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THERMOREGULATORY EFFECTS OF TROPICAL MAN IN ANTARCTICA WITH REFERENCE TO SPECIAL CLOTHING

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INTRODUCTION:

Untamed icy wilderness of Antarctica is a physiological challenge to sojourners for coping of cold (Edholam, 1960). Thermal status prevails at out door is antilogy to comfort. The comfort is achieved in Antarctica by balancing heat-loss and heat gain. One of the ways it can be achieved is by selecting proper clothing, which in turn helps to balance, the heat gained from exercise and sunlight against the heat loss to the cold winds, sky and terrain. But, if the required clothing adjustments is inadequate or delayed, man becomes too hot or too cold for comfort (Bud et al., 1966, Wyndham et al., 1969). Frequent stimulation of cold and warm would affect the underlying vascular system. Most outdoor occupations in Antarctica require greater expenditure of energy than their counterparts in tropical or Temperate Zone. This is the result of the nature of terrain underfoot, wind resistance, and bulky heavy cloth (Bountelier et aL, 1981). In addition, the climate of Antarctica may entice to engage in more active pursuits than he would ordinarily do. As adjustment to exercise, some authors revealed that, although man is free to adjust their clothing for comfort, it was difficult to do so in many outdoor tasks in Antarctica. Consequently, sweating as well as discomfort from warmth, which increases progressively with the physical exertion. Those engaged in heavy work, man feels very hot of the trunk and would end up with sweating (Budd et al., 1969). The overall hectic situation increases heat production of the expedition member in combination with the sophisticated protective measures against the cold and task nature. Increasing the insulation of clothing may allow heat balance to be maintained in the worst weather or blizzards. Conversely, it backlashes the other way around during endurance by posing potential heat stress issues (Budd, 1973), Therefore, insulative coping reassures further studies to understand the adaptation process in subzero temperature.

IBEA (International Biomedical Expedition to Antarctica) had carried out some studies under the leadership of Rivolier (1987), to investigate the heat exchange process of man with the environment. The study was conducted on four volunteers and data collected on sixteen occasions. This study had taken account of cooling ppwer indices (Rivolier et al., 1981) with the determination of heat exchange in specific experimental situations, skin temperature of the both exposed and clothed area of the bodv was routinely recorded to quantify the cold stimuli. The objectives were to determine correlation between microclimate of man within the suit and outside temperature of the clothing in which the man is exposed. Studies have revealed that, living in this severe climate might lead to some habituation, but could not avoid hypothermia in the long run as per the cooling power of the environment.

Physiological coping to subzero climate is a brain twister regarding the residual cold stress. The pre-acclimatization studies of Australian scientific expedition team reported that, prior cold-condition by means of the bath treatment in Sydney had no apparent effect on the thermal discomfort experienced at Antarctica (Rivolier et al. 1986). Physiological response to cold climate of people differs by the nature of exposure such as habitual or occasional. Responses are diversifying in a way that, either by allowing their body temperature to fall or by exchanging insulation to prevent significant cooling or by increased heat production perhaps or by non-shivering thermo genesis. Shivering process, up to an extent maintain the level of deep body temperature by admitting a high metabolic cost. Thus in general terms there are three forms of adaptation such as hypothermic, insulative and metabolic. They might represent a continuum for an individual passing one form of adaptation to another depending on the duration or the intensity of the stimuli. Some time it must be a manifestation of" different genetic potentials.

Man's ability to adapt to hostile environment has been mainly characterized by behavioral changes in addition to the integrated technological achievements of cold protective gadgets. But, adaptation has another dimension, which includes alterations in physiological responses to the particular stress imposed by climatic conditions. This phenomenon was studied in resident population, invariably exposed aborigines, living in inhospitably cold part of the World. There is little conclusive evidence, whether the particular additional response is unique to groups who have lived for generations in the cold (Milan et al., 1961). This might suggest that natural potential habituation level of acclimatization to exist in all humans might be a moot point.

Exposure in laboratory conditions, with the combination of low environmental temperature and insufficient clothes for comfort, has ensured quite unusual levels of cold stress. Such experiments have resulted in more dramatic adaptations as shown by alterations of responses to standard cold stress (Norman, 1965). Consequently, the stimulated environmental studies are difficult to draw clear picture of physiological coping process in field conditions.

Obfuscation results from terms such as adaptation, acclimatization, acclimation and habituation are mean different things to different groups of workers. Folk's (1963) definition of acclimatization is the functional compensation resulting from a complex of environmental factors, for instance when living in a cold climate.

Acclimation, though originally an American elision, is reserved for changes brought about by exposure to a single variable, usually therefore in the laboratory. Habilitation on the other hand describes a dulling of response resulting from repetition of the stimulus. It is an altercation of central nervous mechanism, resulting in change in sensation or a dimension of defensive reaction. Adaptation is a word blending all these, but also embracing behavioral and genetic variations, which assist organisms to survive in new or extreme conditions.

The vasoconstriction reflexes were sharpened by the polar experience, leading in the practical situations, to save body heat. In a case study, 1BEA team revealed the response of subjects to extreme cold water of 00 C. The vessels of the hand had effective vasoconstriction, more unlikely than those persons whose hands are chronically exposed to extreme cold (Korg and Wika, 1978). The blunting of the vasoconstrictor response in persons has been explained by the need to maintain local function of hand in cold situation. The preservation of higher body temperature is essential to protect against freezing injury. From the point of view of survival, loss of vasoconstriction and therefore insulation could equally be regarded as a threat. Further more, mechanism for failure of vasoconstriction when hand is exposed to a very cold stimulus is likely to reside in musculature of the vessels themselves. There is no evidence of failure of sympathetic drive but rather an inability of vessels response to it. This is analogous to the condition of trench foot in which long immersion of cold water leads to severe tissue damage characterized by interference with the normal function of a local vasomotor control. The responses were seen in sojourners of the I8EA, whose exposure to cold was not severe, is nevertheless more pronounced that they would normally experience living in their homes. This may properly be regarded as the element of acclimatization. Furthermore, the enhancement of insulation has an advantage well above that of merely saving the function of integrity of a small part of the body.

