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## Insulation of traditional Indian clothing: estimation of climate change impact on productivity from PHS (predicted heat strain) model

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## **Insulation of traditional Indian clothing: estimation of climate change impact on productivity from PHS (predicted heat strain) model**

*Kalev Kuklane, Karin Lundgren, Tord Kjellström, Vidhya Venogopal, Jintu Fan, George Havenith*

### **Introduction**

There are available major databases on western clothing and their thermal properties, however, information on non-western clothing is lacking. A recent ASHRAE project 1504-TRP, *Extension of the Clothing Insulation Database for Standard 55 and ISO* dealt with the issue. Simultaneously, a co-operation study at Indian workplaces allowed us to acquire some sets of the traditional clothes used at construction sites in Chennai area. The work was related to mapping of present work conditions in order to allow predictions and measures to be taken if the temperature would rise.

### **Method**

We selected ISO 7933 on predicted heat strain (PHS) as a tool to estimate productivity loss in physical work related to reaching safe body core temperature limit of 38 °C. Three sets of clothing were investigated (Figure 1): 2 female sets of traditional clothes churidar (X1) and saree (Y1) modified as used at construction site (added shirt and towel to protect traditional clothes and hair, X2 and Y2, respectively), and a male set (Z) commonly used at the construction sites. The clothing insulation and evaporative resistance were measured on thermal manikins. The climatic conditions were based on weather statistics, and metabolic heat production was based on field observations and the ISO 8996:2004 tables (Ergonomics of the thermal environment — Determination of metabolic rate). The basic conditions were the following: mean activity 200 W, Ta=35 °C, Tg=38 °C, Tr=45.7 °C, RH=70 % in the shade, and mean activity 200 W, Ta=35 °C, Tg=45 °C, Tr=67.3 °C, RH=70 % in the sun. For the future scenarios all basic parameters were left the same except the air temperature was increased by 2 °C (keeping radiation level the same Tg also increased). An acclimatized female (56 kg, 150 cm) and male (64 kg, 167 cm) were selected as reference persons. Productivity loss was based on time difference to reach critical body core temperature at the same activity, or lower continuous work pace (metabolic rate in Watts (W)) to keep core temperature below 38 °C under new climate conditions. On time based difference additional rest breaks of 30 minutes were considered to be able to lower the body core temperature to normal, and total effective work time was compared to expected (480 minutes).

### **Results and discussion**

The higher clothing insulation and evaporative resistance (Figure 1) affected the results showing lower capacity to maintain work pace already under present climatic conditions. Further increase in mean air temperature may decrease the productivity 30-80 % depending on the parameter (limited exposure time or lower work load) that is looked at, and on the previous capacity to carry out the tasks (Figure 2). The present evaluation may have limitations related to better ventilation in traditional than in western clothes that the model is based on. Also, the work-rest schedule may affect the results, as well as availability of cooled recovery areas. Presently, only the shade may be provided while other ambient parameters are the same as during the work. Validation of the presented method application is needed.

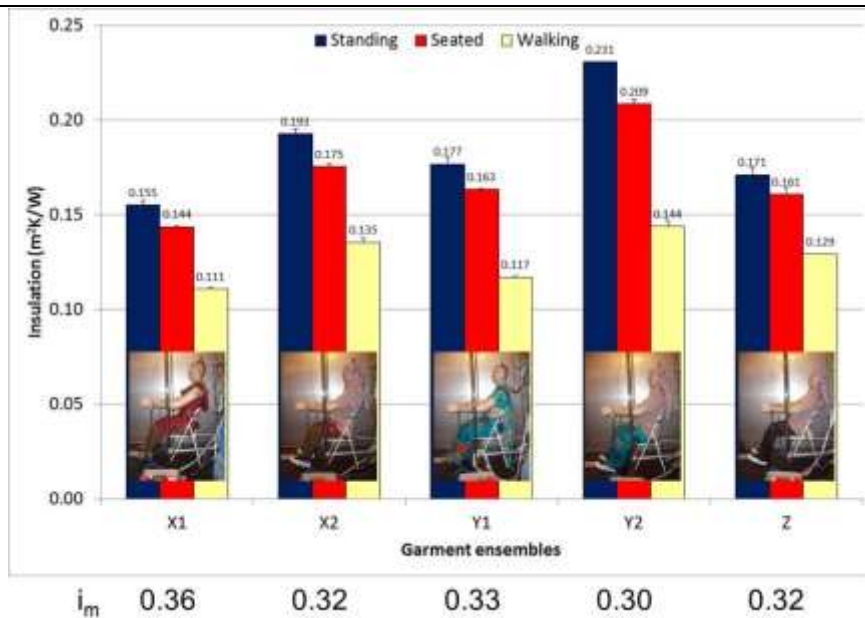


Figure 1. Workers' clothing from Chennai, India tested on thermal manikin Tore.

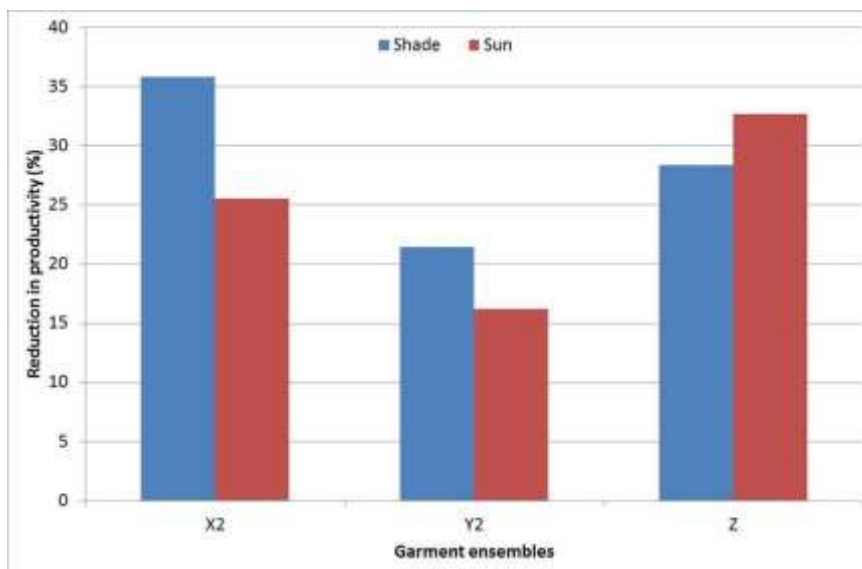


Figure 2. Productivity reduction if the air temperature will be increased by 2 °C for workers in shade or exposed to solar radiation. If calculated body temperature reached 38 °C each time 30 minutes of rest was added to the work schedule.

## Conclusions

Female clothing without shirt and head cover has close insulation to male work wear.

Female workwear has considerably higher insulation than male work wear for standing and seated postures.

Under walking female work wear ventilates better and insulation comes closer to male clothes.

Ventilation effect is not considered in PHS model.

Productivity loss may be expected in most of the cases.

Clothing affects productivity loss.

Productivity loss is reflected in time or lower pace or both.

In male workwear the relative productivity loss was the lowest. In female workwear (Y2) the productivity was already affected under present conditions, therefore, the additional loss was low.

Validation of the predictions is needed – there may be several uncertainties present in system, e.g. ventilation effects in female clothing, effects of breaks etc.

Drinking water should always be available.

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