Original Article

# Cardio-Respiratory Changes to Extreme Cold in the Arctic Environment

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***Effects of acute exposure and acclimatisation to cold on cardio-respiratory functions were investigated on 10 healthy tropical Indian men taken to the arctic. Seven Russian Migrants (RM) and 6 Russian Natives (RN) were also studied. In Indian Subjects (IS), spirometric measures of VC, FVC, $FEV_1$, PEFR and MVV showed initial decreases that significantly increased after 9 weeks of stay at the arctic region. RN & RM subjects also showed improvements after 9 weeks of stay. Resting heart rate (HR), systolic (SBP) and diastolic blood pressure (DBP) showed increase on acute cold exposure; Kerdo's index indicated increased sympathetic activity. On return to Delhi, all the physiological parameters reached near baseline values. RN subjects had significantly higher DBP as compared to initial values of Indian volunteers at Delhi ; they also showed prominence of pulmonary arteries and pulmonary vascular markings.***

Key words : *Acclimatisation to Cold, Autonomic Changes, Ventilatory Mechanics.*

Man may be exposed to extreme freezing temperature either in their natural habitat or during occupation at snow bound areas, and sometimes due to accidents. Scientists have observed changes in cardio-respiratory system during exposure to extreme cold climate[1-5].

In the present study, effects of acute exposure and acclimatisation to cold stress during 60 days' stay at the arctic on cardio-respiratory functions were investigated on healthy tropical Indian soldiers (IS, n=10). The results have been compared with the initial baseline responses at Delhi and on return to Delhi. An attempt has also been made to compare the same physiological variables with those of Russian Migrants (RM) and Russian Natives (RN) in the arctic region.

Some specific environmental factors in the Arctic are extreme cold climate and disturbance of photoperiodicity (polar day and night) leading to dissynchronous syndrome.

## Material and Methods

Ten Indian soldiers (IS) of tropical origin, 7 Russian Migrants (RM) from temperate zone and 6 Russian Natives (RN) from the arctic in the age group of 20-40 yrs volunteered as subjects. Physical characteristics of the subjects are shown in Table I. They were maintained on a diet supplying about 4000 K cals and a controlled physical activity. Snow clearing, fetching water form the frozen river nearby, marching on snow terrain and physical exercise constituted some of the routine activity schedule which provided ample cold exposure in the natural cold environment throughout the period of study. For their daily routine activities they were exposed to environmental temperature ranging from -8.5°C to -37°C.

After completion of initial studies at Delhi in the month of November, IS subjects were airlifted

Table I : Physical Characteristics of Subjects (m +SD)

| Subjects | Age (Yrs) | Height (Cms) | Weight (Kgs) | BSA (Sq.m) |
|---|---|---|---|---|
| IS (n=10) | 25.0 ± 3.20 | 170.0 ± 5.66 | 61.34 ± 4.92 | 1.71 ± 0.90 |
| RM (n= 7) | 29.0 ± 7.44 | 174.9 ± 6.54 | 81.09 ± 14.48 | 1.94 ± 0.13 |
| RN (n= 6) | 31.0 ± 2.96 | 178.0 ± 6.54 | 75.50 ± 15.27 | 1.90 ± 0.14 |

to the arctic region of Russia (70°N 38°E). RM subjects were also airlifted to the arctic region from Moscow and RN were permanent residents of the arctic region. All the three groups of subjects lived in temporary wooden huts (temperature maintained between 15 to 20°C) for 10 weeks.

They were rested in a room maintained at 21 ± 1°C for 15 min before cardio-respiratory functions were recorded. Resting heart rate (HR), blood pressure (BP) and respiratory rate (RR) were measured. Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1st second ($FEV_1$), peak expiratory flow rate (PEFR), and maximum voluntary ventilation (MVV) were recorded on a Vitalograph (UK) using standard methodology.

Kerdo's autonomic index (KAI)[6] was calculated by the formula: KAI=(1-D/R) x 100, where D is diastolic blood pressure in mm Hg and R is heart rate in bpm.

In IS, cardiovascular measurements were made on 10th and 50th day after their arrival and spirometric parameters were recorded during 1st, 5th and 9th week of arctic stay and on return to Delhi. On RM and RN, cardivascular measurements were performed only once on the 10th day of their stay at the arctic and spirometric parameters during 1,5 and 9 week of stay. X-ray chest (PA view) was done on IS once at Delhi and twice at the arctic and once at the arctic on RM and RN subjects.