General acclimatization, though it is certain that peripheral tissues are more exposed to cold, the changes in their circulatory responses are not locally mediated but resulting from the changes in central sympathetic control such as an increased sensitivity. These peripheral parts of the body, the feet and the hands, are the most sensitive controllers of the body temperature. Their greater reactivity will allow central temperature being better maintained. Thus, man exposed in cold climate, such changes have importance in maintaining the central body temperature.

On extensive literature survey, studies regarding the tropical population in terms of physiological coping to Antarctic subzero temperatures are sporadic. To understand the heat exchange process of tropical men in Antarctica with respect to special clothing in subzero climate is of immense interest. By nature, tropical population is exposed to warm climate because of the equatorial proximity, and is adapted for either hot humid (costal area climate) or hot dry (arid or semi arid climate). In Indian subcon tinent this is true except Himalayan regions. Tropical population possesses a well-timed homeostasis with the prevailing warm climate; it will obviously induce physiological problems with subzero climatic situations of the Polar Region. On the other hand most of the cold physiological studies were conducted on Temperate Zone populations and relevance of those findings to tropical population is ambiguous. The studies of Rivolier (1981) on temperate population imply the out door environment of Antarctic continent aggrandize a considerable cooling stress even if the sojourners were well protected by cold protective ensample. Physiological studies conducted in Antarctica by Nair (1988) concluded that, there is an inadequacy in personal protective clothing to provide protection against the subzero climate. This pilot study was conducted by this Institute (Defense Institute of Physiology and Allied Sciences). The above study demands further investigations in the facet of environmental variables of cooling indices. There is no report available regarding physiological coping of sojourners to Antarctic climate with respect to special clothing for tropical population except Nair's study. From the available reports, it is difficult to make a proper assessment regarding the role of cold protective ensembles in coping with reference to the whole body responses to cold as well as psycho-physiological expression. Therefore this study is proposed with a view to understand the physiological expression of tropical populations, in terms of heat gain and heat loss due to outdoor subzero climate. This study is also looking for an appraisal of effective comfort offered by cold protective ensembles provided to the members of Indian Antarctic expedition. Therefore to rectify the bafflement, the present study could be fitted into the category of insulative coping (Hammel, 1964) of tropical men in Antarctic climate.

AIM AND OBJECTIVE OF THE STUDY IN BRIEF:

1) This project is aimed to investigate the thermoregulatory effect of tropical sojourners in Antarctic subzero climate with reference to special clothing taking into consideration of climatic variables of cooling power indices. The inputs of the study would help to predict required clothing insulation (IR.EQ) while working in outdoor Antarctic environment with respect to biometeriological indices with a view to ensure comfortability. Thus present study will help to maintain thermal homeostasis in real life extreme cold environment with proper clothing. Thus present study in real life extreme cold environment will help to reduce the physiological problems to maintain homeostasis as well as to ameliorate mental function.

2) Physiological evaluation of different personal cold protective ensembles in Antarctic field conditions.

MATERIALS AND METHODS:

The XVIII Indian Scientific Expedition to Antarctica sailed from Goa in the month of December. The ship reached India Bay of Antarctic ice shelf after one month and stayed there for the summer period. The scientific community moved to Maitri station and engaged in scientific endeavors. At the end of summer period, the ship sailed back for India in the first week of March.

The protocol of the study is designed as per the expedition package and divided into three phases:

Phase I: Collect basal reading of the volunteers from tropical zone before the ship crosses zero degree latitude on way to Antarctica.

Phase II: Second set of data collected after crossing 400 S latitude (this is the region from where polar climatological impact of coldness begins).

Phase III: Data collection from outdoor Antarctic terrain with cold protec tive ensembles.

Physiological variables recorded:

a) Core temperature (oral temperature).

b) Mean skin temperature (Hardy- Duboi method)
Weightage given as follows: 1) 0.07head, 2) 0.14arm, 3) 0.05hand, 4) 0.18chest, 5) 0.17 back, 6) 0.19 thigh, 7) 0.13 leg and 8) 0.07 foot (temperatures were recorded by YSI telethermometers and leads).

c) Heart rate (BPL defibrillator with lead system II).

d) Sweat loss.

In Phase HI, along with physiological variables, inner and outer layer temperature of clothing were recorded from four different sights representing 1) chest, 2) biceps, 3) thigh and 4) calf.

In phase 1, 20 volunteers of the expedition participated. Volunteers were provided with light breakfast and asked to rest for 30 min, before reporting at medical inspection room. The medical inspection (MI) room was maintained at thermo-neutral temperature (250 C and 50% relative humidity). Volunteers were again asked to rest for 30 minutes in the MI room prior to data collection and empty their bowls before the commencement of experiment. Volunteers were instrumented with probes, fro temperature recording. Mean skin temperature was recorded as per Deboi's method, from 8 sights. Temperature of digits (forefinger tip and big toe) was also recorded. Core temperature was recorded sublingually. ECG surface electrodes were placed over torso according to lead II system. Prior and immediately after exposure (thermo-neutral 25^0 C = 1^0 C), nude body weight was recorded to compute the sweat rate. 20 min exposure was given to each volunteer. Zero and 20 min physiological variables were recorded. Male volunteers wore shorts and the female volunteers a loose thin vest during exposure. Data collection was started third day after the day of sailing and volunteers divided into two groups of 10 each. Each individual received exposure in a gap of ten min from the preceding one in a sequential order.

Phase II, data collection started after the ship crossed 40° S latitude. Venue and plan of data collection as in Phase 1. Due to rolling and pitching of the ship, most of the sojourners were down with seasickness and high degree of physical disturbance was observed. Ten volunteers participated in this session.

