compared to the control group, ONFH patients had a higher percentage of contact area and regional impulse in the heels of both limbs. Compared to controls, ONFH patients displayed significantly greater symmetric stride time, stance time, step length, maximum force, impulse, and contacted area.

Walking at a steady pace requires the body to continue its exercise routine. Using the inertial sensor system RehaGait, Ismailidis and others collected gait data from 22 hip osteoarthritis patients. Hip osteoarthritis patients, according to the findings, walked slower, took significantly fewer strides, and needed fewer single support times than the healthy group. 11 patients with grade IV hip osteoarthritis and 11 healthy controls participated in this study. Using a motion capture system with eight infrared cameras, kinematic analysis was carried out. In accordance with our findings, the gait of hip osteoarthritis patients was characterized by decreased walking speed, stride length, stride frequency, swing phase time, increased support phase, and double support time. In our study, the ONFH group walked at a slower pace than the healthy group; The ONFH group's patients had a shorter propulsive swing phase because their stance phase percentage was higher and their stride and stance times were significantly longer than those of the healthy group. ONFH can cause a rapid limb swing and shorter strides in addition to hip pain, reduced mobility, and weak hip muscle contractures.

Conclusions

Using the plantar pressure system, we were able to distinguish ONFH patients from healthy controls in terms of symmetry, distribution of plantar pressure, and spatiotemporal parameters. Changes in how plantar pressure is distributed are a sign of femoral head osteonecrosis. ONFH patients may interpret these adjustments as an effort to lessen the burden placed on the affected limb. Plantar pressure analysis can provide an objective quantitative indicator for assessing subsequent treatment outcomes and assisting in the diagnosis of ONFH.

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