Infrared thermographic imaging of the human lower limb

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Introduction/Purpose: Infrared radiation (IR) is emitted by all objects at temperatures above absolute zero and the intensity of radiation depends on the temperature of the object. Thermography is a type of infrared imaging in which a thermographic camera can convert the invisible radiation into a visual image providing a temperature distribution map of an object's surface without any contact with it. Infrared thermography has been used to detect temperature variations in the foot which could be related to diabetic foot complications and other diseases affecting the cardiovascular system. This study aims to record the use of thermography to obtain a real-time image of the foot in order to evaluate the skin temperature map of the normal lower human limb. Thermographic images of the lower limb were recorded and analyzed to qualitatively and quantitatively characterize the normal skin temperature distribution and its variations in the human foot.

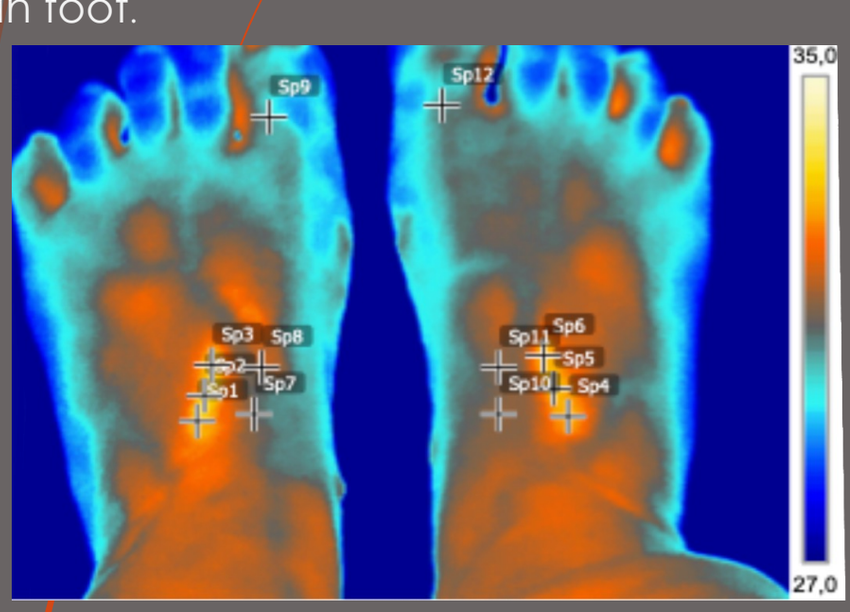

Figure 1: Thermogram of the upper side of the human foot.