In Phase HI, more than 10 volunteers participated, but only six could complete the full set of experiment (five males and one female volunteers). These six volunteers had successfully completed the exposures in Phase I and Phase II. The studies of Phase HI were started after one week of their arrival at Maitri station (15 days after crossing 40° S latitude). Volunteers were asked to report at the field lab (summer camp outside the Maitri station). Prior to reporting at the lab, the volunteers were asked to have light breakfast and rest in thermo neutral MI room of Maitri station for one hour. After the rest period, they were asked to empty their bowls and moved to field lab nearly 300 m away from the Maitri station. The age range of volunteers was between 35 and 45 years. Prior to the commencement of experiments, anthropometric variables were recorded as given in Table I. Nude body weight was recorded and the volunteers instrumented with YSI thermistor probes as well as ECG surface electrodes (as mentioned in Phase II). The volunteers had put on polar clothing ensembles for the experimental exposure. Over the inner layer (polar underwear) and outer layer of clothing (over the out fits) were instrumented with YSI surface electrodes according to Ramanathan formula (1961). The experimental set up of Phase HI was designed for 60 min of outdoor exposure at the prevailing climate (wind chill index of 1000 ± 200) of Shirmarchar Oasis of Antarctic continent. During this period, volunteers were asked to sit in a chair against the wind and physiological variables were collected every 10 min from body like core temperature, mean skin temperature, temperature from digits (finger tips and big toe) as well as over the clothing layers, along with the cardiac frequency. Immediately after the experiment, the nude body weight was again taken to compute the sweat rate.

Volunteers had undergone randomized exposure with two sets of ensembles. Department of Ocean Development provided one set of ensemble. This involved items designed and manufactured by Hally-Hansen (details in appendix-XVIII). The second set of ensembles was provided by DRDO, designed and manufactured by DSMRDE Kanpur (details are given in appendix-XIV). All exposures were scheduled at the same time of the day (morning session) to avoid circadian clashes. Care was taken to exclude people having cardio-respiratory problems as well as high blood pressure. The experimental exposure of female volunteer was avoided during menstrual period. During experiment, volunteers were secured so as not to be affected by hypothermic attack. Volunteers were properly motivated for the successful completion of the study as well as briefed about the cold stress hazards prior to the experiment.

After the experiment volunteers were provided by questionnaire of "Bedford comfort vote" (Revolier, 1987) Appendix - XII to collect subjective feeling regarding insulative coping.

Computation of "global clothing insulation" and heat debt were done according to the formula in appendix-XI.

Statistical analysis: Means and standard deviations were calculated for absolute values. Significant changes between the ensembles were tested by student t-test. $P < 0.05$ was considered as significant for comparative study of ensembles.

RESULTS:

Table - I reflects anthropometric characteristics of the subjects. Table - II is the mean basal reading of volunteers during the tropical zone. Physiological data collected during Phase III were randomized exposure of volunteers put on cold protective ensembles provided by a) Department of Ocean Development (DOD) and b) DMSRDE, Kanpur. The period of outdoor exposure was 60 min; the data for the last 40 min were taken for computation. During outdoor exposure the physiological variables were recorded such as core temperature (oral temperature), Shell temperature (mean skin temperature from eight sites) and digital temperature were recorded. Nude body weight was taken before and after the experiment schedule to compute sweat rate. These raw data were computed to derive the following with respect to DOD and DMERDE ensamples.

The observed mean body temperature deficit for a period of 40 min (towards the end of 60 min outdoor exposure) for DOD was 0.40 (± 0.445) and DMSRDE 0.41^{0}C (± 0.428). Statistically significant difference was not observed (Appendix - V). Basal values from tropical region compared with end exposure values from Antarctica showed a mean body heat dept of 2.2^{0}C (Appendix - IX).

<u>Heat debt observed</u> for DOD was 76 kj ± 84.42 and DMSRDE ensemble 82 kj ±

78.13 (Appendix IV). There is no significant difference observed between in heat debt among the ensembles. Global clothing insulation offered by the ensembles for 40 min outdoor exposure (wind chill index of 1000 ± 200) was 1.47 *clo* ± 0.72 for DOD and 0.87 *clo* ± 0.49 for DMSRDE. The values shown by DMSRDE ensemble are lower than the ensembles provided by DOD, but in comparison there is no significant difference observed (Appendix - VI).

Results of physiological comparisons are given in Appendix - VII & VIII. In this result, volunteers basal physiological expression was compared with the values of experimental exposure at Antarctica. Mean finger temperature during down sailing (Normal condition- Phase I) 32.2 °C ± 2.045 and toe 28.71 °C, during the subzero temperature exposure of 15.8° C± 6.449 and toe 15.3° C± 4.2245. Normal oral temperature 36.6 °C± 0.2167 and experimental exposure 35.7 °C ± 0.4956 (Appendix- II). Heat exchange computation is given in Appendix - XI. Bedford "comfort voting technique" is mentioned in Appendix - XII. Mean sweat rate during the exposure is reflected in Appendix - X, having a statistically insignificant variation.

Discussion:

In the present study, measured heat exchange appears to be mainly a function of clothing insulation. In our experimental exposure, at the end of 60 min exposure the mean core temperature (oral temperature) observed was 35.6° C ± 0.49 and mean skin temperature 28.7^{0}C ± 2.57. Giesbrecht et al. (1994, 1997) and Oiesbrecht and Bristow (1998) reported that core temperature of cold water immersed individuals fell as low as 33.25° C. This study was based on values of 37° C and 33° C for the core and skin temperature respectively. In our study, during the exposure, volunteers not prone to hypothermic symptoms and Bedford comfortable voting revealed that the exposure could be tolerable. A reduction in shivering or null shivering was observed. LaBlance (1975) observed the reduction in shivering, cold-induced muscle tenseness and end heat loss as a process of adaptation. These changes could signify a development of habituation. However, discomfort is reduced, usually at the cost of greater heat debt, by attenuation of thermo-regulatory responses such as shivering and vasoconstriction and the accompanying cold pressure response (Glaser Whittow, 1957 & Eagan et al., 1963) or acclimatization, where thermoregulatory responses become more effective. In the present study, observed heat debt was 79.3 kj during exposure is within the tolerable limits.

