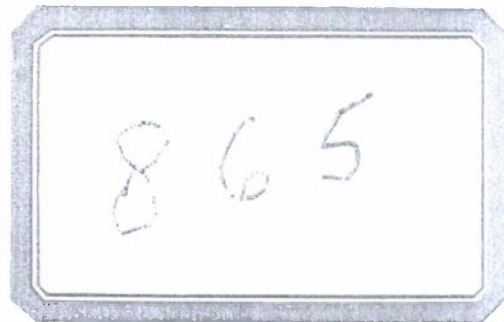


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REPORT NO. 475

CHAMBER COLD ACCLIMATIZATION IN MAN

Thomas R. A. Davis, M. D.



Studies of Physiological Effects of Cold on Man

Task 01

Environmental Medicine

USAMRL Project No. 6X64-12-001



UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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ABSTRACT

CHAMBER COLD ACCLIMATIZATION IN MAN

OBJECT

To determine the physiological effects of chronic cold exposure on unclothed humans.

RESULTS

During the month of March, when seasonal cold-acclimatization is maximal, 10 nude subjects were exposed 8 hours daily for 31 days to an air temperature of $11.8 \pm 0.5^{\circ}\text{C}$. During the month of September when seasonal cold-acclimatization is minimal, another 6 subjects were similarly acclimatized to an air temperature of $13.5 \pm 1.5^{\circ}\text{C}$. At intervals during the two periods of exposure, measurements were made of the responses of shivering, oxygen consumption, rectal temperature and skin temperature to a standard cold exposure of 2 hours in the above respective air temperatures. By the 14th day, shivering in both groups decreased significantly. Heat production remained unchanged in the winter group (30 to 40 per cent above basal) but decreased significantly in the summer group from an initial value of 64 per cent above basal to a value of 39 per cent above basal at the end of the experiment. Basal metabolism did not change in either group. In both groups, rectal temperature remained statistically unchanged for the first 10 days but on the 14th day and thereafter rectal temperatures were significantly lower. Skin temperature in the winter group showed significant fluctuations on the 8th and 14th days but returned to pre-exposure levels thereafter. In the summer group mean skin temperature significantly decreased on the 7th day and thereafter. On the basis of shivering and rectal temperature decrease, it is concluded that man can be artificially cold-acclimatized. The significant decrease in heat production and mean surface temperature in the summer group is related to the initial difference in the degree of cold-acclimatization between the two groups. Failure of cold-elevated metabolism to decrease in the face of a highly significant decrease in shivering indicates the presence of non-shivering thermogenesis in man.

RECOMMENDATIONS

It is recommended that:

1. These studies be carried out in a similar fashion for clothed individuals in both natural and artificial cold environments.

2. That the effect of cold acclimatization upon the incidence of cold injury be studied.

3. That the effect of heat acclimatization and cold acclimatization performed simultaneously be studied.

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CHAMBER COLD ACCLIMATIZATION IN MAN

I. INTRODUCTION

Physiological studies designed specifically to determine whether or not cold acclimatization can be induced in man by artificial or experimental exposure to cold have not been numerous. In 1946 Glickman (1) concluded that, because a smaller decrement in rectal temperature occurred as a result of a 60° F exposure after exposure to -20° F, a definite acclimatization takes place in man. In 1947 Spealman considered that progressive changes in plasma protein in heat and cold were indicative of permanent human adaptations to the environment (2). Glaser studied packed cell volume changes to alternating 72 hour periods of heat and cold and, since the changes obtained were progressive in nature, he concluded that an appreciable degree of acclimatization to cold in man can be achieved after three days in a moderately cool environment (3). Daniels and associates exposed 12 men to 60° F for 12 days and obtained changes in response to an abrupt alteration of air temperature from 85° F to 60° F. The authors considered these findings as furnishing evidence of cold acclimatization (4). Two investigators have concluded that their results could not be interpreted as indicating the presence of cold acclimatization; Horvath exposed five clothed subjects for eight days to -29° C stating that the evidence obtained was too equivocal for a definite statement (5) while Stein considered that the decrease in extremity temperature he obtained on three clothed subjects exposed intermittently to -20° F was not indicative of cold acclimatization (6).

