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Thermal Acclimatization to Cold in Men Exposed to Antarctic Environment during Summer

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Abstract

The finger skin temperature (Tsk) and blood flow (FBF) alterations before and after cold immersion on exposure to Antarctic environment for 8 weeks were studied in 64 subjects. Cold immersion test was performed at non-Antarctic and Antarctic conditions by immersing the hand for 2 min in 0- 4°C cold water. The result of this study indicated that continuous cold exposure in Antarctica resulted in vasodilatation which overrides the stronger vasoactive response of acute cold exposure, thereby preventing cold injuries. Besides these circulatory acclimatization to cold there was increase in body mass associated with redistribution of subcutaneous fats.

Introduction

Acclimatization to cold exposure is one of the most important physiological mechanisms for the men in Antarctica (Budd, 1962; Palmai, 1962; and Sjurley, 1970), so as to favour adequate work performance without developing cold injuries. The changes in skin temperature (Tsk) and hand blood flow to cold exposure have been interpreted as indicators of cold acclimatization (Budd, 1964; Budd and Warhaft, 1966). Morphological changes such as body size and insulation by redistribution of subcutaneous tissue have also been found to be associated with cold exposure (LeBank, 1962). The cold induced vasodilatation response has also been reported to be improved in cold acclimatized men (Glaser *et al.,* 1959). However this has not been clearly demonstrated in non-acclimatized men on exposure to Antarctic cold. Therefore the present study was designed to test the acclimatization pattern of skin temperature, finger blood flow and redistribution of fat of Indian men who participated in Antarctic expedition.

Materials and Methods

The study took place during austral summer, i.e. December 1990 to February 1991 on the members of Tenth Indian Scientific Expedition to Antarctica at the Indian Antarctic station, "Maitri". The air temperature averaged 3°C with winds

upto 25 km/hr. There was 24 hour sunshine with blizzards every 8-10 days lasting for 24 to 48 hrs.

The experiments were conducted on 64 healthy male volunteers. Their mean age was 35.3 yrs (range 25-53 yrs), mean height 168.3 cms and mean weight 64.82 kg. The cold exposure began on 22nd of Dec. 1990 when the expedition ship reached the fast ice of Antarctica. The outdoor activities of off-loading the ship as well as other construction and scientific activities initiated at this time. The cold exposure continued till 26th of February 1991. During these 8 weeks all subjects worked outdoor for 6-8 hrs travelling on foot or on snow vehicles, sleeping in unheated huts (temperature 3-4°C higher than ambient temperature).

Test procedure

Sixty-four subjects were studied and three sets of observations were made. In each set of experiment the number of subjects varied, as on several occasions during the period of test the subjects were not available due to involvement in their own task. Test was made on board the expedition ship (Phase I) which was air conditioned and the air temperature was maintained at 25±2°C. The second set of readings (Phase II) were obtained in late Dec. i.e. one week in Antarctica and 3rd set (Phase III) was obtained 2-3 days before sailing in late Feb. i.e. 8 weeks of Antarctic stay. The experimental procedure was identical in all phases. All experiments were performed in the morning after the subjects had a night's sleep and standard breakfast. The subjects were comfortably clothed and relaxed in a room for 30 min during the experiment before they were exposed to a standard cold test of right hand immersion in stirred cold water at 0°C for 2 min. The Tsk was recorded by means of a digital thermometer using thermistor probe and the finger blood flow (FBF) by the Laser Doppler flowmeter (Type PFID).

Cold pressor test

The subjects were asked to immerse their right hand upto wrist in an ice cold water bath (0°C) which was stirred occasionally for 2 mins. The hand was removed, wiped with a dry towel and within 30 sec of cold water test the Tsk was measured followed by FBF measurement.

Physical parameters

The abdominal girth and midarm circumference were measured in centimetres with the help of a standard measuring tape. The tricep skin fold thickness (in mm) was measured by using a vernier caliper. Besides this the body weight was recorded at each test session.

Statistical analysis

The results from all the subjects were used in the statistical analysis. All data are presented as the mean ± SE values. Student's t-test was performed to evaluate the significance of difference between pre and post cold test readings of each series. All three sets of readings of pre and post test alongwith the difference between them were tested by means of two-way analysis of variance. All the analysis was done in the Microstat programme of the computer.