Bittel (1987) observed cold induced increase in core temperature and delayed onset of shivering. Paradoxical increase in core temperature, of the kind observed in all three series, had long been known to recollect the onset and intensity of vascular responses. Our study also shows upward trend of core temperature at the end of exposure but those are statistically insignificant. Bittel (1989) cited delayed shivering in numerous studies of cold adaptation.

The present findings of reduced shivering and heat production agree with those of many previous studies. Cited by Davias (1963), Horvath (1972), Budd (1974, 1989)of cold exposed men. and in addition show that these changes were not due to habituation or nonshivering thermogenesis, but were accompanied by reduced heat loss, reduced muscle tenseness, and increased sympathetic activity.

Changes in cold tolerances may be determined both locally in peripheral tissue and generally as reflected by changes in metabolism or body temperature. Livingstone et al., (1989) and Gregory et at., (1999) observed, that there are two types of reactions to a general cold stress: the first type is referred to an insulative-hypothermic acclimatization in which the subjects do not increase their metabolic rates and allow core temperature and skin temperature to cool. These type of changes have been observed by Budd (1962), after a stay in Antarctica. In contrast metabolic acclimatization occurs when individuals increase their metabolic rates in response to the cold to maintain body temperature. Scholander et at., (1998) demonstrated types of response in Norwegian students exposed to wheel of late fall camping. Hammel (1964) has showed this response in indigenous people. We assume that the present study has a remarkable edge over this physiological concept.

Young et al., (1986) had concluded that acclimatization was mediated by increased sympathetic activity and an enhanced vascular response to cold. However, because of their finding of reduced T-sk, these authors have suggested that the enhanced vascular response was located in the superficial shell (ie. skin and subcutaneous fat) and muscle perfusion was increased, whereas our own findings favor the opposite conclusion. We should suggest that these differences in apparent site of vascular changes of acclimatization might be the result of differences in acclimatization as a result of long stay in Antarctic continent and in addition to gradual introduction to cold region during sailing by ship (i.e.40^0 latitude to 70^0 latitude of cold oceans). Another supporting factor was the protection provided by the cold protective ensembles. The protective ensembles collectively offered an average global clothing insulation of 1.17 Clo. This value assumed to be provided adequate cold protection during the period of exposure in addition to acclimatization during stay in antarctic continent.

Livingstone et al., (1976) had a difference of opinion regarding general acclimatization. One possible explanation may be that the duration of cold exposure was not enough to cause a definite response similar to the changes observed by hypothermic insulative type of responses in skiers staying for 100 days in cold. Similar response is also observed in subjects acclimatized in cold chambers (Davis, 1961), in Antarctic personnel (Budd, 1962) and soldiers living in Arctic (Leblance, 1956). Rivolier et al,, (1988) did not find any evidence of whole body acclimatization in a group involved in the International Biomedical expedition to Antarctica as this group had only a minimal exposure to cold.

The thickness of the subcutaneous fat. which insulate the body from cold, has been shown to have an inverse relationship with the reduction in core temperature (Budd et al.. 1991) and an increase in metabolic rate after cold exposure. However, none of this relationship was obvious in the results, although the subjects differ in body fat percentage, fat remained at a relatively constant level during the approximately S week duration of the experiment. Some unpublished data from this Institute showed there is a measurable weight gain in Antarctic sojourners. Thus it appears that body fat did not significantly contribute to the changes seen in the response to cold between the tests,

In conclusion, it is difficult to determine which of the changes occurring in response to an experienced cold stress during exposure to Antarctic conditions. It could be due to individual variations, natural exposure due to climatic changes, or some combination of the above. Since all individuals are exposed to the environment to some extent it is difficult to separate normal variations occurring in response after a period of exposure to Antarctic conditions.

As far as the acclimatization status is concerned, average heat loss was recorded as 76.0kj ±84.42 for DOD and 82.6kj+ 78.13 for DMSRDE ensemble during the period of exposure. This is due to the collective average global clothing insulation offered by the clothing such as 1.17 *Clo*. A heat debt of 481.6 kj was observed in Antarctica compared to the their normal tropical thermal homeostasis. The required *Clo* (Global clothing insulation) is computed as 2.17 to maintain tropical homeostasis at the observed levels of Antarctic subzero climate, where wind chill index was recorded as 1000 ±200. The observed reduction in heat debt (79 kj) was brought out by the sojourner adaptation due to the stay in the subzero climate.

Physiological evaluation of cold protective clothing.

The results ofthis study regarding DMSRDE and DOD provided ensembles were comparable to one another. The global insulation offered by the DOD ensemble was 1.47 and DMSRDE 0.88 *Clo*. There was no significant statistical difference record between these values. The mean heat flow as heat loss observed by volunteers was 76.01 ± 84.42 and 82.60 ± 78.13 with respect to DOD and DMSRDE ensembles. These values are statistically insignificant. Subjective feeling of the volunteers was evaluated through the Bedford "comfort voting" technique (Rivolier 1987). which indicates that these ensembles are comparable. Hence we conclude that DMSRDE provided ensemble is as good as that provided by DOD.

Temperature of digits (Finger and Toe)

The study observed that Indians living in hot tropical climate and upon exposure to the severe cold stress of Antarctica weather brought out any remarkable local acclimatization. However, cold injury is prevented by increasing the finger blood flow and maintaining the extremity temperature. Similar response was observed in people living in the Arctic and sub-arctic areas who are habituated to cold (Eisner et al.. 1960 Leblanc et al.. 1960). Reducing the local skin temperature of the human hand from a normothermic level results in cold induced vasoconstriction (CIVC) but the local temperature <18°C may result in cold induced vasodilatation (CIVD). It is assumed that the arteriovenus anatomies (AVAs) are responsible for CIVC and C1VD.

