 Anthropologist, 10(3): 193-202 (2008)

Age Changes in Biological Variables among High Altitude Bodh Males of Lahaul Tehsil, Lahaul-Spiti District, Himachal Pradesh, India

Kanwaljit Singh, M.K. Bhasin and I.P. Singh

Department of Anthropology, University of Delhi, Delhi 110 007, India

KEYWORDS Age Changes of Biological Variables. High Altitude Population. Bodh Males. Himachal Pradesh.

ABSTRACT In the present paper as attempt has been made to analyse the age changes of biological variable among high altitude Bodh males of Lahaul Tehsil. Lahaul-Spiti District of Himachal Pradesh (India). For this study cross-sectional data of 489 apparently healthy Bodh males in the age between 11 and 40 years have been collected to asssess the patterns of growth in terms of "magnitude" and "rate" for 14 anthropometric and 5 physiological variables. The regression equations have been formulated for the prediction of respiratory functions for anthropometric and haematological variables. The differences in the patterns of growth and respiratory functions are discussed considering the results of other reports on this topic.

INTRODUCTION

To cope with various complex environmental stresses, the human body undergoes various adaptive mechanisms allowing "normal" physical and mental activities. Human populations facing these stresses permanently for generations have led Monge (1948) to believe that high altitude natives have become a distinctive breed (Andean Man) superbly fit for life at high altitudes only. However, later studies have not supported this hypothesis (Hiernaux, 1963; Harrison et al., 1969; Dutt, 1976; Garutto and Hoff, 1976). Within the context of altitude (high) and its effect on the population living there, the present study has been carried out on the Bodhs of Lahaul Tehsil, Lahaul-Spiti District, Himachal Pradesh (India), to study and assess the pattern of growth in terms of "magnitude" and "rate" for the various anthropometric and physiological variables and to establish also differences in the patterns of growth and respiratory functions. The results of this study on Bodhs will be compared with those reported for other populations.

AREA AND PEOPLE

According to O'Brian and Bailey (1904) and Bose (1972) the mountaineous range, which separates the upper velleys of Indus and Sutlej, is commonly called the Western Himalayan or Zaskar range. The region between Zaskar range and Pir Panjal (Pangi) range is termed as the Inner Himalayan Zone (altitude 2300 to 3500 meters). Tehsil Lahaul, District Lahaul-Spiti, which is the field area for the present investigation, occupies the Inner Himalayan zone. Its location is shown in figure 1.

The present study deals with Bodhs, who are inhabitants of Lahaul Tehsil of District Lahaul-Spiti. In the records drawn up before the settlement of 1950-51. Bodhs have been described as Kanet. The change from Kanet to Rajput was made during this settlement. In the 1961 Census, the error was rectified and Bodhs were recorded as Bodhs. Bodhs, also sometimes called Bhots, are universal in Bhaga and Chandra valleys in Lahaul. They also live in Pattan valley in small numbers. The origin of Bodhs and their ethnic affinities are not clear. Bodhs are generally of Mongoloid stock and profess Buddhism (District Gazetteer, 1975). Harcourt (1870) has mentioned that the Kanets (now Bodhs) are partly Tibetan and partly true Kanets. Concerning further ethnological and anthropological details we refer to Bhasin et al. (1983)

MATERIAL AND METHODS

The present study is based on cross-sectional data of 489 apparently healthy Bodhs, exclusively from Lahaul Tehsil of district Lahaul-Spiti, Himachal Pradesh. Their ages range from 11 to 40 years (Table 1).

The categorisation of age was done in the following manner. The age of the subject was calculated by substracting the date of birth from the date of investigation. All those subjects who had completed 11 years but were less than 12 years were grouped in the age group 11 + years.

Table 1: Age distribution and sample size of Bodh males of Lahaul

Age	*Mean age (year)*	*Sample size*
11 +	11.32	21
12+	12.46	23
13+	13.26	30
14+	14.55	32
15 +	15.43	31
16+	16.38	35
17+	17.62	30
18+	18.62	24
19+	19.48	25
20+	20.58	22
21 +	21.44	26
22-40	28.85	190

The same pattern has been followed for each age group from 11 to 21 years.

