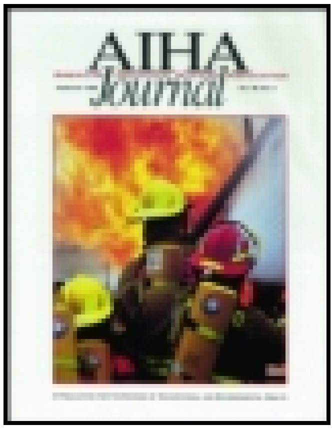

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Physiological Responses to the Wearing of Fire Fighter's Turnout Gear with Neoprene and GORE-TEX® Barrier Liners*

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This study examined the physiological effects of performing moderate and high intensity work while wearing fire fighter's turnout gear with either a neoprene or GORE-TEX® barrier liner. Eight healthy men, experienced with the use of respirators and protective clothing, each performed moderate and high intensity treadmill exercise (44% and 71% of maximum work capacity) in a double-blind study at 27.6° C (50% RH) while wearing complete fire fighter's turnout gear (weighing 23 kg) with either a neoprene or GORE-TEX barrier liner. Physiological measurements obtained included minute ventilation, heart rate, skin temperature, rectal temperature and sweat rate. Subjective evaluations of perceived exertion, comfort, clothing breathability, temperature and perspiration also were obtained. Tests were terminated (tolerance time) when objective or subjective signs of near maximal stress were observed (*i.e.,* 90% of the maximum heart rate, rectal temperature of 39° C, dizziness, *etc.*). Mean tolerance times for the moderate intensity exercise were 27.4 (± 7.3 S.D.) and 30.9 (± 7.9) min, respectively, for the neoprene and GORE-TEX barrier liners and at the high intensity were 7.2 (± 2.1) and 7.5 (± 2.3) min, respectively. Analysis of variance indicated that significant differences caused by liner were observed in skin temperature (0.6° C higher with the neoprene ensemble). No significant differences caused by liner were seen in tolerance time, heart rate, sweat rate or subjective ratings. These results suggest that the physiological benefits normally attributed to vapor permeable garments (such as GORE-TEX barrier liners) are minimized when such liners are used in conjunction with fire fighter's turnout gear during sustained moderate to heavy work in a warm environment.

Introduction

Fire fighting typically is thought of as a very stressful and demanding occupation. Several investigators[1-3] have reported severe physiological strain associated with fire fighting, with heart rates increasing to near maximal levels in only a few moments. Heat exhaustion is also a common hazard faced by fire fighters. Much research has been conducted on the physiological effects and physical requirements of fire fighter equipment,[4-10] and these studies indicate that the thermoregulatory and cardiorespiratory stresses involved in wearing such protective ensembles are significant.

The clothing ensembles which fire fighters typically wear consist of standard fire fighter's coat and fire fighter's pants,[11] boots, gloves, helmet, and coveralls or trousers with shirt, generally worn in conjunction with a positive pressure, self-contained breathing apparatus (SCBA). Total weight of the ensemble generally ranges from 20–25 kg. The outer shell of the clothing usually is a 213-g (7.5-oz.) Nomex III® aramid material, covering a quilted, 85-g (3.0-oz.) Nomex pajama-check liner, with a moisture barrier (E.I. DuPont de Nemours and Company, Wilmington, Del.). The moisture barrier is "designed to prevent the transfer of liquid water from the environment to the thermal barrier."[11] It should be noted that while United States fire fighters typically do wear a moisture barrier, it is not a universal practice. Swedish investigators[12] indicate that, "In our opinion, the concept of vapor barriers is of doubtful validity; . . . no vapor barrier is required in European countries . . ."

The types of materials used in fire fighters' clothing have been reviewed recently.[13] Neoprene and GORE-TEX® barrier liners are the most common types of water barriers worn with turnout gear. GORE-TEX barrier is a trade name for a type of expanded polytetrafluoroethylene, a homopolymer, with, in this case, pores of sufficient size for water vapor molecules to pass through but not large enough for water droplets to penetrate. Neoprene, on the other hand, is a synthetic rubber, a polychloroprene vulcanate, which is impermeable to both water and water vapor. Research addressing the issue of whether GORE-TEX barrier liners effectively reduce the heat stress associated with wearing specific types of protective clothing is limited.[9,14-17] In general these studies report benefits with the GORE-TEX barrier liner in terms of skin temperature, skin wettedness and heart rate. No advantage was reported in terms of core temperature or ventilatory parameters. The studies described above, however, did not include a self-contained breathing apparatus, and all left significant body areas without sealed water barrier covering.