Since a decrease in the shivering response has been established as a good index of acclimatization to cold in rats (7, 8, 9) and since its decrease has been noted in man (10, 11, 12), the present experiment was performed to investigate whether or not, along with indices of rectal temperature, surface temperature and heat production, it would indicate the presence of artificially induced cold acclimatization in man.

II. METHODS

During the month of March when seasonally induced cold acclimatization is maximal (10), ten subjects with a mean age group of 25 years, wearing only shorts, were exposed eight hours daily for 31 days to an air temperature of $11.8 \pm 0.5^{\circ}\text{C}$.¹ During the month of September and October when seasonal cold-acclimatization is minimal another group of six subjects with a mean age group of 28 years were similarly exposed to an air temperature of $13.5 \pm 1.5^{\circ}\text{C}$. None of the subjects had previously been artificially exposed to cold. No exposure was performed on Sundays. One subject in the winter group had participated in under-ice skin diving during the preceding winter but the previous thermal

¹ ± signs refer to one standard deviation.

experience of the remaining subjects was unremarkable and all subjects were laboratory personnel whose occupations were sedentary in nature.

Temperatures were measured with thermocouples using a Brown potentiometer in the following areas: forehead, trunk, upper arm, dorsum of the hand, upper leg, lower leg, dorsum of the foot, pad of the great toe, and rectally with 12.5 cms insertion. Room air was measured at a height level with the subject under measurement, and shivering activity was measured by integrating muscle action potentials by means previously described (13), using surface electrodes placed on upper arms and thighs in such a manner that the arm and leg on one side are connected in parallel. This method of connection insures that as much as possible of the electrical activity of shivering is obtained from all parts of the body. Oxygen consumptions were obtained by analyzing expired air and expressed as per cent above basals obtained at a room temperature of 28°C after a fast of 14 to 16 hours. All values of oxygen consumption were first reduced to STP conditions. The reported values of oxygen consumption and shivering are averages for the second hour of a two hour period of exposure while rectal and surface temperatures are means of values obtained during the last 10 minutes of exposure.

Measurements were made with the subject lying on a mesh cot, and were obtained at intervals during a two hour exposure in the cold room. Nude supine exposure for this period of time to the cold room temperature constituted the cold exposure test for this study.² All statistical analyses for significance were calculated on a paired data basis and contrast between groups is made on the basis of statistical change within the same group only.

III. RESULTS

In figure 1, although heat production in both groups remained significantly ($P < 0.01$) elevated above basal, the winter group showed no statistically significant change ($P > 0.10$) in response to the standard cold exposure. On the other hand, the summer group started with higher heat production values which decreased significantly ($P < 0.05$) after the 14th day and, at the end of the period of acclimatization, approximated the heat production values of the winter group.

The rate of shivering decreased significantly ($P < 0.01$) for both groups, the greatest decrease occurring within the first ten days of exposure. In each group there was one ectomorphic subject and both of these showed the greatest amount of shivering in the early stages of exposure while, during the later stages, they were largely responsible for keeping group means above zero. The skin-diver subject and two

²Nude refers to subjects dressed in shorts only.

