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Infrared plantography as a method to evaluate the functional anatomy of the human foot

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Abstract

The research aims to reveal the symptoms of a healthy and flat foot after short-term load applying infrared thermography. Healthy volunteers (Group 1, n=5) and patients with flat feet (Group 2, n=5) were observed. Thermal images of the subjects' feet were obtained after they had stood on one leg for 30 seconds keeping body balance on a flat horizontal surface. Infrared monitoring was performed by using ThermoTracer TH9100XX (NEC, USA) thermal imager. It was determined that a zone of local hyperthermia appears on the line connecting metatarsophalangeal joints and moves medially in patients with flat feet. The average temperature in the medial part of the line increases by 0,1°C and more compared to the average temperature of the lateral line.

Key words: infrared thermography, functional test, diagnostics, adaptation.

1. Introduction

The knowledge anatomy of the various parts of the human body may be developed applying contemporary functional diagnostic tests which allow to reveal hidden anatomical and functional reserves of human body adaptation. In particular, modern methods of radiation diagnosis can extend the idea of human body functional anatomy. Infrared thermography is a promising method of studying the functional anatomy of the living human body [1,2]. Currently functional tests recommended to improve the accuracy obtained by the infrared thermography data In particular, previous researches showed that infrared thermography is informative and sensitive in studying human body responses to short-term hypoxic exposure while performing cuff occlusion test and voluntary apnea [3,4]. We suggested that the use of infrared thermography may be helpful in evaluating the anatomical and functional condition of the human foot, for example, in platypodia. The foot is a structurally complex skeleton and plays a significant role in determining the level of human functional ability [5]. Modern methods for diagnosing platypodia not allow to draw conclusions about anatomical and functional changes in human feet under load conditions. The commonly applied radiological examination does not always reveal the severity of clinical disorders [6]. Therefore, work is underway to standardise the criteria of the clinical evaluation of disease progression. The pantographic technique has come to be applied ever more frequently in order to evaluate the distribution of pressure exerted by feet on the ground, reflecting the severity of the disorders of foot statics [7]. Thus, the development of methods to evaluate functional anatomy of the human foot is of great importance.

The research aims to reveal the symptoms of a healthy and flat foot after short-term load applying infrared thermography.

2. Materials and methods

Healthy adult volunteers (Group 1, n=5) with body mass 68-80 kg and adult patients with flat feet (Group 2, n=5) with body mass 75-90 kg were observed. We obtained thermal images of the subjects' feet after they had stood on one leg (alternately on the right and left barefoot leg) for 30 seconds keeping body balance on a flat horizontal cold surface. All tested were standing upright. Infrared monitoring was performed by using ThermoTracer TH9100XX (NEC, USA) thermal imager. Thermal imager installed at a distance of 1 meter from the surface of the shield. Ambient temperature of the examination room was 24-25°C, the temperature window of the thermal camera was set to the range of 25 to 36°C. After removal of the foot from the test surface immediately recorded thermal foot print. Evaluated geometric and physical (temperature) parameters obtained footprints. The obtained data were processed using the Thermography Explorer and Image Processor software. The photographs archived in the form of thermomaps atlas. Before the beginning of the research, its protocol was approved by the Ethics Committee of Izhevsk State Medical Academy, based on the principles set in the Declaration of Helsinki of the World Health Organization like. All investigated gave informed consent.

3. Results

Ten subjects participated in the research (Mean age±SD: 42.0±11.5 years, Gender, %female: 6/10 (60). Characteristic of study groups is shown in Table 1. We revealed differences in the average temperature of a healthy foot (figure 1A) and a flat foot (figure 1B) after the subjects had performed the functional test (they had to stand on one leg for 30 seconds). Our results show that infrared thermography allows you to record not only the geometric dimensions of the foot print, but also to identify features of the distribution of temperature zones in normal and pathological conditions. It

was established that the average temperature of healthy foot's thermal image along the metatarsophalangeal joint line in the medial part does not exceed the temperature in the lateral part. The patients with flat feet have a zone of local hyperthermia which moves medially. The average temperature in the medial part of the metatarsophalangeal joint line increases by 0,1°C and more compared to the average temperature of the lateral line. New data obtained by infrared thermography showed the diagnostic value of measurement of the temperature of the foot print for a comprehensive assessment of its functional anatomy. In addition, the diagnostic significance set temperature changes along the metatarsophalangeal joint line.

