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Heart Rate Variability on Exposure to Severe Gold at Antarctica

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Abstract

An attempt has been made to evaluate Heart Rate Variability (HRV) as a reliable index for sympathetic and parasympathetic components of the autonomic nervous system response during the course of acclimatization to severe cold at Antarctica. Two groups (10 each) of healthy men in the age group of 2344 years participated in the study. Group A consisted of fresh inductees to Antarctica for conducting scientific research during austral summer. Group B consisted of winter team members who had already completed 14 months of stay at Antarctica. The HRV experiments were conducted at New Delhi; and on 7th, 30th and 60th day of stay at Antarctica. The HRV was measured as spectral components of low frequency (LF) 0.04-0.05 Hz, related to sympathetic activity and high frequency (HF) 0.15-0.50 Hz due to vagal efferent activity and the sympathovagal balance as LEVHF ratio. The results showed a significant increase ($P<0.05$) in heart rate (HR), systolic blood pressure (SB) and diastolic blood pressure (DBP) at supine rest as well as to standing on 7th day and showed a decline on 30th and 60th days of stay at Antarctica. When compared to winter team, the HR, SBP and DBP were not significantly different in supine position however, the SBP and DBP response to standing was significantly higher ($P<0.05$) in winter team. The skin temperature (SKT) showed a significant decline ($P<0.05$) on 30th day and remained low on 60th day of stay; however, it was not different between the groups. The LF response to orthostatic challenge showed significant increase ($P<0.01$) on 7th day but showed decline on 30th day and 60th day. The HF power also showed a significant decline ($P<0.05$) on 7th day in supine position but was not altered with the change in posture. However, it was not different between the groups. The LF/HF ration in supine as well as in standing position showed a significant increase ($P<0.01$) on 7th day and fell during rest of the stay period. The LF/HF ratio of the winter group also showed a significant ($P<0.05$) increase in supine position as compared to summer, whereas, the response to standing position was not significantly different. The observations suggests that continuous cold exposure to Antarctica (at least for eight weeks) results in attenuated sympathetic tone which, may lead to a gradual shift in the automatic balance towards parasympathetic dominance, which is likely to be responsible for increased cold tolerance and prevention of cold injuries.

Introduction

Acclimatization to cold is one of the important physiological mechanisms for men to achieve adequate work performance without developing cold injuries at Antarctica (1-3). To tolerate such stressful environment, the efficiency of cardiovascular regulatory mechanisms such as autonomic nervous system (ANS) is of particular importance (4). The condition of stress either of physical or psychological origin is first registered by central nervous system resulting in activation of the sympathetic nervous system (SNS). The stimulation of SNS in response to stressful stimuli is an essential component to cope with challenge, which is crucial for the survival of the organism (4).

Prolonged exposure to moderate cold or intermittent exposure to very severe cold has been shown to induce cold acclimatization in rats (5-7). Extensive studies conducted on primitive men who were habitually exposed to severe cold without adequate clothing suggested the possibility of cold acclimatization in such a population. They had developed certain physiological mechanisms to cold as well (8-11). Korean women divers who have dived in cold waters are another example of cold acclimation (12). It has been shown that humans have an extraordinary ability to adapt to any stressful environment (13) and prolonged exposure to cold stress resulted in altered responses which may be categorized as adaptation, acclimatization, conditioning, habituation or tolerance (14-17). Though these regulatory responses are well known to occur, the precise mechanism are not yet understood. The consensus of opinion is that people become acclimatized provided they allow their bodies to be exposed to cold periodically.

Spectral analysis of HRV is a convenient method of a non invasive assessment of the mechanisms involved, especially the ANS. HRV depends on the sympathetic-parasympathetic balance, adjusting HR to changing environmental factors (18-20). The influences of the sympathetic and parasympathetic innervation on modulation of the heart rate are quantified by the power of the heart rate variability spectrum in specific frequency bands (19). Therefore, the analysis of HRV is considered an effective method of assessing the circulating system control, as it makes a distinction between the sympathetic and parasympathetic components of the ANS (20).