## Results

Table II presents mean values of HR and BP in IS, RM and RN under resting conditions. HR, SBP and DBP showed trends to increase in IS during their initial part of stay at the arctic. By 8th week, SBP and DBP showed decrements when DBP was found lower than that noted at Delhi. HR and SBP reverted to near initial values on return to Delhi. RN subjects showed a significantly higher DBP as compared to initial values of IS at Delhi ($p<0.01$).

Initially, VC and FVC showed decrements in IS, thereafter improving and reaching peak values by 9th week ($p<0.01$) (Table III). RM and RN subjects revealed higher values of VC as compared to baseline values of IS ($p<0.01$). Intergroup difference between Russian volunteers (RM and RN) was not significant. Both the groups showed improvements during stay at the arctic. $FEV_1$, PEFR and MVV followed similar trends in IS (Table IV). RM revealed higher values of FVC, $FEV_1$, PEFR and MVV whereas RN had a higher value of MVV ($p<0.05$) as compared to baseline values of IS at Delhi. Intergroup difference in RM and RN during the first week at the arctic was significant ($p<0.01$). Significant improvements were observed in IS and RN in all the parameters during their stay at the arctic ($p<0.01$); RM

**Table II : Cardiovascular Changes in Indian Sojourners and Russian Volunteers (m ± SD)**

| Parameters | IS (n=10) Initial at Delhi | Stay at Arctic (Weeks) Second | Stay at Arctic (Weeks) Eighth | Return Delhi | RM (n=7) | RN (n=6) |
|---|---|---|---|---|---|---|
| HR (bpm) | 59.9 ± 4.6 | 66.6 ± 7.6 | 67.9 ± 6.0 | 58.4 ± 5.7 | 58.8 ± 9.7 | 69.3 ± 9.4 |
| SBP (mmHg) | 121.7 ± 20.0 | 132.6 ± 17.3 | 126.9 ± 17.5 | 123.6 ± 16.8 | 121.4 ± 8.4 | 130.0 ± 6.3 |
| DBP (mmHg) | 75.8 ± 7.4 | 78.0 ± 8.8 | 72.4 ± 5.8 | 74.6 ± 6.6 | 78.0 ± 4.9 | 82.5** ± 4.2 |

** $p<0.01$ as compared to initial IS value at Delhi.

Table III : VC and FVC of Indian and Russian Subjects (m ± SEM)

| Parameters | | Initial At Delhi | At Arctic 1 Week | 5 Week | 9 Week | Return to Delhi |
|---|---|---|---|---|---|---|
| VC (L) | IS | 4.03 ± 0.14 | 3.84 ± 0.17 | 4.37 ± 0.13 | 4.52 ± 0.13** | 4.20 ± 0.12 |
| | RM | - | 5.80 ± 0.26 | 5.98 ± 0.31* | 5.96 ± 0.27* | - |
| | RN | - | 5.05 ± 0.38 | 5.64 ± 0.45** | 5.96 ± 0.27** | - |
| FVC(L) | IS | 3.95 ± 0.12 | 3.51 ± 0.17** | 4.06 ± 0.14** | 4.24 ± 0.14** | 3.96 ± 0.15 |
| | RM | - | 5.43 ± 0.30 | 5.35 ± 0.29 | 5.45 ± 0.34 | - |
| | RN | - | 4.77 ± 0.39 | 5.14 ± 0.34* | 5.29 ± 0.38** | - |

Statistical significance for comparison of Initial with Arctic (1,5 & 9 weeks) values in IS and Arctic 1st week with 5th,9th weeks values in RM and RN are indicated by *p<0.05, ** p<0.01

Table IV : $FEV_1$, PEFR and MVV in Indian and Russian Subjects (m ± SEM)