4. Disscusion

Nowadays, a variety of radiology methods is used for the diagnostics of musculoskeletal system conditions in patients with medical and surgical disorders. In particular, X-ray and X-ray contrast examination, x-radiography, magnetic resonance imaging and ultrasonography are traditionally used to evaluate the condition of the ankle joints, feet, shins and legs. These radiology diagnostic methods have both advantages and disadvantages. One of the major drawbacks of these radiology methods is their low safety; besides, they cannot be used for continuous monitoring aimed at determining dynamics and characteristics of the limbs functional anatomy in their "working" range under natural loads. In addition, these methods do not provide noncontact study of the dynamics of the human limbs functional anatomy from a distance of several meters in living conditions, sports, military and aerospace environments. Besides, their use is limited, due to the fact that they require highly specialized equipment and trained staff [7].

Epidemiological data show that foot deformations affect about 46% of the adult population [8,9]. Flat feet is one of the most spread feet condition. Pantographic examination and pedobarography method are commonly used for early diagnosis of this problem. In these conditions, pantographic examination is typically used to assess the pressure exerted by feet on the ground, and to determine the parameters indicating the static foot deformity. Pedobarography method is used to assess physical leg overload. It is non-invasive and enables us to monitor changes in musculoskeletal system biomechanics [10].

Recently, studying the dynamics of local temperature in limbs by means of infrared thermography using thermal imaging camera has become widely used for assessing the shins and feet condition in patients with diabetes mellitus, Raynaud's disease, and sports injuries [12]. The matter is that this infrared radiology method is absolutely safe, and allows continuous monitoring of the dynamics of the human musculoskeletal system in static and dynamic state. Another important advantage of this method is that it provides the information about the blood supply and the blood vessels structure; appearance of neoplasms, foreign bodies, bruises, and soft tissues contusions; arterial blood and oxygen supply; the degree of ischemic and hypoxic damage; the intensity of metabolism and inflammatory processes; patient's reserves for adaptation; signs of life and death in critical conditions, as well as ensures the possibility to assess the effectiveness of treatments and rehabilitation in real time [13,14]. That is why we suggested that the thermographic radiology method for diagnosing feet condition with a thermal imaging camera would provide additional information and improve diagnostic accuracy.

In order to check this assumption, we studied thermal traces (footprints) in healthy adults and adults with definite flatfoot. The decision was that thermal footprints would be studied in natural state and while doing standard physical exercise. By standard physical exercise we meant 30 seconds still standing on one leg on a flat surface, accumulating the heat of bare feet. At the same time, we assumed that plantography method was vital for assessing the feet condition.

Our preliminary results have fully confirmed our assumption. Infrared plantography proved to be really informative for infrared diagnostics of feet functional anatomy. We became convinced that plantography analysis is extremely important because its findings provides more information about the condition compared to direct measurements. The results allow us to recognize the graphic description of the observed disorders as well [11].

To conclude, infrared thermography does not only reveal anatomical changes in the feet soles, but also allows us to assess the functional state of the foot based on temperature changing in thermal images after functional loads. Using functional tests extends the scope of infrared thermography application.

Figures and tables

Table 1. *Characteristic of study groups*

	Group 1 (n=5)	Group 2 (n=5)
Gender, %female	3/5, 60	3/5, 60
Mean age±SD (years)	38.0±10.5	42.8±12.0
BMI (Body Mass Index, kg/m^2)	24.6±1.8	30.2±2.4

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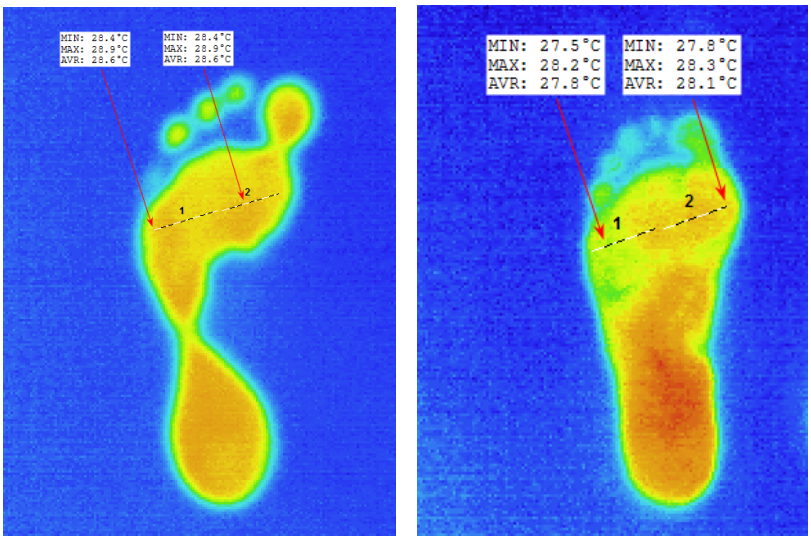

A **B**

Fig. 1. *Thermal images of a healthy volunteer's (A) and a flat-footed patient's (B) right foot. Minimal (MIN), maximal (MAX) and average (AVR) temperatures of the medial (2) and lateral (1) parts of metatarsophalangeal joint line are given*

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