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Body composition & cardiovascular functions in healthy males acclimatized to desert & high altitude

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Background & objectives: **Several physiological changes affecting physical fitness occur in humans whenever they are exposed to extremes of environments such as heat, cold and high altitude (HA). The present study was undertaken to evaluate effect of stay in desert and HA on physical fitness and body composition of physically active individuals.**

Methods: **Study was conducted on three groups of male soldiers (n=30 in each group) at different climatic conditions *i.e.,* temperate (plains of north India), hot desert (Rajasthan), and HA (3600 m) in Western Himalayas. Subjects were acclimatized to hot and HA environments and had similar BMI (body mass index). Body fat, lean body mass, haemoglobin levels were determined along with, blood pressure and physical fitness index (PFI).**

Results: **The body fat of subjects at temperate, desert and HA was found to be 15.4, 12.8 and 16.9 per cent respectively. The resting heart rate and blood pressure were higher in altitude group in comparison to others. PFI score of volunteers at temperate, desert and HA were found to be 97.4 ± 10.3, 92.4 ± 14.4 and 83.8 ± 6.2 respectively.**

Interpretation & conclusions: **A combination of different factors *i.e.,* higher resting pulse rate, increased blood pressure and body fat may be responsible for lower PFI at HA. The observed differences in body fat content of different groups could be an adaptive feature to the environment.**

Key words Body fat - cold - high altitude - hot desert - physical fitness index

Physical fitness of an individual depends on body composition, age, sex, training, nutritional status and environmental factors[1,2]. Human beings are able to live and work under different environments either by modifying the environment or by metabolic adaptation. Extreme climate of desert is characterized by hot dry environment whereas high altitudes (HA) (terrestrial heights > 2700 m above sea level) have cold and hypobaric hypoxia, which adversely affect human performance[3]. Various metabolic and physiological changes occur in human body for successful adaptation to environmental extremes[4]. High heat stress decreases performance and acclimatization helps in restoring work performance[5,6]. Similarly at HA physical work capacity and performance are reduced[7-10]. HA induction affects aerobic fitness directly by reducing in pO_2 in the lungs that compromises oxygen tension and per cent saturation of oxygen in arterial blood. The initial handicap of reduced oxygen availability is met by increased oxygen delivery through a greater amount of blood volume circulated by increased heart rate[9]. With acclimatization arterial oxygen content is increased to sea level value while $VO_{2\ max}$ remains reduced[10].

Regular physical activity has beneficial effects on the cardiovascular, respiratory and locomotor systems as well as on the general metabolism[11]. Determination of $VO_{2\ max}$ is the criterion to measure the cardiorespiratory fitness and is primarily limited by the oxygen transport capacity of the cardiovascular system[11,12]. However, measuring $VO_{2\ max}$ under field conditions is difficult. The Harvard Step Test[13] is economical and reliable test under field conditions to measure physical fitness. Several laboratories have validated the test score against the benchmark of $VO_{2\ max}$ per unit body weight for Indians[13,14].

Studies on effect of extreme environments on physical fitness and health are important because a large number of Indians live and work at HA and hot desert environments. The present study was therefore undertaken to evaluate effect of acclimatization to hot desert and HA on physical fitness and body composition of healthy individuals.

