Coll. Antropol. **29** (2005) 1: 37–43
UDC 572.512:612.21(540)
Original scientific paper

Body Structure and Respiratory Efficiency among High Altitude Himalayan Populations

Satwanti Kapoor and Anup Kumar Kapoor

Department of Anthropology, University of Delhi, Delhi, India

A B S T R A C T

To understand the morphological and physiological variations among the temporary and permanent residents of high altitude, this study was undertaken at Leh, Ladakh. It is situated at 3500 m (11500 feet) above sea level, the mean barometric pressure was 500 tors and air temperature varied from 2 °C to 20 °C. The highland Tibetans showed broadest chest and most developed musculature closely followed by Ladakhi Bods. These high altude natives also displayed significantly higher value of vital capacity, forced vital capacity, and inspiratory capacity. The better respiratory efficiency observed among high altitude residents indicates higher degree of adaptation to high altitude hypoxia. Temporary residents were observed to be tallest and fattest with lower trunk fat predominance of all the four groups and showed narrowest chest and lower respiratory efficiency as compared to high altitude natives. The duration of stay at high altitude has clearly brought about a perceptible difference in body dimensions and respiratory functions of various groups of adult males studied at same altitude.

Key words: *hypobaric hypoxia, adaptation, permanent and temporary residents*

Introduction

It has been proven beyond doubt that genetic factors guide the course to maturity and the environmental factors accelerate or retard this course. This explains to larger extent, the differences in body structure among different population groups. The important factors to affect the human morphology and physiology are extremes of environmental temperature, nutrition and altitude.

Millions of people of the world live permanently at an altitude of 3000 m or above and are exposed to harsh environmental conditions of high altitude, which comprises of a mosaic of stresses namely hypoxia, cold, rugged terrain, high solar radiation and limited resources etc. It is a common observation that striking differences exists between high and low altitude human populations with respect to various biological traits[1–3].

Several morpho-physiological and demographic studies have been carried out in different high altitude populations worldwide to study the pattern of growth and development, sexual maturation, structural, compositional and physiological variations[4–18].

Although effect of high altitude could be felt on growth and development in almost all these studies, they have yielded inconclusive results with respect to existence of large deep chest. Comparison of high land Asian populations with high land Andean populations revealed that chest circumferences of high altitude Sherpa children in Himalayas in Nepal, Kirghiz children in Pamirs in the Soviet Union and Tibetan boys in India were smaller as compared to their Quechua counterparts in Peru[5,19,20]. According to Beall[21], although the universal problem at high altitude is to deliver sufficient oxygen to maintain aerobic metabolism under conditions of reduced O_2 availability, the solution to that problem varies from population to population.

Apart from slow rate of growth, delayed adolescent spurt, a trend towards increase in age at menarche with increase in altitude had also been observed[22]. But the total fertility period remained similar as early menarche has been found to be associated with early onset of menopause and late menarche with late menopause[23].

Even though the pervasive stress of hypoxia has not changed in its properties nor the humans have been able to conquer over this stress there seems a definite improvement in the other environmental condition over

Received for publication March 4, 2003

time as is apparent from secular trend in stature observed among Himalayan populations[24].

Besides morphometry and respiratory differences, the low and high altitude people also displayed variations in body composition and regional distribution of body fat[25,26]. Body composition of human beings is an important aspect of study as it undergoes adaptive changes, when faced with environmental stresses. The stress can be temperature extremes, high altitude or changing physical activity levels. Most of body composition oriented studies have been conducted on Indian soldiers, either native of high altitude or sea level residents during their sojourn at high altitude. Although significant body composition changes have been observed among sea level troops when they were posted at Leh, paradoxically the body composition of high altitude natives and sea level residents was not much different from each other[27]. On prolonged stay at high altitude, the soldiers from plains exhibited a significant decline in body fat content despite better nutrition but without much change in body weight thereby indicating a simultaneous increase in lean body. Whereas inspite of reduced calorie, the high altitude native on their descent to plains showed greater fat content than the group located at high altitude. These high altitude natives were also hyperhydrated and it could be an adaptive response to the changed environment of plains[25].

