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EFFECT OF NECK WARMING AND COOLING ON THERMAL COMFORT

Bill A. Williams and Alan B. Chambers
Ames Research Center

INTRODUCTION

Efforts to remove metabolic heat by partial or differential body cooling have been undertaken for many body regions (refs. 1-5). Recent studies have shown the potential use of head cooling as a means of removing significant amounts of heat from the body (as much as 30 percent) in attempts to alleviate thermal stress (refs. 6-8).

Studies conducted in this laboratory have taken a different approach by using only local neck cooling in an area superficial to the cerebral (carotid) arteries. The purpose of these experiments was to determine the effects of a small local heat flux applied to this neck area on subjective feelings of thermal comfort and other physiological parameters during exposure to heat or cold stress.

METHODS

Six men aged 21 to 40 were used in this study. The subjects were seated and inactive in a controlled environment room dressed only in shorts. Each experimental run consisted of two sequential test periods with identical air temperature profiles. At the beginning of each test the subject was allowed to come to equilibrium in the room at 25° C (30-40 min). The first test period was then begun. The room temperature was raised to 33° C (or lowered to 19° C) for 20 min. This was followed by a recovery period at 25° C for 20 min. The second test period was then begun and the air temperature changes were repeated.

Experimental data collected during the first test period were used as baseline control information. During the second period the temperature of the neck superficial to the carotid arteries was lowered to 16° C (or raised to 43° C) by circulating cold or hot water through two copper discs (7 cm^2 each) held firmly against the neck (fig. 20.1). The skin surface area covered by these discs represented less than 0.0006 of the total skin surface area.

Three subjective indices of thermal comfort were recorded: (1) thermal zone, graded from hot to cold; (2) Comfort index, graded comfortable to very uncomfortable; and (3) air temperature estimate, an estimation of ambient temperature by the subject (fig. 20.2). The subjects orally reported the subjective responses every 5 min via a closed circuit TV system.

The following physiological data were measured: heart rate, ambient air temperature, skin temperature (six locations), rectal temperature, and ear canal temperature. Thermocouples located directly inside the circulating water measured the inlet and outlet temperatures used to determine the approximate heat load added to or removed from the neck by the collar.

The physiological data were automatically recorded and stored on magnetic tape at 30-sec intervals. The data were later processed and plotted by a digital computer.

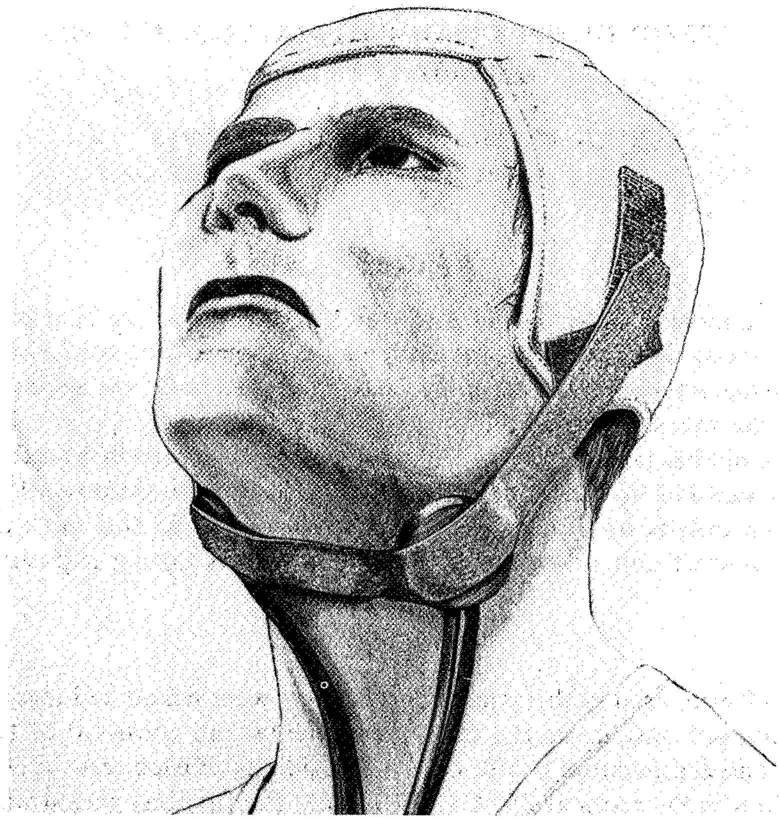


Figure 20.1 *Collar placement on the neck of the subject. Velcro straps on collar and on hat allow the discs to be adjusted for each subject.*

RESULTS

The subjects, after training sessions, were able to consistently estimate thermal zone, comfort level, and room air temperature in response to air temperature changes. Since each subject served as his own control, emphasis was placed on the *relative* rather than the absolute subjective responses. When a subject became consistent in his estimations of the comfort indices he was exposed to the experimental protocol.

