MEASURING GARMENT SPATIAL SWEAT ABSORPTION: GRAVIMETRIC AND INFRARED APPROACH

Introduction

Understanding sweat and moisture absorption in personal protective clothing (PPC) is important for a number of reasons. Moisture accumulation can affect the ability of PPC to protect against prolonged exposure to heat (Barker et al. 2006), influences the acceptance and usage frequency of the PPC by the worker, and will affect the workers performance and productivity through its impact on various aspects of discomfort (Raccuglia et al. 2016, 2017). Building on our laboratory's work on mapping sweat production distribution across the body (Havenith et al. 2008, Smith et al. 2011, 2012), the aim of the present study was to obtain detailed spatial maps showing how this sweat migrates into the clothing during physical work in a single clothing layer. Currently, the only direct method available to quantify local garment sweat absorption and distribution is a 'destructive' gravimetric method developed in the current study. Therefore, a secondary aim was to apply infrared thermography to assess whether it could be used as indirect method to estimate local garment sweat content distribution, in a 'non-destructive' fashion.

Method

Sweat production was induced in 8 male participants, during running exercise in warm environment (27 °C, 50 %, 1.5 $m \cdot s^{-1}$ wind speed). Sweat absorption was mapped across a short sleeved, 100% cotton upper garment, at 5-min intervals over a total running time of 50-min. As a 'destructive' gravimetric method was adopted to quantify regional sweat absorption, each participant performed (on separated days) 10 running trials, characterised by different durations: 5 MIN, 10 MIN, 15 MIN, 20 MIN, 25 MIN, 30 MIN, 35 MIN, 40 MIN, 45 MIN and 50 MIN. Immediately after each running trial, the garment was dissected into 22 different parts, 12 for the front and 11 for the back. Analyses of local sweat absorption were conducted at the end of each run duration, by cutting up the marked garment regions and weighing the individual sections before and after drying. Additionally, infrared pictures of front and back of the wet garment (fitted on a T-Shirt-like shape stand) were taken to assess whether the temperature patterns at different garment zones (local garment temperature drop from environmental temperature) were related to the gravimetric sweat absorption data (local garment sweat absorbed in grams). Whole body sweat production, heart rate (HR) and core temperature (T_{core}) of the participants were measured.

Results

After 50-min , T_{core} rose from 37 ± 0.2 °C to 38.6 ± 0.3 °C, HR increased from 69 ± 15 bpm to 163 ± 12 bpm ($p < 0.001$) and body sweat production was 586 ± 86 $g \cdot m^{-2}$. At 50-min, garment total sweat absorption was 126 ± 57 $g \cdot m^{-2}$. Medial mid-back and medial lower-back were the most saturated garment parts: 56% and 51%, respectively. These were followed by upper back, collar and chest medial (40-45%), and next to these, lateral mid-back, lateral chest and lateral abdomen reached between 30 and 39% of the saturation. Shoulders, sleeves front and back and lateral lower-back were 20-29% saturated and the lowest saturation level was shown by front and back low hems together with lateral abdomen (7-12 %). Although visual similarities were observed between the mean infrared (temperature) and the mean gravimetric (grams of sweat) maps, the liner relation between infrared and gravimetric data was not very strong ($r^2 = 0.3$), despite showing significance ($p < 0.001$).

Conclusions

A clear pattern of sweat absorption reduction from the top to the bottom and from the centre to the sides of the garment was observed, both for front and back sides. The inter-regional differences in garment sweat accumulation can be explained by the interactions of physiological (sweat production), anatomical (curvature of the body) and clothing (fit, contact) factors. Knowledge of garment regional absorption data can support the development of PPC's base layers, to effectively manage moisture absorption and drying properties, with the end goal to prevent workers heat-related injuries and reducing discomfort. Furthermore, these data can support the creation of evidence-based textile test methods as well as influence clothing design, e.g. with spatial variation of textile types.

The relation between local garment temperature drop and sweat content in grams, while showing a correlation at low absorption levels, levels off at around 30% garment saturation, where temperature does not drop further with increasing moisture content. Therefore, whilst infrared thermography can be applied as qualitative method to visually detect moisture distribution in a single garment, it cannot be used to make quantitative accurate estimation of regional garment sweat content when saturation levels are high.

Key words

Garment wetness, garment sweat saturation, garment sweat maps, PPC design

References

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