The purpose of this study was to examine the physiological effects of performing low and high intensity work while wearing fire fighter's turnout gear with either a neoprene or GORE-TEX barrier liner.

Materials and Methods

The subjects in this investigation were 8 male volunteers who were nonsmokers and ranged in age from 22 to 29 yr (mean =

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TABLE I
Description of the Subjects

	Age (yrs)	Ht (cm)	Wt (kg)	Fat (%)	FEV_1 (L)	FVC (L)	Max Heart Rate (BPM)	Max $\dot{V}O_2$ (mL/kg·min)
	26	178	80.2	21	4.2	4.97	200	43.7
	26	191	76.9	19	4.5	5.57	197	43.0
	29	175	95.3	26	5.4	6.27	192	37.4
	29	178	89.0	18	3.6	6.28	187	43.8
	22	173	75.0	19	4.7	5.68	200	43.3
	29	188	78.6	16	5.5	6.82	196	51.5
	24	173	73.4	18	4.4	4.64	197	46.1
	29	185	72.4	17	4.3	5.92	192	43.5
MEAN	26.8	180	80.1	19.3	4.6	5.77	195	44.0
SD	±2.7	±6.6	±8.0	±3.1	±.6	±.72	±4.5	±3.9

26.8 yr). They were experienced local fire fighters or emergency service personnel who had prior experience using respirators and protective clothing. Prior to inclusion in the study, subjects signed a National Institute for Occupational Safety and Health (NIOSH) informed consent statement and were screened by way of a medical examination (including 12-lead electrocardiogram) and exercise tolerance test to insure physical health. Subjects were financially compensated for their participation.

The physical characteristics of the subjects are shown in Table I. Percent body fat was estimated from the sum of 4 skinfold measurements (biceps, triceps, subscapular and supra-iliac).[18] Maximal heart rate and aerobic capacity were determined from the exercise tolerance test that used a modified Balke protocol.[19] The test was a series of 2-min stages, beginning with a work load of 5.6 kph (3.5 mph), 2.5% grade and incrementing 2.5% grade until the test was terminated because of attainment of maximal exertion levels. (If the maximal treadmill elevation of 25% grade was obtained by the subject, work load was progressively incremented by increasing the speed of the treadmill.) Maximal aerobic capacity was determined by recording the peak oxygen consumption measured by a Beckman Horizon Metabolic Measurement System (Sensormedics Corporation, Anaheim, Calif.).

The subjects performed a series of 4 submaximal exercise tests in a 2 X 2 (ensemble x work load) design. Most tests were spaced 1 week apart, although in all cases a minimum of 48 hr separated each test. Each type of liner (neoprene or GORE-TEX barrier liner) was worn in a double-blind format with complete fire fighter's gear (including coat, pants, boots, gloves, hood, helmet and SCBA). The neoprene ensemble consisted of shorts (50% cotton, 50% polyester) and Chemklos II one-piece coveralls (made of a lightweight, flame resistant, modacrylic material with good air permeability) (Mine Safety Appliances Company, Pittsburgh, Pa.) worn underneath fire fighter's turnout gear including Janesville NFPA 1981 coat and pants (with a 7-1/2 oz. quilted Nomex liner and neoprene-coated poly/cotton vapor barrier) (Janesville Apparel, Dayton, Ohio), Ziamatic Nomex hood (Ziamatic Corp., Yardley, Pa.), Firecraft gloves (Western Fire Equipment Co., Brisbane, Calif.), Cairns 660C metro helmet (Cairns and Brother, Clifton, N.J.), Servus bunker boots, (Servus Rubber Co., Inc., Rock Island, Ill.), and suspenders. A GORE-TEX barrier liner was substituted for the neoprene liner for the second clothing ensemble.

Two work loads were chosen for the submaximal tests. Work was performed on a Quinton motor driven treadmill (Model Q55, Quinton Instrument Co., Seattle, Wash.) at a predetermined walking speed and elevation indicative of either 30% or 60% of the maximum work capacity for each individual, while not wearing SCBA or protective clothing. The speed and elevation selected for each subject was based on actual oxygen consumption data obtained during the preliminary maximal exercise test. Average treadmill speeds and elevations were 5.4 kph (3.4 mph), 2.0% grade for the moderate intensity work load and 5.6 kph (3.5 mph), 9.1% grade for the high intensity work load. The first work load was chosen to be representative of that which could be continued for an entire work shift,[20,21] while the high work load was representative of that which might be performed during an escape maneuver.[6,22] As noted in the Results section of this paper, however, the fire fighter's ensemble increased mean oxygen consumption to 44% of maximum in the first (moderate) work load and to 71% of maximum at the high work load.