The results of this study are in agreement with the finding of earlier investigators, indicating that induced tissue insulation apparently produced by sympathetic vasoconstriction of the blood vessels of the extremity (Krog et al.. 1960). The fall in skin temperature, after 1 and 8 weeks of acclimatization suggests vasoconstriction of the cutaneous blood vessels. This also affirms the view that the CIVD response in cold acclimatized subjects is more rapid (Korg et al., 1960.) At the end of exposure finger temperature was recorded at 15.8°C ± 6.449 and toe temperature 15.3°C ± 4.22. However the time of onset of vascular response was within the first minute after the maximum vasoconstrictor response when the T-digits fell below 15°C; but the provided polar gloves prevented the down fall of extremity temperature further below.

Oberg et al., (1983) cited onset of vasodilatation as increase in finger blood flow after cold immersion. This could be considered as a peripheral vasodilator response due to persistent Antarctic cold exposure, although the blood flow was increased by cold acclimatization, the finger skin temperature was lower compared to the normothermic state. This indicates that the amount of cutaneous vasodilatation in hand was insufficient to raise the tissue temperature. Naidu et al., (1993) cited that increase in the flow of cooled blood could not bring out skin temperature alterations (Barocroft and Edhom 1943).

Present study observed a decrease in digital temperature even though protected by polar gloves. When blood temperature is low the vasodilatation does not warm the skin. This vasodilatation could be a contributory factor for maintaining the strained supply to the skin without the participation of heat conductance, thus preventing cold injuries and hypothermia of digits. As per Rivolvier (1987) observed two groups, a) the extremities (forehead, hand and toe) b) trunk and thigh (usually clothed) and two ranges of temperatures were considered for each of these: <15°C for the extremities and for the <20°C trunk to maintain the status of cool. And the observed extremities temperature falls with in the limit of cool as mentioned by Rivolvier (1987).

SUMMARY OF CONCLUSION

Studies were conducted in outdoor environment having a wind chill index of 1004 ± 200.

1. Observed mean heat debt of sojourners for the last 40 minute of 60 minute out door exposure is 79,3kj. The heat debt observed while wearing D O D (Department of Ocean Development) ensemble was 76kj and 82.6kj for D M S R D E ensemble.
2 Mean body temperature debt during exposure was recorded as 0.4°C for sojourners wearing D O D ensemble and 0.41 °C for D M S R D E ensemble. A fall of 2.2°C was observed in mean body temperature with respect to tropical climate.
3. Regarding the basal condition in tropical situation, the computed heat debt is 481.6 kj. During the stay in Antarctica the heat debt was 79.3kj for the last 40 minute of 60 minute out door exposure.
4. Observed heat loss by the skin under the cloth was 73.61 Wm^{-2}.
5. Observed average global clothing insulation of the ensembles during exposure was 1.17 c/o. Required global clothing insulation computed for the exposure is 2.17 *clo*.
6. The above mentioned observed values were within the limits of subjective feeling of tolerance (according to Bed Ford comfort voting). However, physiological variables showed lowest side of physiological expression and the tolerability is acquired by the benefit of physiological coping to subzero temperature.

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Table -1 Appendix -1

PHYSICAL CHARACTERISTIC OF SUBJECTS

	AGE years	WEIGHT kg	HEIGHT cm	BSA sqm
SUBJECT I	38	53.00	161	1.50
SUBJECT 11	32	80.20	175	1.95
SUBJECT III	39	64.10	159	1.65
SUBJECT IV	45	55.40	163	1.60
SUBJECTV	42	52.30	169	1.58
SUBJECT VI	43	57.24	160	1.70
Mean	39.8	60.40	164.5	1.66
SD ±	4.62	10.59	6.25	0.15