| Parameters | | Initial At Delhi | At Arctic 1 Week | 5 Week | 9 Week | Return to Delhi |
|---|---|---|---|---|---|---|
| $FEV_1$ (L) | IS | 3.26 ± 0.14 | 2.96 ± 0.15* | 3.41 ± 0.12 | 3.42 ± 0.11 | 3.26 ± 0.13 |
| | RM | - | 4.43 ± 0.19 | 4.35 ± 0.25 | 4.38 ± 0.20 | - |
| | RN | - | 3.74 ± 0.30 | 4.12 ± 0.36** | 4.05 ± 0.33** | - |
| PEFR (L/min) | IS | 548.0 ± 16.7 | 504.0 ± 45.5 | 621.0 ± 0.23* | 627.8 ± 9.7* | 564.3 ± 22.9 |
| | RM | - | 619.9 ± 26.2 | 642.1 ± 21.1 | 684.7 ± 15.1* | - |
| | RN | - | 482.0 ± 29.9 | 572.3 ± 38.2* | 561.3 ± 33.3* | |
| MVV (L/min) | IS | 124.6 ± 7.0 | 130.1 ± 8.7 | 160.3 ± 7.8** | 166.7 ± 9.7** | 146.2 ± 11.1 |
| | RM | - | 191.4 ± 6.1 | 195.0 ± 9.8 | 216.3 ± 11.4* | - |
| | RN | - | 151.8 ± 14.4 | 177.3 ± 18.2* | 180.7 ± 18.1* | - |

Statistical significance for comparison of Initial with Arctic (1,5 & 9 weeks) values in IS and Arctic 1st week with 5th,9th weeks values in RM and RN are indicated by *p<0.05, ** p<0.05

showed improvements in PEFR and MVV ($p<0.05$) during these days.

Table V shows individual values of Kerdo's index in IS, RM and RN. Many of the IS showed increased sympathetic activity during their arctic stay which reverted to baseline values on return to Delhi.

X-ray chest (PA view) in all three groups did not show any lung parenchymal changes. Each lung field was divided into four quadrants at the hyla and each lung field was critically examined for air entry and parenchymal changes, interstitial disease and pneumonic consolidation[7]. Three IS subjects showed minimal cardiac enlargement and one showed a significant enlargement of more than 2 cm (Fig 1&2). RM did not show any appreciable changes. RN showed prominence of pulmonary artery and pulmonary vascular markings (Fig 3).

Table V : Kerdo's Autonomic Index Changes (KAI) in Indian and Russian Volunteers

| Subjects | Initial At Delhi | At Arctic 10th day | At Arctic 50th day | Return to Delhi | RM | RN |
|---|---|---|---|---|---|---|
| 1. | -20.0 | -39.0 | - | -38.0 | -13.0 | -32.0 |
| 2. | -05.0 | -12.0 | -07.0 | 0 0 | -24.0 | -13.0 |
| 3. | -40.0 | -55.0 | -05.0 | -04.0 | -52.0 | 0.0 |
| 4. | -15.0 | 0.0 | +12.0 | -14.0 | -10.0 | -19.0 |
| 5. | -16.0 | -13.0 | 0.0 | -33.0 | 0.0 | -12.0 |
| 6. | -06.0 | -28.0 | +08.0 | -56.0 | | |
| 7. | 0.0 | +12.5 | +22.0 | -02.0 | | |
| 8. | -39.0 | -09.0 | -03.0 | -25.0 | | |
| 9. | +15.0 | +25.0 | +20.0 | -16.0 | | |
| 10. | -10.0 | 0.0 | -03.0 | -29.0 | | |

