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Relation between dorsal and palmar hand skin temperatures during a cold stress test

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ABSTRACT

Hand skin temperature measurements have previously been performed on either dorsal or palmar sides and it is possible to find arguments for the advantage of both locations. Therefore, the aim of this study was to use dynamic infrared (IR) imaging to examine the relationship between dorsal and palmar hand skin temperature. The palmar and dorsal hand skin temperature before and after a cold stress test was measured with IR thermography in 112 healthy participants. Calculation of surface average temperature was made from nine regions of interest on each hand's dorsal and palmar side. Temperature values were recorded at baseline, directly after immersion of hands in vinyl gloves for one minute in water at 20 ± 0.5 °C (gloves removed), and after eight minutes rewarming. Results showed that: a) the skin temperatures on the dorsal and palmar sides of the hand are strongly correlated; b) the correlation is stronger on the fingers than on the carpometacarpal (CMC) area; c) the palmar side of the CMC area is warmer than the dorsal side, but this is reversed in the fingers so that the nail bed is warmer than the finger pad; and d) the temperature difference ΔT between the dorsal and palmar sides of the fingers is independent of the skin temperature, though ΔT on the CMC area of the hand is temperature dependent. Such differences can be important in detailed investigations of thermal phenomena in the hand. In conclusion, results showed a strong correlation between the dorsal and palmar temperatures. If both sides cannot be measured, the purpose of the investigation should determine which side of the hand should be measured.

1. Introduction

Infrared (IR) imaging is a non-contact method widely used in biomedical studies of skin temperature and thermoregulation mechanisms of the human body (Ring and Ammer, 2012; Diakides et al., 2012). This is possible since the skin temperature depends on the subcutaneous perfusion (Anbar, 1998, 2002; Pascoe et al., 2012). Dynamic IR imaging has been referred to as the best choice when studying a dynamic process such as the hand rewarming or recovery process following temperature stress such as a cold stress test (CST) (Pascoe et al., 2012; Wilson and Spence, 1989; Anbar, 2002). This skin surface temperature change rate, related to the skin perfusion, can be displayed and followed with dynamic IR imaging.

An understanding of cutaneous blood-circulation and micro-anatomical organization has developed during the latter part of the twentieth century (Braverman, 1997). The main vascular architecture of the hand has two arteries: the radial and ulnar. The radial artery supplies the dorsal part of the hand through the dorsal metacarpal arteries and the ulnar artery supplies the palmar part via the superficial palmar arch. The thumb and fingers are supplied via the digital arteries deriving from the hand arches. All these vessels have perforators that abundantly supply the hand integument. These quite small perforators are often only named from their origin by the major branches. Furthermore, the inter-variability in vascular anatomy is well known in medicine (Thomas et al., 2013).

One task of peripheral blood circulation to the skin at acral body parts, such as skin on the hand, is to take part in thermoregulation and thermohomeostasis, which maintain a fairly constant core body temperature at approximately 37 °C. The skin situated arterio-venouse anastomosies (AVAs) play a crucial role in heat exchange between the skin and the environment (Walløe, 2016). The hand skin temperature is thus affected by the core temperature, thermal stress derived from the body itself, and from the environment (Romanovsky, 2014). In addition, other factors such as circadian rhythm, hormonal status (Charkoudian, 2003), and physical activity can also affect the hand skin temperature. An example of external thermal stress is the immersion of all or part of the body in cold water (Leijon-Sundqvist et al., 2015b, 2016).

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Previously, hand skin temperature measurements have been performed on either dorsal or palmar sides (Gold et al., 2004; Horikoshi et al., 2016; Isii et al., 2007; Jankovic et al., 2008) and it is possible to find arguments for the advantage of both locations. An argument for investigations on the dorsal side is that AVAs are described as being plentiful in the finger nail-beds (Walløe, 2016). Investigations on the palmar side can be motivated by the fact that humans use the hand as the common tool for activities in daily living and thus the palm skin is subjected to varying temperature challenges (Chen et al., 1996; Jay, 2004). In the current literature, there is a lack of investigations aimed at evaluating the relationship between dorsal and palmar hand skin temperature. Therefore, the aim of this study was to use dynamic IR imaging to examine the relationship between dorsal and palmar hand skin temperature before and after a CST.

2. Materials and methods

2.1. Participants

To recruit healthy, 18–40-year-old participants, an invitation was sent to the Norrbotten regiment of the Swedish Armed Forces and to students at Luleå University of Technology. Exclusion criteria were a history of thermal injuries, significant hand injuries, or symptoms of circulation disorders (e.g., whitening fingers). One hundred and twelve participants (mean age 25 ± 6 years) fulfilled the inclusion criteria and were willing to participate. All participants were given oral and written information about the testing procedure and to avoid cooling by the use of warm clothes and gloves. In addition they were asked not to use ointment, disinfection solution or similar products on hands.

