A PHYSIOLOGICAL ASSESSMENT OF ARCTIC SLEEPING BAGS UNDER COLD WEATHER CONDITIONS

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ABSTRACT

Arctic sleeping bags of two different designs were tested simultaneously over a period of four weeks using four test subjects sleeping overnight in the DREO cold chamber. Tests were conducted at ambient temperatures of -20°C and -40°C to compare the thermal protection afforded by each type of bag during repeated use. No significant differences between types of sleeping bag were found.

RÉSUMÉ

Deux sacs de couchage pour climat arctique, de fabrication différente, ont été simultanément mis à l'épreuve durant quatre semaines. Pendant cette période, quatre sujets ont passé chaque nuit dans ces sacs, à l'intérieur d'une chambre froide et à des températures de -20°C et -40°C, afin de comparer la protection thermique offerte par chacune des enveloppes. Aucune différence marquée n'a été constatée entre les deux sacs de couchage.

INTRODUCTION

Canadian Forces personnel have observed that the presently used Arctic sleeping bag* does not provide sufficient thermal protection in the field. The lack of protection was thought to be due to migration of the insulating material from the centre to the ends of the sleeping bag during repeated use. To reduce this migration, a newly designed sleeping bag in which the quilting runs transversely rather than longitudinally but containing approximately the same amount of insulating material as the present design was proposed.

Prototype sleeping bags were manufactured and submitted to DREO with the request that physiological evaluations be conducted to compare the thermal protection provided by the transversely-quilted (NEW) and longitudinally-quilted (OLD) types of sleeping bag during repeated use by test subjects (1). Tests were to include the possibility that a soldier neglected to redistribute the filling of the bag before retiring into it. When used in the field, the sleeping bags normally are expected to provide warmth for six hours of rest.

Each design (NEW and OLD) consists of a liner plus an inner and an outer component and may be used in two configurations:

(a) temperate: liner and outer component alone for temperatures down to -20°C, and

(b) Arctic: liner and inner plus outer components for temperatures between -20°C and -40°C.

A separate hood** to protect the head from cold is worn when the sleeping bag is used in either configuration. The evaluations described in this report were conducted using the sleeping bags in the temperate and the Arctic configuration.

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* Bag, Sleeping, Arctic, Cl, Stock Numbers 8465-21-842 - 6078, 6079, 6080.

** Hood, Sleeping Bag, Stock Number 8465-21-842-6081.

OBJECTIVES

Two sleeping bags of each type were tested simultaneously over a period of four weeks using four test subjects sleeping overnight in the DREO cold chamber. One two-week series of tests at -20°C and another at -40°C were conducted with the following objectives:

(a) to measure temperatures at various points inside each type of sleeping bag while being used by test subjects overnight to determine if there was a significant difference in the thermal protection afforded by each type of sleeping bag;

(b) to record the subjective opinions of the test subjects regarding thermal protection afforded by each type of sleeping bag;

(c) to measure the number of hours of sleep obtained by each test subject during each test period.

METHOD OF TEST

Four members of the CF/DREO Test Team participated in the evaluation. They were young, male, active military personnel and their physical characteristics are given in Table I. All of the participants had had previous experience in using the CF Arctic sleeping bag.

The evaluation was conducted over a period of four weeks (16 test sessions) using the test subjects who slept overnight in the DREO cold chamber. Two sleeping bags of each design were tested simultaneously. During the first two weeks of the evaluation (sessions 1-8), the sleeping bags were tested in the temperate configuration at an ambient temperature of -20°C and during the final two weeks (sessions 9-16), they were tested in the Arctic configuration at an ambient temperature of -40°C. Each type of sleeping bag was used alternately by the test subjects as shown in Table II so that each subject slept in the NEW and OLD design in each configuration an equal number of times.