Table-2 Appendix - II

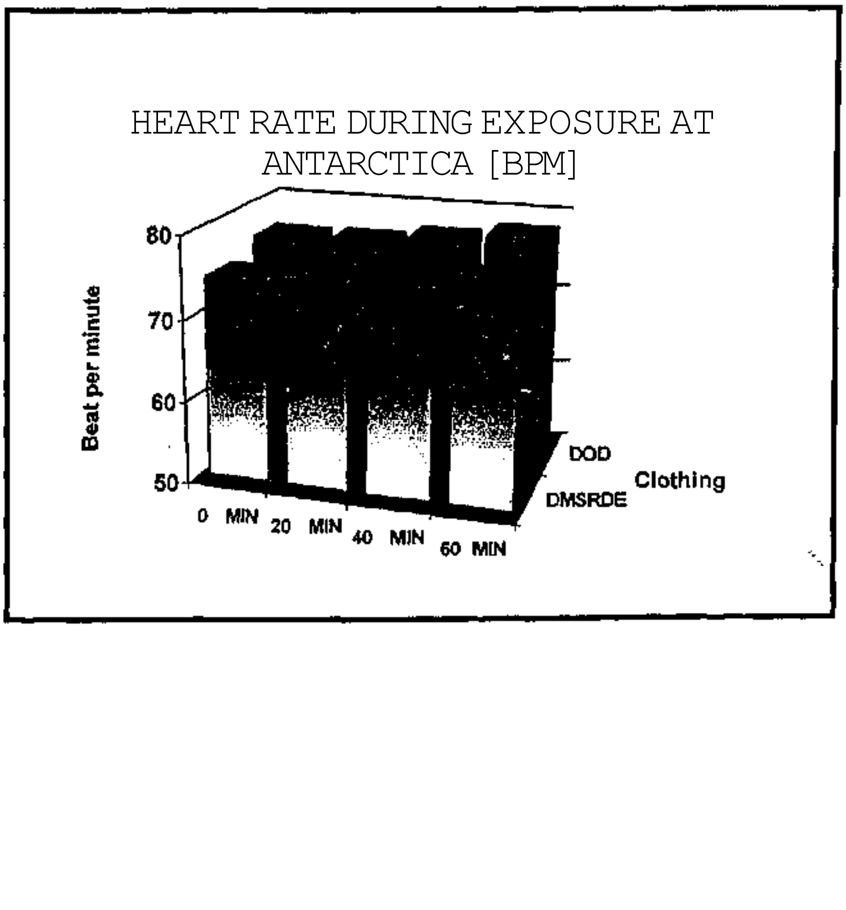
Temperature of Digits

	Normal	Experimental
Finger	32.2 ±2.04	15.8±6.4
Toe	28.4 ±6.44	15.3 ±4.22

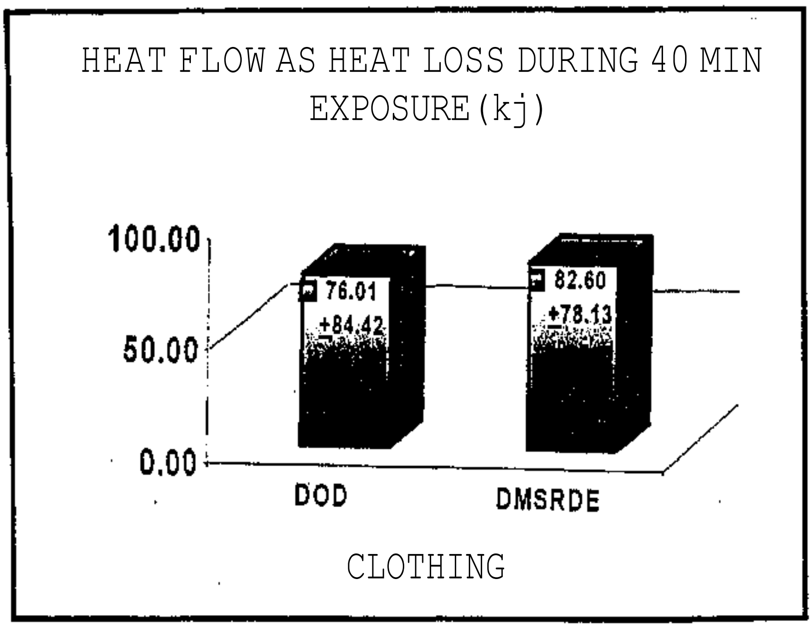
Body Temperature

	Normal	Experimental
Oral	26.5±022	35.6±0.495
Mean skin	31.66 + 0.35	28.66±2.57

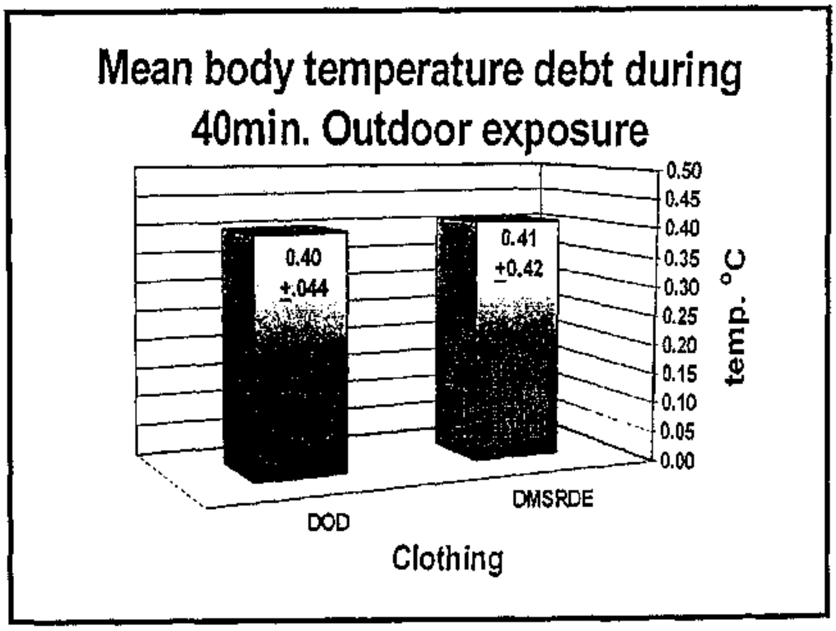
Graph -1 *Appendix III*



Graph - 2 ***Appendix IV***

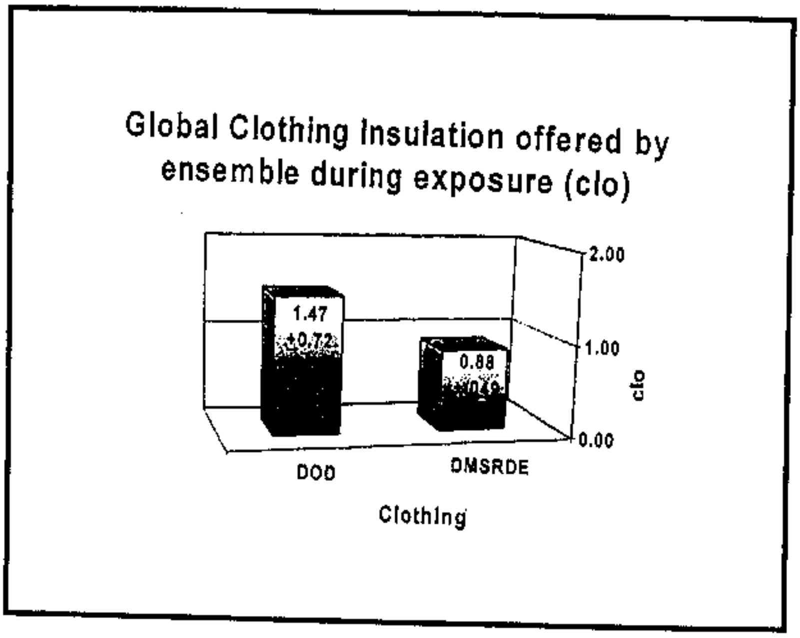


Graph-3 **Appendix V**

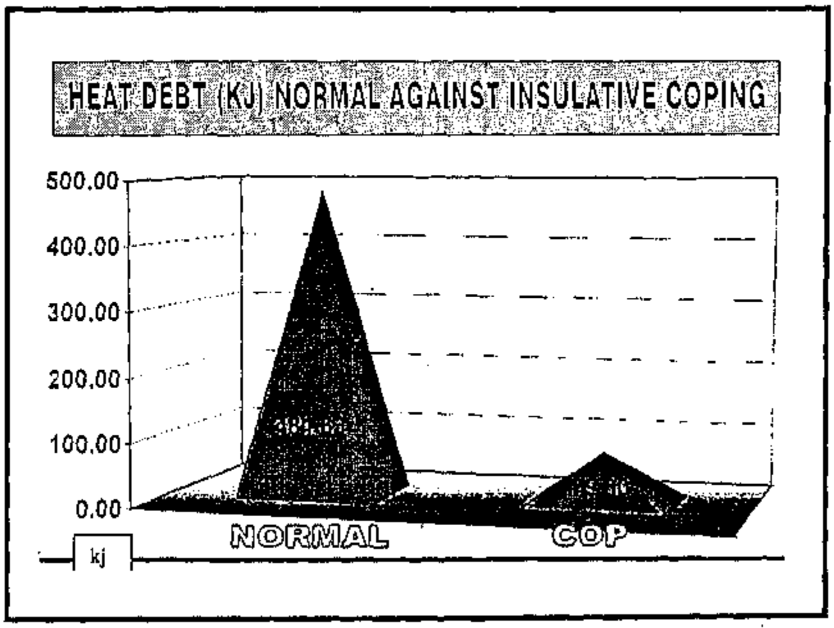


Graph - 4

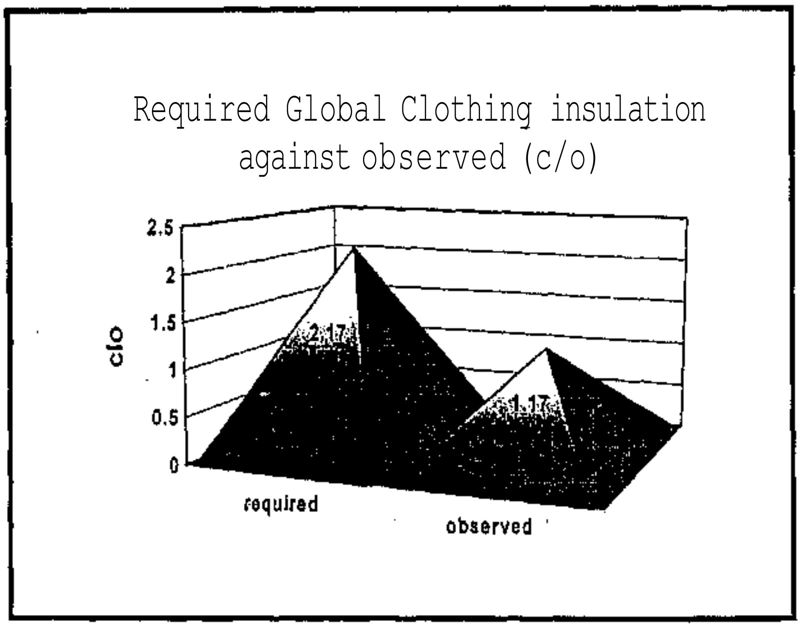
Appendix VI



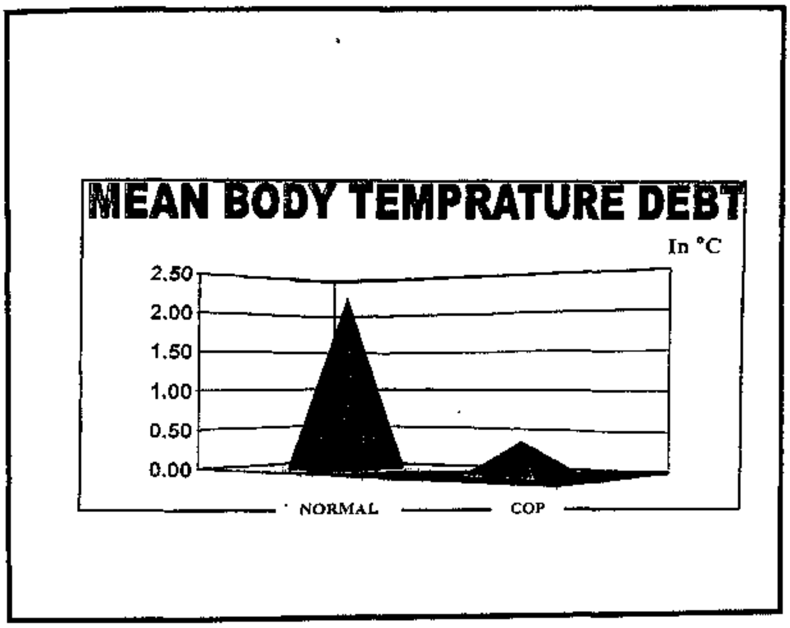
Graph- 5 **Appendix VII**



Graph - 6 ***Appendix VIII***



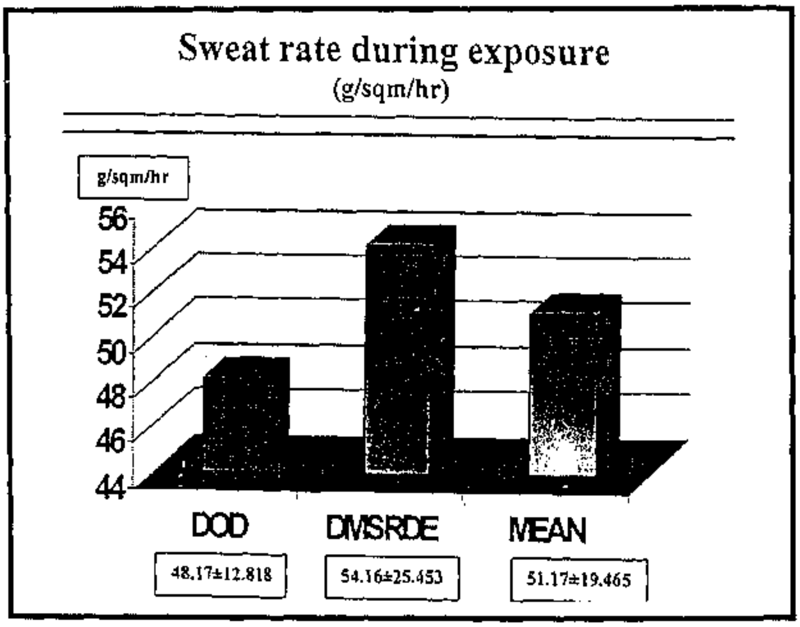
Graph - 7 ***Appendix IX***



Normal : Basal mean body temperature (at tropical Zone) is compared with end exposure value of Antarctica out door exposure

Cop: Heat debt during Antarctica out door exposure.

Graph - 8 ***Appendix X***



APPENDIX-XI

HEATEXCHANGE

Mean body temperature:

$$b = (_s x\ 0.21) + (_{or} x\ 0.79)$$

Where $_s$ = mean skin temperature; and = oral temperature

Heat debt:

$$QS = \blacktriangle\ _b \times m \times Cp (kj)$$

Where $\blacktriangle\ _b$ = changes in mean body temperature, m = body mass in (kg);
and Cp = mean body specific heat (3.475 kj kg^{-1})

Heat debt given as heat flow:

$$SE = \frac{m \times 3475 \times \blacktriangle\ _b}{1800X/4D}$$

where AD = body surface area (m 2)

Heat flow lost bv the skin under clothes, (W m -2)

