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*A method for whole-body  
skin temperature mapping in  
humans (Eine Methode zur  
Aufzeichnung der  
Hautemperatur des gesamten  
menschlichen Körpers)*

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**Citation:** FOURNET, D., REDORTIER, B. and HAVENITH, G., 2012. A method for whole-body skin temperature mapping in humans. *Thermology International*, 22 (4), pp.157-159.

**Metadata Record:** <https://dspace.lboro.ac.uk/2134/11948>

**Version:** Published

**Publisher:** © Austrian Society of Thermology and European Association of Thermology

Please cite the published version.

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# A Method For Whole-Body Skin Temperature Mapping In Humans

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## SUMMARY

The described method provides a novel way to quantitatively and qualitatively report thermographic assessments of different humans. It combines a segmentation of defined body regions as well as a morphing technique in order to produce skin temperature body maps regardless of anthropometry and body position. This mapping method can be suitable for the creation of a skin temperature database of healthy individuals in various situations and environments.

**KEY WORDS:** Segmentation, temperature mapping, database

## EINE METHODE ZUR AUFZEICHNUNG DER HAUTTEMPERATUR DES GESAMTEN MENSCHLICHEN KÖRPERS

Die beschriebene Methode bietet eine neuartig quantitative und qualitative Bewertung thermographischer Befunde von unterschiedlichen Personen. Es kombiniert eine Segmentierung der definierten Körperregionen mit einer Morphing-Technik zur Herstellung Hauttemperatur-Karten, die unabhängig der Anthropometrie und Körperposition sind. Diese Kartenerstellung eignet sich für die Schaffung einer Hauttemperatur-Datenbank gesunder Personen in verschiedenen Situationen und Umgebungen.

**SCHLÜSSELWÖRTER:** Segmentierung, Temperatur-Kartenerstellung, Datenbank

## Introduction

Infrared thermography is a powerful tool with the great potential of mapping the skin over large areas of the human body. Large body views are beneficial for many fields of research. In the field of sport, thermographic studies often report their quantitative findings by regions of interest (ROI) arbitrarily obscuring the natural variation of skin temperature. Furthermore, they usually display a single thermogram only, questioning its representativeness for several participants. A processing technique enabling the joint analysis of several thermograms can take advantage of the thermographic mapping potential by providing population-average whole-body maps of skin temperature. The purpose of the described method is therefore to obtain human maps representing the average values of a large population.

## Challenges

Inter-individual variability in body dimensions and intra-individual variability in body position during repeated infrared measurements correspond to the two main challenges when several thermograms must be aligned for mapping. The proposed method aims at overcoming the above issues using a specific image processing technique inspired by the work on human hands [1] and applied to the whole human body.

## Procedure

The image processing method was entirely custom made under MATLAB. It combines a standardised segmentation

with 51 ROI (based on superficial muscles) and a morphing procedure required to average several thermograms.

A) Participant is standing in an anatomical position following the body views 1 and 2 of the Glamorgan protocol [2] in a controlled environment.

B) Each thermogram is processed using image registration using 133 control points (CP) over the whole body. An automatic mask of CP from the reference image is positioned over the input image. CP are then manually adjusted to the defined anatomical landmarks.

C) CP coordinates are used for image morphing using a 3<sup>rd</sup> order polynomial algorithm transformation. This morphing is performed adequately to a reference body shape, defined *a priori* as the participant with the population median values (height, weight, body fat). Anthropometrical characteristics are standardised without losing the spatial information of the original thermogram. Selected morphed thermograms of a population can then be averaged to create various whole-body maps.

## Outcomes and Application

Quantitative results (mean, min, max, median, standard deviation) are obtained for 51 ROI. Quantitative results (skin temperature distribution) can also be visually observed via the population-average *absolute* whole-body map of skin temperature (Figure 1A). Averaging pixels over the entire body gives a true estimation of the mean skin temperature

