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Normal range and lateral symmetry in the skin temperature profile of pregnant women

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HIGHLIGHTS

- This study defines the pattern of skin temperature in the pregnant human body.
- A negative correlation between BMI and skin temperature in the pregnant women was verified.
- Age showed a strong influence on the skin temperature.
- In normal pregnant subjects, the skin temperature is symmetrically distributed.
- Thermography could represent an important tool for diagnosis in the gestational period.

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ABSTRACT

Body skin temperature is a useful parameter for diagnosing diseases and infrared thermography can be a powerful tool in providing important information to detect body temperature changes in a noninvasive way. The aim of this work was to study the pattern of skin temperature during pregnancy, to establish skin temperature reference values and to find correlations between these and the pregnant population characteristics. Sixty-one healthy pregnant women (mean age 30.6 ± 5.1 years) in the 8th–40th gestational week with normal pregnancies were examined in 31 regions of interest (ROI). The ROIs were defined all over the body in order to determine the most influenced by factors such as age or body mass index (BMI). The results obtained in this work highlight that in normal pregnant women the skin temperature is symmetrically distributed, with the symmetrical areas differing less than 0.5 °C, with a mean value of 0.25 ± 0.23 °C. This study identified a significant negative correlation between the BMI and temperature. Age has been shown to have great influence on the skin temperature, with a significant increase of temperature observed with age. This work explores a novel medical application of infrared thermography and provides a characterization of thermal skin profile in human pregnancy for a large set of ROIs while also evaluating the effects of age and BMI.

1. Introduction

The skin temperature of the human body is an important physiological parameter and an accessible and useful measurement for investigating some aspects of peripheral circulation, thermoregulation and structural changes in several diseases that causes localized increases in temperature, which show as hot spots or as asymmetrical patterns in skin temperature [1–3]. Thermography has several important features for medical measurements, such as noninvasive, non-contact, reliable, capable of producing multiple recordings at short time intervals, and safe for patients and clinicians [3,4]. Moreover, advances in infrared detectors (better temperature sensitivity and spatial resolution) boosted the use of this technology in medical applications and it is becoming an accurate medical diagnostic tool for abnormal temperature pattern measurements [5].

Infrared thermography has been successfully used in diagnosis of several diseases and proved as a useful tool to access important information that may help in disease diagnosis and monitoring the

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therapeutic effect and the evolution of pathologic conditions [3,6]. The visualization of temperature distribution on the surface of the human body can provide valuable diagnostic information, and is mostly a reflection of the processes inside the body [7–9]. Altered temperature is often the first sign of tissue lesions, before structural or functional changes can be observed [7,10]. Abnormalities such as inflammation and infection cause localized increases in temperature [6,11]. Differences in the surface temperature were verified in breast cancer, with higher values in malignant breast than in normal ones [8]. The use of thermography was referred as an important tool for preliminary screening procedure in asymptomatic women to pin-point those with high risk of breast cancer [12]. The asymmetry in the temperature between corresponding sites of the left and right foot is an early warning sign of foot disease in diabetes [13–15]. In the Raynauds phenomenon, thermography provides useful information to quantify the damage, the time evolution of the disease, and to assess recovery after the treatment [5]. In rheumatoid arthritis, thermography was used to identified the abnormal temperature distributions over joints and to evaluate the therapeutic efficacy of different treatment approaches [3,5,16]. In plastic and reconstructive surgery, thermography allows to identify dominant vessels before flap surgery, and to monitor the perfusion after connecting its vessels (artery and vein) to the site of reconstruction [16]. Thermal research of skin temperature on human athletes allows screening individuals sports injuries and exercise-induced physiological functions [17]. The efficacy of therapeutic drugs that can change the blood flow through the skin vessels and alter the heat radiation of the skin surface can be studied and monitored using thermography [18,7].

Thermal information have been used to quantify changes in skin temperature in relation to certain diseases or features of the subject such as the age or body mass index [19,9]. Studies on the effect of the BMI in core temperature have shown that core temperature varies inversely to the BMI value [19–22]. In the specific region of the abdominal area skin temperature was found to be significantly lower in obese subjects than in normal BMI subjects [19,21]. The study also empathizes the need of future work that evaluates the temperature in more regions of interest [21]. The skin temperature was not extensively studied with age-related changes. However, in the upper regions of the body, skin temperatures in aged people are higher than in young individuals [23].

