EFFECTIVENESS OF COLD ACCLIMATISATION ACQUIRED AFTER TWENTY EXPOSURES

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Cold acclimatisation after 20 exposures to –2°C to –8°C in partially clad state has been studied in 32 subjects. Experimental subjects developed significant degree of cold acclimatisation. This acclimatisation was not affected adversely by reversion to routine duties with normal snow clothing. On the other hand these subjects were shown to be better acclimatised to cold at the end of winter compared to controls who also developed certain degree of cold acclimatisation by their normal stay with full snow clothing in sub-zero high altitude areas during winter months. It is suggested that initial cold stimuli as experienced in exposures is essential to achieve significant degree of cold acclimatisation. For maintenance of this acclimatisation normal stay in snow bound areas in winter is enough. It has also been suggested that cold acclimatisation acquired in winter by exposure regime may not be lost during summer.

There is enough evidence that exposure to cold can induce acclimatisation in men and animals. At present due to operational necessity a large number of troops have to stay in winter in areas where minimum temperature goes down up to-40 degree centigrade. The maximum insulation of clothing that can be worn without impairing mobility or dexterity of troops is about 5 clo. This insulation is adequate to keep thermal balance at 5°C when quietly sitting (Energy expenditure 1 Met i. e. metabolic rate of 5 Cal/m^2/hr). The same clothing but with an energy expenditure of 2 met (light activity such as walking) can protect up to –40°C (Stokes, 1960). Hence in these regions with maximum clothing there will be few periods when temperature will fall down enough so as to cause sensation of cold. Evidently such periods will be mostly in nights when most of the troops will be sleeping comfortably in their sleeping bags. In the day even when the ambient temperature will be sub-zero there will be considerable 'heat gain' because of solar radiation and this will reduce the cooling demand of the environment. In exceptionally calm weather a thermal radiation increment can be up to 25°C which would be equivalent to raising an ambient air temperature of 5 to 20°C. Even in the presence of cosiderable wind the increment varies between 5 and 10°C (Pugh, 1961). In view of these considerations it is possible that the well protected persons such as Military Troops may not be getting adequate cold stimuli to get them completely acclimatised. Actually such were the observations of Devis et al. (1963) in their experiments to find out the effect of altitude on cold response. These workers recommended that a regime of outside exposure to sub-zero conditions of partly clad individuals will provide a substantial cold acclimatisation.

Later work (Gupta et al. 1963) showed that twenty exposures to 0°C of three hours duration per day will be adequate.

The present work deals in investigating in what way the cold acclimatisation achieved by this regime of twenty exposures at onset of winter will be affected by reversions back to normal routine with adequate protective clothing during the rest of the winter months and whether subjects so exposed were any better in cold adaptation than controls at the end of winter.

MATERIALS AND METHODS

In mid November 1963, 32 subjects of age group 20 - 30 years and of same ethnic origin were selected from a battalion reached in high altitude areas in summer of 1963. They were divided into 2 groups of 16 subjects each. One group consisted of experimental subjects while the other served as control. All the 32 subjects were tested for their tolerance to cold by noting their reaction to nude exposure to 0 to 2°C for one hour. Each subject reported in a heated tent with an ambient temperature from 12 - 15°C. After removal of clothes, rectal thermester was inserted for a distance of 3 inches into the rectum for recording deep body temperature. For recording average skin temperature 8 copper constantan thermocouples were fixed, one each, on right side of forehead, chest, abdomen, right upper arm, right hand, right thigh, calf and foot. Subject was then made to lie on a stretcher in the heated tent. After every 15 minutes rectal and skin temperatures were recorded. Total ventilation for 5 minutes in Douglas bag was also collected after every 15 minutes and a sample of exhaled air was analysed by Haldane apparatus to determine oxygen consumption. When skin, rectal temperature and ventilation were stabilised after 30 to 45 minutes, the subject was taken out in cold where temperature ranged between 0°C to −2°C. Site selected was such that wind velocity was less than 2 miles per hour.

Each subject was made to stay nude in this temperature for one hour, during which skin and rectal temperature, ventilation and oxygen consumption were measured after 30 and 60 minutes.

After this initial testing for cold acclimatisation, control subjects were sent back to their normal duties and they were allowed to use their normal snow clothing. The experimental subjects were however exposed for 3 hours each day to a temperature ranging between 2°C and 8°C. During the exposures the subjects were dressed with veststring, Angola shirt, Jersey pullover, woollen pant, cap comforter and rubber combat boots with one woollen sock in each for first ten days, after which jersey pullover was taken away. After 20 exposures the experimental subjects were again tested for their cold acclimatisation by noting skin and rectal temperature, ventilation and oxygen consumption before and after one hour nude stay at 0°C. This phase of work was finished by 15th December, 1963.

The experimental subjects were also then sent back to their unit to resume their normal duties with authorised snow clothing consisting of veststring, angola shirt, jersy pullover, parka coat, woollen long drawns, parka pant, cap comforter and combat rubber boots with two woollen socks in each.