Studies on tropical natives suggested the possibility of physiological habituation or acclimatization to cold as a result of repeated exposure inside a cold chamber for a considerable length of time (21). The data are available on ANS responses of low- landers during exposure to high altitude where cold co-exists with hypoxia (22-25). However, detailed information about the responses of tropical men during exposure to the natural cold environment of Antarctic is not available. Hence the present study was conducted to evaluate the role of sympathetic and parasympathetic components of ANS in HR regulatory mechanisms in clinically healthy subjects, during their short as well as long term sojourn at Antarctica

Materials and Methods

Subjects:

Two groups of (10 each) healthy male subjects in the age group of 23-44 years participated in the study. They were homogeneous in respect of physical characteristics like age, height and body weight (Table-1). Group A consisted of fresh inductees to Antarctica for conducting scientific research during austral summer. Group B consisted of previous Winter Over Team members who had already completed 14 months of stay at Antarctica. The study was approved by Institute's Ethical Committee and all the subjects gave written consent for voluntarily participation in the investigation.

Table 1: Physical Characteristics of Summer & Winter Members

	Summer (n=10)	Winter (n=10)
Age (Yrs)	33.7 ± 1.7	32.9 ± 1.5
Weight (Kg)	68.7 ± 2.9	65.8 ± 1.8
Height (cm)	172.3 ± 2.2	164.8 ± 2.3
BMI	23.1 ± 0.7	24.2 ± 0.4

Group A (summer team members—short term sojourn) consisted of tropical Indian subjects. The baseline study was conducted at Delhi (29°N, 77°E) in the month of November at on ambient temperature ranging from 20.5 to 33.5°C. The same experiments were repeated again during first week of voyage as well as on 7th, 30th and 60th days of stay at Antarctica. The members were initially airlifted from Goa to Cape Town (located at 40°S, 12°E), South Africa during the first week of December. The voyage started from Capt Town on an Ice Class ship after a brief stay in Cape Town, South Africa. These subjects were then transported to the Indian Antarctic Station. Maitri where they stayed for a period of two months. Maitri is located at Schirmacher Oasis at 70°S, 12°E on a moraine. Being some distance below the Antarctic Circle the sun is continuously seen above the horizon from December to January with the result, the months from November to February are called summer months (Polar day). From May to July the sun remains below the horizon resulting in winter months (Polar night).

At Antarctica, the subjects were accommodated in centrally heated huts in which the temperature was maintained between 18-20°C. They stayed at Antarctica for two months and carried out various scientific research during their stay. The mean ambient temperature and wind speed were - 0.94 ± 0.28°C and 14.7 ± 0.95 Kts during that period. They consumed a diet of 3500 to 4000 kcal/day. In addition, dry ration was provided during their outdoor duties. While performing the outdoor duties, they used special polar clothing provided by the Department of Ocean Development (DOD to protect them against extreme cold. However, to carryout routine duties like taking scientific observations and collection of samples etc., their hands and face were frequently exposed to the external environment. The daily cold exposure during their stay was about 4 to 5 h/day.

Group B (winter team members—long term sojourns) consisted of tropical Indian subjects who stayed at Maitri for 14 months. Identical experiments were also carried out in winter members for cross comparison with summer team. They were provided with regular supply of warm running water and other amenities. The temperature inside Maitri was maintained between 22 to 28°C even though the outside temperature dropped down to - 38°C during winter. They experienced both polar days and nights. The highest temperature of +6°C was recorded in January and the lowest temperature, - 43°C was observed in August. The volunteers were primarily engaged in their specialized jobs mostly inside laboratory, while the others were responsible for operation and maintenance of scientific equipment fitted outside the station. During outdoor work too, they were protected with proper polar clothing and footwear. Further, during peak winter, when the environmental conditions worsened with minimum temperature dropping to - 38°C along with frequent high velocity blizzard and occasional packed weather conditions for days together, the subjects mostly remained confined inside the station. Moreover, the observers had no control over the duration and frequency of their day-to-day outdoor exposure, which was a genuine difficulty with the subjects.

HRV Recording

Subject preparation:

On the study day after relaxing for 1 hr in a thermo-neutral room (20-22°C) the subjects were made to lie down comfortably on an examination table for half an hour before the experimental observation. During the experiment and the preceding day, the participants did not take any medication, coffee or alcohol or tobacco smoking. The standard bipolar limb lead II electrocardiogram (ECG) was recorded continuously using a computerized polygraphic recording system (MP 100, BIOPAC Systems, Inc, USA) for 10 min. in supine position. Heart rate, blood pressure, oral and index finger skin temperatures were also recorded after 10 min. of supine rest. Then the subjects were made to stand and the ECG recording was repeated for 10 min. to examine the ANS response to postural challenge (25a). The orthostatic tolerance was evaluated to assess the effects of change of posture on the BP and HR and to quantify the vasomotor reactivity of the subjects. The BP and HR were measured while subjects were lying down and after three minutes of change in posture to standing position. The degree of variation of these parameters during the change in posture was analyzed using Crampton's index (26). In this scoring system the highest scores are awarded to increase in BP with negligible rise in HR and subjects whose BP cannot be maintained in spite of tachycardia get the lowest score.