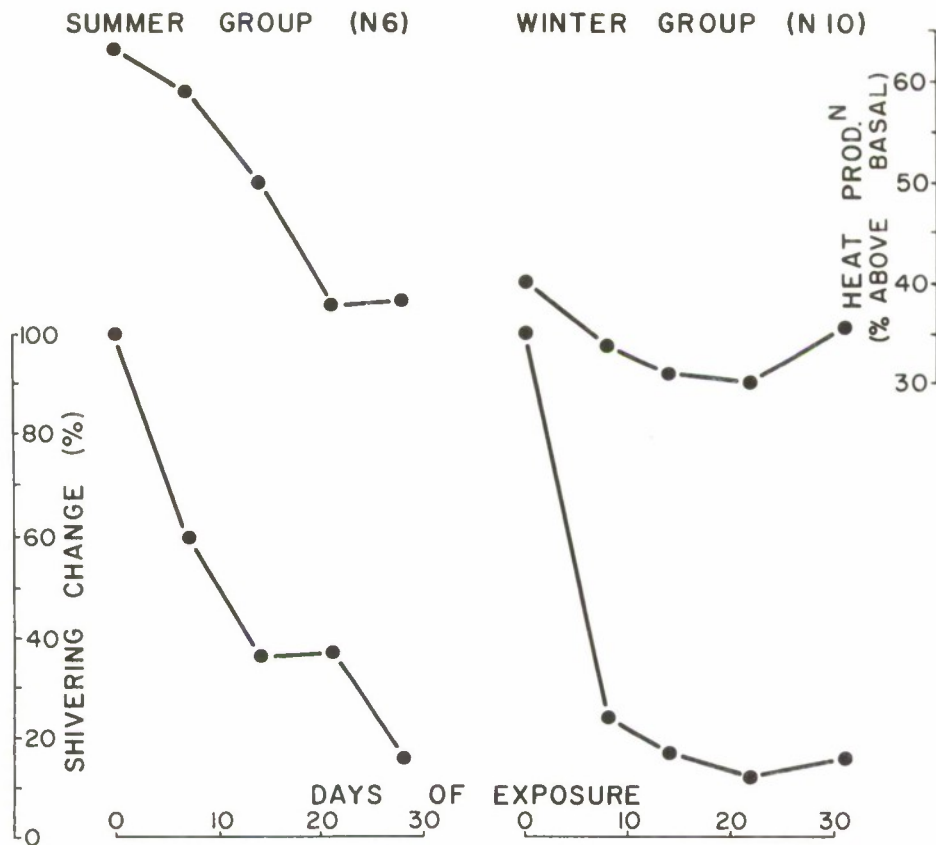


Fig. 1. Alterations in mean shivering and mean heat production in nude subjects exposed 8 hours daily in a cold room. Measurements were made under standard conditions of exposure. Heat production elevation in the cold shows no change ($P > 0.05$) in the winter group and a decrease in the summer group ($P < 0.05$) while shivering decreases significantly by the 10th day of exposure ($P < 0.01$).

others showed the least initial amount of shivering. All gradations of shivering levels between these individuals and the ectomorphs were encountered in the remaining subjects.

In figure 2, page 4, rectal temperature in both groups shows a significant ($P < 0.01$) drop on the 14th day. Although there is some recovery on the 22nd and 31st days in the winter group, these values are still significantly lower than the values on the 1st and 8th days ($P < 0.01$). Although fluctuations in this group can be observed on the 8th and 14th days of exposure, mean skin temperature showed no significant ($P > 0.05$) change between the 1st day and the 31st day.

On the contrary, mean skin temperatures in the summer group showed a small but significant fall in response to the test exposure ($P < 0.05$).

