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Investigation of the use of thermography for research and clinical applications in pregnant women

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ABSTRACT

Background: The possibility of using thermal imaging, as a non-invasive method, in medicine may provide potential ability of advanced imaging. *Objective:* The conduction of a preliminary study in healthy non-pregnant females in order to investigate the imaging ability of thermography and its implementation; and to determine hot and cold areas in order to create a "map" of temperature distribution of the abdomen and the torso. *Methods:* Participants were 18–45 years old non-pregnant women (n = 10), who were measured at 4 different distances. Two thermal imaging cameras and their corresponding software were used to measure abdomen, low back, left and right side of the torso. *Results:* There were no statistically significant differences in the mean values of the exported temperatures according the distance and the angle between the camera and the subject. The inferior part of the rectus abdominis muscle recorded the coldest zone and the umbilicus appeared as the most prominent hot spot. *Conclusions:* Thermography shows to be a potential non-invasive technique offering new options in the evaluation of pregnant and laboring women.

1. Introduction

Many studies have been conducted in order to better understand the nature and consequences of fetal and maternal movement during pregnancy and childbirth. These include analyses of the function and structure of the body of the pregnant woman, and of the fetus [1–7]. Research in this area has, however, very rarely examined the dynamic interaction of the mother and the fetus at the biomechanical level, especially during the process of labour. This is despite the fact that there is good quality evidence from applied studies that upright positions and maternal movement during labour are associated with positive outcomes for mother and for baby. One of the barriers to such research has been the lack of appropriate, non-invasive, safe imaging techniques for visualizing the position and movements of the fetus in relation to those of the mother during the process of labour.

Thermography (digital infrared thermal imaging) is a non-invasive method with the ability of real-time monitoring and imaging, which has been used in medicine since the early 1960s. It uses no radiation and no contact, is free from any limitations or contra-indications, is easy to use, and provides objective data. To date, the method has been introduced in the clinical research area for diagnosis, and for the prevention of various diseases [8–13]. However, to the best of our knowledge, apart from some applications of the method in the evaluation of preterm premature rupture of the fetal membranes [14], chorioamnionitis [15] and peripheral temperature of abdominal wall [15,16], there are no scientific studies to investigate the use of thermography in pregnant women. The possibility of using this method in pregnant women may provide advanced imaging of fetal movements and the potential ability to record the movements of the mother and the fetus, simultaneously, to see how they interact and inter-relate as the fetus negotiates the pelvis, in the process of being born.

The purpose of this research was to undertake a preliminary study in healthy non-pregnant female volunteers in order to investigate the imaging ability of thermography and its implementation in relation to the female abdomen and torso; to determine hot and cold areas; and to create a "map" of temperature distribution in this field, as a basis for future modeling and empirical studies that can be applied to pregnancy and labour.

2. Participants and methods

2.1. Participants

10 healthy non-pregnant female volunteers aged 18–45 years took part. All participants were provided with a participant's information sheet, informing them in detail about the purpose of and

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Table 1
Exclusion criteria and participants' protocol.

Exclusion criteria	Participants' protocol
Any medication affecting the cardiovascular system	No ointments or cosmetics on the RI on the day of exam
Pain medication at the day of exam	No alcohol intake or smoking 24 h before the exam
Solarium or sunbathing 5 days before exam	Not allowed tight fitting clothing and shaving of the RI 4 h prior the exam
Any pathology or inflammations in the region of interest (RI)	No physical therapy and exercise 24 h before exam
Medical implants in the body in the RI	No hot or cold packs application 24 h before the exam
Women during menstruation	Bathing or shower no closer than 1 h before exam

the protocol for the study, and all gave written consent. Exclusion criteria and participants' protocol are presented in Table 1. The study was conducted exclusively in women, as it is the first stage in developing a flexible, non-invasive technique for assessing maternal/fetal movement during pregnancy and birth, and as intended for further use in pregnant and due to uniformity of the sample, and as it is known that the difference in the anatomy of human body between women and men and the different temperature emitted by vessels and organs within the body, results in the export of different temperatures from the same anatomical sites [17,18].

