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SUMMARY

Problem

U.S. Navy personnel often are subjected to extreme thermal environments that may produce marked thermal strain. Severe and/or chronic heat stress conditions may jeopardize the health and safety of these individuals to the point where decrements in work performance may compromise successful completion of the mission. Countermeasures to prevent or reduce the incidence and severity of thermal strain are needed.

Objective

The purpose of this investigation was to evaluate the effectiveness of a passive microclimate cooling vest in reducing thermal strain during 4 hr of seated rest in a hot environment.

Approach

Eleven male volunteers completed a 4-hr heat exposure on 4 consecutive days in a climatic chamber with a thermal environment of 43°C dry bulb and 45% relative humidity. The activity level consisted of seated rest and performance of a series of computer tasks. A passive microclimate cooling garment (Steele ice vest) was worn during two of the heat exposures. Physiological variables measured included heart rate, rectal temperature, mean skin temperature, mean arterial pressure, whole-body sweating rate, forearm blood flow, and skin blood flow. After determining that statistical difference existed in the physiological responses observed during the two non-ice vest tests, data from both non-ice vest tests were averaged to provide one non-ice vest value for each variable. Data from both ice vest tests were treated similarly.

Results

Heart rate, rectal temperature, mean skin temperature, and whole-body sweating rate were significantly lower in the vest condition compared to the nonvest condition by 17 bpm, 0.3°C,

2.6°C, and 0.27 L/hr, respectively. Although mean arterial pressure remained within a normal range in both vest conditions, nonvest values were significantly lower. Forearm blood flow and skin blood flow results were unchanged in either vest condition.

Conclusion

The ice vest was effective in reducing thermal strain as demonstrated by lower heart rate, rectal temperature, mean skin temperature, and sweat rate. Use of this ice vest will provide a safer work environment for naval personnel exposed to high-heat conditions by reducing the potential for heat-related injuries. Results from this baseline study provide the basis to proceed with further research into the development of ice vest Physiological Heat Exposure Limit Curves.

INTRODUCTION

Many shipboard activities and operations possess the potential for heat stress-related injuries. In response to this problem, the U.S. Navy developed a heat exposure policy for naval personnel (see Chapter 3 of The Manual of Naval Preventive Medicine [NAVMED P-5010-3, 1988]). Central to the prevention of heat stress in the Navy was the development of maximal safe heat exposure (stay) times, commonly referred to as the Physiological Heat Exposure Limits (PHEL curves). The PHEL curves (Figure 1), which are used throughout the fleet to set duty station work schedules (OPNAV Instruction 5100.20C, 1985), are based on the metabolic level of the work being performed and the thermal environment (dry bulb, wet bulb, globe temperature) within the work space (Dassler, 1977). Despite adherence to PHEL policy, heat-stress conditions can be exacerbated in situations where shipboard ventilation systems are unable to compensate for extreme environmental conditions. The Persian Gulf experience in the mid-1980s demonstrated the need for additional relief from frequent and severe heat-stress conditions. During the summer months, ambient temperatures in excess of 38°C and ocean temperatures in the range of 27°C can generate shipboard temperatures in excess of 54°C. In addition, Navy vessels deployed in this region frequently operate in an enhanced readiness posture (General Quarters) work schedule, which can further increase the physical and environmental stress imposed on a ship's crew.

As a possible countermeasure to these severe thermal conditions, the Navy Clothing and Textile Research Facility, Natick, MA, conducted a series of investigations exploring the effectiveness of air- and liquid-cooled microclimate cooling systems (Pimental, Janik, & Avellini, 1988). The findings from these studies suggested that a passive microclimate garment (ice vest) could be used to reduce thermal strain in the fleet (Pimental & Avellini, 1989). Preliminary field studies conducted at the Naval Health Research Center, San Diego, CA, demonstrated that the ice vest not only reduced thermal strain but also reduced ratings of tension/anxiety during shipboard operations (Banta & Braun, 1992; Burr, Banta, Coyne, Hodgdon, & Chesson, 1990; Burr,