Both work loads were performed at an environmental temperature of 27.6 ± 1.6° C dry bulb, 20.3 ± 1.2° C wet bulb, 22.5° C WBGT (50% RH). The duration of work was not limited but from prior experience was not expected to be greater than 1 hr. Subjects were instructed not to eat or drink anything except water for at least 2 hr prior to each test session.

Both ensembles were worn with a Mine Safety Appliances (MSA Model 401, MSA, Pittsburgh, Pa.) open circuit, pressure demand, full facepiece SCBA with a 30-min composite compressed air cylinder. Mask physical dead space was 757 mL. The measurement of respiratory response was made possible by mechanically modifying the mask to allow continuous monitoring and collection of expired air, while the resistance and protection offered by the respirator were not altered. Breathing air was supplied to the subjects through the respirator's regulator which was attached to a large (6550 L) compressed air cylinder. Previous research[10] indicated that this manifolding would be necessary to assure that tests would be terminated because of physiological response and not because of consumption of air from the 30 min cylinder. Total weight of the ensemble with the neoprene liner was 22.1 kg, while the weight with the GORE-TEX barrier liner was 21.6 kg.

A Hewlett Packard (H-P) Series 200 (3497A) data acquisition system with a 3456A digital voltmeter, plotter and printer (Hewlett Packard, Palo Alto, Calif.) was utilized to acquire the physiological data obtained during the tests. Laboratory instrumentation was interfaced to the H-P system allowing direct measurement of the following at one-minute intervals: heart rate, skin and rectal temperature, facepiece temperature and pressure, and sweat rate. Additionally, a Beckman Horizon Metabolic Measurement System (Sensormedics Corporation, Anaheim, Calif.) was utilized to measure minute ventilation, tidal volume, respiratory rate, carbon dioxide production and oxygen consumption. Heart rate was monitored utilizing a Physiocontrol Life Pak 6 (Physio-Control Corporation, Redmond, Wash.) interfaced through the Beckman to the H-P system.

Temperature measurements were obtained utilizing the thermocouple compensation features of the H-P system. Core temperature was measured using a flexible, vinyl-covered probe (Type 401, Yellow Springs Instruments Co., Inc., Yellow Springs, Ohio) inserted 10 cm into the rectum. Local skin temperatures were measured at 6 locations with copper-constantan thermocouples. Mean skin temperature was calculated by weighting the temperatures using the following calculation:

$$Tskin = [.125(T_1) + .125(T_2) + .125(T_3) + .125(T_4) + .07(T_5) + .1(T_6)]/.67$$

where T_1 = lateral thigh; T_2 = medial thigh; T_3 = back; T_4 = chest; T_5 = arm; T_6 = cheek.[23]

A Setra Systems (Model 239) pressure transducer (range ± .5 psi, response time less than 1 msec) (Setra Systems, Inc., Acton, Mass.) was utilized for measurement of facepiece pressure. Each minute the transducer signal was sampled for 590 readings (at a sample rate of 73 readings/sec). Maximum and minimum pressures were recorded by the H-P system.

Total sweat production was estimated as the change in nude body weight, measured before and after the test session, and corrected for water intake. Water drinking was allowed *ad libitum* during recovery only. A platform scale (GSE, Inc., Farmington Hills, Mich.), accurate to ± 5 g, was used for weighing of the subjects.

Subjective responses were obtained utilizing a Psy-Med Associates Data Collection System® (which uses a Commodore C-64 controller and 1802 color monitor) (Psy-Med Associates, Honolulu, Hawaii).[24] The H-P system electronically cued the initiation of the scales every other minute. Subjective responses during the last minute of exercise for the following parameters are reported here: perceived exertion (overall), comfort of clothing, clothing breathability, temperature in clothing, and perspiration in clothing. All scales were 0-20 point scales, with 0 being most favorable and 20 being least favorable, For example, the descriptive words and their associated scale numbers for temperature in clothing were the following: 0 – neutral; 4 – very warm; 10 – hot; 16 – very hot; 20 – unbearable. The scales were developed specifically for this study, and there are no data available on their reliability and validity. Subjects indicated their ratings during the tests through the use of a joystick which would move the cursor up or down the vertically aligned scale on the color monitor. Subjects would depress a button, or "fire," when the cursor indicated the response corresponding to their perception.