Material & Methods

Study design, volunteers and locations: This cross-sectional study was conducted on three different groups of healthy and physically active male subjects of similar age (range 20-30 yr) from Indian Army at three different locations (n=30 at each location). Group I, which with subjects working in temperate plain of north India was studied at Ferozpur (Punjab) during the first week of May (ambient temperature (T) = 30-35°C, RH 60-70%), Group II in desert conditions during summer season in June (T = 35-45°C, RH 40-50%) at Jaishalmer (Rajasthan). The study on group III was conducted at a location near Leh in Northern Himalayas at a height of 3600 m during second week of May (T= -4°C to 24°C, RH 50-60%). Subjects studied in hot environment were acclimatized for about 1 month whereas high altitude group spent 3-6 months at altitude of 2700-4300 m above mean sea level (MSL). Subjects were selected by simple random sampling procedure for which a list of 300 soldiers willing to participate in the study was prepared after applying exclusion criterion (any one who was not acclimatized to environment was excluded) at each location. Of these 300 volunteers, 30 were selected by picking out name chits in front of whole unit during morning assembly, a practice followed in army installations. Subjects were explained about the study and written consent was obtained. Study protocol was approved by the Institute's Ethic Committee. At temperate plains, volunteers were engaged in various activities for about 16 h while at mountains outdoor activities were restricted to daytime and in desert there was restriction on outdoor activity during midday due to hot winds. The three groups were almost identical with respect to age and dietary habits (Table I). They represented all parts of the country with majority from plains of north India. They were taking their meals from common mess at each location and intakes were considered adequate, as volunteers have not experienced any change in their body weight over the period of time.

Volunteers reported to field laboratory (set up by study team at each location) in morning hours (0700-0800 h) after over night rest. The resting heart rate (radial pulse count) and blood pressure (BP, diastolic and systolic) of volunteers were measured in supine position with adequate rest.

Analysis of body composition and haemoglobin: The height (cm) and body weight (kg) were recorded using calibrated height rod weighing scale of same make (Seca Ltd. Medical Scales and Measuring Systems, Bermingham, UK; least counts 1 mm and 100 g respectively). Body mass index (BMI) was calculated as weight/height^2 (kg/m^2).

Body fat content and lean body mass were measured using bioelectrical impedance analysis (BIA)[15] with a body fat analyzer using disposable electrodes (BF

Table I. Age, physical characteristics and dietary habits of volunteers

Study groups	Age (yr) (mean±SD)	Dietary habit		Smoking		Alcohol	
		Veg	Nonveg	Yes	No	Yes	No
1-Temperate plains	24.9 ± 2.8	7	23	3	27	4	26
II-Hot desert	23.7 ± 2.8	6	24	4	26	3	27
III-High altitude	24.5 ± 3.2	7	23	2	28	5	25

N=30 in each group

906, Maltron International Ltd., Rayleigh, Essex SS6 9SN, UK) using standard operating procedure of the equipment. The instrument was calibrated using Maltron calibration resistor MCR 1201-510 Ω. The instrument has resolution of measuring body fat in increments of 0.1 per cent with accuracy of 1.0 per cent across the impedance range of 350-1000 Ω respectively. The test was performed using four sensor pads applied to the hand, wrist, foot and ankle of the subject. The sites were cleaned with alcohol swab, properly wiped and allowed to dry before the application of the sensor pads. Details like height, weight, age, *etc*., were fed in the instrument as per instructions. A low-level battery current was then induced at 50 KHz through the sensor pads placed on the hand and foot and the drop due to impedance detected by sensor pads on the wrist and ankle. BIA measures were taken from right side of the body, laying down on non conductive surface in a normal ambient temperature. It was ensured that the legs and arms were apart. The volunteers were asked not to consume coffee or any alcoholic beverage 12 h prior to the tests.

Haemoglobin in venous blood with K_3 EDTA as anticougulant was measured photo-metrically with Drabkin's reagent using automatic Haematology analyzer (MS4, Melet Schloesing Laboratories, Codex, France).

Measurement of physical fitness indexes (PFI): PFI was measured under indoor conditions of field laboratory set up at each location and 2 h after light breakfast and rest. Harvard step test was used with a difference that stepping height of bench was kept 46 cm as per recommendations[16]. Individual stepped up and down at a rate of 30 steps per minute for 5 min or until exhaustion whichever was early and time in seconds was recorded using stopwatch. Exhaustion was defined as when volunteer could not maintain the stepping rate. The recovery heart rates (from radial pulse count) were measured at 1 to 1 ½, 2-2 ½, 3-3½ min of recovery. Physical fitness was scored as PFI = [Duration of exercise in sec x 100] / [2x (sum of 1 to 1 ½ min, 2-2 ½ min, 3-3 ½ min recovery heart rate].