Both the groups spent the winter in snow bound areas where the mean temperature will be sub-zero (0 to 20°C) up to the end of March. Both experimental and control subjects were examined again in the end of winter 1964 for the cold acclimatisation acquired by both the groups during their stay in those areas in months of December, January, February, and March and part of April.

RESULTS

Average skin and rectal centigrade temperatures in control subjects in Nov. '63 and in April '64 are shown in table I. Average skin and rectal centigrade temperatures in experimental subjects in Nov.'63, after twenty exposures in January '64, and in April '64, are shown in table II. Average differences between basal reading and those recorded after one hour at 0°C in Nov.'63, January '64 and April '64, in control and experimental subjects are shown in table III. Oxygen consumption basal and after one hour at 0°C in experimental and control subjects during Nov. '63, January '64 and April '64 are shown in table IV.

TABLE I

Average centigrade Skin and Rectal Temperatures - Basal and Observed after one hour nude stay at O°C in Control Subjects during November '63 and April '64.

Site	November '63			April '63		
	Basal	After one hour at 0°C	Difference	Basal	After one hour at 0°C	Difference
Foot	28.00	21.07	6.93	28.83	23 30	5·53
Calf	30.60	26.75	3 85	31.00	27.92	3.08
Thigh	32.00	28 00	4.00	32.44	29.01	3 43
Abdomen	34.25	30.00	4.25	34 50	31.00	3.50
Chest	34.05	30.75	3.30	34.06	31.07	2.99
Upper Arm	31.05	27.05	4.00	31.71	28.25	3 46
Hand	30.25	25.75	4.50	30.64	26 42	4.22
Forehead	32.05	30.50	1.55	32.08	31.03	1.05
Weighted skin-temperature	32.48	28.60	3.88	32.19	28.88	3.31
Rectal Temperature	37.02	37.00	0-02	37.00	36.65	0.35

TABLE II

Average centigrade Skin and Rectal Temperature – Basal and Observed after one hour nude stay at O°C in experimental subjects during Nov. '63, after exposure in Jan. '64 and in April '64.

Site	November '63			After exposure in Jan. '64			April '64		
	Basal	After 1 hr. at 0°C	Difference	Basal	After 1 hr. at 0°C	Difference	Basal	After 1 hr. at 0°C	Difference
Foot	28.52	22.46	6.06	30.38	25 04	5.34	31.05	26.75	4.30
Calf	31.42	27.00	4.42	32.41	29.67	2.74	31.05	29.00	2.05
Thigh	32.44	27.89	4.55	33.33	30.32	3.01	32.48	30.00	2.48
Abdomen	33.02	32.48	3 54	35.06	33.24	1.82	35 23	33.36	1.87
Chest	34.08	32.70	1.38	34.63	33.22	1.41	35.43	33.49	1.94
Upper Arm	32.01	28.52	3.49	30.64	27 05	3.59	32.18	30.15	2.03
Hand	30.82	25.60	5.22	31.00	26.62	4.38	32.00	28 70	3.30
Forehead	34.80	32.08	2.72	33.79	32.82	0 97	34 02	33.14	0.88
Weighted skin temperature	32.62	28 08	3.54	32 08	30.00	2.08	33.82	31.44	2.38
Rectal Temperature	37.17	36.80	0.37	37.20	36.42	0.78	37.18	36.48	0.70

TABLE III

Average differences between Centigrade Temperatures before and after one hour nude stay at O°C in control and experimental Subjects during Nov. '63, January '64 and April '64.

Site	Control Subjects		Experimental Subjects		
	November '63	April '64	November '63	After Exposure January '64	April '64
Foot	6.93	5.53	6.06	5.34	4.30*
Calf	3.85	3.08*	4.42	2.74*	2.05**
Thigh	4 00	3 43	4 55	3.01*	2.48*
Abdomen	4.25	3 50	3.54	1.82*	1.87**
Chest	3.30	2.99	1.38	1.41	1.94
Upper Arm	4.00	3.46	3 49	3.59	2.03*
Hand	4.50	4.22	5.22	4.38	3.30*
Forehead	1.55	1.05	2.72	0.97	0.88*
Weighted Skin temperature	3.88	3 31	3.54	2.08*	2.33*
Rectal Temperature	0.02	0.35	0.37	0.78*	0.70*

Note :—Differences in January '64 and April '64 have been compared to those observed in Nov. '63.

* Difference significant at 5% level.

** Difference significant at 1% level.

TABLE IV

O_2 Consumption in c.c. per cent before and after one hour at 0°C in Control and Experimental subject.

Subjects	November '63			After Exposures Jan. '64			April '64		
	Basal	After 1 hr. at 0°C	Difference	Basal	After 1 hr. at 0°C	Difference	Basal	After 1 hr. at 0°C	Difference
Control (16)	216.4	261.4	45.0 (20.8%)	—	—	—	214.49	246.9	32.5* (15.1%)
Experimental (16)	203.8	260.4	56.6 (27.77%)	204.5	245.8	41.3* (20.89%)	203.8	230 6	26.8** (13.15%)

Note :— Differences in oxygen consumption between basal and after one hour exposure at 0°C in January '64 and April '64 have been compared to those observed in November, '63.