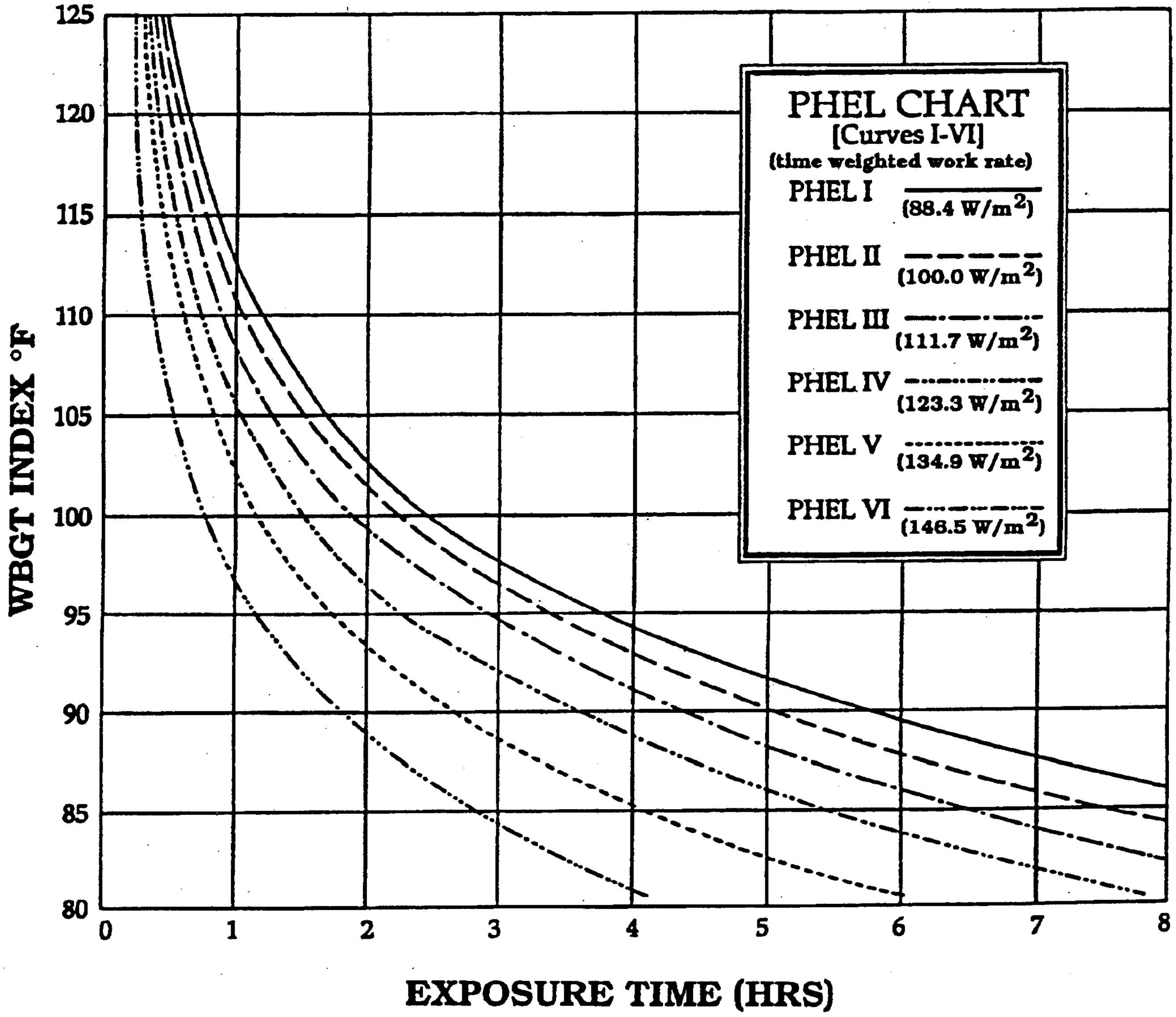

Figure 1. Physiological Heat Exposure Limits (PHEL Curves).*

*Modified from: U.S. Navy Manual of Naval Preventive Medicine. Chapter 3, Ventilation and thermal stress ashore and afloat. NAVMED P-5010-3 (1988), Naval Medical Command, Washington, D.C.

Heaney, Banta, & Sopchick, 1993). Findings from these studies suggest that use of the ice vest might provide longer PHEL stay times. The Bureau of Medicine and Surgery, Department of the Navy, requested a thorough physiological evaluation of the ice vest and its effectiveness in reducing thermal strain prior to endorsing any modification of the existing PHEL policy. Thus, a series of laboratory investigations have been scheduled to evaluate the ability of an ice vest to reduce thermal strain during exercise in the heat at selected intensity levels. This report presents the findings of a baseline study that investigated the effectiveness of the ice vest in reducing thermal strain during 4 hr of seated rest during exposure to high-heat environmental conditions.