Data acquisition:

The ECG was recorded using standard bipolar limb lead II configuration and an AC amplifier with 1.5 Hz high pass filter and 75 Hz low pass filter setting (BIOPAC System, Inc., USA). The ECG was digitized using a 16 bit analog to digital converter (ADC) at a sampling rate of 500 Hz using MP100 hardware, BIOPAC System, Inc., USA, and stored on the hard dist of a P II, 501T Laptop PC (Acer Extensa, USA) using Acknowledge 3.7.1 BIOPAC System, Inc., USA software (27).

Analysis:

Time domain: The recorded ECG was visually inspected off-line and only noise free data were included in the analysis. The R waves were detected to obtain point event series of successive R-R intervals from which the beat to beat heart rate series was computed using the menu option, which uses a simple formula:

$$IHR = 1/RRi,$$

where

IHR = Instantaneous Heart Rate ;

RRi = Successive RR intervals

RRi represents successive RR interval. This function is not an accurate representation of heart rate since, it is a discrete function whereas, the output of the sinus node is a continuous function of time. Furthermore, the inverse RR equation can only provide one value of rate for each beat, representing the rate corresponding to the previous beat. For spectral analysis, a continuous time function is preferable to a discrete one. A more ideal heart rate function therefore, would provide an instantaneous rate function, which is smoothed and valid for all points of time. Such smooth function that is known as instantaneous heart rate was derived as described by Berger et al. (1981). The derived IHR from the processed ECG data was displayed and stored as a separate channel in the same file. The domain parameters like mean and standard error mean (SEM) was calculated from the IHR data file.

Frequency domain: The beat to beat HRV were only included after removing the mean and trend from the heart rate series for analysis. The data ends were padded with zeros until the number of samples became a power of two. A hamming window was applied on the data in order to avoid the spectral leakage. The HRV power spectrum was obtained using Fast Fourier Transform (FFT) analysis. The energy in HRV series of the following specific frequency bands was studied, viz. the low frequency component (0.04 Hz to 0.15 Hz), high frequency component (0.15 Hz to 0.50 Hz) and ratio between the former with later (LF/HF ratio) (Figure-1). The low frequency and high frequency values were expressed as normalized unites (29).

Statistical analysis: Statistical analysis of multiple comparison of various physiological responses with in the group under different conditions was done by the method of two way classification of ANOVA using the criterion of least significant difference. Unpaired 't-test' for comparison between two different groups and paired 't-test' for comparing paired group were also used. For statistical comparison only 60th day readings of the summer group were taken to compare with winter group's physiological responses as most of the responses observed initially, declined to normalcy on 60th day of stay assuring the cold acclimatization. The values are expressed as mean ± SEM.

Results

Physical characteristics: The physical characteristics of the subjects are shown in Table-1. The age, body weight, height and body mass index were comparable in both the groups.

Resting Parameters:

Heart rate, Blood pressure: The resting heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) did not show any