TABLE I

Physical Characteristics of Test Subjects

Subject No.	Age (years)	Height (cm)	Weight (kg)
1	27	177	93.7
2	30	177	64.7
3	21	167	65.8
4	28	184	94.5

TABLE II

Type of Sleeping Gear Used by Test Subjects

Configuration	Session Numbers	Subject Number 1	2	3	4
Temperate (-20°C)	1 - 4	NEW	OLD	NEW	OLD
	5 - 8	OLD	NEW	OLD	NEW
Arctic (-40°C)	9 - 12	OLD	NEW	OLD	NEW
	13 - 16	NEW	OLD	NEW	OLD

In order to simulate field conditions and to reduce the effect of wind caused by the circulation of air from the refrigeration unit, subjects slept in a CF five-man Arctic tent erected in the cold chamber. The sleeping bags rested on pneumatic mattresses placed on the wooden floor of the chamber inside the tent. The only items of clothing worn by the test subjects while in the sleeping bags were CF extreme cold weather drawers and undershirt and the CF sleeping bag hood.

Temperatures within the sleeping bags were measured using thermistors sewn to the inner layer of each bag in the waist and chest areas. Thermistors taped to the right great toe of each test subject were used to monitor toe temperatures. All temperatures were measured to the nearest 0.1°C and these were recorded by technical personnel at 30-minute intervals during each test session.

A method described by Haley and King (2) was used to determine the number of hours of sleep obtained by each of the subjects during test sessions. A hand button was placed inside each sleeping bag and subjects were instructed to press the button in response to a faint alarm which sounded inside the tent every fifteen minutes. The volume of the alarm was adjusted so that it did not awaken sleeping personnel but could be heard by those not sleeping. Subjects were considered to be asleep during any fifteen minute period in which they did not press the hand button. Pressing the button caused a deflection of one of the pens of a four-channel chart recorder which operated throughout each session.

Test subjects and technical personnel arrived at the DREO site at approximately 22:00 each evening. Between the hours of 22:00 and 22:30 thermistors were fixed to each subjects' great right toe and the clothing to be worn overnight was donned. At 22:30 each subject removed his sleeping bag from its protective carrier bag and entered the cold room. No attempt to "fluff up" or redistribute the insulation in the sleeping bag was made. All of the subjects retired at 23:00 and remained in the cold room until awakened at 06:00 the following morning. Each sleeping bag was rolled up immediately and placed in its carrier bag where it remained at room temperature until the start of the next test session.

Each morning the subjects assessed the degree of thermal protection afforded by their sleeping bag by answering the following question:

"How well did the sleeping bag work for you last night, protecting your:

- feet
- head
- arms and hands
- entire body."

using the following rating scale:

6 - much too warm
5 - too warm
4 - comfortable
3 - could have been warmer
2 - too cold
1 - much too cold

At the end of session 8 and session 16, the test subjects were asked to compare each type of bag, stating which they preferred.

RESULTS AND DISCUSSION

Mean toe temperatures and mean temperatures in the waist area of the sleeping bags after 2, 4 and 6 hours in each type of bag at -20°C and at -40°C are shown in Tables III and IV. As is the case with most physiological experiments, the results of measurements made on individual test subjects (from which the mean values shown in these tables are derived) vary considerably. Tables VII and VIII (Annex A) are included to illustrate the nature of the variation. However, the "comparison-rotation" test design used in this evaluation (Table II) minimizes the effect of the variation between test subjects when final results are calculated.

All of the above-mentioned results were analyzed statistically using the Student's t-test. It was found that there was no significant difference ($P = 0.005$) between the longitudinally-quilted and transversely-quilted sleeping bags with regard to temperature measurements made in the toe or waist areas.

Temperature measurements made in the chest/neck area of the sleeping bags are not included in this report since these results varied widely during each test session due to the natural movement of the test subjects while sleeping. Temperatures in this area often fell below the minimum range of the measuring instrument (0°C). It was felt that this data was not representative of the thermal environment that existed within the sleeping bags and could not be used to compare the two types of bag.