Kapoor[26] studied the pattern of subcutaneous fat distribution among young adult females at high altitude and in plains. The high land females were found to exhibit a different fat storage pattern as compared to the females in the plains. A more uniform distribution of subcutaneous fat was observed among the high altitude females and they also had relatively more fat in the trunk region as compared to their counterparts in the plains.

The studies conducted so far on high altitude populations presents data mostly on the growth aspects and nearly all of them have reported that the growth in height and weight at high altitude is delayed as compared to sea level norms. Work on morphology and associated lung functions of adults belonging to different ethnic groups but residing at same altitude is relatively less. Beall[28] points that a comparison of recently arrived and long established high altitude population can be useful in distinguishing between physiological or developmental acclimatization and genetic adaptation that might occur among high altitude natives. So the present study was undertaken to assess the differential adaptation of various population groups (permanent and temporary residents) to high altitude stresses and also to find out if better respiratory efficiency is reflected in chest dimension or not.

Materials and Methods

This study was carried out at Leh, the district headquarter of Ladakh. It is situated at an altitude of 3500 meters above sea level. The maximum temperature inside the laboratory was 18 °C and that outside was 20 °C. The minimum temperature inside the laboratory was 16 °C and outside it was 2 °C. The wind velocity was 27.4 MPH and the water boiled at 89 °C. The work was undertaken on 88 adult male subjects who volunteered to participate in the study after its nature and purpose had been explained to them. They were physically fit and free from any disease and none of the group was malnourished. The subjects were divided in to the following 4 groups:

- Group 1: 27 Ladakhi Bods (LB) living permanently at an altitude of 3500 meters (m) or more. They were all born and brought up at Leh and had never visited the low altitude (age range: 20–34 years).
- Group 2: 20 Ladakhi Muslims (LM) living permanently at an altitude of 3500 m or more (age range: 20–35 years).
- Group 3: 21 Tibetans (TT) whose parents were permanent residents of Tibet and they later migrated to India about four decades back (age range: 20–34 years).
- Group 4: 20 Temporary residents of Leh (TR) who had come from low altitude and had stayed at 3500 m or more for a period of 6 to 12 months prior to study (age range: 20–35 years).

The Ladakhi Bods were the first settlers in Ladakh followed by Muslims around the middle of 14th century; Tibetan invasion started around 1646[29], but the majority migrated from Tibet about four decades earlier.

Using standardized techniques as described by Weiner and Laurie[30], the following body measurements were taken on each subject: body weight, stature; biacromial, bitrochanteric, chest, elbow, wrist, knee and ankle diameter; chest circumference (during normal respiration and maximal inspiration), waist circumference, abdominal circumference, hip circumference, upper arm circumference, wrist circumference, thigh circumference, calf circumference and ankle circumference; biceps, triceps, subscapular, abdominal and suprailiac skin fold thicknesses. Besides anthropometrics measurements, several lung functions were measured like vital capacity (VC), forced vital capacity (FVC), Forced expiratory volume in first second FEV_1, peak expiratory flow (PEF), maximum voluntary ventilation (MMV), inspiratory capacity (IC) and breath holding time (BHT).

All the body measurements were recorded in centimeters except body weight, which was recorded in kilograms and skinfold thicknesses which were recorded in millimeters. Skinfold thickness were measured with the help of Holtain skinfold calipers to the nearest 0.2 mm, a flexible steel tape was used for measuring circumferences to the nearest 1mm, spring weighing machine was used for taking body weight to the nearest 0.5 kg and anthropometer for taking stature to the nearest 1 mm. The lung functions were measured using computerized pulmonary function test apparatus, which consisted of a wedge spirometer, cathoderay oscilloscope, computer and recorder. The systemic blood pressure was measured by aneroid sphygmomanometer from brachial artery.

Results

The basic data of the subjects in all the four groups are given in Table 1. The means and standard deviation of various body diameters, circumferences and skinfold thicknesses are presented in Table 2. To know the significance of the difference between two sample means 't' test was applied, its value with level of significance is presented in Table 3. The various lung volumes and capacities are presented in Table 4 as means and standard deviation along with values of 't' and its level of significance.