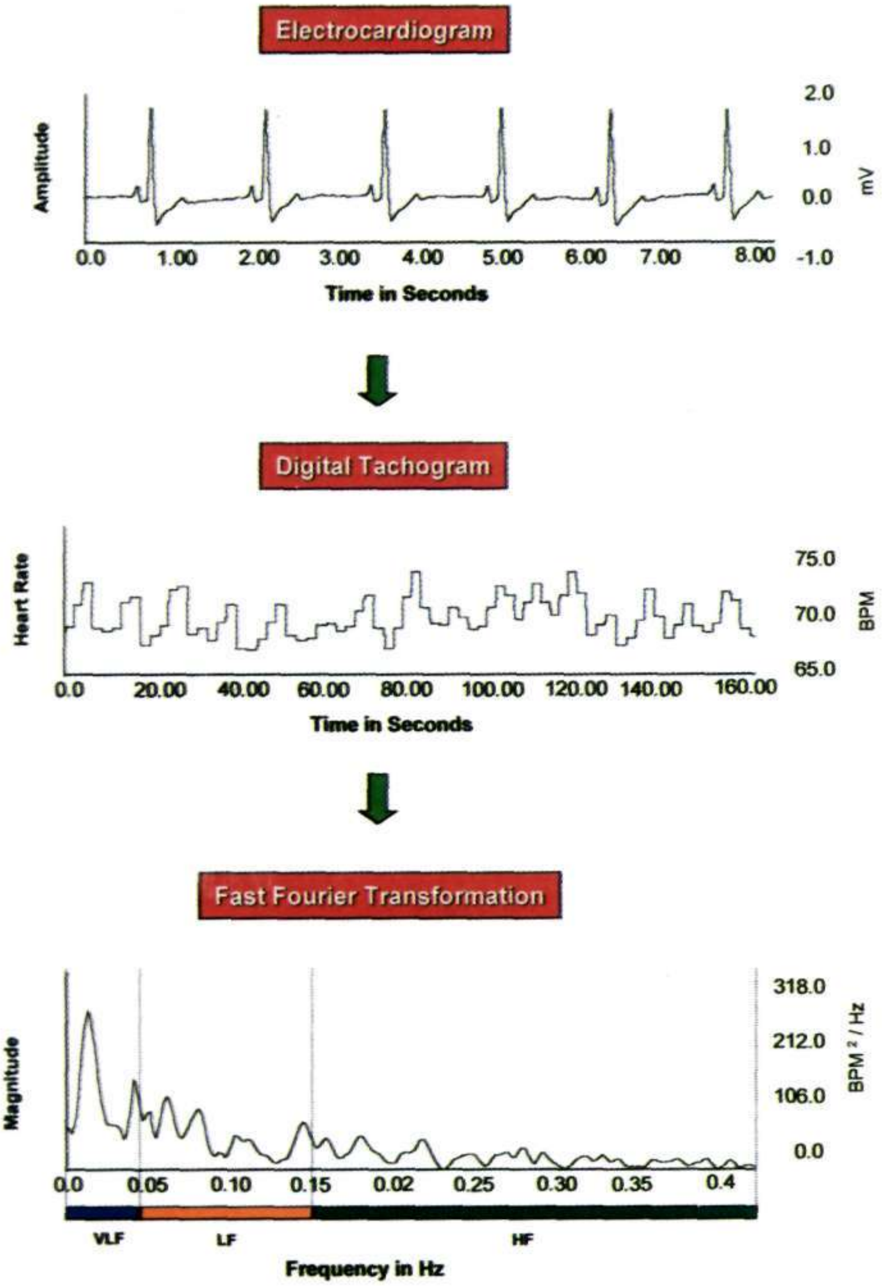


Fig. 1: Schematic Representation of Heart Rate Variability (HRV) Analysis of A Single Subject Recording

significant change during the voyage, but were found to be significantly increased on day 7th of arrival at Antarctica. The HR and SBP started declining thereafter and the mean values on day 30th and 60th of stay at Antarctica were not significantly different from the New Delhi values. As compared to SBP, the DBP on day 30 of stay at Antarctica was still significantly higher ($P<0.05$) and returned to New Delhi values by 60th day (Figure 2). The HR, SBP and DBP on day 60th of stay at Antarctica in the summer team members were not significantly different than the winter group values (Table 2).

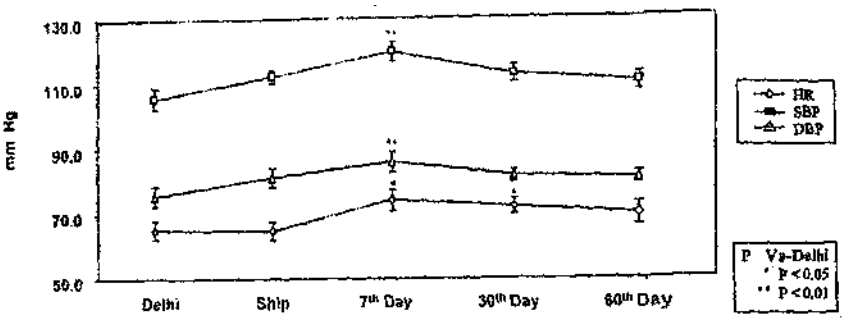


Fig. 2: HR, SBP & DBP on Different Days of Stay at Antarctica

Table 2: Physical Characteristics of Summer & Winter Members

	Summer (n=10)	Winter (n = 10)
HR (BPM)	72.8 ± 2.2	73.0 ± 3.6
SBP(mmHg)	121.6 ± 2.5	121.2 ± 2.5
DBP (mmHg)	82.2 +1,9	85.4 ± 2.4
OT (OC)	36.6 + 0.2	36.8 ± 0.3
SKT (OC)	31.0 ± 2.0	26.3 ± 3.0