2.2. Data collection

Data collection was performed during November 2015 and March to April 2016. Measurements were made in a room with an ambient temperature of 23 ± 1 °C. The study used FLIR® IR cameras (FLIR Systems, Inc., Wilsonville, OR, USA): a T640 with an image resolution of 640 × 480 pixels and thermal sensitivity of < 0.05 °C at + 30 °C; and a T660 (FLIR®, FLIR Systems, Inc., Wilsonville, OR, USA) with an image resolution of 640 × 480 pixels and thermal sensitivity of < 0.02 °C at + 30 °C. Spectral emissivity was set to 0.98 since human skin almost behaves as a blackbody with an emissivity of 0.96–0.99 (Ring and Ammer, 2012; Sanchez-Marin et al., 2009). The temperature data was stored as radiometric images every second during the measurement. Before the experiment, the cameras were calibrated by FLIR Systems AB in Täby, Sweden.

The IR camera was switched on 30 min before measurements began. The camera temperature reading was repeatedly checked against a container filled with water at 20 ± 0.5 °C, which was continuously monitored with a digital thermometer.

Before the CST, each participant rested for at least 15 min to acclimatize to the temperature of the room. The measurement started with a baseline hand skin temperature recording for one minute. The participants' hands in vinyl gloves were then immersed to the wrist for one minute in water at 20 ± 0.5 °C. Thereafter, the gloves were removed and the rewarming was measured continuously for eight minutes. The water temperature was monitored with a thermometer before each CST and the radiometric images were stored in a computer for later analyses.

During thermal image acquisition, the participants had their hands positioned at the approximate level of the heart, with splayed fingers resting on a net framed box – one hand with the palm up and the other with the palm down – and the IR camera, attached to a tripod, positioned perpendicular 70 cm above the hands, as shown in Fig. 1. The box contained water at a temperature that afforded a well-defined thermal background. Participants turned their hands every 10th second during the measurement.

Fig. 1. The setup with participant seated in front of a water filled net framed box, resting one hand with palm and the other with dorsal side on the net. During measurement – every 10th second simultaneously turning both hands.

2.3. Data analysis

After the data collection, a FLIR ResearchIR Max®, Version 4.30.1.70, (FLIR Systems, Inc., Natick, MA, USA) was used to analyze the radiometric images in two steps. The first step was a qualitative visual analysis of the thermograms using a color pallet together with a temperature scale. To make a valid and repeatable description of temperature distributions, the dynamic IR images were viewed several times by the first author and controlled by the second and fifth authors. The second step was to collect numerical data using Regions of Interest (ROI).

Eighteen ROIs, nine on each side of the hand, as illustrated in Fig. 2, were used to measure the skin surface temperature. Of the nine ROIs, one was placed on the distal phalanges of each finger, one on each proximal phalange, and one on the carpometacarpal (CMC) area. The CMC area is defined here as the part of the hand between the wrist (styloid process of ulna and radius) and the base of the fingers (metacarpophalangeal joints). The ROIs on the CMC area had a size of approximately 400 pixels and were positioned at the warmest part of the palmar and the dorsal side, respectively. On the distal and proximal phalanges of fingers, digitals 2–5, the ROIs had a size of approximately 200 pixels. The proximal ROIs were placed between the metacarpophalangeal joints and the proximal interphalangeal joints. The distal ROIs were positioned between the fingertip and the distal interphalangeal joint, similar to the description in a previous study (Anderson et al., 2007). The thumb was not measured since a perpendicular view of the thumb was not possible to obtain in the described setup.

The dorsal T_D and palmar T_P temperatures were collected three times during the process. First, a baseline temperature was taken prior to the

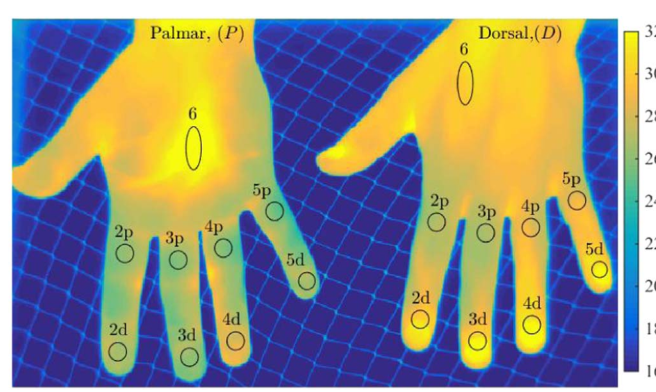

Fig. 2. Thermogram with nine ROIs on the palmar side of the right hand and nine ROIs on the dorsal side of the left hand.