Resting data were obtained with the subject dressed in the specific clothing ensemble and standing on the treadmill. The test then commenced at the specified work load and continued until one of the following criteria was met: (1) 90% of maximum heart rate; (2) rectal temperature of 39.0°C; (3) skin temperature equaling or exceeding rectal temperature; (4) objective or subjective signs of severe discomfort or fatigue (dizziness, nausea, *etc.*). The time at which any one of these criteria was met was recorded as tolerance time. The test then was terminated and data collection continued for an additional 10 min during a light work-recovery walk at 1.6 kph on the treadmill. During this time the respirator and turnout coat were removed and water was offered *ad libitum*. Data thus were available for 3 activity levels: rest, work and recovery.

Data were analyzed as a randomized complete block experiment with a 2 X 2 X 3 (liner X work load X activity level) factorial arrangement of treatments where subjects formed the blocks. Except where indicated, all data recorded over time (including rest, work and recovery) for each subject were included in the analysis. In addition, a separate

TABLE II
Metabolic and Ventilatory Responses[A]

Parameter	Clothing Ensemble	Work Load: Moderate Intensity	Work Load: High Intensity
$\dot{V}O_2$[B] (L/min)[C]	Neoprene	1.51 (.19)	2.48 (.26)
	GORE-TEX®	1.58 (.19)	2.51 (.33)
$\dot{V}CO_2$[D] (L/min)[C]	Neoprene	1.50 (.23)	2.72 (.38)
	GORE-TEX	1.47 (.23)	2.77 (.42)
$\dot{V}E$[E] (L/min)[C]	Neoprene	59.5 (9.6)	85.3 (20.5)
	GORE-TEX	59.0 (9.0)	79.5 (22.7)
TV[F] (L)[C]	Neoprene	1.74 (.21)	2.62 (.52)
	GORE-TEX	1.84 (.30)	2.39 (.45)
RR[G] (breaths/min)	Neoprene	34.7 (6.1)	33.3 (8.1)
	GORE-TEX	32.9 (6.8)	33.6 (8.0)

[A]Values represent mean (± SD) obtained during the last two minutes of the test.
[B]$\dot{V}O_2$ = oxygen consumption
[C]Moderate intensity values significantly lower than high intensity values ($p < 0.05$)
[D]$\dot{V}CO_2$ = carbon dioxide production
[E]$\dot{V}E$ = minute ventilation
[F]TV = tidal volume
[G]RR = respiratory rate

