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ANALYSIS OF THERMAL PERFORMANCE OF SLEEPING BAGS

Hannu Anttonen, Risto Paso & Veikko Halonen

Address for reprints:
Hannu Anttonen
Oulu Regional Institute of Occupational Health
P.O. Box 451, SF-90101 Oulu, Finland

Thermal insulation measured according to existing standards is frequently used to evaluate the performance of sleeping bags in cold environments. In this work we considered the usability of these measurements by performing purely physical material tests and by comparing their results to cold chamber studies performed with human subjects. The effect of moisture on heat loss was studied by using artificial sweating skin equipment to determine the operational thermal resistance of the materials. Reliability of the sweating skin measurements was evaluated by using a numerical model of the combined diffusion of heat and water vapor through clothing (1). In addition to vapor condensation the freezing of liquid water was included. The physiological parameters measured in cold chamber studies were skin temperature (15 sites), great-toe and rectal temperatures and oxygen consumption.

The measurements and calculations show that the most important parameters for the evaluation of the total heat loss from sleeping bags are thermal resistance, water vapour resistance and compressibility. Heat loss to the ground is determined by the compression of the sleeping bag and with no camping mattress this can be as high as 80 % of the total heat loss. The thermal performances of the sleeping bags studied were quite equal; differences were found in toe temperatures only (max. 8°C). In the table below the thermal resistances calculated from the heat balance equation (column 1) are given together with material measurements according to standard DIN 54101 (column 2). In column 3 the operational thermal resistances from the sweating skin model measurements (-25°C, 70 g/m^{2}h) are given.

sleeping bag	1	2	3
A	5.5 clo	6.7 clo	3.7 clo
B	6.0	10.4	4.9
C	6.4	8.9	4.4

The sweating skin measurements show that the regain is not an essential parameter for the thermal performance of sleeping bags in cold environments. Neither does the freezing of liquid water or the use of an impermeable surface have much effect on total heat loss.

Standardized material tests can be used to quantify the thermal performance of sleeping bags but only if the compression of the sleeping bag is included in the calculations and if the effect of a camping mattress is carefully considered.

(1) B. Farnworth: A Numerical Model of the Combined Diffusion of Heat and Water Vapor Through Clothing. Textile Research Journal 56, 653-665, 1986.