The Ladakhi Bods were the heaviest among the four groups studied followed by Tibetans and the lightest were Ladakhi Muslims. The differences in mean body weight of the four groups of subjects were however statistically non-significant.

Temporary residents were the tallest of the lot and Ladakhi Muslims were the shortest. The differences in the stature between Ladakhi Muslims and Tibetans and that between Ladakhi Muslims and Temporary residents and between Bods and Temporary resident were statistically significant.

The four groups of subjects were not statistically significant for biacromial diameter, but Temporary residents, however, had the broadest shoulder. The Ladakhi Bods and Tibetans showed the broadest hips. However the differences for bitrochanteric width between various groups were statistically non-significant. The Temporary residents were fattest of all the groups as evident from their skin old thickness measurement values.

The Tibetans had the broadest chests as evident from chest measurements and Temporary residents showed the smallest mean values for the all the chest measurements. The second largest chest was displayed by the Ladakhi Bods. The chest circumference (normal) of Bods and Tibetans showed statistically significant difference when compared with Temporary residents. The chest circumference (max. inspiration) showed significantly higher value ($p<0.01$) in Ladakhi Bods and Tibetans as compared to Temporary residents.

The values of various lung functions also varied between different groups. The vital capacity lit. BTPS (VC) and forced vital capacity lit. BTPS (FVC) were significantly higher in Ladakhi Bods and Tibetans as compared to Temporary residents. There was however no significant difference between the values of forced expiratory volume in first second lit. BTPS ($FEV_{1.0}$) between

TABLE 1
THE BASIC DATA OF THE SUBJECTS IN DIFFERENT GROUPS

Subjects	N	Age (years) Mean±SD	Weight (kg) Mean±SD	Height (cm) Mean±SD
Ladakhi Bods	27	24.4±4.6	57.8±5.4	164.3±6.4
Ladakhi Muslims	20	27.1±4.2	53.8±3.9	161.8±3.8
Tibetans	21	24.9±3	56.4±6.4	165.9±6.4
Temporary Residents	20	26.4±3.8	54.8±4.3	167.2±3.9

TABLE 2
ANTHROPOMETRIC MEASUREMENTS OF THE SUBJECTS IN DIFFERENT GROUPS

Variables	Ladakhi Bods Mean±SD	Ladakhi Muslims Mean±SD	Tibetans Mean±SD	Temporary Residents Mean±SD
Biacromial Diameter (cm)	36.5±1.3	36.4±1.3	36.6±2.5	37.0±1.4
Bitrochanteric Diameter (cm)	30.1±1.5	29.4±1.4	30.0±1.3	29.7±0.9
Chest Diameter (cm)	26.9±1.7	26.6±1.2	27.3±2.2	25.3±1.3
Chest Circumference (normal)	82.8±4.0	82.4±3.2	83.7±5.4	80.0±3.1
Chest Circumference (max. inspiration) (cm)	87.5±3.6	86.1±3.1	87.6±5.3	83.8±3.3
Biceps Skinfold (mm)	3.1±1.1	3.0±0.6	3.1±0.6	3.3±1.1
Triceps Skinfold (mm)	6.6±2.6	5.8±2.0	6.1±1.7	6.7±3.4
Subscapular skinfold (mm)	7.4±1.8	7.7±1.7	7.5±1.2	8.1±2.3
Abdominal skinfold (mm)	7.3±3.9	7.7±2.8	6.8±2.3	11.6±6.0
Suprailiac skinfold (mm)	5.8±2.3	6.7±2.6	6.0±2.4	8.3±4.5