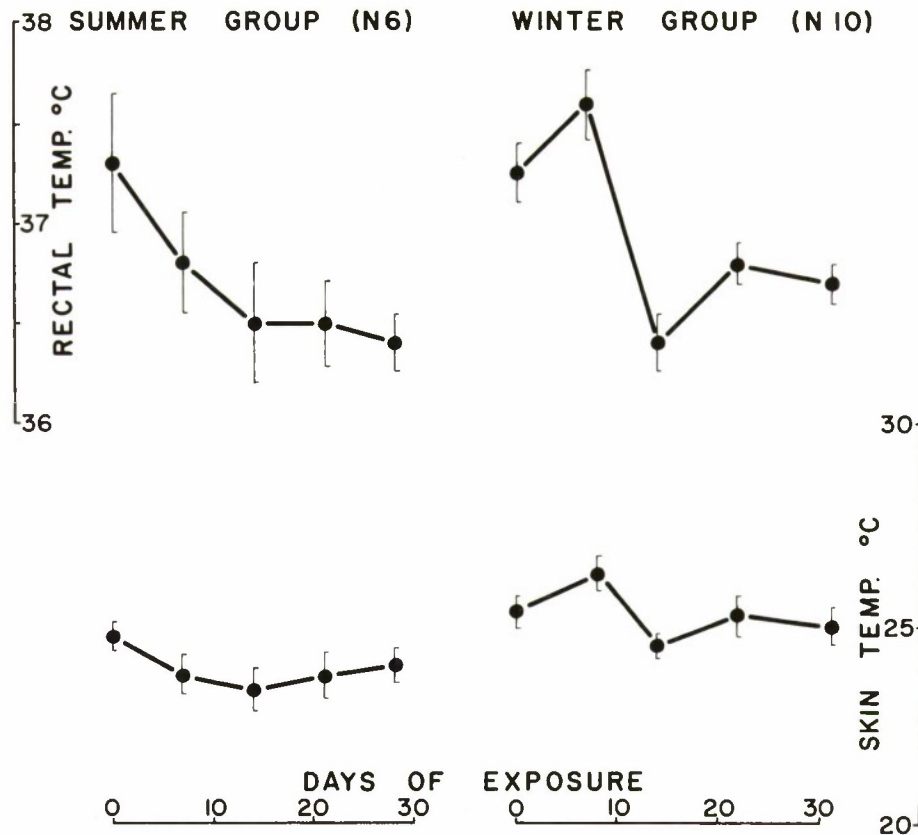


Fig. 2. Alterations in mean rectal and mean skin temperature in subjects exposed 8 hours daily in a cold room. Measurements were made under standardized conditions of exposure. Rectal temperature is significantly lower after the 10th day of exposure ($P < 0.01$). Skin temperature after some significant variations on the 8th and 14th day is unchanged in the winter group by the total period of exposure while in the summer group a decrease is evident ($P < 0.05$). Vertical bars are standard errors of the mean.

Between the first and last days of exposure, the change in mean temperature in the individual areas measured in both groups is given in Table I. For each area in the winter group, the surface temperature changes were not statistically significant. In the summer group, although there was a significant decrease at the five per cent level of confidence in mean skin temperature, only two areas, the foot and the head, contributed significantly to this decrease. Of all the eight areas measured only the calf and the hand showed an increase which was not statistically significant.

TABLE I

The effect of cold exposures of 8 hours daily for 31 days to an air temperature of 11.8°C during March and for 28 days to an air temperature of 13.5°C during September on surface temperatures in human subjects measured under standardized conditions of exposure.

WINTER GROUP				SUMMER GROUP		
Area	Temp Change	Stand Error	P	Temp Change	Stand Error	P
toe	-0.04	±0.26	>0.50	-0.42	±0.76	>0.50
foot	+0.94	±0.51	>0.10	-2.61	±0.97	<0.01*
calf	+0.29	±0.17	>0.10	+1.90	±0.83	>0.05
thigh	+0.20	±0.13	>0.10	-1.75	±1.02	>0.10
hand	+0.79	±0.63	>0.10	+1.23	±0.69	>0.10
arm	+0.59	±0.33	>0.10	-1.07	±0.93	>0.10
trunk	+0.99	±0.48	>0.05	-0.97	±1.15	>0.50
head	-0.05	±0.24	>0.50	-1.40	±0.51	<0.05*
mean skin	-0.42	±0.31	>0.10	-0.98	±0.35	<0.05*
*indicates significance						

IV. DISCUSSION

The results presented on shivering and heat production are similar to those previously obtained on rats (7, 8, 9). Although there is a highly significant decrease in shivering, a similar decrease in cold-elevated heat production does not take place. Therefore, as already reported in rats (9, 14), a non-shivering heat production appears to exist in man when acclimatized to artificial conditions of cold exposure. Although there are some indications as to the sources of non-shivering heat production (9, 15, 16), there is insufficient evidence to allow more than statements of conjecture.