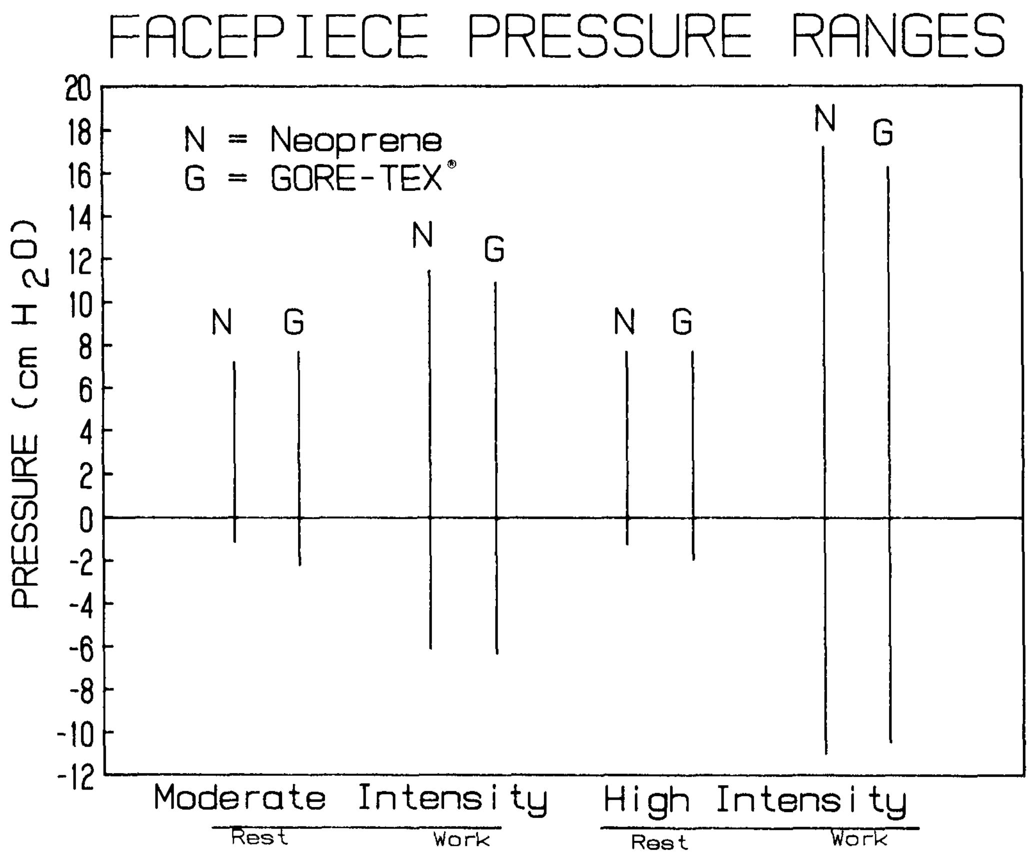

Figure 1—Mean facepiece pressures (maximum and minimum) during rest and work

comparison was made between the GORE-TEX and neoprene liner data, averaged over work load, using only the work activity level data (excluding rest and recovery data). An analysis of variance (ANOVA) was used, and tests were made at a 0.05 level of significance.

Results

Metabolic and ventilatory parameters measured during the last 2 min of each test are shown in Table II. Because of work intensity, there were significant differences for oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), minute ventilation ($\dot{V}E$), and tidal volume (TV), but not for respiratory rate (RR). No significant differences were observed because of ensemble liner. Although the estimated work loads without the fire fighter's ensemble were 30% and 60% of the maximum, the mean measured $\dot{V}O_2$s with the ensembles were approximately 44% and 71% of the mean maximum value. Alterations in maximum and minimum facepiece pressures also were related to work intensity (as well as to activity level) but not to ensemble liner (Figure 1).

Test termination during the moderate intensity tests was after the subject's attainment of heart rate criteria (90% of HR max) for 12 of 16 tests. The remaining tests were stopped because of the subject's intolerance of the work (nausea and light headedness in 1 of 8 tests with the neoprene liner and 2 of 8 tests with the GORE-TEX barrier liner; and fatigue in 1 of 8 tests with the GORE-TEX barrier liner). One subject did not perform the high intensity tests, and his data were not used in comparing moderate versus high intensity values. During the high intensity tests, reasons for stopping were the subject's attainment of 90% of maximum heart rate (12 of 14) and intolerance of the work ("stitches in side" in 1 of 7 neoprene tests, fatigue in 1 of 7 tests with the GORE-TEX barrier liner).

Mean tolerance times for the moderate intensity tests were 27.4 (± 7.3 S.D.) and 30.9 (± 7.9) min, respectively, for the neoprene and GORE-TEX barrier liners. The high intensity mean tolerance times were 7.2 (± 2.1) and 7.5 (± 2.3) min, respectively. There were significant differences caused by work intensity ($p < .01$) but not caused by the ensemble liner.

Mean heart rate responses are presented in Figure 2. The last 10 min of data, included in the overall means, reflect recovery.) There were no significant differences caused by ensemble liner (overall mean = 144.4 and 143.3 BPM for neoprene and GORE-TEX barrier liners, respectively; work data mean = 152.1 for both liners). Heart rate was significantly higher during work (mean = 152.1 BPM) than during rest (mean = 91.2 BPM) or recovery (mean = 135.5 BPM). Near maximum heart rates were reached within 7 min during high intensity tests compared to over 25 min during moderate intensity tests (Figure 2).

Figure 3 depicts the changes in rectal and skin temperatures over time for each of the 4 experimental conditions. Analysis of variance indicated significant differences ($p < .01$) in skin temperature because of ensemble liner, work intensity and activity level. These results are illustrated in Figure 4. Averaged over both work intensities, mean skin temperature was approximately 0.6° C higher with the neoprene liner, using either the entire data set or the work level data alone. Examining the individual skin temperatures of the 6 locations, these trends generally were consistent across the 6 sensor locations, with ensemble liner differences being significant ($p < .01$) at the lateral and medial thigh and the back. Time to achievement of skin temperatures of 35° and 36°C are depicted in Table III. These criteria levels were obtained significantly sooner with the neoprene liner. No significant differences were observed because of work intensity.