TABLE 3
VALUE OF t-TEST AND ITS LEVEL OF SIGNIFICANCE FOR VARIOUS BODY MEASUREMENTS

Variable	Muslims vs. Bods 't' level of significance	Muslim vs. Tibetans 't' level of significance	Muslim vs. Temp. Resi. 't' level of significance	Bods vs. Tibetans 't' level of significance	Bods vs. Temp. Resi. 't' level of significance	Tibetans vs. Temp. Resi 't' level of significance
Weight	0.30 ns	1.59 ns	1.29 ns	–1.68 ns	–0.98 ns	0.94 ns
Stature	–0.86 ns	–2.55 p<0.05	4.49 p<0.01	–1.55 ns	–2.40 p<0.05	–0.81 ns
Biacromial diameter	–0.06 ns	–0.33 ns	–1.61 ns	–0.04 ns	0.31 ns	–0.78 ns
Bitrochanteric diameter	–1.56 ns	–1.57 ns	–0.94 ns	0.42 ns	0.84 ns	0.79 ns
Chest diameter	0.63 ns	–1.37 ns	–3.17 p<0.01	–0.70 ns	3.25 p<0.01	–3.55 p<0.01
Chest Circumference (normal)	–0.34 ns	–0.95 ns	1.00 ns	–0.21 ns	2.42 p<0.05	2.69 p<0.01
Chest Circumference (max.inspiration)	1.30 ns	0.32 ns	2.28 p<0.05	0.04 ns	3.37 p<0.01	2.72 p<0.01
Biceps skinfold	–0.46 ns	–0.47 ns	0.27 ns	0.11 ns	–0.73 ns	–1.03 ns
Triceps skinfold	–1.09 ns	–0.45 ns	–0.01 ns	0.80 ns	–0.11 ns	–0.84 ns
Subscapular skinfold	0.43 ns	0.33 ns	0.66 ns	–0.38 ns	–0.01 ns	–1.00 ns
Abdominal skinfold	0.36 ns	2.45 p<0.05	–2.60 p<0.05	1.10 ns	–4.17 p<0.001	–4.77 p<0.001
Suprailiac skinfold	2.14 p<0.01	2.13 p<0.05	–0.84 ns	–0.31 ns	–2.21 p<0.05	–2.00 ns

ns = non significant

TABLE 4
LUNG FUNCTIONS AND BLOOD PRESSURE OF THE SUBJECTS IN DIFFERENT GROUPS

Variables	Ladakhi Bods Mean±SD (1)	Ladakhi Muslim Mean±SD (2)	Tibetans Mean±SD (3)	Temporary Residents Means±SD (4)	Significance of the difference
VC l. BTPS	4.9 ± 0.5	4.5 ± 0.3	4.8 ± 0.8	4.3 ± 0.5	1vs4 (p<0.001) 3vs4 (p<0.001)
FVC l. BTPS	4.8 ± 0.6	4.4 ± 0.3	4.7 ± 0.8	4.2 ± 0.5	1vs4 (p<0.001) 3vs4 (p<0.05)
FEV_1 l. BTPS	3.8 ± 0.9	3.4 ± 0.7	4.1 ± 0.7	3.7 ± 0.4	ns
FEV_1 /FVC%	80.1 ± 12.6	78.3 ± 12.4	88.0 ± 10.9	87.7 ± 0.3	1vs4 (p<0.05) 2vs4 (p<0.01)
IC l. BTPS	3.4 ± 0.7	3.0 ± 0.4	3.1 ± 0.6	2.8 ± 0.4	ns
MVV l. /min BTPS	173.1 ± 41.4	152.8 ± 28.3	181.9 ± 35.7	172.8 ±24.1	2vs4 (p<0.05)
PEF l./sec BTPS	6.9 ± 2.3	7.3 ± 1.8	7.0 ± 2.0	6.8 ± 1.9	ns
BHT (sec)	36.3 ± 11.3	34.6 ± 10.4	36.7 ± 13.4	29.6 ± 8.0	ns
Systolic Blood Pressure (mmHg)	120.1 ± 9.2	118.9 ± 8.4	116.5 ± 7.5	119.5 ± 6.4	ns
Diastolic Blood Pressure (mmHg)	84.1 ± 7.2	86.2 ± 8.5	80.7 ± 5.9	83.8 ± 3.6	3vs4 (p<0.05)

ns = non significant

diffent groups as also for peak expiratory flow lit. $BTPS/_{sec}$ (PEF) and inspiratory capacity lit. BTPS (IC). The breath holding time (BHT) was lowest in Temporary residents.