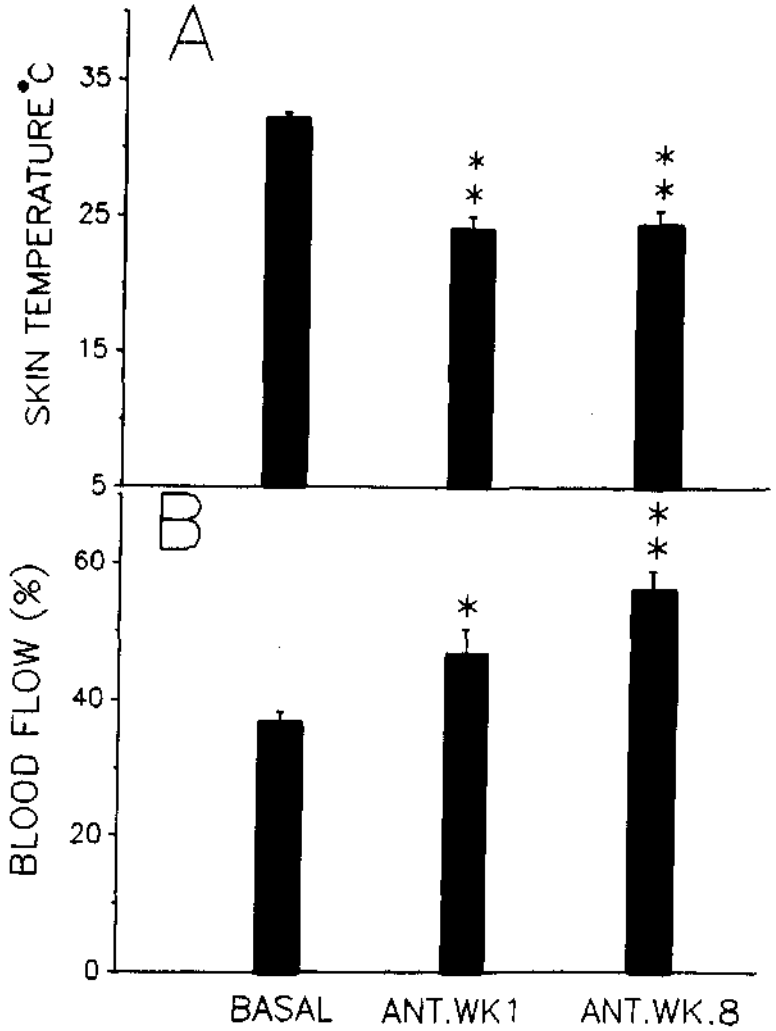

Fig. 1. Finger skin temperature (A) showing a significant reduction ($p < 0.001$) after I week of Antarctic stay with no further decrease after 8 weeks of stay. Blood flow (B) showing a significant progressive increase after 1 ($p < 0.01$) and 8 weeks ($p < 0.001$) of Antarctic stay.

Results

Basal skin temperature and blood flow

The resting finger Tsk before cold immersion in phase I was 32.13±0.39°C. After 1 week of stay in Antarctica the Tsk reduced to 24.13 ± ().88°C ($p<0.01$), This value of Tsk did not change after 8 weeks of exposure to Antarctic cold (Fig. 1 A) and remained at 24.57 ±1.02°C *($p<0.01$)*.

The mean resting finger blood flow was 36.84 ± 1.35 *%* in phase I before cold immersion. After 1 week in Antarctic cold the basal FBF gradually increased to 46.85 ± 3.33% *($p<0.01$)* and after 8 weeks of stay (phase III) it further increased (Fig. IB) to 56.18 ±.2.75 % ($p<0.01$). In the warm environment of the ship the Tsk was 32.13°C and the FBF was 36.84% of the maximum upper cut off point of 100% whereas after 8 weeks of Antarctic stay the Tsk was 24.57±l .02°C and FBF was 56.18 ± 2.75% (Table 1). Here it can be observed that the fall in skin temperature

Table 1: The Mean ± SE of Skin Temperature and Finger Blood Flow at Warm Environment, alter 1 and 8 Weeks of Antarctic Exposure, and after Cold Water Immersion Test