Mean rectal temperatures at the end of the moderate intensity exercise were 37.8°C and 37.9°C for the neoprene and GORE-TEX barrier liners and at the high intensity were 37.2°C and 37.4°C, respectively ($p > .05$). Over the duration of the tests (including recovery), the average rectal temperatures also were very similar with each of the 2 liners. This slight difference (0.06°C higher with the GORE-TEX liner) was significant ($p < .05$), however. During the work activity level alone, this difference was 0.09°C, also significant. Analysis of the gradient for heat exchange (core temperature minus skin temperature) revealed significant differences ($p < .01$) caused by ensemble liner, work intensity and activity level. The mean gradients for heat exchange were 1.72 (± .88)° and 2.40 (± .75)°C, respectively, for the neoprene and GORE-TEX barrier liners during the moderate intensity tests and were 2.80 (± .69)° and 3.15 (± .44)°C, respectively, during the high intensity tests.

The mean body weight losses (corrected for water intake) following the moderate intensity tests were .978 (± .333) and .894 (± .257) kg, respectively, for the neoprene and GORE-TEX barrier liners and were .364 (± .114) and .384 (± .090), respectively, following the high intensity tests. There were no significant differences caused by ensemble liner. The effect of work intensity was significant ($p < .01$), with weight losses being greater following the longer duration, moderate intensity exercise.

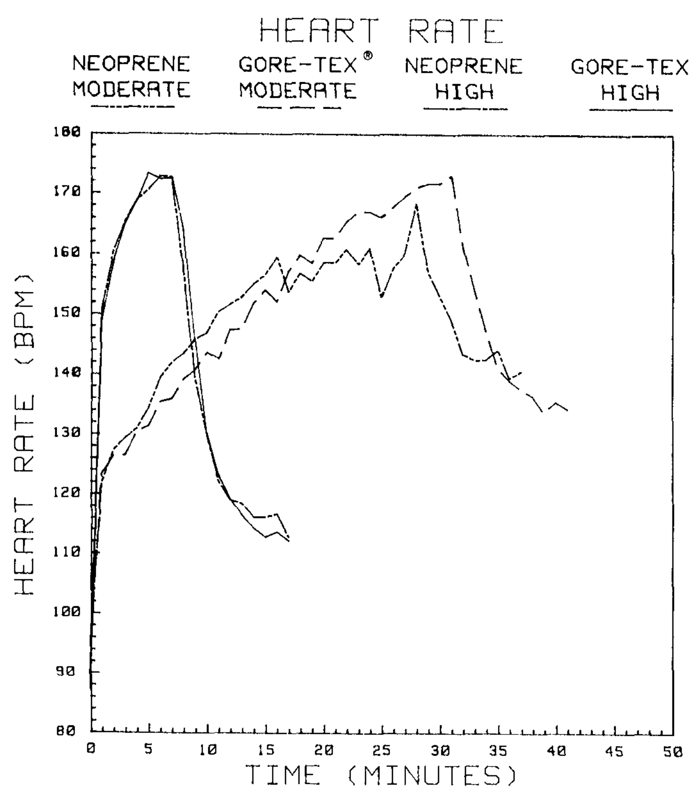

Figure 2—Mean heart rate response

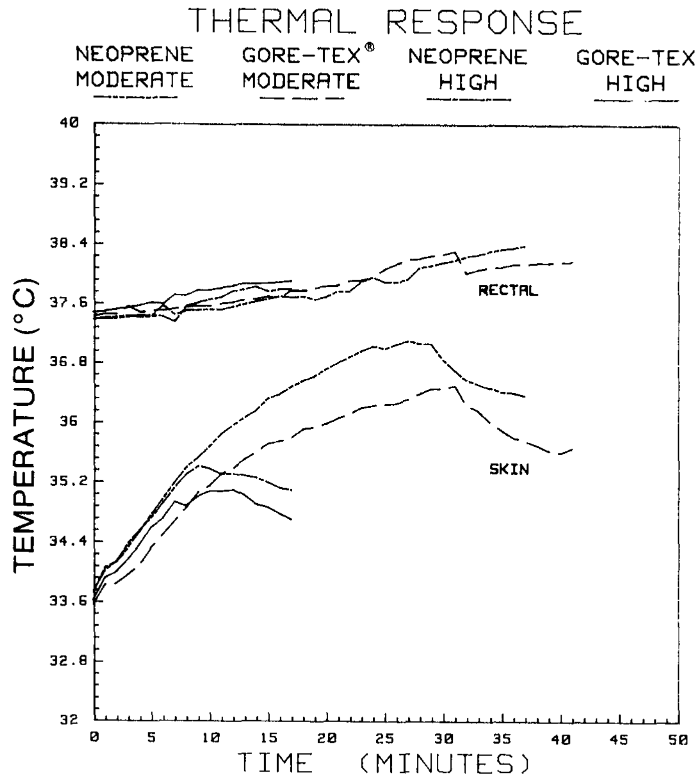

Figure 3—Mean skin and rectal temperature response

Analyses of each of the five subjective ratings obtained during the last minute of the test indicated no significant effect caused by ensemble liner. Significant effects of work intensity, however, were observed in ratings of breathability, temperature in the clothing, and perspiration in the clothing, where subjects reported higher (less favorable) ratings during the longer duration, moderate intensity tests. Mean values for the five scales are presented in Table IV.