No significant difference was noted in the systolic blood pressure (SBP) in any of the four groups studied. Diastolic blood pressure (DBP) was significantly higher (p<0.05) in TR as compared to TT but between rests of the groups it was non-significant. The blood pressure value was within normal limits in the entire four groups studied. Hultgren[31] reported that longer duration of the residence at high altitude, decreased SBP more. Diastolic blood pressure was affected less than SBP.

Body fat, which is both essential as well as hazardous, depending on its quantity, has drawn attention of scientist in the field of human biology and medicine for a considerable time. Literature is full of studies on adiposity, obesity and its possible association with degenerative diseases. Of late it has been found that not only the quantity of fat but also the way it is distributed in the

TABLE 5
MEASURES OF ADIPOSITY AND REGIONAL DISTRIBUTION OF FAT IN SUBJECTS OF DIFFERENT GROUPS

Variable	Ladakhi Bods	Ladakhi Muslims	Tibetans	Temporary Residents
BMI (kg/m^2)	21.4	20.5	20.5	19.6
GMT (mm)	5.9	6.2	5.74	7.6

body is also very important. The various measures of adiposity and regional distribution of fat in different group of subjects have been presented in Table 5.

Body mass index (BMI) has been used extensively as an index of obesity or overweight. It is determined as weight divided by stature^2 in meter. The BMI values of temporary residents were the lowest followed by LM and TT. Ladakhi Bods had maximum value of BMI.

The Tibetans were the leanest when the Grand Mean Thickness (GMT) in various groups was compared and Temporary residents were the fattest.

To assess the distribution pattern of subcutaneous fat, the skinfold sites were arranged in ascending order of their thickness for the Temporary Residents. The skinfold thickness at five sites in LB, LM and TT were arranged accordingly. The distribution pattern of subcutaneous fat so obtained for all the four groups of subjects has been presented in Figure 1. Although the site of minimum fat stores remained biceps skinfold thickness the site of maximum fat store differed from group to group. In the Temporary Residents the abdomen site stored maximum fat where as in LB and TT it was the subscapular site and in LM who were leanest of all, both subscapular and abdomen sites were equal in subcutaneous fat storage.

The pattern of subcutaneous fat distribution was as follows:

TR: Biceps<Triceps<Subscapular<Suprailiac<Abdomen

LB: Biceps<Triceps<Suprailiac<Abdomen<Subscapular

LM: Biceps<Triceps<Suprailiac<Abdomen=Subscapular

TT: Biceps<Triceps<Suprailiac<Abdomen<Subscapular

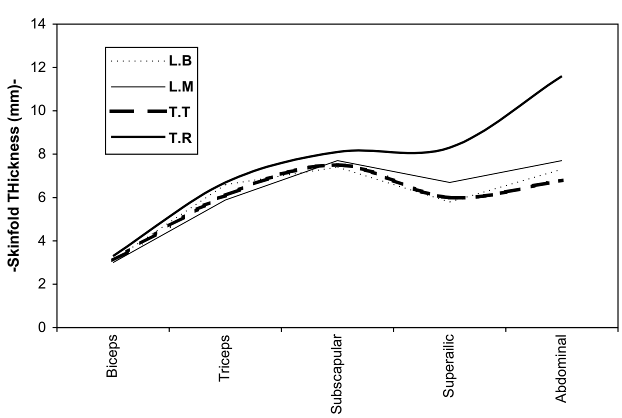

Fig 1. Distribution pattern of subcutaneous fat in different group of subjects.

Discussion

It has been revealed from the results that Ladakhi Bods were heaviest; Tibetans showed broadest chests and most developed musculature closely followed by Ladakhi Bods. The Ladakhi Bods possessed broadest hips and broadest lower trunks. Temporary Residents were tallest and fattest of all the four groups and showed narrowest chests.

Khalid[16] also observed high altitude residents (3150 m above sea level) to be significantly heavier but not different in fat mass as compared to low altitude males in Saudi Arabia. The highland females on the other hand showed significantly higher fat mass and fat mass index as compared to low land females. He attributed these differences in physiques to the effect of environmental factors.