TABLE III

Mean Toe Temperatures Within Sleeping Bags

	Mean Toe Temperature (°C) After					
	2 Hours		4 Hours		6 Hours	
TYPE OF BAG	NEW	OLD	NEW	OLD	NEW	OLD
AMBIENT TEMPERATURE						
-20°C	29.4	29.4	26.3	24.0	22.0	20.0
-40°C	30.7	31.8	26.2	27.6	22.5	23.2

TABLE IV

Mean Waist Temperature Within Sleeping Bags

	Mean Waist Temperature (°C) After 2 Hours		4 Hours		6 Hours	
TYPE OF BAG	NEW	OLD	NEW	OLD	NEW	OLD
AMBIENT TEMPERATURE						
-20°C	25.2	25.1	25.6	24.9	24.5	23.1
-40°C	25.2	24.8	24.1	23.4	23.7	22.6

A summary of the subjective ratings given to each type of sleeping bag by the test subjects is given in Table V. In general, all subjects complained of cold feet and, in general, subjects were more comfortable at -40°C using the sleeping bags in the two-component configuration than at -20°C when only one component was used.

TABLE V

Subjective Rating of Sleeping Bags

Question: How well did your sleeping bag work for you, protecting your:	Mean Rating of Sleeping Bags by Test Subjects at -20°C		at -40°C	
	NEW	OLD	NEW	OLD
Feet	3.1	2.7	3.6	4.2
Head	4	4	4.9	4.9
Arms and Hands	4	3.7	4.9	5.2
Entire Body	3.6	3.3	4.6	4.9

Rating scale: 6 - much too warm, 5 - too warm, 4 - comfortable
3 - could have been warmer, 2 - too cold,
1 - much too warm.

Subjectively, there was no difference in the thermal protection afforded by either type of bag at each of the ambient temperatures. When the test subjects were asked to compare each type of sleeping bag, stating which they preferred, the following responses were obtained.

At the end of test session 8:

Subject 1 felt that the OLD bag was warmer.
Subject 2 said that he slept better in the NEW bag.
Subject 3 felt that the NEW bag was warmer.
Subject 4 felt that there was no difference between bags.

At the end of test session 16:

Subjects 1, 2 and 4 felt that there was no difference between bags.
Subject 3 felt that the NEW bag was warmer.

When used in the Arctic configuration (2 components), most of the test subjects complained that both types of sleeping bag were too short and too narrow in the chest area. It should be noted that none of the subjects was an exceptionally large person. The test subjects also found that due to their natural movements inside the bags while sleeping, the flannelette liners often became twisted. This caused the material to rip in some instances. It is felt that this problem could eliminated by using additional tie-on tapes in the central area of the liner.

During test sessions 9 to 16 at -40°C, the metallic outer zipper on each type of sleeping bag often became frozen shut due to condensed moisture vapour. Test subjects experienced difficulty in getting out of their sleeping bags in the morning. This situation could present a serious hazard during an emergency in which rapid exit was required. It is felt that the problem might be alleviated with the use of plastic zippers.

The mean number of hours of sleep per session obtained by the test subjects using each type of bag at -20°C and at -40°C is shown in Table VI. Statistical analysis using the Student's t-test ($P = 0.005$) indicated that there was no significant difference in the number of hours of sleep obtained using either type of bag.

TABLE VI

Mean Number of Hours of Sleep Obtained by Test Subjects

	Mean* Number of Hours of Sleep at -20°C		at -40°C	
TYPE OF BAG	NEW	OLD	NEW	OLD
	5.22 (1.18)	5.43 (1.06)	5.58 (0.96)	5.97 (0.66)

* standard deviation in parentheses

One of the requirements for CF Arctic sleeping bags is that they must provide for six hours of rest. The distinction between "hours of rest" and "hours of sleep" should be noted. Except for the brief initial period of discomfort experienced when first entering the sleeping bags, the test subjects were able to rest in reasonable comfort for the duration of the seven hour test period. Although the mean number of hours of sleep in each situation was less than six, each of the bags met the "hours of rest" requirement. Even when the test subjects were resting and producing metabolic heat at a reduced rate, sufficient thermal insulation was provided by each type of sleeping bag and the subjects were not prevented from sleeping because they were excessively warm or cold.