Discussion

The results of this study revealed a tendency for subjects' responses to be similar at both moderate and high work intensities while they were wearing either of the 2 liners (neoprene and GORE-TEX barrier liners) in a warm environment. Tolerance times between moisture barriers differed by only 3.5 and 0.3 min for the moderate and high intensity work. Heart rate responses also were very similar with the 2 liners (Figure 2), differing on the average by approximately 1 beat per minute. The magnitude of the subject's heart rate increase in each of the 2 ensembles indicated significant cardiac stress in response to working in the ensembles. These results are similar to those of an earlier study[4] and to one[10] in which a fire fighter's ensemble (with neoprene liner) was compared with 3 other protective clothing ensembles. Another study[14] reported higher heart rate responses to wearing

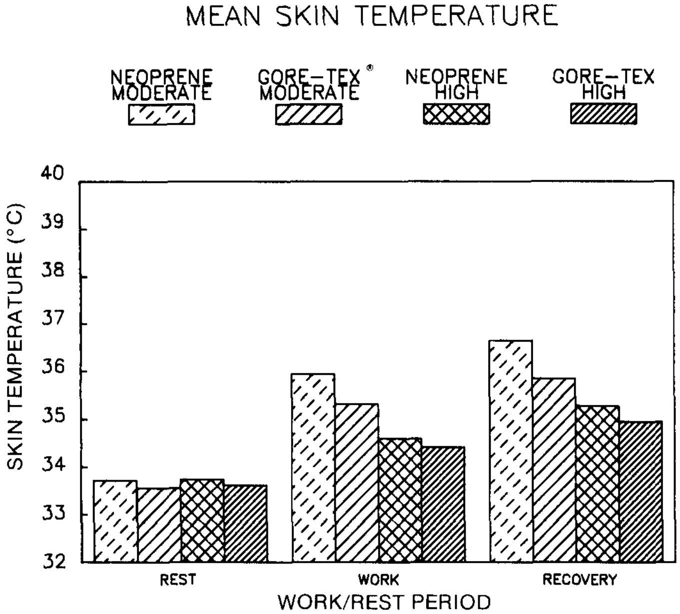

Figure 4—Mean skin temperature response during rest, work and recovery

vapor-impermeable overgarments than with either a track suit or GORE-TEX barrier parka with track suit pants. Comparison of that data with results from the present study is difficult because of the nature and intensity of the exercise and the type of ensembles worn.

Exercise with both ensembles at both work loads created physiological strain in subjects, as measured by skin and rectal temperatures (Figure 3). The skin temperature results indicate a slight (0.6°C) but statistically significant benefit from wearing the GORE-TEX barrier liner. The magnitude of the skin temperature decrease with the GORE-TEX barrier liner is similar to the 0.6° to 1.0°C difference reported by others[9,17] when comparing vapor permeable and impermeable garments. The absolute skin temperatures in the present study (for both liners), however, are higher (by approximately 5°C) than those previously reported.[9,17] This difference may be the result of the use of a complete fire fighter's ensemble (including SCBA) in the present study or perhaps may be caused by differences in ambient temperature, air velocity, or clothing design. Note that in the present study, the only difference between the 2 experimental garments was the liner (*i.e.*, coat length, ventilation openings, *etc.*, remained constant). The time to achieve a skin temperature of 35°C is a suggested useful measure of thermoregulatory stress.[25] As shown in Table III, times to achievement of skin temperatures of 35° and 36°C favor the GORE-TEX barrier liner. The gradient for heat exchange, which also has been suggested to be a good indicator of heat strain,[26] provides additional support for slight benefits associated with the ensemble with the GORE-TEX barrier liner.

These results, then, are in agreement with other studies[9,14-17] reporting that wearing a GORE-TEX barrier liner helps reduce the thermal stress of working in heavy protective clothing. Under these experimental conditions, however, the overall effect on worker tolerance is minimal, as indicated by the similar core temperatures, tolerance times and heart rate responses.