Warming the collar to 43° C produced no significant changes in subjective responses or physiological parameters during exposure to either high or low air temperature. On the other hand, a dramatic alteration of subjective comfort occurred while the collar was being cooled. This alteration was most apparent during collar cooling in the hot (33° C) environment. In all cases the subjects at an air temperature of 33° C responded to collar cooling by indicating improvement of thermal comfort (fig. 20.3). The "thermal zone" estimations were markedly improved during collar cooling. All subjects indicated more "neutral" thermal comfort levels (fig. 20.4) and felt more "comfortable" during collar cooling in the high air temperature. Since each subject served as his own control for the "room air temperature" estimations, the results are best represented as the estimation of *change* in air temperature indicated by each subject (fig. 20.5(a), (b)).

It is apparent from all of these subjective indices that a relative improvement in comfort could be produced using neck cooling in a warm environment.

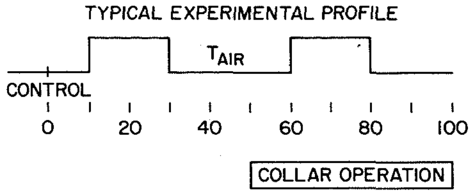
Control experiments conducted with the collar inoperative during the second temperature profile did not show any alteration in subjective comfort levels. Responses in this case were identical in both profiles indicating that the alterations in comfort were not merely the result of the second exposure.

The physiological parameters measured remained mostly unaffected by the neck cooling. No differences were observed in the rectal and skin temperature responses to the ambient temperature changes with or without collar warming or cooling. However, the ear canal temperature showed a significant alteration during neck cooling. In this case the ear canal temperature did not rise as high during neck cooling as it did during the control period. The cooling effect of the collar appears to have spread to this area to produce the slight lowering in ear canal temperature in response to the rise in ambient air temperature (fig. 20.6).

Another physiological change that occurred was the initiation of shivering during exposure to 19° C, while cooling the collar. The subjects did not, in any instance, shiver during exposure to 19° C without neck cooling.

Alteration of subjective thermal comfort also occurred with neck cooling during cold (19° C) exposure. In this case, however, the alterations were all detrimental to the overall well-being and comfort of the subject.

Adverse subjective reaction to the cold was magnified during neck cooling (fig. 20.7).



ENVIRONMENTAL CHAMBER

COLLAR	COLD	WARM
WARM	1	4
COLD	2	5
NEUTRAL	3	6

SUBJECTIVE RESPONSES (3)

A. "COMFORT LEVEL"
1. COMFORTABLE
2. SL. UNCOMFORTABLE
3. UNCOMFORTABLE
4. VERY UNCOMFORTABLE

B. "THERMAL ZONE"
1. COLD
2. COOL
3. SL. COOL
4. NEUTRAL
5. SL. WARM
6. WARM
7. HOT

C. ESTIMATION OF AMBIENT AIR TEMPERATURE, °F

Figure 20.2 *Experimental Protocol. (Top) Air temperature during experiment profile and collar operation. Air temperature was raised to 33° C (or lowered to 19° C) from the equilibrium temperature of 25° C. (Center) Combinations of temperature exposures and collar operation. (Bottom) Three subjective indices used for determination of comfort. Rating scales and air temperature estimates were recorded every 5 min.*

DISCUSSION

We have demonstrated that it may be possible to improve the subjective assessment of a hot thermal environment by direct neck cooling.