METHODS

Subjects

Upon obtaining informed consent, 11 male, U.S. Navy engine room personnel volunteered to undergo repeated heat exposures in a climatic chamber. Mean (± SE) physical description data for the subjects were as follows: age = 23 ± 1 years, height = 180.5 ± 2.7 cm, weight = 75.0 ± 2.6 kg, and body fat (from neck and abdominal circumferences [Hodgdon & Beckett, 1984]) = 15.8 ± 1.7 %. All subjects completed a 4-hr heat exposure on 4 consecutive days, which included 2 days with and 2 days without wearing a cooling vest. The subjects were clothed in the Navy utility uniform, which consists of a T-shirt; long-sleeved cotton, chambray shirt; underwear; denim trousers; socks; and work boots.

Microclimate Cooling System

The cooling vest selected for use in the fleet is the Steele ice vest (IV) (STEELE Inc., Kingston, WA). The IV consists of a flame-retardant, cotton shell with three horizontal pouches across the chest and three across the back. Each pouch contains a strip of frozen gel material (a water and cornstarch mixture). The IV has a total weight of 5.1 kg, including 4.6 kg of frozen gel packs. A thermal manikin evaluation of the IV in a thermal environment of 35°C found the IV to

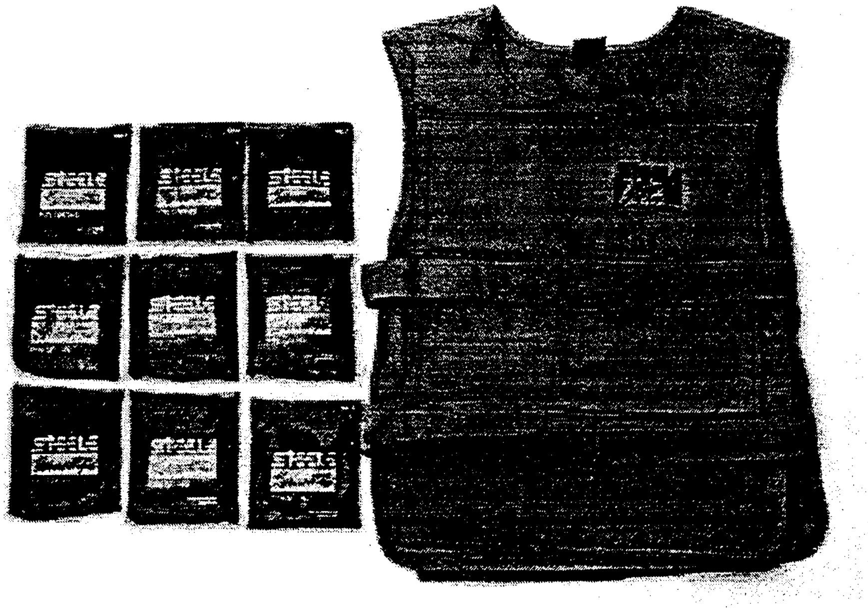

Figure 2.

The Steele ice vest and gel packs.

provide a cooling rate of 135 watts and a duration of 2 hr (per single ice charge) yielding a total cooling capacity of 270 watt/hr (Masadi, Kinney, & Blackwell, 1991).

During IV trials in the current study, the vest was worn over both the T-shirt and the chambray shirt. The gel packs were frozen at -29°C and replaced after 2 hours. The vest condition on the first test day was randomly assigned and then alternated daily such that each subject completed 2 heat-exposure tests wearing the IV and 2 heat-exposure tests wearing no ice vest (NV).

Activity Level

During each heat exposure, the subjects sat in an upright position and performed a short computer task each hour. The subjects were permitted to occasionally stand and walk around the inside of the chamber room. The metabolic rate of this activity was estimated to be 53 Kcal/m^2/hr, which is slightly higher than a typical resting rate (49 Kcalm/m^2/hr).

Thermal Environment

Based on data from field studies, thermal conditions in the climatic chamber were designed to simulate a typical shipboard environment during deployment in the Persian Gulf. A RSS-220 heat stress meter (Rueter-Stokes, Canada, Ltd.) was used to monitor the chamber environment operating at the following set points: dry bulb = 43°C, wet bulb = 32°C, globe temperature = 45°C, wet bulb globe temperature = 36°C, relative humidity = 45%, and partial vapor pressure = 31mmHg. Twelve infrared lights (250 watts/per bulb) were installed to simulate the radiant heat load observed in shipboard engine rooms.