The ventilatory data showed substantial increases in minute ventilation, $\dot{V}O_2$ and $\dot{V}CO_2$, over that which typically is seen at similar treadmill work levels without protective clothing/respirator ensembles.[27] The respiratory responses, however, are very similar to those reported elsewhere during exercise while wearing fire fighter's ensembles.[8,10,28] The magnitude of the SCBA facepiece pressure changes observed in the present study are most probably the result of the large ventilations required to work in protective clothing, as indicated by the observance of significant differences caused by activity level and work intensity. No significant differences in facepiece pressures because of ensemble liner were observed. Note that even though the SCBA worn in this study was a positive pressure unit, momentary negative pressure spikes were detected, as has been reported by others.[29] The practical significance of these brief spikes should be the focus of future research.

The results of the subjective ratings for clothing breathability, temperature in the clothing, and perspiration in the clothing tend to reflect some of the physiological responses. For example, skin temperatures and weight loss (reflecting sweat rate) were both highest during the moderate intensity tests with the neoprene liner. Subjects also perceived this experimental condition as the most stressful. These results do not contradict findings from the literature, indicating that subjects are able to perceive accurately their level of exertion.[30-33] It should be noted, however, that the subjective results were not statistically significant as far as subjects being able to detect subtle differences between the two ensemble liners, and subjects indicated no clear preference of one liner over another. Thus, there appears to be no improved comfort associated with the use of GORE-TEX barrier liners under the conditions of this study.

Conclusions

In summary, this study has demonstrated a significant, though minimal, difference in skin temperature between the

TABLE III
Skin Temperature (Tskin) Response

Clothing Ensemble/ Work Load	Mean	Standard Deviation	Number of Cases
Time (min) to Tskin ≥ 35°C			
Neoprene/moderate	6.25	1.16	8/8
GORE-TEX®/moderate	8.88	1.36	8/8
Neoprene/high	5.33	1.15	3/7
GORE-TEX/high	6.50	2.12	2/7
Time (min) to Tskin ≥ 36°C			
Neoprene/moderate	12.88	1.96	8/8
GORE-TEX/moderate	20.40	2.61	5/8
Neoprene/high	11.00	—	1/7
GORE-TEX/high	—	—	0/7

neoprene and GORE-TEX barrier liners when used in conjunction with fire fighter's turnout gear and respirators during continuous work in a warm environment. Other objective and subjective stress indicators (tolerance time, heart rate, sweat rate and subjective ratings) indicated no significant differences between the two barrier liners. It is suspected that other components of the fire fighter's ensemble, coupled with the nature of the exercise, may have reduced significantly any differences in the heat stress characteristics of the liners, per se.

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TABLE IV
Subjective Responses during Last Minute of Test[A]

Parameter	Clothing Ensemble	Work Load: Moderate Intensity	Work Load: High Intensity
Perceived exertion Overall	Neoprene	16.2 (2.6)	13.4 (2.1)
	GORE-TEX®	15.0 (3.7)	13.1 (2.0)
Comfort of clothing	Neoprene	17.5 (1.9)	15.1 (0.7)
	GORE-TEX	16.1 (3.8)	14.4 (1.1)
Breathability of clothing[B]	Neoprene	17.8 (1.2)	15.3 (1.1)
	GORE-TEX	16.5 (2.5)	15.3 (1.1)
Temperature in clothing[B]	Neoprene	18.5 (1.0)	11.9 (3.1)
	GORE-TEX	17.3 (2.4)	13.3 (3.1)
Perspiration in clothing[B]	Neoprene	18.7 (1.6)	13.3 (1.3)
	GORE-TEX	17.3 (2.6)	14.0 (1.4)

[A]Values represent mean ± standard deviation (the range for all scales was 0–20 with 20 being the least favorable).

[B]Moderate intensity values significantly higher than high intensity values

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NIOSH: Current Intelligence Bulletin No. 50 Carcinogenic Effects of Exposure to Diesel Exhaust

ABSTRACT

This bulletin presents recent information on the potential carcinogenicity of diesel exhaust. Included are discussions of recent animal studies that confirm the relationship between cancer and exposure to whole diesel exhaust. Also discussed is epidemiologic evidence that associates lung cancer with occupational exposure to diesel engine emissions. On the basis of the results of these studies, NIOSH recommends that whole diesel exhaust be regarded as a potential occupational carcinogen in conformance with the OSHA Cancer Policy (29 CFR 1990).

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