The statistically significant decrease in cold-elevated heat production in the summer group is similar to that previously reported for seasonal acclimatization to cold (10) observed between October and February and indicates that heat production induced by a standard cold exposure is higher in summer than in winter. In this report this same change in heat production was induced in a matter of 3 to 4 weeks daily exposure in a cold chamber. This decrease in heat production was not observed in the group acclimatized in March, presumably because this

group was already seasonally cold-acclimatized and the change in cold-induced heat production also demonstrated in this study indicates that cold-acclimatization, whether achieved naturally or artificially, produces an increased economy of energy expenditure for the purposes of homeostasis. This increased economy is probably achieved by a reduction in heat loss by methods previously discussed (10). Basal metabolism showed no change in either group as a result of acclimatization.

In the seasonal study no clear-cut reduction in rectal or skin temperature was observed as in this study, presumably either because the degree of seasonally induced acclimatization is much less than that achieved by nude chamber exposure or because the one hour standard acute exposure used in the seasonal study was not sufficient to produce a measurable change. In this study the significant fall in rectal temperature means a reduction in total body heat content and therefore a decreased heat production requirement to maintain homeostasis. More often than not, previous cold-chamber studies have been short term and it would now seem that if they had been continued for a longer period rectal temperature change may have eventually taken place. The reduction in surface temperature in the summer group means a decrease in heat loss to the environment. The failure to obtain a similar reduction in mean skin temperature in the winter group cannot be readily explained unless seasonal acclimatization had already achieved this change in this particular group of individuals. Previous studies of acclimatization of temperate, arctic, and subarctic indigenous groups report an increase in peripheral temperatures, especially of the extremities (17). Studies on the Australian aborigine (18, 19) report a greater fall in surface and rectal temperatures on exposure to cold when compared to caucasian controls. The arctic and subarctic groups achieved their cold acclimatization mainly in the clothed condition while the Australian aborigine and the subjects in this study achieved theirs by nude exposure. If we can exclude genetic differences, the presence of clothing may determine whether or not surface temperature rises or falls during acclimatization to cold. The adequately clothed individual is well protected except for the extremities and it may be that the protected body can afford the type of acclimatization which increases blood flow to the extremities. The unclothed individual on the contrary can afford no such luxury and may have to decrease heat loss by lowering surface temperature. The other method by which heat loss may be decreased is through the possible reduction of convection loss through shivering and by a reduction of the hyperpnoea which accompanies shivering (20). All these methods of reducing heat loss probably have a limit beyond which heat production must be increased. In the acclimatized individual it appears that this is achieved by non-shivering rather than by shivering thermogenesis.

On the basis of the data presented, physiologic acclimatization to artificial cold exposure takes place in man after a 3 to 4 week nude exposure to cold. The acclimatization so achieved is best indicated by

a decrease in or an extinction of shivering. A comparable decrease in cold-induced heat production does not take place and indicates that man is capable of non-shivering heat production. This postulation of non-shivering heat production in the acclimatized state implies either that a substantial change in metabolic processes has taken place or that there is an increased contribution of existing mechanisms which in the unacclimatized state are masked by shivering and do not play an obvious role in heat production. Until these non-shivering mechanisms are brought into play by acclimatization, shivering must play an important role as a stop-gap but inefficient heat producer (10). Although the previous reports of increased peripheral temperature are not substantiated by this study, the decrease in core temperature and surface temperature in the acclimatized state reported here indicates that some attempt at heat conservation takes place.

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