Pregnancy represents a period characterized by numerous changes in the body and might be associated with several diseases, such as hypertension or venous insufficiency [24]. Biomedical research aims to continuously improve diagnostic devices and to develop new ones for less invasive monitoring. Despite infrared thermography having been applied with important results in several fields of medicine, their use in obstetrics remains unexplored. Thermography could become an important tool for diagnosis in the gestational period since it allows the identification of asymmetry and detection of abnormal temperatures for the specific regions. It might even have applications in examination of local anomalies in outpatients, or monitoring during labor. Therefore, it is extremely relevant to investigate in more detail the thermal profiles associated with pregnancy. This study is a followup of preliminary work developed with pregnant women during in the late gestational period, on 10 ROIs [24]. The present paper presents an extensive study of body temperatures that explores 31 ROIs in the anterior, posterior and lateral views of human body in 61 pregnant woman within a wide range of gestation. The correlation of skin temperature and physiological characteristics were evaluated in order to define the areas most influenced by age, BMI and gestational age. Our main aim was to establish skin temperature reference values for pregnant females, a descriptive work never before reported. Although we did not have the possibility to include also a control group of non-pregnant subjects in this study, we hope this will be possible in the future. Nevertheless, the agreement between the results obtained in this work and the main results obtained in the studies with non-pregnant healthy women, referred in most recently studies, were verified and discussed.

2. Materials and methods

The study protocol was approved by the ethical committee of the Braga Hospital, Portugal. All the subjects were volunteers and gave a written informed consent before participation in the study. All volunteers consented to have their vital signals and thermal body image collected as well as information regarding age, gestational age and BMI. They were recruited at the time of their regular obstetrics appointment at the Department of Obstetrics.

2.1. Study group

The group consisted of 61 pregnant women at different gestational age (between 8 and 40 weeks). All subjects were considered clinically healthy individuals and undergoing a normal pregnancy. The characteristics of the volunteers are presented in Table 1.

According to World Health Organization [25], the BMI is defined in five categories. The BMI classification used in this study is a generalist classification; however, the objective was to study the effect of spectrum of weight ranks in the mean temperature; for this reason the BMI classification was used in order to stratify the population with different weights. The underweight ($\leqslant$18.5 kg/m^2), 1 subject in the moment of their thermography images were captured with 34 years old and 10 pregnancy weeks; normal weight (18.5–24.9 kg/m^2) was characterized by 32.6 ± 4.0 years old and 22.5 ± 12.2 pregnancy weeks; overweight (25–29.9 kg/m^2) with 32.0 ± 4.4 years old and 31.0 ± 10.8 pregnancy weeks; obese type 1 (30–34.9 kg/m^2) with 27 ± 5.4 years old and 37.0 ± 1.7 pregnancy weeks; and in the last category considered obese type 2 ($\geqslant$35 kg/m^2) was characterized by 28 ± 6.7 years old and 37.0 ± 2.9 pregnancy weeks. The values for the BMI were determined for the moment of the data was acquired, which means that could be an effect from the advancement of pregnancy and not only an obesity process.

Focusing on the analysis of the population based in pregnancy quarter category, the study group with a gestation time until 12 weeks (9.9 ± 1 pregnancy weeks), with 10 subjects, had a mean age of 33.1 ± 4.3 years old, and a value of 23.2 ± 3.2 kg/m^2 for the BMI. The group with gestation time between the 13 to 24 (16.2 ± 3.8 pregnancy weeks), composed by 11 subjects, was characterized by 30.5 ± 4.4 years old and with a BMI of 23.2 ± 2.5 kg/m^2. The study group in the last trimester (36.7 ± 2.3 pregnancy weeks), composed by 45 subjects, had a mean age of 30.0 ± 5.3 with a BMI of 29.3 ± 4.7 kg/m^2.

The three categories defined by age were composed by 26 pregnant women 30 years (mean age of 26 ± 3.1 years old), and with a gestation time of 30 ± 11 pregnancy weeks, and 30 ± 5.4 kg/m^2 BMI. The group with age between 30 to 39 years old (34 ± 2.4 years) was composed by 34 subjects with a mean 28 ± 11.9 pregnancy week, and 26 ± 4.6 kg/m^{2}BMI. The last group, subjects with more than 40 years, was composed by 2 subjects

Table 1
Main characteristics of the studied group.

Characteristics (n = 61)	Mean ± SD
Age, years	30.6 ± 5.1
Gestational age, weeks	29.3 ± 11.5
BMI (kg/m^2)	27.5 ± 5.1