Oral and skin temperature: The oral temperature (OT) did not show any significant change during the voyage or on arrival at Antarctica and the mean values were not significantly different than the winter team values (Figure 3, Table 2). The skin temperature (SKT) did not show any significant change during the voyage or on day 7 of arrival at Antarctica but showed a significant decrease on day 30th and 60th of stay. The skin temperature in winter team tended to decline but the values were not significantly different than the summer team day 60th values.

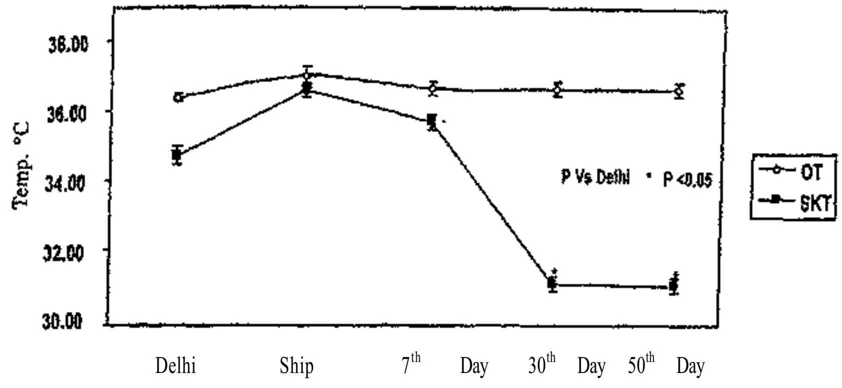


Fig. 3: Oral and Skin Temperature on Different Days of Stay at Antarctica

Orthostatic response:

Change in posture from supine to standing position significantly increased HR and DBP in the summer team at New Delhi and on different days of stay at Antarctica as well as in the winter group (Figures 4 and 5). However, the HR and DBP response to change in posture on different days of stay at Antarctica was not significantly different than the New Delhi values. Similarly in the winter team the HR and DBP response to change in posture was not significantly different than the summer team values. However, the SBP response did not show any significant change. The Crampton' s score derived out of delta HR with delta ABP tended to decline on day 7th of arrival and Antarctica in the summer team but the change

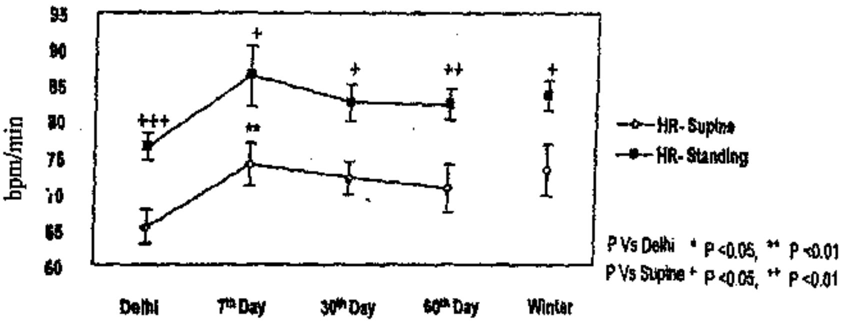
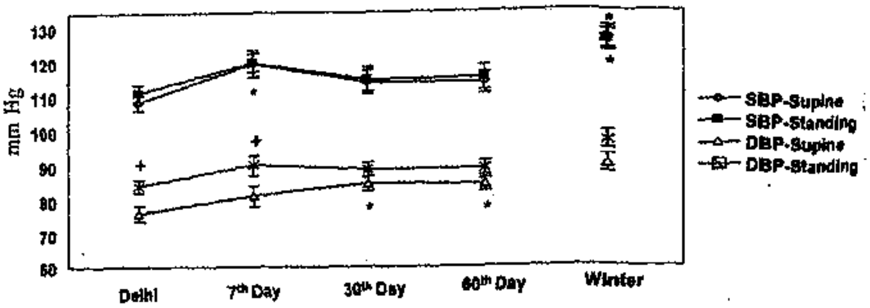


