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Regional and total insulation and evaporative resistance values of clothing for sugarcane harvesters and chemical sprayers in Latin America

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Introduction

The work in agriculture needs to be done in right time and often they are connected with warm or warm and wet period of the year. Jobs related to sugarcane production are not exceptions. The regional climate is hot and the exposure is connected to heavy physical labour. Such exposure together with insufficient water replacement has been related to Chronic Kidney Disease (CKD) that is associated with high mortality rate and has taken epidemics measures in several hot regions, including Latin America, e.g. Nicaragua, Costa Rica. Clothing has a strong thermal impact on humans. In order to reduce impact of clothing on heat stress, the knowledge on thermal properties of clothing and used protection is required. This study aimed to measure the insulation and the evaporative resistance of the clothing for 2 jobs in the sugarcane fields – harvesting and spraying pesticides.

Methods

The thermal manikin Tore at Lund University, Sweden was used for testing [1]. The tested clothes were the ones that the sugar industry provides to their field workers (Figure 1). The insulation tests were carried out at 20.0±0.1 °C with 0.21±0.08 m/s air velocity in static (I_T) and dynamic ($I_{T,r}$, walking 90 steps/min corresponding to the speed of about 3.5 km/h) conditions. Evaporative resistance (R_{et}) was measured at so-called isothermal conditions with manikin surface and air temperature being set to 34 °C and air velocity to 0.54±0.16 m/s). Air layer and textile skin insulation and skin evaporative resistance were also measured. Textile skin was tested only in standing conditions. Insulation was measured with hair, and evaporative resistance without it. Each condition was tested twice. The results were acquired for individual zones, regional areas and as total values. The insulation results were sorted by percentage of difference in static compared to dynamic conditions. The evaporative resistance results were organized by the magnitude of the difference between measured and corrected (according to [3]) total evaporative resistance values.

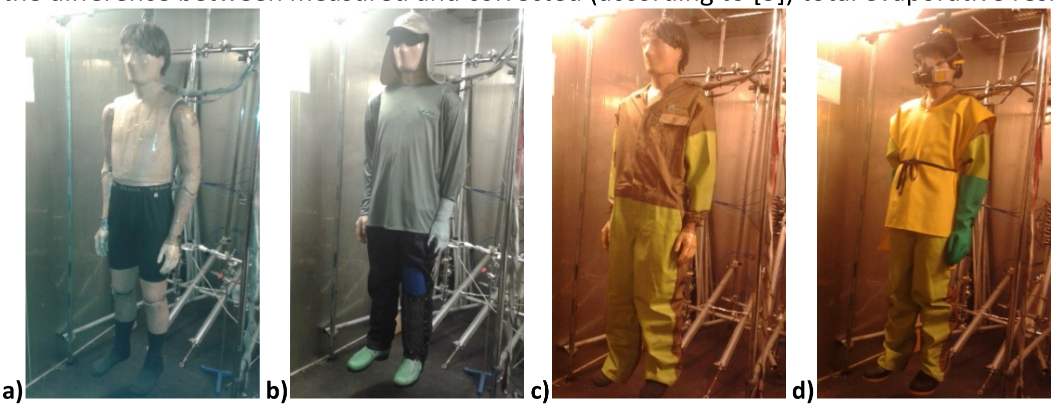

Figure 1. Tested clothing: a) underwear for both systems (provided by the laboratory); b) sugarcane harvester's outfit (glove only on one hand and leg protector on one leg); c) chemical sprayer's protective coverall on top of underwear; d) chemical sprayer's complete outfit with outer protective layers.

Results and discussion

Total and total resultant clothing insulation of the air layer (AL), sugarcane cutters (SC) and chemical sprayers clothes (CS) were 0.098 and 0.076, 0.191 and 0.143, 0.257and 0.188 m^2K/W, respectively. This means reduction in total insulation by 22.0, 25.3 and 26.8 %, respectively. However, insulation in different body parts could change from +6 (head in AL) to - 49 % (left hand in AL). In SC and CS the changes were from 0 (Head) to -48 (right hand) and from -2 (head) to -39 (upper arms) %, respectively. The results, especially from AL, show clearly the effect of body parts' swinging radius or being rigidly fixed in the walking manikin tests. The biggest change is for hands and feet followed by arms and legs, then torso zones and finally the head. Variation with clothing is modified by body area coverage, e.g. asymmetrical protection of hand and lower leg in SC (Figure 1b), and air permeability of the layers on the body (see CS in Figure 1c-d). Partly the differences could be related to the variation in local air velocity. Total thermal insulation of the textile skin (TS) coveraging the body completely (including hands, feet and head) was 0.131 m^2K/W. The corrected total evaporative resistance of TS, SC and CS was 8.2, 20.9, 81.0 m^2Pa/W (SC and CS include the skin and air layer resistance). Regional total thermal resistance of TS shifted from 4.6 (right hand, a thin cotton glove was applied) to 10.3 (right lower leg) m^2Pa/W. Some of this effect could be related to variation in local air velocity around specific zones, but in this case also to the thickness of the skin and some overlap of separate layers (gloves at hands, socks on feet used for skin simulation). Values for different parts of SC varied from 6.0 (right hand, nude but with slight coverage by the sleeve) to 65.6 (feet in boots) m^2Pa/W. Variation in CS was 20.4 (head with some parts uncovered) to above 500 (belly with two impermeable layers on top of each other). There has been a discussion on how exclusion of the zones not covered by wet textile skin may potentially affect total evaporative resistance. Here total; total excluding head, hands and feet; total excluding hands and feet, and total excluding hands was calculated. The difference from total was in average 2.0 (8.3-8.4 m^2Pa/W), 2.2 (20.6-22.2 m^2Pa/W) and 0.0 (73.7-92.2 m^2Pa/W) % for TS, SC and CS, respectively, showing the influence of even or uneven evaporative resistance distribution. I.e. depending on tested clothing, the elimination of some body parts may have different influence on total evaporative resistance.

Conclusions

Two sets of clothing from sugarcane fields were tested. After some adjustments, e.g. considering f_{cl}, the thermal properties may be utilized in evaluation of the workers' exposure and for organizing the work to diminish heat stress. Detailed information on different body regions may allow clothing improvement for better heat dissipation or, in the case of chemical protection, generating new ideas for supporting specific solutions. In addition, regional clothing properties can be an input for advanced thermo-physiological models. However, some methodological considerations were raised. The differences between the zones or changes have the specific reasons that don't match the reality. This may be built in the established predictive equations, e.g. for walking. Application of wind during testing may need to be considered to compensate for that. For example, manikin walking at 3.5 km/h might require 1 m/s wind to simulate the realistic influence of the motion. The same issue may be raised, to a certain degree, if manikin results are validated on the humans walking on treadmill.

References

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