Exptl. Condn.	Pre CI Tsk(°C)(n=62)	Post CI TSK(°C)(n=62)	Pre CI FBF(%)(n=64)	Post CI FBF(%)(n=64)
Warm environ.	32.13	18.16[2]	36.84	I4.55[2]
(In the Ship) -	±0.39	±3.93	±1.35	±1.17
Cold environ,	24.13[1]	12.82[2]	46.85[1]	28.92[2]
(Ant. 1st Week)	±0.88	±0.57	±3.33	±4.12
Cold environ.	24.57[1]	13.80[2]	56.18[1]	55.50
(Ant. 8th Week)	±1.02	±083	±2.75	±3.01

Significant difference between warm environment and Antarctic exposure is expressed as (1)=p<0.01.

Significant difference between the pre and post cold immersion test is expressed as (2) = p<0.01

Table 2 : The Mean ± SE of the Difference in Skin Temperature and Finger Blood Flow at Warm Environment after 1 and 8 Weeks of Antarctic Exposure, and after Cold Water Immersion Test

Antarctic Stay	Tsk (°C)		SkBF(%)	
	PreCI(n=19)	CI(n=19)	Pre CI(n=23)	Cl(n=23)
1 st week	8.56±1.3	10.71 ±0.88	8.61±3.58	17.(X)±4.34
8th week	10.79+1.75	9.18±.93	20.43±4.78	1.61±4.68*

* Denotes significant difference between 1st and 8th weeks of Antarctic *($p < 0.01$)*.

was significant ($p < 0.001$) after 1 week of stay in Antarctica, but did not drop further even after 8 weeks of stay (Table 2).

Cold Immersion Test Response

Following cold immersion (CI) the Tsk decreased significantly ($p<0.001$) from 32.13+0.39 to 18.16±93°C in Phase I, i.e. warm environment (Fig. 2A). No significant difference in the degree of fall in Tsk of the phases I, II and III was seen, i.e. after 1 or 8 weeks of stay in Antarctic cold (Table 2).

Cold immersion test in warm environment reduced the FBF by 61 % (Fig. 2B) of the pre-immersion value (36.84 ±1.35 to 14.55±1.17%) which was highly significant ($p<0.001$). But 1 week of Antarctic stay led to a lesser decrease in blood flow (from 46.85±3.33 to 28.92±4.12%) which further progressively decreased with duration of acclimatization, i.e., 56.18+2.75 to 55.5+3.01% after 8 weeks of stay in Antarctica (Fig. 2B and Table 1).

It was observed finally that finger blood flow did not decrease after cold immersion with 8 weeks of acclimatization (Table 2).

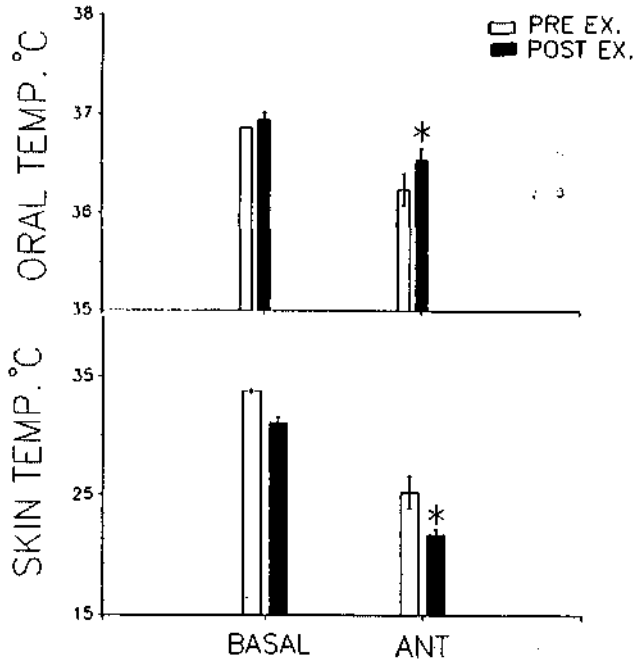

Fig. 2. Finger skin temperature (A) following cold immersion decreased significantly ($p < 0,001$) but the difference in the degree of fall was not significant in basal, 1 week and S *weeks of Antarctic stay. Blood flow (B) following cold immersion test reduced significantly ($p < 0.001$) in basal and after 1 week of Antarctic stay but not after 8 weeks.*