$$H = M + S_E - H_{res}$$

Where M= 80 W^{-2} m^2 and H_{res} (respiratory heat loss) = 8% of M.

$$H = 73.6 + S_E$$

So clothing insulation:

$$Lcl = \frac{s^{-}\ d}{Hx0.155} \quad (clo)$$

APPENDIX-XII

BEDFORD "COMFORT VOTE" TECHNIQUE

GRADING SCALES:

Record comfort as -3 to +3 corresponding to

+3 Much too warm	:	Too warm for comfort
+2 Just warm	:	
+ 1 Comfortably warm	:	Comfortable
0 Neutral	:	
-I Comfortably cool	:	
-2 Just cool	:	Too cool for comfort
-3 Much cool	:	

DOD and DMSRDE ensembles were recorded as −2 by volunteers.

Individual items on card

This is your Comfort vote number used in different phases.
Comfort grade -3 to +3 for each of the four sites: trunk, face, hand and feet.

Numbness, pain: Grade 0 to 3 for each of the above four sites

Individual item points were marked-1 to 0 in the above mentioned four items

Sweating, Shivering: Grade 0 to 3 for your overall response.

Individual item points were marked 1 to 2 in the above mentioned four items

Remarks: Note cold spot or other relevant information.

There were no cold spots reported

Activity: Describe in words what you have been doing in the past 10 min (eg. Sitting, Walking, Strenuous exercise), and record numerically (after Effort). Your estimate of level of execration, ranging from 0 (minimal exertion eg. Sitting or Standing) to 3 (Strenuous execration, Example shoveling, running).

Activity recorded 0

