

Bellows Effect of Sarong and Trousers

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Abstract : The bellows effect of two garments—sarong and trousers—upon the ventilation of the skin of the lower limb was measured by determining the loss in weight of pieces of a volatile substance, paradichlorobenzene, placed inside wire cages which were attached to the leg and thigh during 30 minutes of walking. The weight loss was of the order of 100 mg and there was no significant difference between sarong and trousers, or leg and thigh, with regard to the weight loss. The bellows effect is due to a wind created *in situ* under the garment rather than to a wind entering the garment from below.

1. Introduction

Garments have a bellows effect, that is, the movement of garments gives rise to the pumping of air over the skin which is covered by the garments. This gives rise to convective exchange of heat between the body and the air. In warm climates, the bellows effect is helpful in promoting heat loss from the clothed body during movement if the air is cooler than the skin.

The sarong and trousers are the commonest garments worn by men in contemporary Sri Lanka. Both hang down from the waist and cover the lower part of the trunk and the lower limbs. The sarong is a simple untailored tube of thin cloth, whereas trousers are tailored to fit the crotch and each lower limb separately with cloth of variable thickness. Many people have the custom of wearing trousers to work, and sarong during relaxation or sleep.

The present investigation sought to estimate the bellows effect of sarong *versus* trousers upon the lower limb.

2. Experimental

The principle of the method used in this investigation is to attach a sublimable substance to the lower limb between the garments and the skin ; the loss of substance during movement is assumed to be an index of the bellows effect.

If the skin is painted with an alcoholic extract of asafoetida, the bellows effect removes the asafoetida ; and the observer's nose can detect the decrease or disappearance of the odour of asafoetida from the skin. This method is, of course, subjective and non-quantitative.

Nishi and Gagge used naphthalene held near the skin to measure convectioal loss of heat from the skin. Naphthalene balls, 3 cm in diameter, were held 3 cm off the skin at various points in the body. The ventilation of the skin was held at 30 feet per minute. Activities tested were sitting, walking and cycling.

The volatile substance paradichlorobenzene (PDB) which is commonly used, like naphthalene, as an insecticide for domestic articles such as textiles, is more sublimable than naphthalene. Whereas the weight loss of a piece of naphthalene held in a wire cage on the leg under a sarong or trousers was of the order of 10 mg at the end of a half hour's walk, that of a similar piece of PDB was of the order of 100 mg. The weight loss of a 1.7 g piece of PDB if it were simply kept in a wire cage on a laboratory table for half an hour was found to be about 25 mg ; if a fan blew air on it with a wind speed of about 280 metres per minute the weight loss increased to about 60 mg. If it were kept outside the wire cage the weight loss was about 50 mg, or about 90 mg with a fan blowing on it.

The PDB was cut into roughly square blocks about 1.0 to 1.5 cm long. It is assumed that small differences between the shape and size of the blocks used in the present series did not have any important effect on the loss of weight of the blocks. A block of PDB was put into a wire cage. The shape of the cage was cylindrical with a length of about 5 cm and a diameter of about 1 cm. The wire was thin (gauge 0.2 mm) and of close mesh (2 mm square). The wire cage was weighed and then attached to the middle of the leg, or the junction of the lower and middle thirds of the thigh on its medial side, by means of a wire handle and rubber bands. One cage was attached to the left limb and another to the right. The subject then walked outside the laboratory for 30 minutes. He took a stopwatch with him so as to time the walking. At the end of the walking, the cages were detached and weighed to determine the loss in weight of the PDB inside the cage.

3. Results

The results are shown in the accompanying table.

None of the differences between the mean values for subject ERM (sarong vs trousers, or left vs right, or leg vs thigh) was statistically significant, except possibly for the difference between leg and thigh with trousers (mean value for leg 101, thigh 84, t value 2.1 ; $0.05 > P > 0.02$).

4. Discussion

There is a very appreciable loss in weight in the block of paradichlorobenzene attached to the leg or thigh during walking. It is of the same order of magnitude as that produced in a similar piece of the substance by blowing air over it at nearly 300 m/min.

TABLE I. Weight loss of a piece of paradichlorobenzene placed in a wire cage attached to the leg or thigh during $\frac{1}{2}$ hour of walking in sarong or trousers. Mean \pm standard deviation.

	Number of determinations	Weight loss of the wire cage (mg)		
		Left side	Right side	Both sides
A. Wire cage attached to the leg				
Subject ERM R				
Resting (sitting) with sarong tucked up to expose the legs	1	20	25	23
Walking for $\frac{1}{2}$ h wearing—				
Sarong	8	96 \pm 30	90 \pm 41	93 \pm 35
Sarong tucked up to expose the legs	1	90	70	80
Trousers	8	89 \pm 26	78 \pm 24	84 \pm 22
Subject RP				
Walking for $\frac{1}{2}$ h wearing—				
Sarong	1	97	60	79
Trousers	1	92	80	86
B. Wire cage attached to the thigh				
Walking for $\frac{1}{2}$ h				
Subject ERM R wearing—				
Sarong	8	112 \pm 35	111 \pm 18	111 \pm 27
Sarong tucked up to expose the legs	1	63	60	62
Trousers	8	93 \pm 23	109 \pm 28	101 \pm 26
Subject RP wearing—				
Sarong	1	58	60	59
Trousers	1	156	170	163
Subject BMP B wearing				
Sarong	1	102	114	108
Trousers	1	148	127	138

Possible causes of the loss in weight of the block of PDB are (i) sublimation of paradichlorobenzene and (ii) dropping off of pieces of paradichlorobenzene as powder or flakes. The latter is not likely to be important. In experiments done with the wire cage enclosed in a cloth bag there were no flakes or powder to be seen in the bag at the end of the experiment and there was no increase in the weight of the bag alone. The paradichlorobenzene still lost weight but the weight loss was halved, presumably because sublimation was hindered by the cloth bag.

The similarity in the order of magnitude of the weight loss of PDB in the leg and thigh sheds some light on the mechanics of the bellows effect. Let us consider two hypotheses: (a) the bellows effect is due to a current of air entering and leaving through the lower open end of the garment, and (b) it is due to a mixing and a blowing about of the air which already exists between the garment and the skin. If hypothesis (a) were correct we would expect the loss in weight of PDB to be greater on the leg than on the thigh. Since in fact there was no significant difference

between leg and thigh, hypothesis (b) seems more likely to be correct than (a). This conclusion was further supported by the finding that the application of a ligature on the trousers above the ankle or knee had little or no effect on the weight loss of the PDB.

5. Conclusions

The weight loss of the paradichlorobenzene (PDB) placed in a wire cage attached to the leg or thigh during 30 minutes of walking was of the order of 100 mg. There was no significant difference whether the garment worn was sarong or long trousers. The weight loss of the PDB is attributed to a "bellows effect" i.e. a wind created under the garment during movement. This wind seems to be created *in situ* under the garment rather than one which enters the garment from below.

References

1. NISHI, Y., & GAGGE, A. P., (1970). *Direct evaluation of convective heat transfer coefficient by naphthalene sublimation. J. Applied Physiol.* **29** : 830-838.