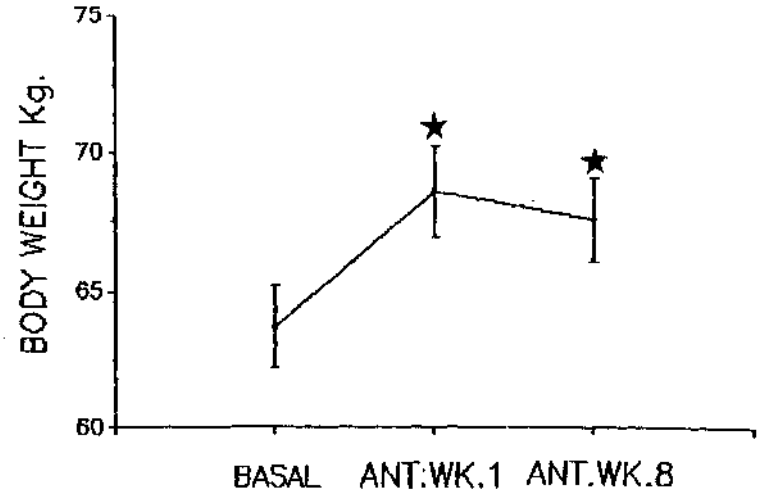

Fig. 3. Body weight showing a highly significant increase ($p < 0.001$) after 1 and 8 weeks of Antarctic stay.

Table 3 : The Mean ± SE of Body Weight (BW), Midarm Circumference (MAC), Skin Fold Thickness (SkFT) and Abdominal Girth (AbG) at Warm Environment, after 1 and 8 Weeks of Antarctic Exposure

Exptl. Condn.	BW (kgs) (n=20)	MAC (cms) (n=15)	SkFT (mm) (n=I3)	AbG (cms) (n=I5)
Warm Environ.	63.7	24.22	10.16	85.13
(In the Ship)	±1.53	±0.39	±0.73	±1.83
Cold Environ.	68.55**	23.45	10.23	83.33*
(Ant. 1st week)	+1.65	+0.49	±0.64	+2.01
Cold Environ,	67.55**	24.69	9.92	83.40*
(Ant. 8th week)	+1.52	±0.40	±0.70	±1.90

Significant difference between warm environment and Antarctic exposure is expressed as (*)=/> < 0.05 and *(**)* = $p < 0.001$.

After 8 weeks of acclimatization the change in FBF following cold immersion was "an after increase" or no change instead of "an after fall" as seen in phase I. This indicates triggering of cold induced vasodilatation (CIVD) response following fall in Tsk. The chronic cold exposure of 1 week was sufficient to initiate the CIVD as reflected by lesser decrease in blood flow following fall in Tsk (18.16±3.93 to 12.82±0.57°C) after cold immersion. The CIVD response progressively increased with duration of acclimatization of 8 weeks as observed with aTsk of 13.80±0.83°C after cold immersion showed 55.50±3.01% of FBF (Table 1). One of the most

important prerequisites for obtaining the consistent response was to immerse the hand to a constant cold temperature of 0°C which was obtained by rapid on and of stirring of ice-water bath.

Body weight and fat distribution

There was a significant increase ($p < 0.001$) in the body weight of the subjects from the basal value (63.7 ± 6.83 kg) after one and eight weeks (68.55 ± 7.38 and 67.55 ± 6.78 kg respectively) of Antarctic stay (Fig. 3, Table 3).