Whether or not we are actually affecting the brain thermostat to produce these alterations is unresolved. During the sessions when the collar was being cooled there was a substantially greater difference ($\Delta T = 18°$ C) between the neck skin temperature (34° C) and the disc temperature (16° C) than in sessions when the discs were being warmed ($\Delta T = 9°$ C). Since we could not directly measure the changes in brain or blood temperature in our subjects, a computer-simulated model of the

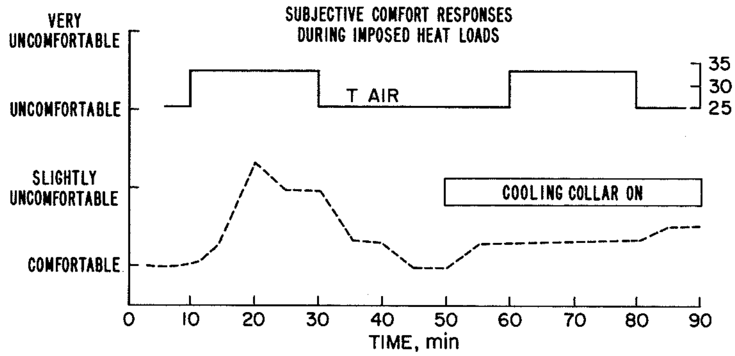


Figure 20.3 *Mean change in comfort rating with collar cooling in hot room. The second half of the graph (collar cooling) illustrates the improvement in thermal comfort.*

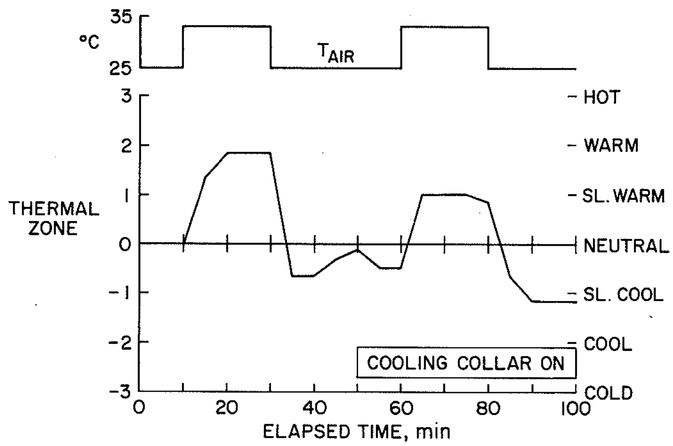


Figure 20.4 *Mean response to the "thermal zone" index illustrating improvement in comfort rating (more neutral) during collar cooling in hot room.*

interaction of our cooling patches with the carotid arteries was created to determine theoretically whether the cerebral blood could have been cooled enough to produce changes in brain temperature. Our data and parameters were used to plot the potential interactions of the cooling patches with the carotid blood (fig. 20.8). The lines of isothermy indicate predicted thermal gradients below the patches.

The computer simulation predicts that a carotid blood temperature change in the order of only 0.1° to 0.2° C is possible using this technique. Such a gradient *directly* below the patches would surely be insufficient to change the temperature of the brain thermostat.

The only indication that the collar altered cerebral blood temperature was the lower increase of ear canal temperature in response to an air temperature rise indicating that the ear area was slightly cooled, possibly by the blood perfusing it. Further, *exact* placement of the discs over the carotid area was necessary for the subjective thermal improvement.

It is also possible that the noticeable effect on subjective thermal comfort may be due to a "local" sensor effect or a change in the integration of total skin temperature input to the brain.

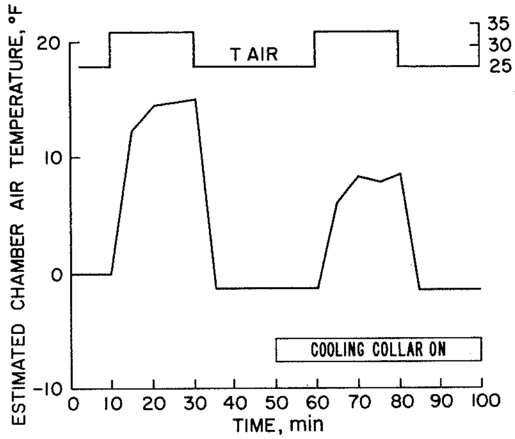


Figure 20.5(a) *Mean normalized responses of subjects in hot room with collar cooling. Estimations of air temperature were dramatically lowered with collar cooling. Responses of each subject were normalized for comparison.*