The highlanders in the present study were leaner than temporary residents thereby displaying an impact of high level of habitual physical activity in the harsher environment of high altitude. Kapoor[26] found the high altitude adult females to be leaner and to store more fat on the trunk region as compared to females from plains, thereby pointing towards the fact that not only the quantity of fat but also the way it is distributed over the body's surface differs among females inhabiting two contrasting environmental situations.

The larger chest among the high altitude natives as also found by Frisancho[32], Greska and Beall[33], may be a morphological trait associated with the pulmonary structural adaptation to high altitude hypoxia. The larger chest dimensions were also found to be associated with superior respiratory efficiencies in Ladakhi Bods and Tibetans as displayed by larger VC, FVC and IC values in them. The Temporary Residents were least acclimatized as they showed significantly less PEF, FVC, VC and BHT but significantly high MVV. This difference between high altitude natives and temporary residents giving them differential level of adaptation may be a direct consequence of hypoxaemia[32,34] during growing/developmental period influencing the growth of lungs resulting in larger size as is found among Ladakhi Bods and Tibetans. The decreased VC in TR may be due to a decrease of maximum force of expiratory muscles causing a failure to exhale as much as at sea level[35]. The BHT was markedly reduced in Temporary Residents as compared to high land natives. It has been noticed that the BHT at high altitude in general was reported to be significantly less than the sea level values, which is about 52 seconds. A better respiratory efficiency among highlanders as adjudged from FVC values was also observed among Quechua[36] and among Sherpas[37,38].

The differences in more pulmonary function tests between HA natives & TT are published elsewhere[39]. It is apparent that 6–12 months period of stay at high altitude is not sufficient to bring about the same degree of acclimatization as demonstrated by Ladakhi Bods as they were inhabiting the high altitude for many generations and the Tibetan migrants had their parents migrated to India during Chinese aggression on Tibet almost four decades back. The Tibetan migrants in the present study were born and brought up in India, their parents were permanent residents at Tibet. Besides of genetic origin, the larger lung dimension and superior lung capacity of Ladakhi Bods and Tibetan migrants could also be attributed to high level of habitual physical activity rendering them better adaptability to low oxygen tension at HA. Their type of acclimatory change might be a direct consequence of hyoxaemia during developmental period influencing the growth of the lungs and consequently of chest morphometry.

Besides respiratory and body measurements the subjects from plains also differed with respect to total body fat and subcutaneous pattern of fat distribution.

The high altitude natives were more robust as compared to lowlanders on the basis of their BMI values. It in contrast to the finding on Kirghis highlanders who had lower values of BMI as compared to their counterparts from low altitude[40].

The present study however points towards the limitation of BMI as an index of obesity. The temporary residents who by virtue of lower BMI could be classified relatively less overweight compared to the HA subjects, were in fact the fattest as evident from their skinfold thickness values. So the use of BMI with skinfold thickness would provide a better insight into the body composition of an individual.

On the basis of fat profile of high altitude natives and lowlanders, the upper trunk fat predominance is clear in the former. Although a clear age related re-distribution of fat in favour of trunk has been reported[41,42] among the highlanders who have yet not reached their mid-age their pattern may provide some adaptive advantage to the delicate organs situated in the upper trunk region against the harsh climatic status of high altitude. To sterns then this hypothesis more data is needed exclusively on distribution pattern at subcutaneous fat among the highlanders.

Acknowledgements

The financial assistance from I.C.M.R. and the co-operation of all subjects is gratefully acknowledged. S. K. and A. K. K. are thankful to UGC for providing Career Award and Research Award respectively.