Physiological Variables

The following physiological responses were monitored continuously throughout each test: heart rate (HR); rectal temperature (T_{re}) measured at a depth of 15 cm past the anal sphincter; and 4 skin temperatures (T_{sk}) - chest, arm, thigh, and calf. HR, T_{re}, and T_{sk} were recorded each minute using a solid-state data logger (1200 series Squirrel logger, Eltek Ltd., England). Mean skin temperature (T_{msk}) was derived from a 4-site equation (Ramanathan, 1964). Systolic and diastolic blood pressure were obtained by manual auscultation every 30 min and converted to provide a mean arterial pressure (MAP) estimate using the standard equation, (systolic + [diastolic x 2]) ÷ 3. Prior to and following each heat exposure, dry, nude, body weights were measured to the nearest 0.1 kg. Body weight differences, corrected for fluids consumed and urinary output, were used to calculate a whole-body sweating rate (SWR). Estimates of respiratory heat loss were not performed because it was assumed to be negligible in across all IV and NV trials.

Forearm blood flow (FBF) and skin blood flow (SBF) measurements were obtained on 7 of the 11 subjects (n = 7) using mercury-strain-gauge plethysmography (EC-4 Plethysmograph, D.E. Hokanson, Inc., Bellevue, WA) and a laser doppler (Laserflo BPM 403, Vasamedics Inc., St. Paul, MN), respectively. FBF and SBF were evaluated each day: at rest prior to entering the heat, and during the first, second, and third hour of the heat exposure. Blood flow data could not be obtained at the end of the fourth hour due to a conflict with evaluating other experimental parameters not discussed in this report.

Statistical Analysis

Steady-state values for HR, T_{re}, and T_{msk} were derived from averaging data during the last 10 min of each hour. After determining that no statistical difference was present in the physiological responses observed during the two NV tests, data from both NV tests were averaged to provide one NV value for each variable. Data from both IV tests were treated similarly. SWR was analyzed using a paired t-test, and all other variables were treated using a repeated-measures analysis procedure, Multivariate analysis of variance (MANOVA). Statistical significance was evaluated at the 0.05 level.

RESULTS

HR, T_{re}, and T_{msk} responses were significantly lower for IV compared to NV responses (Table 1 and Figure 3). HR response in the IV condition was virtually unchanged, ranging from 79 to 84 bpm while the drift in NV HR significantly increased from 85 to 101 bpm. Main effects for vest, time, and a vest-by-time interaction were found to be significant for the HR data. Although final IV T_{re} (37.2°C) was statistically lower than NV (37.5°C) and significant main effects for vest, time, and a vest-by-time interaction were found, the rise in T_{re} was not physiologically significant in either vest condition. IV T_{msk} values were significantly lower than NV values by approximately 2.8°C throughout the heat exposure, but no significant time effect or vest-by-time interaction was observed. Individual skin temperature values (°C) were as follows: chest IV = 26.2, NV = 36.1; arm IV = 36.7, NV = 36.6; thigh IV = 36.3, NV = 36.2; and calf IV = 35.8, NV = 35.1. Although MAP results in both vest conditions were within normal ranges, NV MAP values were significantly lower than IV values. A significant time effect or a

Table 1.

Heart Rate, Rectal & Mean Skin Temperatures, and Mean Arterial Pressure Results

n = 11 (X ± SE)	Hour 1 IV	 NV	Hour 2 IV	 NV	Hour 3 IV	 NV	Hour 4 IV	 NV
HR (bpm)	80 ±4	85 ±3	79 ±4	88 ±4	79 ±4	94 ±4	84 ±5	101 ±5
T_{re} (°C)	37.1 ±.06	37.1 ±.06	37.2 ±.05	37.4 ±.04	37.2 ±.07	37.5 ±.05	37.2 ±.07	37.5 ±.10
T_{msk} (°C)	33.3 ±.23	36.3 ±.07	33.4 ±.35	36.1 ±.10	33.2 ±.27	36.1 ±.10	33.2 ±.30	35.8 ±.22
MAP (mmHg)	89.7 ±1.8	86.5 ±1.4	89.7 ±2.4	87.4 ±2.4	89.9 ±2.7	83.4 ±1.9	93.6 ±2.1	87.7 ±1.5

vest-by-time interaction was not present. FBF and SBF values (Table 2 and Figure 3) were not significantly different between conditions. A time effect was observed because the heat exposure values were significantly higher than the pre-heat exposure values; however, a significant vest-by-time interaction was not present. Mean IV SWR was significantly lower than NV SWR (0.22 L/hr vs. 0.49 L/hr, respectively).

