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Measuring spatial and temporal changes in garment sweat absorption: comparison of gravimetric and infrared methods

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Introduction

Temperature and moisture management in clothing is a main focus of the clothing industry with regards to garment performance optimisation and wear discomfort reduction. Building on our laboratory's work on mapping sweat production distribution across the body [1-3], 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. While this currently is the only methodology that permits direct and analytical measurements of garment regional sweat absorption, the latter approach is time-consuming and expensive, therefore of limited applicability. As such, the second goal of this study was to assess whether infrared thermography (IRT) could be used as an indirect method to estimate garment regional sweat content in a quick and 'non-destructive' fashion. We assumed that garment zones characterised by higher sweat retention would be affected by higher evaporative cooling, resulting in bigger local temperature drops from their dry state. Therefore, a relation between the amount of moisture absorbed and the temperature drop of wet textile areas was expected.

Method

Eight male runners were recruited for this study. A short sleeved, 100% cotton T-Shirt was used. Sweat absorption and temperature across the T-Shirt were mapped over a total running time of 50-min. As a 'destructive' gravimetric method was adopted to quantify regional sweat absorption, each participant performed 10 running trials on a treadmill, characterised by different durations (5-50 min, 5 min increments). Immediately after each partial running trial, the T-shirt was removed from the body, fitted to a T-Shirt-like shape stand and image acquisition was performed. This was done to cancel-out the impact of regional differences in participants' skin temperature which could have affected garment's temperature. After performing image acquisition, the T-Shirt was dissected into 21 different regions of interest (Figure 1). Using a gravimetric approach (wet weight – dry weight) the time-course and distribution of sweat absorption of each garment was defined. The same 21 garment regions were examined to extrapolate regional temperature data from each infrared picture. As in dry state the temperature of the T-Shirt by definition equals ambient temperature, the temperature of each garment region was considered as temperature drop from ambient temperature.

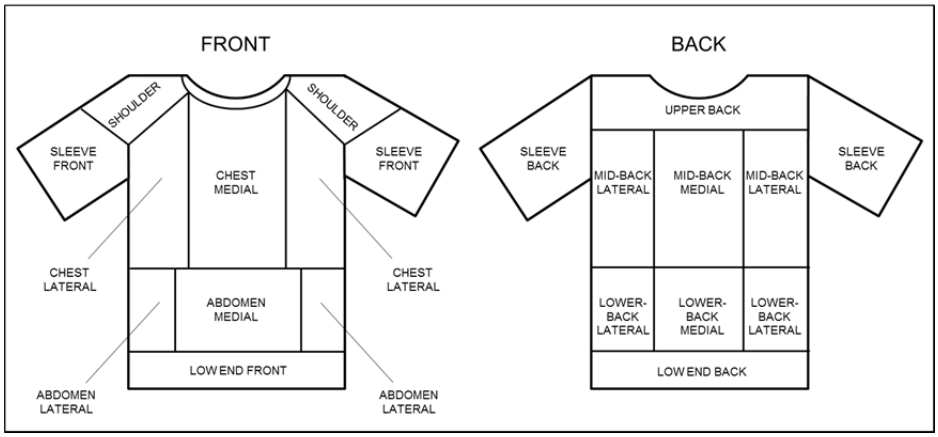

Figure 1 Schematic representation of the experimental T-Shirt marked into the 21 regions of interest for the analyses of local sweat accumulation and temperature. Front and back of the T-Shirt were mapped into 11 and 10 zones, respectively.

Results

T-Shirt sweat absorption increases significantly with exercise duration, but starts to plateau after 35 minutes. After 50 minutes of running exercise, the garment reached, on average, 41% of the total absorption capacity. Medial mid-back and medial lower-back were the most saturated garment parts: 56% and 51%, respectively. The lowest saturation level was shown by front and back low hems together with lateral abdomen (7-12 %). A clear pattern of sweat absorption decrease from medial to lateral and from the top to the bottom, both for front and back of the T-Shirt was observed. Garment regional temperature drops only statistically explained 52% of the variance in regional sweat content. The exponential shape of the curves describing the relation between local sweat absorption and temperature indicates that local temperature changes can predict local sweat retention up to a certain moisture saturation value, this being around 50 $g \cdot m^{-2}$.

Conclusions

IRT allows qualitative assessments of garment sweat absorption in a 'non-destructive' way. Nevertheless, IRT cannot be used for quantitative estimations of spatial and temporal sweat retention in garments, with the main limitation being a moisture content threshold above which no further effect on temperature is observed. Regional and over-time changes in sweat absorption, obtained with the gravimetric method can be used to design functional base-layers, to validate thermophysiological models and manikin testing.

References

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