Statistical analysis: The data were analyzed using prizm3 software (Graph Pad, USA). Levene's test[17] was done to test the homogeneity of variance for all the variables while performing ANOVA. Comparisons between different groups were made using one way ANOVA with Newman-Keuls multiple comparison test and the $P \leq 0.05$ was considered significant. Significance of correlation coefficient was tested by using t-test.

Table II. Body composition, haemoglobin content, physiological variables and physical fitness index (PFI) score of volunteers in different group.

Variable	Temperate plains	Hot desert	High altitude (3600 m)
Age (yr)	24.9 ± 2.8	23.7 ± 2.8	24.5 ± 3.2
Height (cm)	172 ± 4.9	170 ± 4.4	171 ± 6.6
Weight (kg)	64.3 ± 7.2	62.2 ± 5.6	64.1 ± 6.2
BMI (kg/m^2)	22.7 ± 1.8	21.5 ± 1.8	22.1 ± 2.3
Fat (%)	15.4 ± 4.2	12.8 ± 3.9$^+$	16.9 ± 4.2*
Fat (kg)	10.02 ± 3.4	8.04 ± 3.05$^+$	10.8 ± 3.7*
Lean body mass (kg)	54.8 ± 5.3	54.1 ± 3.61	53.2 ± 4.2
Haemoglobin (g/dl)	14.3 ± 1.0	14.2 ± 1.4	17.5 ± 1.3^{++},*
Resting heart rate (Beats/min)	70.6 ± 8.7	64.2 ± 8.5^{++}	80.4 ± 9.4^{++},*
Blood pressure-systolic (mm Hg)	110.7 ± 20.1	108.8 ± 10.8	128.0 ± 12.4^{++},*
Blood pressure-diastolic (mm Hg)	65.8 ± 9.1	65.7 ± 10.0	77.9 ± 8.0^{++},*
PFI	97.4 ± 10.3	92.4 ± 14.4	83.8 ± 6.2^{++},*

Values are mean ± SD (n=30 in each group)
*P<0.01 in comparison with hot desert
P^+<0.05; $^{++}$<0.01 in comparison with temperate plains

Results

Significantly lower levels of body fat were observed in volunteers studied under hot desert conditions as compared to temperate plains (P<0.05). On the other hand, fat content was significantly higher (P<0.01) in the group studied at high altitude compared to desert group, although all the three groups had similar BMI. The lean body mass was almost similar in all the groups (Table II). The volunteers of the three groups had almost similar dietary habits (vegetarian and non-vegetarian) and lifestyle *i.e.,* consumption of alcohol, therefore, effect of these variables were not separately analyzed.

Haemoglobin levels of volunteers in temperate and hot desert conditions at sea level were similar. At high altitude blood haemoglobin content were higher (P<0.01) in comparison to sea level (Table II).

Resting heart rate was found elevated in subjects stationed at high altitude in comparison to other two groups. Subjects stationed at hot desert condition have lower resting heart rate in comparison to groups studied at temperate plains and high altitude (P<0.01). Systolic and diastolic blood pressures were also significantly

Table III. Correlation of PFI with resting heart rate, fat content and BMI of volunteers of different groups

Study group	Variable	Correlation coefficient	*P* value
Temperate plains	Resting heart rate	-0.248	>0.05
	Fat %	-0.321	>0.05
	Fat mass in kg	-0.250	>0.05
	BMI	-0.244	>0.05
Hot desert	Resting heart rate	-0.513	<0.01
	Fat %	-0.287	>0.05
	Fat mass in kg	-0.269	>0.05
	BMI	-0.235	>0.05
High altitude	Resting heart rate	-0.416	<0.05
	Fat %	-0.191	>0.05
	Fat mass in kg	-0.274	>0.05
	BMI	-0.213	>0.05

Not significant (ns)

high (P<0.01) in high altitude acclimatized volunteers as compared to other groups. There was no significant difference in blood pressures between volunteers working in temperate plains and hot desert condition. Significantly lower physical fitness index (P<0.01) was observed in volunteers stationed at high altitude when compared with volunteers at temperate sea level and hot desert conditions (Table III). The PFI had shown a negative correlation with both the resting heart rate and fat percentage (Table III). However, statistically significant correlation was seen only between PFI and heart rate in case of desert (r- 0.513, P<0.01) and high altitude group (r -0.416, P<0.05).