* Difference significant at 5% level.

** Difference significant at 1% level.

DISCUSSION

It will be seen in Table I that control subjects have shown invariably higher skin temperatures at various sites and the weighted temperature after one hour nude stay at 0°C during April '64 as compared to those recorded at the onset of winter in November 1963. The average differences between the basal temperatures and those observed after one hour nude stay at 0°C in April 1964 are less than the differences noted in November 1963 (Table II). Decrement at calf is significant at 5% level ($P<.05$) while at other sites including the weighted temperature significance of decrement lies between 5 and 10% ($P<0.1$). Cold elevated oxygen consumption has fallen significantly ($P<.05$) from a value of 20.79% above basal in November 1963 to 15.1% above basal in April 1964 (Table IV). Fall in rectal temperature after one hour nude stay at 0°C has increased from 0.2°C in November 1963 to 0.32°C in April 1964. In our previous work (Gupta et al. 1963) we have shown that decrease in fall of skin temperature, diminished elevation of cold induced metabolism and increase in fall of rectal temperature after one hour nude stay at 0°C can be regarded as fairly good criteria of cold acclimatisation. Using these criteria in our control subjects it will be observed that they have acquired a certain degree of cold acclimatisation in winter months from November 1963 to mid April 1964. There has been a significant reduction in cold elevated metabolism although the amount of exposure was generally insufficient to produce a significant change in skin and rectal temperatures. Davis and Johnston (1961) have also observed similar metabolic changes in the man getting acclimatised to cold seasonally although consistent alteration in surface on rectal temperatures could not be demonstrated.

From Table II it is observed that in experimental subjects after twenty exposures of 3 hours duration each, skin temperature at various sites and weighted skin temperature after one hour nude stay at 0°C are relatively higher in January 1964 compared to those recorded initially in November 1963. The fall in skin and weighted temperatures after one hour stay at 0°C is significantly less ($P<.05$) in calf, thigh and abdomen compared to initial values in November 1963 (Table III). Cold elevated oxygen consumption has gone down significantly from 27.77% over basal to 20.89% ($P<.05$). Average fall in rectal temperature after one hour nude stay at 0°C in January 1964 is 0.78°C. So in terms of peripheral and core temperatures and cold induced elevated O_2 consumption it is observed that partially clad experimental subjects have acquired significant degree of cold acclimatisation after twenty exposures to −2 to −8°C.

In April 1964, at the end of winter it is seen that the experimental subjects have improved their degree of cold acclimatisation. Skin temperatures at various sites and weighted skin temperatures were higher after one hour nude stay at 0°C compared to those observed after twenty exposures in January 1964. Decrease in fall of these temperatures from basal to those observed after one hour nude stay at 0°C became highly significant in hand, calf and abdomen and became significant in forehead, upper arm and foot, where it was not so at the end of exposures. Increase in fall in rectal temperature was as significant as before. Increase in cold induced oxygen consumption was reduced from 20% to 13.4% over basal. Difference compared to initial value of 27% became from significant ($P<.05$) at the end of exposures in January 1964 to highly significant ($P<.01$) at the end of winter in April 1964.

It appears that during twenty exposures to −2 to −8°C in partly clad conditions man gets enough cold stimuli in the form of shivering to get the body acclimatised to cold to a significant level. Once the body gets this acclimatisation whatever cold sensation that a fully clad person in sub-zero condition will feel from time to time will be enough not only to maintain the cold tolerance achieved after 20 exposures but also to improve it. In persons, not exposed to cold exposures, but fully clad the cold stimuli experienced in sub-zero condition does produce certain degree of acclimatisation but this is much inferior than that achieved by persons who had undergone regime of cold exposures.

The results of these trials negativates any fear that reversion to routine duties with normal snow clothing during winter will have deleterious effect on cold acclimatisation achieved by exposures at the onset of winter. However, how much of this acclimatisation will be lost by the intervening summer before next winter in the high altitude areas will require further work. Ames et al. (1948) showed that cold acclimatisation was completely extinguished after 34 days in temperate conditions and was almost abolished at the end of 17 days. Devis and Johnston (1961) also concluded that man seasonally acclimatises to cold and that this acquired acclimatisation is lost during the summer months. In high altitude areas above 11500 feet, which is mostly our concern, although clear sunny days are quite hot, there is a great diurnal variation of the ambient temperature and so in the night minimum temperature comes down to 5°C. It is hoped that subjects who have achieved considerable degree of cold acclimatisation by undergoing exposure regime followed by normal stay in sub-zero conditions during winter will be able to maintain their cold acclimatisation by such cold stimuli that they may be able to get in nights during summer. It may also be possible that they may lose a part of their acclimatisation but may be able to restore it much quickly and more efficiently than the control subjects at the onset of next winter. However, further observations of physiological reaction to nude stay at 0°C for one hour of both the experimental and control subjects at the end of winter may be able to elucidate this facet of problem—that is, the effect of summer in High Altitude areas on cold acclimatisation.

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