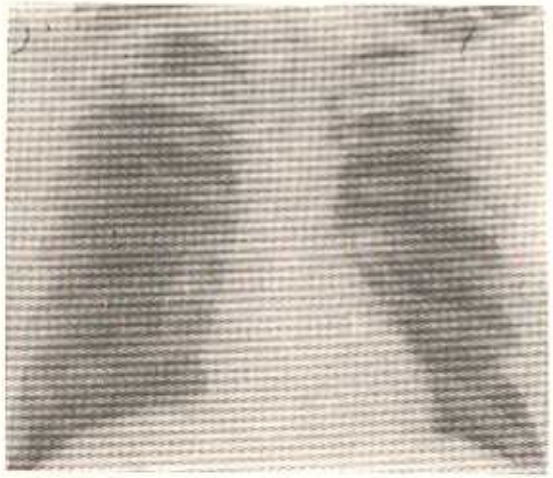

Fig. 1 X-Ray Chest (PA View) of IS (Sl. No.8) at Delhi

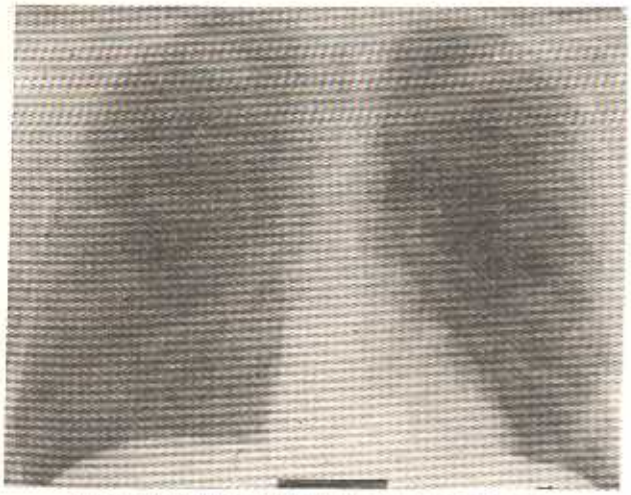

Fig. 2 X-Ray Chest (PA View) of IS at Arctic

Fig. 3 X-Ray Chest (PA View) of RN Subject Showing Prominent Pulmonary Artery and Vascular Markings.

## Discussion

During short term stay of human in the polar region, mobilisation of adaptive reactions of the circulatory system manifests itself as an increase in HR and elevated blood pressure[8]. In the present study on IS, acute exposure to cold resulted in an increase in HR due to sympathetic activation and declined to normal values on return to Delhi due to reduced sympathetic tone achieved during sojourn in the arctic[9]. Scientists all over have reported an increase in blood pressure[8,10]. In IS subjects, there was a tendency to increase in blood pressure which showed reduction at the end of arctic stay. BP reverted to normal on return to Delhi.

KAI values indicated a predominance of parasympathetic activity at Delhi. Majority of the subjects (8 out of 10) revealed negative KAI values indicating parasympathetic overtone (Table V). During arctic stay (10th day), out of these 8 subjects, 4 showed increased or sustained parasympathetic dominance, 2 had decreased parasympathetic dominance and other 2 subjects sympathetic dominance (KAI being 0 or positive). Initial sympathetic dominance revealed in two subjects was increased during 10th day of arctic stay. On 50th day, 7 out of 8 IS subjects showed increase in sympathetic dominance and in the other 2 sympathetic dominance was maintained. Strengthening of sympathetic activity enhances individual's capacity for adaptation. The findings could be an indicator of adaptive process taking place[11] to overcome the adverse effects of extreme cold. Both RM and RN exhibited a parasympathetic dominance similar to the initial response of IS at Delhi.

VC and FVC declined immediately on exposure to cold. Mehler and Loke[12] concluded that a decrease in VC on cold exposure could be due to poor effort, airway obstruction, changes in pulmonary compliance and respiratory muscle fatigue. Poor effort is unlikely to account for the decline as the subjects in the present study were highly motivated and co-operative. A minimal airway obstruction due to engorgement of nasal mucosa and upper respiratory tract is logically feasible. In addition, the reflex increase in bronchomotor tone could have led to an increase in airway obstruction[13]. Respiratory muscle fatigue might have also contributed, as a constant increase in tonus of muscles of thoracic cage does occur as a result of acute exposure to cold[14]. Landysheva et al[15] opined that dilatation of pulmonary capillaries took place as a result of acute cold exposure leading to pulmonary hypertension. In turn, the decrease in compliance of the lung as a result of restrictive changes led to significant decrease in VC.

FEV1 also showed a decrease. Cold inspired air acts on the larger airways and leads to a reflex broncho-constriction which in turn increases airway resistance[16,17]. PEFR is a resultant of number of factors including expiratory effort, airway resistance and volume of air displaced. The initial reduction in PEFR indicates the effect of acute cold exposure in increasing airway resistance[18]. The results of ventilatory functions after 5 weeks of acclimatisation were near the baseline values at Delhi. There were further significant improvements after 9 weeks stay at the arctic possibly due to increased muscle power and relaxation of upper airways as acclimatisation sets in.

RM were physically active soliders drawn from Russian Armed Forces. RN subjects were relatively sedentary subjects viz Doctors or Research scientists with less intense physical activity. RN showed improvements in all ventilatory functions probably due to regular exercise schedule and a balanced and supervised nutrition. RN subjects showed significantly higher DBP as compared to IS at Delhi. They also had prominence of pulmonary artery and pulmonary vascular markings.

Most of the physiological changes reverted to the baseline value on return to Delhi in IS subjects thus proving that there were no permanent changes during short stay at extreme cold conditions.

**Acknowledgements**. We would like to thank Dr T.R. Sharma, Adviser (Life Sciences) and Dr J Sengupta, Ex-Director, DIPAS for providing all encouragement, the Indian and Russian volunteers for their utmost co-operation in the study. Thanks are due to Dr SS Varma for statistical analysis of data.

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