Discussion

Body fat plays a key role in energy storage and metabolic homeostasis along with thermoregulation. The range of total body fat associated with optimum health is 8-24 per cent in males and 21-35 per cent in females[18,19]. However, levels may be in lower range for active individuals and elite athletes[19]. Very low amount of fat mass in Indian soldiers has been reported by Bhardwaj *et al*[20] on prolonged exposure to altitude. They have reported slight increase in fat mass after 10 months stay at an altitude of 3750 m in comparison to basal using anthropometric measurements. In another study[21] no change in fat% was observed after acclimatization. Since redistribution of body fat is reported at HA[22], which can affect the measurement of fat content. Therefore in the present study we have used BIA method for determination of body fat. BIA method measures fat content accurately in case of active individuals such as athletes and is easy to use in field conditions[23]. The higher level of fat mass observed by us in high altitude acclimatized subjects and lower fat levels in hot environment may be an indicator of adaptation. Subcutaneous fat acts as the insulating layer for thermoregulation and adiposity may be influenced by environmental temperature. However, the cross-sectional nature of present study does not allow us to draw a definite conclusion.

The haemoglobin levels were in higher range at high altitude. The increase in haemoglobin levels during acclimatization to altitude is well documented[3,21]. Since these subjects were acclimatized for 3-6 months at altitude therefore higher haemoglobin levels were persistent.

Resting heart rate was found to be lower in case of desert group and this is considered as a feature of heat acclimatization of volunteers[14]. Resting heart rate increases initially under hot environment, which subsequently decreases with 3 days of successful acclimatization[14].

Measuring VO_2 max under field conditions is a difficult task and therefore the Harvard step test was used to measure physical fitness under field conditions. Several laboratories have validated the test score against the benchmark of $VO_{2\,max}$ per unit body weight for Indians[13,14]. However, the studies on Indians using physical fitness scores are limited to field workers, school children, and players with limited number of subjects or restricted to a particular sub population[13,14].

Physical fitness scores were lower in desert group, though it was not statistically significant in comparison to group studied under temperate environment at plains. It is reported that aerobic function drops with rise in environmental temperature[24]. The ambient temperature is a main confounder in studies using step test[25] and to minimize this the test was performed in indoor laboratory set up where temperature was maintained at 25-27°C.

The PFI scores were significantly low in case of high altitude acclimatized group compared to other two groups. High altitude exposure is known to cause decrease in physical work capacity in lowlanders[3,26]. At high altitude (3000-8000 m), full recovery of aerobic capacity is never achieved[27]. PFI scores obtained in the present study were similar to those reported in road construction workers at high altitude in an earlier study[28]. The negative correlation between PFI and resting heart rate has been reported by various workers[29,30]. Since step test is based on recovery in heart rate, the higher basal values have negative impact on performance. Significance of resting pulse rate in relation to physical fitness and training is well documented in early studies using Harvard step test[29,30]. The subjects having lower values of basal heart rate generally show better recovery after exercise still it cannot be taken as single predictive marker of fitness[29]. Low PFI scores indicate that bioavailability of oxygen at tissue level is not restored even after a stay at HA for more than three months although haemoglobin content was also significantly high. Lundby *et al*[10] have shown reduction in maximal blood flow and oxygen conductance in legs during exercise at HA as possible reason of low $VO_{2\ max}$.

The combination of different factors such as higher resting pulse rate, increased blood pressure and body fat may be responsible for lower PFI observed at altitude. The observed differences in body fat content of different groups could be an adaptive feature to the environment. A longitudinal study under different climates with acclimatization and sufficient rehabilitation time in between the change over from one to another climate is required to confirm the findings.

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