Table 2.

Forearm and Skin Blood Flow Results

n = 7 (X ± SE)	Pre IV	 NV	Hour 1 IV	 NV	Hour 2 IV	 NV	Hour 3 IV	 NV
FBF (ml/100ml/min)	2.6 ±.2	2.3 ±.3	3.4 ±.5	3.6 ±.3	3.1 ±.3	4.2 ±.8	3.6 ±.5	3.9 ±.8
SBF (blood flow units)	2.0 ±.5	2.4 ±.5	3.9 ±.7	3.0 ±.6	3.4 ±.5	4.4 ±.6	4.4 ±.4	5.5 ±.5

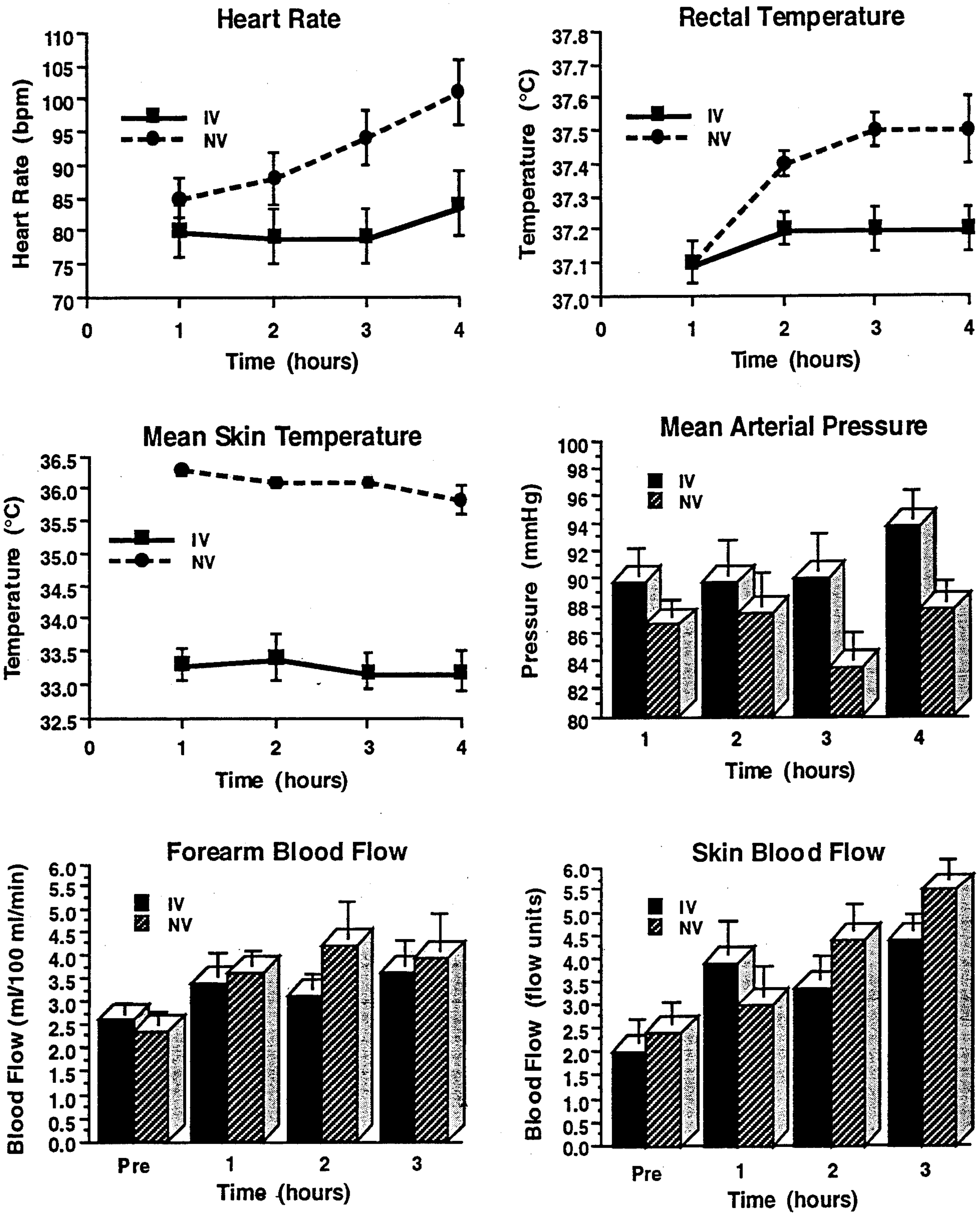

Figure 3. Physiological Response Results (X ± SE)

DISCUSSION

This study demonstrates the effectiveness of a passive microclimate cooling garment in reducing thermal strain during exposure to a hot/humid environment at a low activity level. Evidence of reduced thermal strain is provided by the significantly lower HR, T_{re}, T_{msk}, and SWR values when the IV was worn.

IV HR remained constant throughout the heat exposure, and by the end of the fourth hour was 17 bpm lower than NV HR. Reduced HR with IV usage has been demonstrated in previous cooling vest investigations (Banta & Braun, 1992; Pimental & Avellini, 1989). The higher HR in the NV condition likely is due to cardiovascular drift. Cardiovascular drift is characterized by an increase in HR over time (at a steady-state activity) due to a decrease in stroke volume (Brooks & Fahey, 1985). Additionally, it has been observed that HR will also increase (drift) during exposure to a warm/hot environment due to a decrease in cardiac filling as more blood is shunted to the peripheral vasculature to facilitate heat dissipation (Sawka & Wenger, 1988). The drop in stroke volume is thought to be caused by an increase in blood flow to the peripheral vasculature. Venous pooling increases which in turn will reduce the volume of venus return and result in a decreased central blood volume. A compensatory increase in HR must occur to maintain cardiac output and systemic blood pressure. The ability of the IV to prevent HR drift suggests that stroke volume is not reduced and greater central blood volume is maintained, thereby reducing cardiovascular strain.

When exposured to the heat, the human body has a limited range in core temperature (37°C to 41°C) in which normal physiological functions can be maintained (Astrand & Rodahl, 1977). Additionally, human heat tolerance is so individualistic that the ill effects of hyperthermia may occur at core temperatures $\leq$ 39.0°C. Due to the low activity level in this study, T_{re} did not increase beyond normal body temperature ($\leq$ 37.5°C) in either vest condition. However, evidence of a lower IV T_{re} response in this study is similar to the trend reported in previous investigations (Banta & Braun, 1992; Pimental & Avellini, 1989).