CONCLUSIONS

As a result of the evaluations described in this report, the following conclusions were drawn:

(a) There was no significant difference between the longitudinally-quilted and transversely-quilted sleeping bags with regard to the thermal protection afforded to the toes and waist areas of test subjects;

(b) Subjectively, there was no difference in thermal protection afforded by either type of bag. In general, subjects were more comfortable at -40°C (using two components of each of the sleeping bags) than at -20°C;

(c) There was no significant difference in the number of hours of sleep obtained by test subjects using either type of bag.

REFERENCES

1. DCGEM, letter 10055-69-024 (DCGEM 2-3), 28 May 1975.

2. Haley, R.L. and King, D.A., "Development Test II (Service Phase) of Cold Weather Sleeping Gear Under Arctic Winter Conditions. Final Report". U.S. Army Arctic Test Center, APO Seattle, 98733, 31 May 1973.

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ANNEX A

TABLE VII

Mean Toe Temperature Within Sleeping Bags
(ambient temperature: -40°C)

Type of Bag	Mean Toe Temperature (°C) After 2 Hours		4 Hours		6 Hours	
	New	Old	New	Old	New	Old
Run No.						
9	29.8	32.3	27.3	30.2	27.8	30.6
	29.0	34.4	18.7	28.0	13.4	28.0
10	23.0	31.3	18.2	34.2	12.8	32.6
	30.3	32.5	19.0	32.6	17.4	32.1
11	26.8	30.4	14.4	31.3	15.6	29.5
	29.4	33.6	20.4	26.8	16.2	18.1
12	30.3	34.0	30.1	32.1	25.0	29.8
	27.3	32.9	17.9	30.8	12.2	23.8
13	33.4	34.6	33.2	34.9	35.4	29.4
	35.1	29.2	34.3	19.4	27.4	14.4
14	33.6	29.8	31.0	21.4	25.2	11.7
	32.2	28.0	33.2	20.4	31.8	14.1
15	31.8	33.4	30.0	30.3	16.2	26.1
	32.7	30.6	31.8	21.8	29.7	18.2
16	32.5	30.6	27.7	23.8	26.8	17.5
	33.6	31.8	32.1	22.9	26.4	14.5
mean	30.7	31.8	26.2	27.6	22.5	23.2
standard deviation	3.12	1.96	6.83	5.22	7.48	7.43

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TABLE VIII

Mean Waist Temperature Within Sleeping Bags
(ambient temperature: -40°C)

	Mean Waist Temperature (°C) After					
	2 Hours		4 Hours		6 Hours	
Type of Bag	New	Old	New	Old	New	Old
Run No.						
9	25.5	22.2	21.8	24.7	24.2	22.9
	21.8	27.6	19.8	29.4	20.0	19.2
10	24.2	27.0	25.3	20.8	18.0	21.6
	21.1	25.2	18.2	19.0	20.0	16.8
11	21.8	25.3	24.8	23.2	22.0	20.2
	20.6	20.8	23.1	30.5	22.7	25.0
12	27.1	25.2	23.4	25.1	26.2	18.0
	27.9	24.0	18.2	19.4	22.9	24.8
13	29.0	24.6	26.0	15.8	28.2	23.3
	30.0	23.4	31.0	21.8	23.3	23.6
14	25.1	24.3	28.6	23.9	23.0	24.4
	29.2	24.8	32.2	25.4	32.5	24.4
15	23.1	24.2	17.9	22.6	19.4	27.9
	26.3	26.1	26.7	24.6	26.6	22.1
16	25.0	23.2	24.6	22.0	25.6	19.7
	26.0	29.1	23.1	26.6	25.1	27.9
mean	25.2	24.8	24.0	23.4	23.7	22.6
standard deviation	2.98	2.03	4.32	3.76	3.67	3.23