Place out doors /indoors (O/I), cross out which ever does not apply, and record where you were (eg. In tent, caravan etc. 0). After how long/. Record duration of your present indoors or out doors, if you are out door, note after 'in sun' whether not (Ø), you are in sunlight, if so whether it is weak (1), moderate (2) or strong (3).

PlaceI,1 and 2

Hourly comfort vote card

Time: F/N Activity: Effort:
Place: (I/O) How long? .....1 h ......00 min lnsun....1&2

	Trunk	Face	Hand	Feet
Comfort				
Cold	*	*	*	*
Numbness		*	*	*
Pain				*

Sweating: NO Shivering: NO
Clothing changing: NO

DOD ensembles: *Appendix - XIII*

Trunk		Hand	
Long Johns	Y	Mittens wind proof	Y
Pyjamas		Mittens, wool (A,F)	
Trousers		Wristlets	
Down Parks	Y	Gloves lined leather	L
(A,F)		Gloves unlined leather	
Wind proof parks	Y	Gloves wool	
Singlets		Gloves silk	
Shirts		Feet	
Sweats		Mukluks	M
Down Parks (A,F)		Vapour barrier boots	
Wrist		Leather boots	Y
Band		Camp boots	
Head		Sox wool	Y
Cap		Mukluk inners	
Balclava (cap, Hel)	Y		
Blizzard mask			
Parka hood up	Y		
Scarf			

Other items: Nil

DMSRDE ensembles: Appendix-XIV

Trunk		Hand	
Long Johns		Mittens wind proof	
Pyjamas		Mittens, wool (A,F)	
Trousers	Y	Wristlets	
Down Parks		Gloves lined leather	Y
(A,F)		Gloves unlined leather	
Wind proof parks	Y	Gloves wool	
Singlets		Gloves silk	
Shirts		Feet	
Sweats		Mukluks	M
Down Parks (A,F)		Vapour barrier boots	V
Vest	Y	Leather boots	
Band		Camp boots	
Head		Sox wool	Y
Cap		Muklukinners	
Balclava (cap, Hel)			
Blizzard mask			
Parka hood up	Y		
Scarf			

Other items: Nil