Investigators from two different studies, which included an exercise component in evaluating the effectiveness of the IV to reduce thermal strain, observed a similar reduction in IV HR and core temperature response compared to NV values (Pimental & Avellini, 1992; Bennett, Hagan, Huey, Minson, & Cain, 1993). These results suggest that IV use during future PHEL curve investigations, which will impose a greater environmental stress (higher temperature and humidity) and metabolic stress (increased work loads), may allow longer PHEL stay times by attenuating the rise in HR and T_{re}.

A significantly lower IV chest temperature (IV = 26.2°C vs. NV = 36.1°C) was principally responsible for the difference in T_{msk} between the vest conditions. Mean arm and thigh skin temperatures were identical, while IV calf temperature was significantly higher than NV calf temperature (35.8°C vs. 35.1°C, respectively). Since cooling the whole torso resulted in a lower T_{re}, reduced IV T_{msk} in the extremities would also be expected. However, peripheral T_{msk} may respond differently with IV use in that both active vasoconstriction and active vasodilation have been shown to occur in the extremities (Blair, Glover, & Roddie, 1960). Since the temperature of blood circulating at the skin surface ($T_{msk} \leq 36.3$°C) was lower than the temperature of blood leaving the core (37.1°C), core-to-skin heat transfer was possible in either vest condition. In theory, circulating blood will be cooled as it returns from the superficial vasculature and passes through deep body tissue and vasculature before returning to the periphery (Sawka & Wenger, 1988). However, when the ambient temperature is greater than the T_{msk}, the core-to-skin heat exchange will not provide a thermoregulatory benefit (Nadel, 1988). Heat loss via convection and radiation is not possible leaving evaporative cooling as the only means to cool the body. The response of T_{msk} will be more closely evaluated in the next series of IV studies since the work load and ambient temperature will increase, resulting in a greater thermoregulatory challenge.