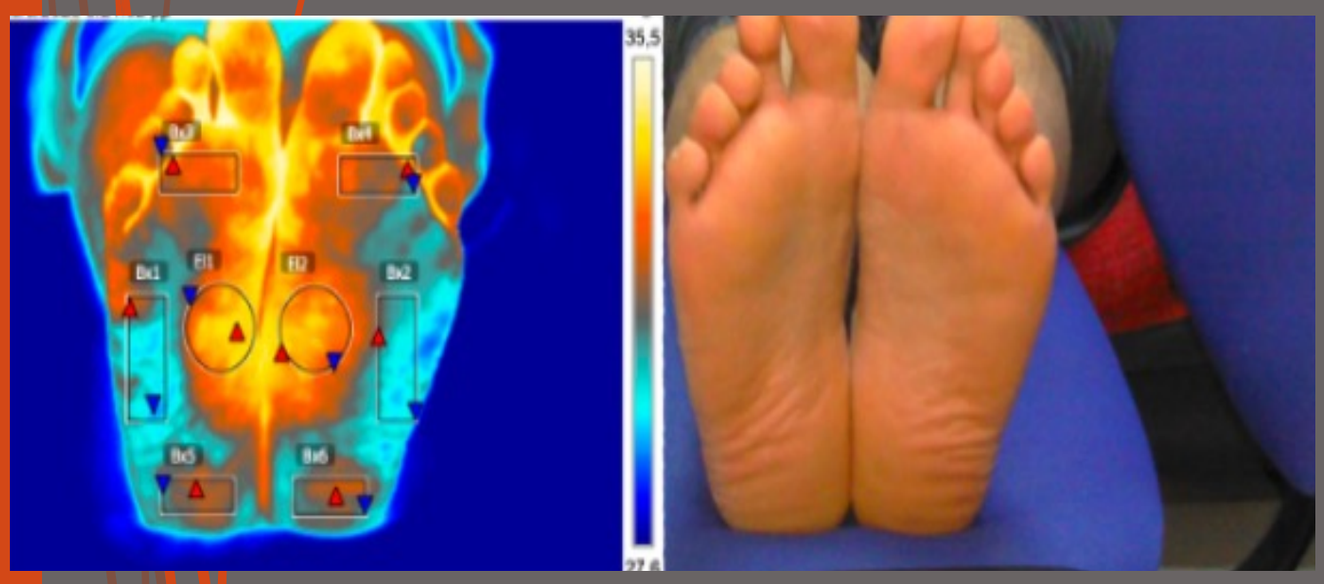

Figure 2: Thermogram of the sole of the human foot.

Conclusion: Surface temperature distribution of the normal human foot is recorded using infrared thermography imaging. The temperature pattern is characterized by similar temperature variations between subjects and symmetry between the two feet. Thermography imaging appears as a promising tool for achieving a better visualization of superficial veins and producing a healthy thermal limb temperature map which could be used as a useful reference in medical diagnostics.

Materials & Methods: Thermograms of the upper site and of the sole of the foot of 20 healthy volunteers were recorded with the FLIR T440 Thermal Imaging camera. The thermograms were obtained after shoes removal and a ten minutes adaptation period. All thermographs were processed in the FLIR TOOLS application. Points of Interest (Sp) were selected in and out of the veins, as well as at the fingers area of the upper side of the foot (Figure 1). The temperature deviation index was calculated based on the formula $T_{index}=(T_{in}-T_{out})/T_{out}$. For the sole of the foot, 4 symmetrical areas were selected on each patient giving the maximum and the minimum temperature of each area and the average temperature within the area (Figure 2).

Point of measurement	Temperature (^{0}C)	Tindex
Sp1	33,90±1,31	6,97%±3,82%
Sp2	34,00±1,26	
Sp3	33,73±1,13	
Sp4	33,53±1,14	
Sp5	33,50±1,06	
Sp6	33,48±1,10	
Sp7	32,27±1,60	
Sp8	31,65±1,84	
Sp9	30,83±2,40	
Sp10	32,25±1,52	
Sp11	31,58±1,83	
Sp12	30,68±2,73	

Table 1:Temperature (mean ± standard deviation) of the upper side of the human foot.

	Tmax (^{0}C)	Tmin (^{0}C)	Tavg (^{0}C)
Box1	31,00±2,02	28,18±1,92	29,53±1,89
Box2	30,67±2,03	28,38±2,08	29,53±2,00
Box3	30,95±2,47	28,88±1,98	29,82±2,20
Box4	30,78±2,76	28,78±2,29	29,62±2,49
Box5	31,32±2,54	28,85±1,98	29,97±2,09
Box6	30,68±2,94	28,72±2,69	29,53±2,81
El1	32,27±1,33	30,75±1,13	31,65±1,36
El2	32,18±1,57	30,75±1,51	31,48±1,54

Table2: Temperature (mean ± standard deviation) of the sole of the human foot.

Results: According to our results, there is no overlap in the temperatures in and out of the veins at the upper side of the foot. In all cases veins are clearly projected. The finger area is generally the colder area of the upper foot side, while the two feet are symmetrical on respect to temperature distribution (Table 1).

The temperature of the foot sole shows a more even distribution compared to the upper site of the foot. Higher temperatures were observed in the area of the arch and the lower side of the fingers. The symmetry of temperature distribution is observed for the soles of the two feet (Table 2).