REFERENCES

1. BAKER, P. T., M. A. LITTLE.: Man in the Andes. A Multidisciplinary Study of High Altitude Quechua. (Dowden, Hutchinson and Ross, Stroudsburg, Pa, 1976). — 2. BAKER, P. T.: The Biology of High Altitude People (Cambridge Univ. Press, 1978). — 3. KAPOOR, A. K., S. KAPOOR: Study of some haematological traits among high altitude human population. In: SELVAMOORTY, W. (Ed.): Contribution to Human Biometeorology. (Academic Publishing, The Netherlands, 1987). — 4. HANNON, J. P., J. L. SHIELDSAND, C. W. HARRIS, Am. J. Phys. Anthrop., 31 (1969) 77. — 5. FRINSANCHO, A. R., P. T. BAKER, Am. J. Phys. Anthrop., 32 (1970) 279. — 6. MIKLASHEVSKAYA, N. N., J. S. SOLOVYEVA, E. Z. GORDINA, V. M. KONDIK: Growth process in man under conditions of high mountains. (Transactions of the Moscow Society of Naturalists. 43, 1972). — 7. BHARADWAJ, H., Hum. Biol., 44 (1972) 303. — 8. BEALL, C. M., P. T. BAKER, T. S. BALER, J. D. HASS, Hum. Biol., 49 (1977) 109. — 9. MUELLER, W. H., W. N. SCHULL, N. J. SCHULL, P. SOTA, F. ROTHHAMMER, Ann. Hum. Biol., 5 (1978) 329. — 10. STINSON, S., A. R. FRINSANCHO, Hum. Biol., 50 (1978) 57. — 11. STINSON, S., Am. J. Phys. Anthrop., 52 (1980) 377. — 12. SCHUTTE, J. E., R. E. LILLJEQVIST, J. R. JOHNSON, Am. J. Phys. Anthrop., 61 (1983) 221. — 13. GREKSA, L. P., H. SPIELVOGEL, L. PAZ. PAREDES-FERANANDEZ, M. ZAMARA, E. CACERES, Am. J. Phys. Anthrop., 65 (1984) 315. — 14. SINGH, I. P., A. K. KAPOOR, S. KAPOOR, J. Ind. Anthrop. Soc., 22 (1987) 205. — 15. VILLENA, M., H. SPIELCOGEL, E. VARGAS, P. OBERST, A. M. ALARCON, C. GONZALES, G. FALGAIRETTE, H. C. KEMPER, Int. J. Sports Med., 2 (1994) 575. — 16. KHALID, M., Ann. Hum. Biol., 22 (1995) 459. — 17. KAPOOR, A. K.: Effects of altitude and migration on child growth. In:. KAPOOR, A. K., S. KAPOOR (Eds.): Biology of Highlanders (Vinod Publishers, Jammu & Kashmir, India, 1995). — 18. KAPOOR, A. K.: Effects of high altitude and seasonal migration on the Demographic structure of semi-nomadic populations of Himalayas. In: TRIPATHY, K. C., N. K. BEHURA (Eds.): Biocultural Frontiers in Anthropology (Mittal Publications, New Delhi, 1996). — 19. MIKLASHEVSKAYA, N. N., V. V. SOLOVYEVA, E. Z. GORDINA: Growth and development in high altitude regions of Southern Krighizia, (U.S.S.R. Field Projects, Miami, Florida, 1973). — 20. PAWSON, I. G., Proc. Roy. Soc. London (B)., 194 (1976) 83. — 21. BEALL, C. M., Hum. Biol., 72 (2000) 201. — 22. SATWANTI, R. BHALLA, A. K. KAPOOR, I. P. SINGH, Z. Morph. Anthrop., 74 (1983) 232. — 23. KAPOOR, A. K., S. KAPOOR, Int. J. Biometeor., 20 (1986) 212. — 24. KAPOOR, A. K., S. KAPOOR, Anthrop. Kozl., 29 (1985) 85. — 25. BHARADWAJ, H., S. C. VERMA, K. P. CHAKRABORTY, SATWANTI: Body composition in relation to high altitude acclimatization. In: BASU, A., K. C. MALHOTRA (Eds.): Proceedings of the India Statistical Institute Golden Jubilee International Conference on Human Genetics and Adaptation, Vol. 2, Human Adaptation, (Calcutta, ISI, 1982). — 26. KAPOOR, S., J. Hum. Ecol., 11 (2000) 101. — 27. BHARADWAJ, H., S. S. VERMA, T. ZASHARIAH, M. R. BHATIA, S. KISHANII, Report No. DIPAS/1/76, 1976. — 28. BEALL, C. M.: Genetic bases of oxygen transport at high altitude: traditional and new approaches. In: LEON, M. F., A. ARREGUI: Hipoxia: investigaciones basicas y clinicas. Homenaje a Carlos Monge Casinelli. Lima (Instituto Frances de Estudios Andinos, Universidad Peruana Cayetano Heredia, 1993). 29. MANN, R. S.: The Ladakhi. A Study in Ethnography and Change. (The Director, Anthropological Survey of India, Government of India,1986). — 30. WEINER, J. S., J. A. LAURIE: Practical Human Biology. (Academic Press, New York, 1981). — 31. HULTGREN, H. N.: Reduction of systemic arterial blood pressure at High Altitude. In: VOGEL, J. H. K., S. BASEL, P. KARGER (Eds.): Advances in Cardiology (Hypoxia, High Altitude and the Heart, 1970). — 32. FRISANCHO, A. R.: Human Adaptation and accommodation (Ann. Arbor, University of Michigan Press, 1993). — 33. GRESKA, L. P., C. M. BEALL: Development of chest size and lung function at high altitude. In: LITTLE, H. M. A. J. D. HASS (Eds): Human Population Biology: a trans-disciplinary science. (Oxford University Press, Oxford. 1989). — 34. CRUZ, J.C., Respir. Physiol., 17 (1973) 146. — 35. BRISCOE, W. A., Am. Physiol. Soc., (1965) 1363. — 36. TARAZONA-SANTOS, E., M. LAVINE, S. PASTOR, G. FIORI, D. PETTENER, Am. J. Phys. Anthropol., 111 (2000) 165. — 37. SLOAN, A. W., M. MASALI, Ann. Hum. Biol., 5 (1978) 453. — 38. MAJUMDAR, P. P., R. GUPTA, B.