Despite a 4-hr heat exposure to an ambient temperature of 43°C, the low IV and NV SWRs measured during this study (0.22 and 0.49 L/hr, respectively) reflect the subjects' low activity level (minimal metabolic heat production). A typical SWR during a high-heat exposure and moderate activity level would be at least 1.0 L/hr. However, IV SWR results were significantly lower because the reduced body temperature required even less evaporative cooling, hence less sweating occurred. Long-term sweating at moderate rates (or short-term sweating at high rates) can result in a fluid (sweat) loss that will significantly reduce plasma volume, which may ultimately lead to a level of dehydration that impairs work performance. Reduced SWRs with use of the IV should help maintain plasma volume, thereby reducing the level of thermal strain.

During this study NV MAP values were observed to be lower than IV values. HR and T_{msk} responses in the NV condition suggest that central blood volume was reduced. Although the lower NV MAP values in this study were still within a normal range, it is possible that this reduction in MAP represents the initial stage of a compromised circulatory system. The effects of a long-duration heat exposure on the distribution of circulating blood flow, in addition to the effects of cardiovascular drift, may further reduce central blood volume such that a hypotensive response may occur. The IV vasoconstricting properties appear to help preserve central blood volume, thereby maintaining a more stable blood pressure. It will be important to evaluate this relationship during future investigations.

Although FBF and SBF values obtained during the heat exposure were unremarkable in either vest condition, they were significantly higher than observed resting values. FBF values at the end of the third hour (3.75 ml/100ml/min) were 53% higher than resting values (2.45 ml/100ml/min), but well below the maximal FBF values of 20 ml/100ml/min reported by Brengelmann (1983). It has been demonstrated that FBF represents the total blood flow (muscle and skin blood flow) in that region of the arm (Edholm, Fox, & MacPherson, 1956), and since muscle blood flow does not increase with heat exposure alone (Roberts & Wenger, 1979), any increase in FBF can be attributed to an increase in SBF. While the primary stimulus responsible for increasing SBF is an elevated T_{msk} (Robinson, 1949), the low-heat load generated in this study (indicated by T_{re} values < 37.5°C) did not require a dramatic increase in SBF to allow effective thermoregulation. The response of FBF and SBF with use of the IV during exercise performed in the heat will be examined more closely in future studies.

CONCLUSION

In a high-heat environment with an extremely low activity level, the Steele ice vest was effective in reducing thermal strain as demonstrated by lower heart rate, rectal temperature, mean skin temperature and whole-body sweating rate values. These results agree with the findings reported in previous laboratory and field investigations. Use of this ice vest will provide a safer work environment for naval personnel exposed to high-heat conditions by reducing the potential for heat-related injuries.

REFERENCES

Astrand, P. O., & Rodahl, K. (1977). Temperature Regulation. Textbook of Work Physiology (p. 525). New York, NY:McGraw-Hill Book Co.

Banta, G. R., & Braun, D. B. (1992). Heat strain during at-sea helicopter operations in a high heat environment and the effect of passive microclimate cooling. Aviation, Space, and Environmental Medicine, 63, 881-885.

Bennett, B. L., Hagan, R. D., Huey, K. A., Minson, C., & Cain, D. (1993). Comparison of two cool vests on heat-strain reduction while wearing a firefighting ensemble in a hot/humid environment (Technical Report No. 93-10). San Diego, CA: Naval Health Research Center.

Blair, D. A., Glover, W. E., & Roddie, I. C. (1960). Vasomotor fibers to skin in the upper arm, calf and thigh. Journal of Physiology, London, 153, 232-238.

Brengelmann, G. L. (1983). Circulatory adjustments to exercise and heat stress. Annual Review of Physiology, 45, 191-212.

Brooks, G. A., & Fahey, T. D. (1985). Exercise Physiology: Human Bioenergetics and Its Applications (p. 316). New York, NY:Macmillian Publishing Co.

Burr, R. G., Banta, G. R., Coyne, J. T., Hodgdon, J. A., & Chesson, C. V. (1990). Effects of a passive cooling vest on tension/anxiety and fatigue in a high heat and high humidity (Technical Report No. 90-23). San Diego, CA: Naval Health Research Center.

