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ORIGINAL RESEARCH

Protection Against Cold in Prehospital Care: Wet Clothing Removal or Addition of a Vapor Barrier

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Objective.—The purpose of this study was to evaluate the effect of wet clothing removal or the addition of a vapor barrier in shivering subjects exposed to a cold environment with only limited insulation available.

Methods.—Volunteer subjects (n = 8) wearing wet clothing were positioned on a spineboard in a climatic chamber (–18.5°C) and subjected to an initial 20 minutes of cooling followed by 30 minutes of 4 different insulation interventions in a crossover design: 1) 1 woolen blanket; 2) vapor barrier plus 1 woolen blanket; 3) wet clothing removal plus 1 woolen blanket; or 4) 2 woolen blankets. Metabolic rate, core body temperature, skin temperature, and heart rate were continuously monitored, and cold discomfort was evaluated at 5-minute intervals.

Results.—Wet clothing removal or the addition of a vapor barrier significantly reduced metabolic rate (mean difference ± SE; 14 ± 4.7 W/m^2) and increased skin temperature rewarming (1.0° ± 0.2°C). Increasing the insulation rendered a similar effect. There were, however, no significant differences in core body temperature or heart rate among any of the conditions. Cold discomfort (median; interquartile range) was significantly lower with the addition of a vapor barrier (4; 2–4.75) and with 2 woolen blankets (3.5; 1.5–4) compared with 1 woolen blanket alone (5; 3.25–6).

Conclusions.—In protracted rescue scenarios in cold environments with only limited insulation available, wet clothing removal or the use of a vapor barrier is advocated to limit the need for shivering thermogenesis and improve the patient's condition on admission to the emergency department.

Key words: hypothermia, heat loss, thermal insulation, emergency medical services

Introduction

Admission hypothermia, defined as a core body temperature less than 35°C, is an independent predictor of increased mortality and morbidity in trauma patients.[1–6] The reported incidence of hypothermia varies from 1.6% to 43% with severity and mechanism of injury, the presence of shock, duration of evacuation, and prehospital induction of anesthesia as predictive variables of the trauma patient arriving hypothermic to the emergency department.[7–10]

In addition to immediate care for life-threatening conditions, early application of adequate insulation to reduce heat loss and prevent body core cooling is an important part of prehospital trauma care.[11–13] If the patient is wet, most prehospital guidelines on protection against cold recommend the removal of wet clothing before insulation or the use of a vapor barrier between the wet patient and the insulation.[14–20] In the field, however, the removal of wet clothing might be impeded because of harsh environmental conditions or the patient's condition and injuries. Also, encapsulation in a vapor barrier might restrict necessary access and monitoring of the patient during transport.

Using a thermal manikin, we previously demonstrated that independent of insulation thickness (1, 2, or 7 woolen blankets), wet clothing removal or the addition of a vapor barrier reduced total heat loss by about one-fourth (19%–31%) in a cold environment (–15.4°C) and one-third (27%–42%) in a warm environment (+11.0°C); the absolute reduction, however, was greater

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in the cold environment and with fewer blankets applied.[21] A similar reduction in total heat loss was also achieved by increasing the insulation from 1 to 2 blankets or from 2 to 7 blankets. These findings suggest that the clinical relevance of wet clothing removal or the addition of a vapor barrier is greater in a sustained cold environment with only limited insulation available.

To verify these findings and evaluate the effect of wet heat loss reduction on human thermoregulation, a follow-up human trial was designed. The objective of this study was to evaluate the effect of wet clothing removal or the addition of a vapor barrier in shivering subjects exposed to a cold environment with only limited insulation available. The primary outcome measure was metabolic rate, with core body temperature, skin temperature, heart rate, and cold discomfort as secondary outcome variables. Our hypothesis was that wet clothing removal or the addition of a vapor barrier would significantly reduce shivering thermogenesis and abate peripheral vasoconstriction, thus lowering the metabolic rate, increasing skin temperature, and improving cold discomfort. We anticipated no significant differences in core body temperature.

Methods

DESIGN, SETTING, AND SUBJECTS

The study was conducted in October 2010 at the Thermal Environment Laboratory, Lund University, Lund, Sweden. Ethical approval was obtained from the Regional Ethical Review Board in Umea.

The study was designed to evaluate shivering thermogenesis, core body temperature, skin temperature, heart rate, and cold discomfort in cold-stressed subjects wearing wet clothing during an initial cold exposure followed by 4 different insulation interventions: 1) 1 woolen blanket (control condition); 2) vapor barrier plus 1 woolen blanket; 3) wet clothing removed plus 1 woolen blanket; or 4) 2 woolen blankets.

Four male and 4 female nonsmoking healthy students at the Faculty of Medicine, Lund University, volunteered for participation (Table 1). Each subject served as his or her own control and participated in all 4 conditions. Each subject was randomly assigned to complete the trials in a unique order following a balanced design, scheduled at about the same time of day on 4 separate occasions, 1 week apart. The subjects abstained from smoking, alcohol, or drug use, had a minimum of 6 hours of sleep and adequate meals, and avoided physical exertion during the 24 hours before the trials.

The climatic chamber ($2.4 \times 2.4 \times 2.4$ m) was set to –20°C, and in concordance with the previous study using a thermal manikin,[21] 1 and 2 woolen blankets (Swedish Rescue Agency) were chosen to provide low (2.8 ± 0.2 clo) and moderate (3.8 ± 0.1 clo) insulation in relation to the ambient temperature (1 clo = 0.155 m^{2}°C/W). Each blanket measured approximately $199 \times 150 \times 0.5$ cm and weighed 2.150 g, ie, 2.15 kg. The vapor barrier was made up of 2 large plastic bags taped together to form a large sack measuring approximately 250×85 cm with a weight of 250 g. The wet clothing worn by the subjects consisted of light, 2-piece cotton/polyester thermal underwear (Swedish Armed Forces) with a total dry weight of approximately 575 g.

MONITORING

Ambient air temperature was continuously monitored using 3 sensors (PT 100, Pico Technology Ltd., UK; ±0.03°C) positioned in level with the supine subject, adjacent to the ankles, the mid trunk, and the head. No wind was applied, but intrinsic airflow in the climatic chamber was checked with a directionally independent

Table 1. Characteristics of subjects

Subject	*Sex*	*Age (y)*	*Height (cm)*	*Weight (kg)*	*BMI (kg/m²)*[a]	*BSA (m²)*[b]	*Body fat (%)*[c]
1	M	32	182	81	24	2.0	13
2	M	25	186	87	25	2.1	18
3	M	24	196	89	23	2.2	12
4	M	24	185	82	24	2.1	18
5	F	25	172	61	21	1.7	21
6	F	21	166	56	20	1.6	14
7	F	21	162	54	21	1.6	18
8	F	23	169	62	22	1.7	16

[a] Calculated according to McArdle et al.[22]
[b] Calculated according to Du Bois and Du Bois.[23]
[c] Calculated according to Durnin and Womersley.[24]
BMI, body mass index; BSA, body surface area.