Fig. 4: HR, SBP & DBP Responses to Standing on Different Days of Stay at Antarctica



Fig, 5: HR, SBP & DBP Responses to Standing on Different Days of Stay at Antarctica

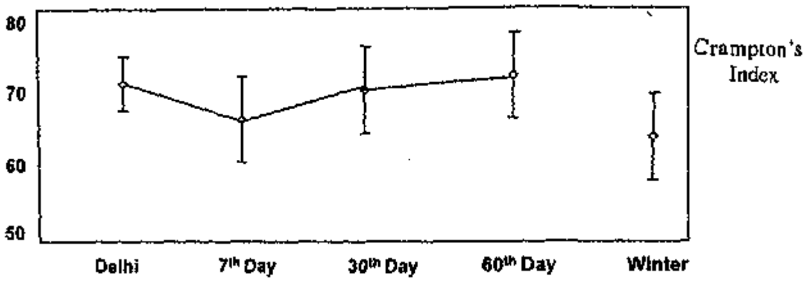


Fig. 6: HR, SEP & DBP Responses to Standing on Different Days of Stay at Antarctica

was not significant different. Similarly, in the winter group the Crampton's score was not significantly different than the summer team vales (Figure 6).

HRV response:

The LF power in supine position tended to increase on day 7th of arrival at Antarctica but was not significantly different. The LF power values as day 30th and 60* of stay at Antarctica were not significantly different than the New Delhi or winter team values. However, LF power response to change in posture from supine to standing position caused a significant increase on day 7th of arrival at Antarctica and started declining thereafter. In winter team members, the LF power response to standing was nor significantly different than the day 60th summer team values (Figure-7). The supine HF showed a significant decline on day 7th of arrival at Antarctica and started increasing thereafter. However, the HF power

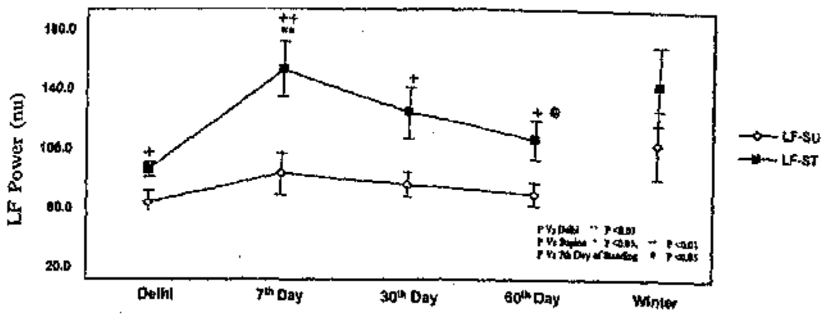


Fig. 7: HRV Response to Standing at Different Days of Stay at Antractica

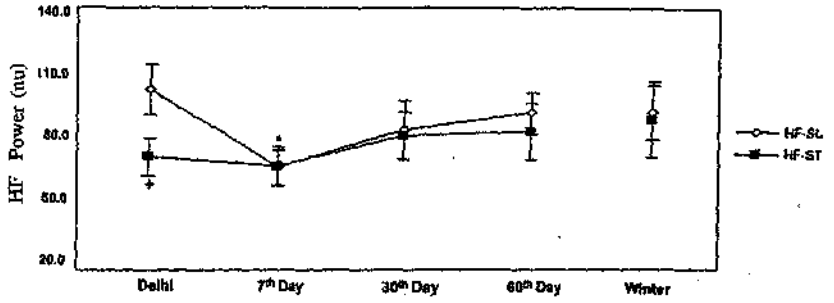


Fig. 8: HRV Response to Standing at Different Days of Stay at Antarctica

response to standing did not show any appreciable change (Figure 8). The LH/HF ratio showed a significant increase ($P<0.01$) on day 7th of arrival at Antarctica and started declining thereafter. However, the values were still significantly higher on day 30th of stay and returned to New Delhi values by day 60th. The supine LH/HF ratio in winter team was significantly higher ($P<0.05$) than the summer team day 60th values. Change of posture to standing position significantly increased ($P<0.01$) LF/HF ratio on day 7th of arrival and declined thereafter and the values on day 60th of stay were not significantly different than the winter team values (Figure 9).