Burr, R. G., Heaney, J. H., Banta, G. R., & Sopchick, T. L. (1993). Microclimate cooling effect on tension/anxiety and fatigue in field and laboratory settings (Technical Report No. 93-11). San Diego, CA: Naval Health Research Center.

Dassler, A. R. (1977). Heat stress, work function and physiological heat exposure limits in man. Thermal Analysis-Human Comfort-Indoor Environments. Washington, DC:National Bureau of Standards.

Edholm, O. G., Fox, R. H., & MacPherson, R. K. (1956). The effect of body heating on the circulation in skin and muscle. Journal of Physiology, London, 134, 612-619.

Hodgdon, J. A., & Beckett, M. B. (1984). Prediction of percent body fat for U.S. Navy men from body circumferences and height (Technical Report No. 84-11). San Diego, CA: Naval Health Research Center.

Masadi, R., Kinney, R. F., & Blackwell, C. (1991). Evaluation of five commercial microclimate cooling systems for military use. Natick, MA:United States Army Natick Research, Development and Engineering Center.

Nadel, E. R. (1988). Temperature Regulation and Prolonged Exercise. In D. L. Lamb, & R. Murray (Eds.), Perspectives in Exercise Science and Sports Medicine: Volume 1, Prolonged Exercise (p. 134). Indianapolis, IN:Benchmark Press Inc.

OPNAV Instruction 5100.20C. (1985). Department of the Navy, Office of the Chief of Naval Operations, Washington, DC.

Pimental, N. A., Janik, C. R., & Avellini, B. A. (1988). Microclimate cooling systems: A physiological evaluation of commercial systems (Technical Report No. 164). Natick, MA: Navy Clothing and Textile Research Facility.

Pimental, N. A., & Avellini, B. A. (1989). Effectiveness of three portable cooling systems in reducing heat stress (Technical Report No. NCTRF 176). Natick, MA: Navy Clothing and Textile Research Facility.

Pimental, N. A., & Avellini, B. A. (1992). Effectiveness of a selected mircroclimate cooling system in increasing tolerance time to work in the heat (Technical Report No. NCTRF 181). Natick, MA: Navy Clothing and Textile Research Facility.

Ramanathan, N. L. (1964). A new weighing system for mean surface temperatures of the human body. Journal of Applied Physiology, 21, 1757-1762.

Roberts, M. F., & Wenger, C. B. (1979). Control of skin circulation during exercise and heat stress. Medicine and Science in Sports and Exercise, 11(1), 36-41.

Robinson, S. (1949). Physiological adjustments to heat. In L. H. Newburgh (Ed.), Physiology of Heat Reglation and the science of Clothing (pp. 193 231). Philadelphia, PA:Sanders.

Sawka, M. N., & Wenger, C. B. (1988). Physiological responses to acute exercise-heat stress. In K. B. Pandolf, M. N. Sawka, & R. R. Gonzalez (Eds.), Human Performance Physiology and Environmental Medicine at Terrestrial Extremes (pp. 97-151). Indianapolis,IN:Benchmark Press Inc.

U.S. Navy (1988). Ventilation and thermal stress ashore and afloat. Manual of Naval Preventive Medicine (pp. 1-34). Washington, DC:NAVMED P-5010-3, Navy Medical Command.

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13. ABSTRACT *(Maximum 200 words)*

U.S. Navy personnel are often subjected to extreme thermal environments that may produce marked thermal strain. The purpose of this investigation was to evaluate the effectiveness of a passive microclimate cooling vest in reducing thermal strain during 4-hours of seated rest in a hot environment. Eleven male volunteers completed a 4-hour heat exposure on four consecutive days in a climatic chamber with a thermal environment of 43°C dry bulb and 45% relative humidity. The activity level consisted of seated rest. A passive microclimate cooling garment was worn during two of the heat exposures. Physiological variables measured included heart rate, rectal temperature, mean skin temperature, mean arterial pressure, whole-body sweating rate, forearm blood flow, and skin blood flow. Heart rate, rectal temperature, mean skin temperature, and whole-body sweating rate were significantly lower in the vest condition compared to the non-vest condition by 17 bpm, 0.3°C, 2.6°C, and 0.27 L/hr respectively. The remaining variables did not differ by vest condition. The ice vest was effective in reducing thermal strain and use of this ice vest will provide a safer work environment for naval personnel exposed to high-heat conditions by reducing the potential for heat-related injuries.

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