2.2. Technique and measurement procedure

After acclimatization, all measurements were conducted in the same laboratory environment at a constant temperature of 24.5–25.5 °C [19,20]. Only the research team and the participant were in the room there the measurements took place, ensuring a consistent number of people in the room, to avoid the influence of human body at room temperature. On the arrival at the lab, participants were asked to remove all their jewelry and the clothes in the area of measurement (abdomen/back). Then they were asked to stand for 15 min with the abdomen/back exposed to achieve skin temperature equilibration with the temperature of the room [21,22].

The image processing equipment and other devices were sited away from the participants' location, to avoid heat disturbance [23]. For the measurement procedure two thermal imaging cameras (ThermoVision A40M and RayCAm C.A. 1884) and their corresponding software were used. ThermoVision A40M was mounted on a tripod height 1.2 m and RayCAm C.A. 1884 was carried by an examiner, at the same height as the other camera, having the hand stabilized in a base. The distance between the cameras and the participant were identified by the lens which is integral to the camera. The cameras' lenses were parallel to the area of measurement. Human skin emissivity was set at 0.97–0.98 [23].

The types of measurements were as follows:

(a) All participants were measured at 4 different distances from the cameras (5 m, 4 m, 3 m and 2 m). They were asked to stand still in an anatomical position at defined points, facing the camera, for as long as the region of interest (RI) was recorded. Examinees were asked to place their index fingers at the Anterior Superior Iliac Spine (ASIS), to define two reference points for analysis reasons.
(b) At the last point (2 m), 4 measurements were performed by a rotation around the vertical axis (abdomen, back, left and right side of the torso) (Fig. 1).

The Ethics Committee of University of Central Lancashire, UK, approved this study.

2.3. Statistical analysis

Repeated measures analyses of variance (ANOVA) with Bonferroni adjustment were used to test whether there was a significant difference in temperature recordings at 5, 4, 3 and 2 m. It was also

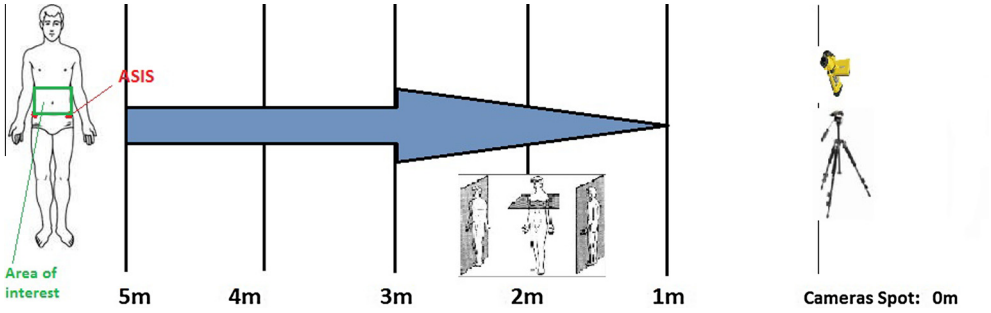

Fig. 1. Graphical representation of the measurement procedure.

Table 2
Demographic characteristics (participants: females $n = 10$).

	Mean value & SD		Mean value & SD
Age (years)	35.8 (±8.19)	Height (m)	1.67 (±0.08)
Weight (kg)	63.69 (±9.21)	BMI	22.94 (±3.84)
Ethnicity	Caucasian $n = 7$		
	Asian $n = 3$		
Exercise	Yes $n = 9$	Once a week $n = 1$	2–3 times/week n = 6
	No $n = 1$	4–5 times/week $n = 2$	6–7 times/week $n = 0$
Smoking	Yes $n = 1$	<1 pack/day	
	No $n = 9$		
Alcohol	Yes $n = 9$	<1 drink/week $n = 1$	1–4 drinks/week $n = 4$
	No $n = 1$	5–10 drinks/week $n = 3$	