Discussion

The study was aimed to investigate the role of sympathetic and parasympathetic components of the autonomic nervous system in HR

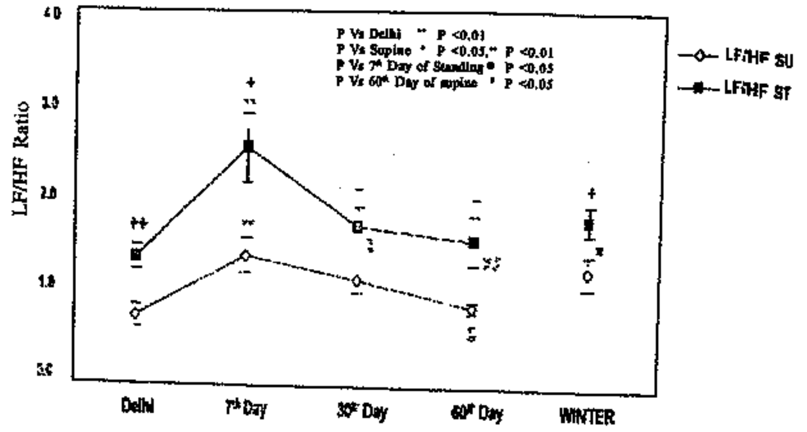


Fig. 9: HRV Response to Standing at Different Days of Stay at Antarctica

regulatory mechanisms during the course of acclimatization to severe cold at Antarctica.

Short term sojourn:

The present study showed that there is increase in heart rate and blood pressure in supine position at rest as well as during change of posture from supine to standing during initial days of arrival at Antarctica, which showed a decline on 60th day of stay. SKT as well as OT also showed a drop initially which was maintained low during the rest of the period of stays. These findings suggest sympathetic arousal during the initial period of stay at Antarctica and there was a shift autonomic equilibrium towards a parasympathetic side, after acclimatization.

The frequency spectral analysis of HRV a non invasive measure of autonomic sympathetic and parasympathetic reactivity confirms the similar phenomenon as the LF power an index of sympathetic activity (29) showed a significant rise during standing position on the 7th day of arrival and showed a significant decline on 60th day of stay at Antarctica. On the other hand HF Power a well proven marker of vagal restraint over the heart (29) showed a significant decline at supine position on 7th day, showed a trend of recovered on 30th and recovered significantly on 60th day of stay. The LF/HF ratio a sympathovagal balance (29) also showed a significant increase on 7th day and showed a significant decline on 60th day of stay.

This observation suggests that eight weeks of regular exposure to an Antarctic environment can trigger changes in physiological responses to cold in summer period towards acclimatization. This was mainly due to their assigned occupational duties by which they were required to undergo general exposure to atmospheric cold quite frequently and regularly. This also suggests that even comparatively mild cold extended over some weeks can be effective in triggering changes in physiological responses to cold. Attenuated sympathetic tone may lead to a gradual shift of in a autonomic balance towards parasympathetic dominance, which is likely to be responsible for increased cold tolerance (31 and 31). These findings corroborate with the observation of Rivolier, et al. (1988) at Antarctica. Almost similar findings have been reported from the studies conducted in the Arctic region and the Antarctica following different cold acclimatization patterns (33-41).

Long term sojourn :

Compared to summer, winter group showed high LF/HF ratio indicating the maintenance of higher sympathetic activity even after there prolonged residency at Antarctica suggesting that the cold acclimatization of man is not possible just by living in the coldest region of the globe even for prolonged period. This can be primarily due to insufficient frequency and severity of cold exposure (42). These subjects preferred behavioural adaptation with all the comforts and amenities available at the station, which is in accordance with an earlier finding (43).

Conclusion

Till very recently, physiologists were of the opinion that man is a tropical animal and he can get acclimatized to heat only, but not to cold. A remarkable reversal of this popular belief has come as a result of this study conducted in the extreme cold region of Antarctica, that acclimatization is possible even in Indian men normally living in a hot tropical climate, provided they allow their bodies to get exposed to ambient cold periodically, rather than just having lived in a cold environment for prolonged period. Thus regular exposure to ambient cold is a mandatory factor in developing cold acclimatization in human, which necessitates recording of the nature, duration and severity of cold stress to which the subjects are exposed.

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