MUKHOPADHYA, P. BHARTI, K. R. SUBRATA, M. MASALI, A. W. SLOAN, A. BASU, Am. J. Phys. Anthrop., 70 (1986) 373. — 39. NAYAR, H. S., A. K. KAPOOR, J. PRASAD, Ann. Nat. Acad. Med. Sci. (India)., 24 (1988) 179. — 40. FIORI, G., F. ACCHINI, O. ISMAGULOV, A. ISMAGULOVA, E. TARAZONA-SANTOS, D. PETTENER, Am. J. Phys. Anthrop., 113 (2000) 47. — 41. BORKAN G. A., A. H. NORRIS, Hum. Biol., 49 (1977) 495. — 42. KAPOOR, S., R. TYAGI: Fatness fat patterns and changing body dimensions with age in adult males of a high altitude population. In: BHASIN, M. K., S. L. MALIK (Eds.): The science of Man in Service of Man. (Department of Anthropology, University of Delhi, 2001).

S. Kapoor

Department of Anthropology, University of Delhi, Delhi-110007, India
e-mail: satwanti@yahoo.com

STRUKTURA TIJELA I EFIKASNOST RESPIRACIJE U POPULACIJI HIMALAJE KOJA ŽIVI NA VELIKOJ VISINI

S A Ž E T A K

Ova studija je provedena u mjestu Leh, Ladakh, da bi se istražila morfološka i fiziološka raznolikost kod modernih stalnih stanovnika na velikim visinama. Lokalitet se nalazi na 3500 m nadmorske visine, sa srednjim tlakom od 500 tor-a i temperaturom koja varira od 2°C do 20°C. Tibetanci su imali najšire prsne koševe i najrazvijeniju muskulaturu, a nakon njih su Ladakhi Bodi. Ove dvije skupine imale su i veće vrijednosti vitalnog kapaciteta, forsiranog vitalnog kapaciteta i inspiratornog kapaciteta. Bolja respiratorna efikasnost uočena je kod visinskih populacija koje su prilagođene životu na visini. Privremeni stanovnici bili su viši i deblji, s depozitima masti na donjem dijelu trupa i užim prsnim košem, te manjom respiratornom efikasnosti nego trajni stanovnici. Trajanje boravka na visini ima značajan učinak na dimenzije tijela i respiratorne funkcije različitih grupa odraslih muškaraca na istoj visini.