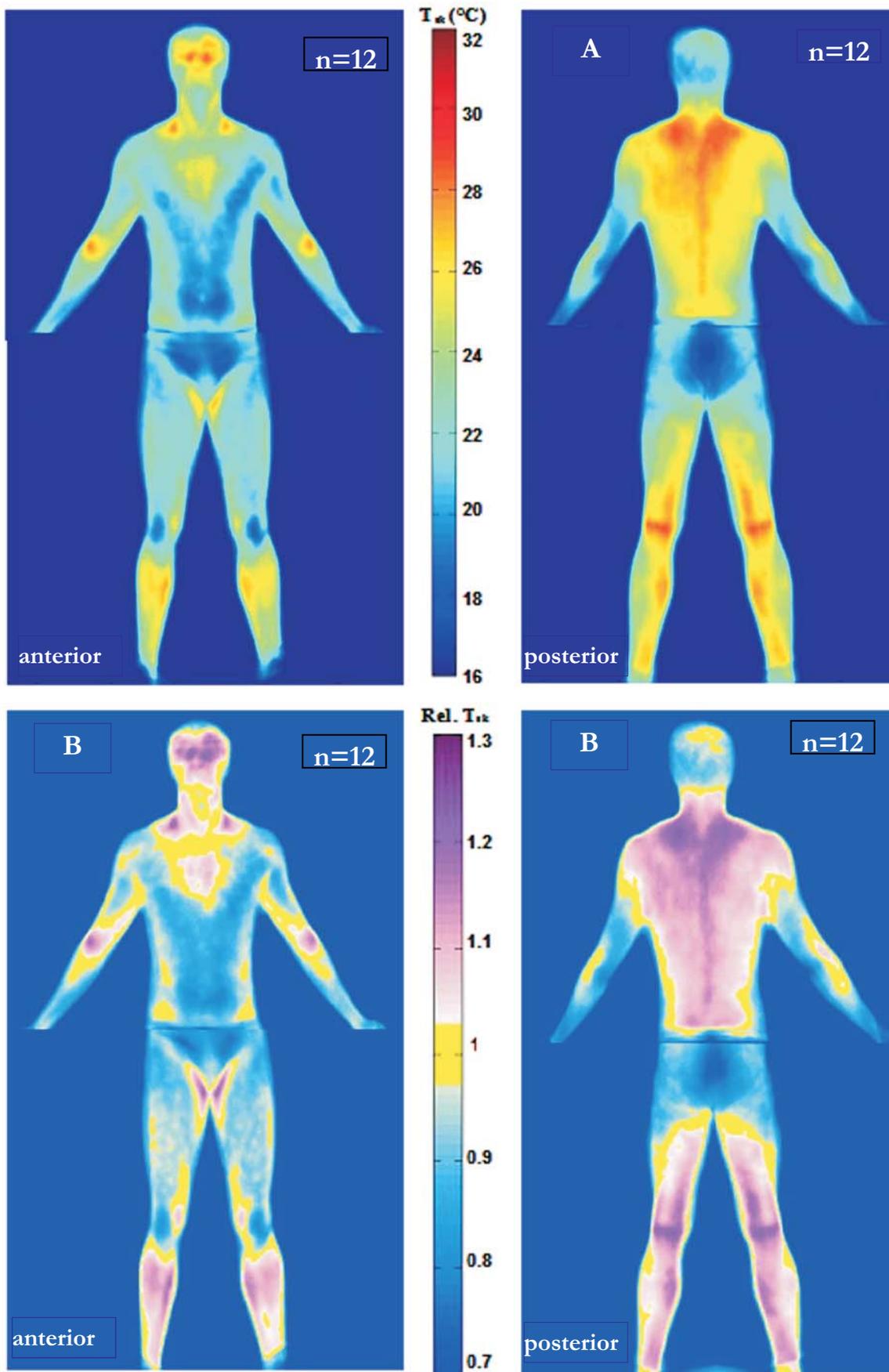


Figure 1  
 Population average absolute (A) and relative (B) whole-body maps of skin temperature after 40 minutes of running at 70% in a  $10^{\circ}\text{C}$  environment for a group of healthy males after morphing individual images of 12 participants onto a reference body shape. Relative body maps are obtained by dividing the absolute body map by the group mean skin temperature at this specific stage. A value of 1 corresponds to the group mean skin temperature.

for the group. This body mean skin temperature is then used to obtain a population-average *relative* whole-body map of skin temperature (Figure 1B). Our first results highlight the importance of exercise-specific active muscles (calves, hamstrings) as well as the exercise-induced vasomotor changes in a cold environment in line with thermographic data during exercise [3]. A dynamic interplay between heat production, heat transport to the surface and heat loss to the environment necessarily contributes to the distribution of skin temperature.

## Conclusions

The standardised method offers a unique approach with a limited number of body views [2] providing a whole-body representation of skin temperature, particularly applicable to exercising protocols. A normal database can be obtained in order to compare spatial and temporal variations of skin temperature between various exercise types, intensities and various populations (age, gender, body fat, fitness level). In thermal physiology, the detailed knowledge of regional skin temperature distribution may bring new insights in the autonomic and behavioural processes involved in human thermoregulation. This knowledge can be used for thermal manikin design and physiological modelling similarly to recent advances in body mapping of sweat production [4]. Improvements in the CP selection will be interesting in order to apply the method to a wider range of fields such as sports medicine, medical research or other applications.

## Acknowledgments

The assistance of Dr Vardasca (Glamorgan University) and Dr Kerr (Loughborough University) is gratefully acknowledged.

The paper received the “Kurt Ammer” prize at the XII European Association of Thermology Congress in Porto (2012).

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