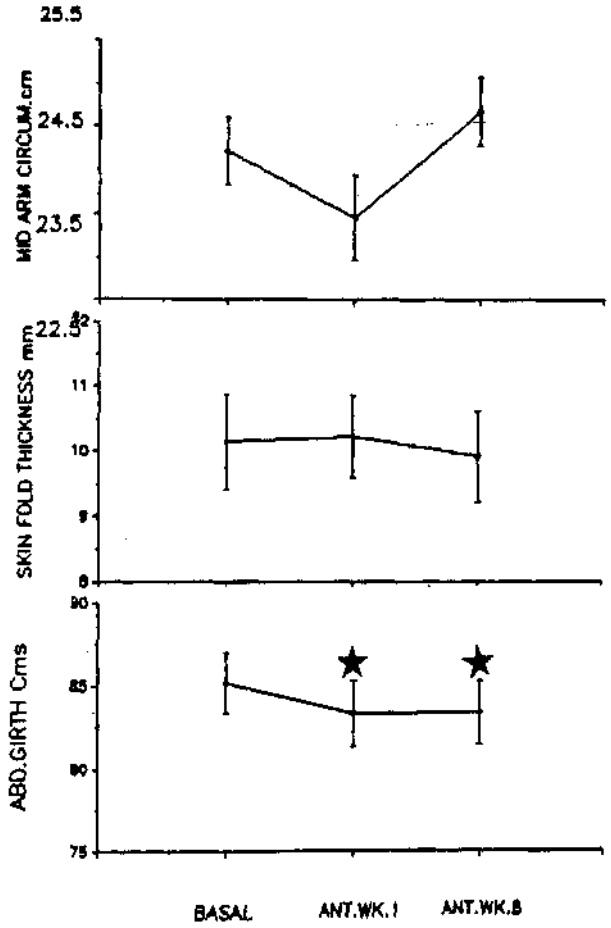

Fig. 4. Midarm circumference (cms) and skinfold thickness (mm) did not show any significant change after one and eight weeks of Antarctic stay. Abdominal girth (cms) showed a significant reduction ($p < 0.05$) after one week of Antarctic stay which showed no further fall after 8 weeks of stay.

Though Antarctic stay led to an increase in the midarm circumference the changes were not significant (Table 3), Similarly the skin fold thickness also did not show any significant change though there was a slight increase on 1st week followed by a fall on 8th week of Antarctic stay (Table 3, Fig. 4). But a significant decrease was observed in the abdominal girth after one ($p < 0.02$) and eight ($p < 0.05$) weeks of Antarctic stay (Fig. 4).

Discussion and Conclusion

This study has demonstrated that Indian men living in hot tropical climate when exposed to severe cold stress of Antarctica can acclimatize to cold and prevent cold injury by increasing the finger blood flow and maintaining the extremity temperature. This is similar to that observed in the people living in Arctic and subarctic areas who are accustomed to cold (Eisner *et al,* 1960; LeBlanc *et al.,* 1960).

The results of this study are in agreement with earlier investigators indicating increased tissue insulation apparently produced by sympathetic vasoconstriction in the blood vessels of extremity (Krog *et al.,* 1960). The fall in skin temperature after 1 and 8 weeks of acclimatization suggests vasoconstriction of cutaneous blood vessels in our subjects. The result also affirms the view that CIVD response in cold acclimatized subjects is more rapid (Krog *et al.,* 1960; Sinoway *et al.,* 1986).

The onset of vasodilatation was indicated as increase in finger blood flow after cold immersion. This could be considered as peripheral vasodilator response due to persistent Antarctic cold exposure. This vasodilatation could be a contributing factor for maintaining the nutrient supply to skin but not participating in the heat conductance, thus preventing cold injuries and hypothermia in Antarctica.

The increase in body weight implies that there has been an increase in tissue mass. Fig. 4 also illustrates that abdominal girth dropped after 8 weeks, and skin fold thickness increased slightly during summer stay in Antarctica. The increase in body weight does not correlate with no change in skin fold thickness after 8 weeks of stay and probably this was due to intake of high caloric diet in Antarctica. The later decrease in abdominal circumference does suggest redistribution of body fat. However, it is worthwhile to re-valuate these parameters in future expeditions.

In conclusion, results from the present study support the hypothesis that cold acclimatization in Antarctica results in increase of cutaneous blood flow, however this effect cannot be detected by monitoring skin temperature. A small increase in skin blood flow as measured by Laser Doppler flowmeter could be responsible for prevention of cold injuries. The vascular cold acclimatization is initiated within one week of stay in Antarctica and by 8 weeks it is complete as no further increase in blood flow was induced after cold immersion. The nature of neural or vascular

changes resulting in alteration of CIVD in Antarctic acclimatized men needs to be investigated.

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