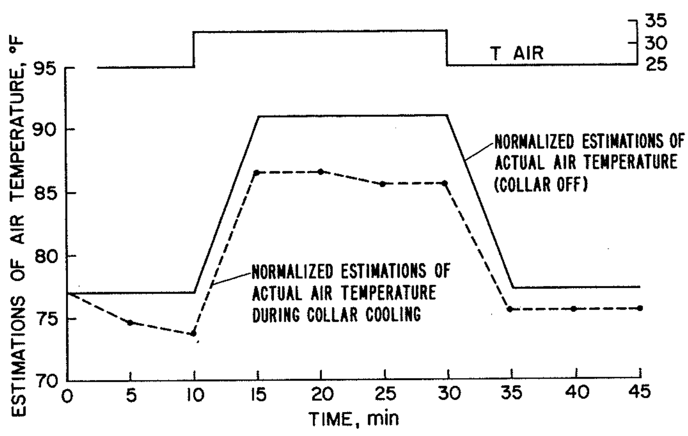


Figure 20.5(b) *Illustration of the effect of collar cooling on estimation of air temperature by the subjects.*

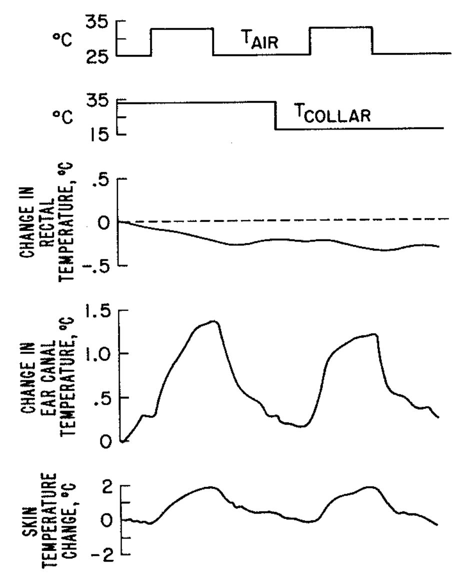


Figure 20.6 *Some physiological responses occurring during collar cooling in hot room. There was no significant change in any observed physiological parameters except the slight depression of ear canal temperature (see text).*

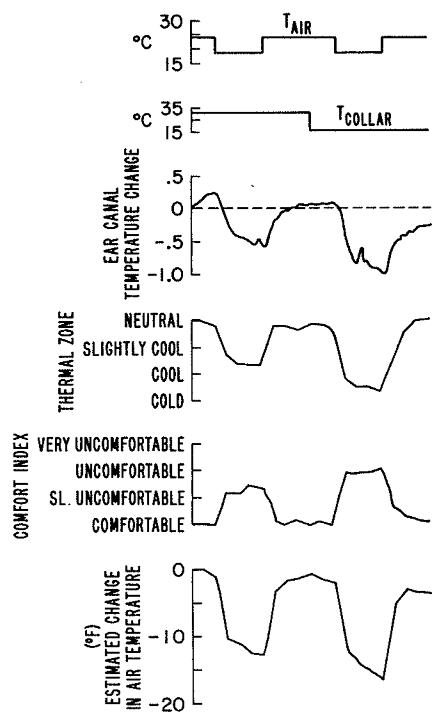


Figure 20.7 *Some changes during collar cooling in cold room. Note increased depression of ear canal temperature and detrimental effect on subjective comfort responses.*

It is evident from these data that thermal comfort may be improved in a hot environment by cooling the neck in the area of the carotid arteries. The means of achieving this subjective thermal improvement are not clearly delineated, but indicate that important consideration must be given to neck and head cooling in any attempts to use artificial cooling for thermal comfort and heat balance. In our laboratory we are attempting to integrate this concept into potential means of improving total thermal comfort using head-neck cooling in heat stressed aircrews. Further, consideration should be given to head cooling integration into any LCG system.

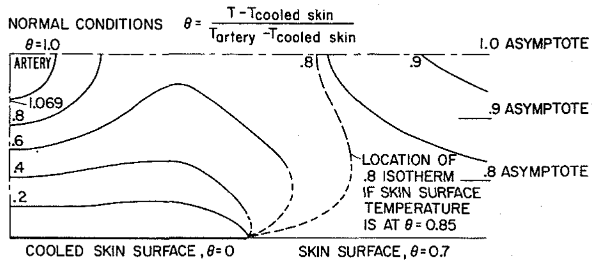


Figure 20.8 *Representation of the interaction of the collar with surface and deep tissues of the neck as determined by computer simulation. Lines of isothermy relate theoretical heat flow under the collar using data and parameters of the experiment.*

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