Following the standard techniques of Martin and Saller (1957), Consolazio et al. (1963), Singh and Bhasin (1968), Weiner and Lourie (1969), and Seivard (1975) a total of 19 biological variables (14 anthropometric measurements and 5 physiological variables) have been taken for each individual. The measurements are :

I. Anthropometric Measures

1. Body weight

A. Projective Height Measurements of the Body

2. Stature
3. Sitting height vertex
4. Posterior trunk height

B. Breadth of Trunk

5. Biacromial breadth
6. Biiliocristal breadth

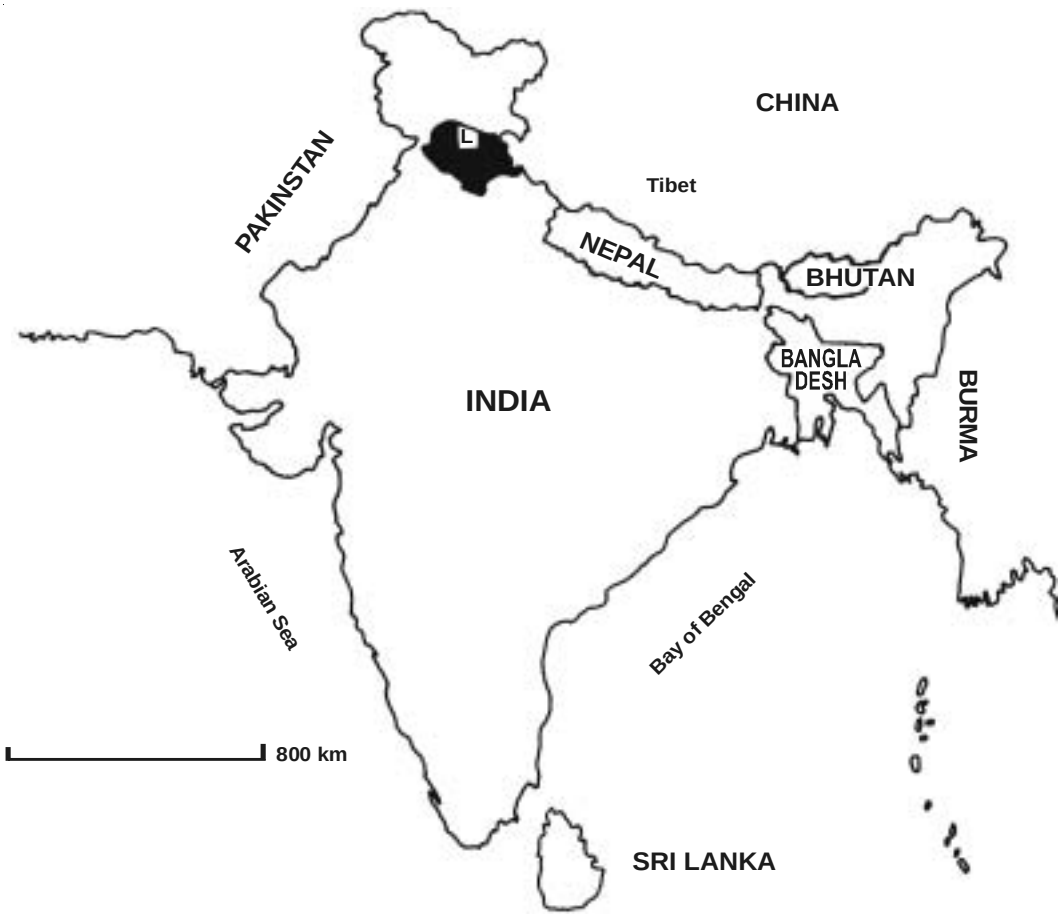

Fig. 1. Location of Himachal Pradesh (black) and Lahaul Tehsil (L).

C. Head Measurements
7. Head length
8. Head breadth

D. Girths
9. Chest circumference - normal
10. Chest circumference - inspiration
11. Chest circumference - expiration
12. Upper arm circumference
13. Calf circumference
14. Head circumference

II. Physiological Measures

A. HaematologicaI Measures
1. Haemoglobin
2. Red blood cells

B. Respiratory Functions
3. Forced vital capacity (FVC)
4. Forced expiratory volume - 1st second (FEV_1)
5. Maximum voluntary ventilation (MVV)

These measures have been analysed statistically with the help of electronic computer model IBP 360/IV in order to interpret the data in numerical terms.

RESULTS AND DISCUSSION

The manitude of growth has been studied on the basis of analysis of distance and velocity curves, occurrence of adolescent spurts and evaluation of growth gradients, coefficients of correlation and regressions.

The analysis of the data reveals that all the 19 biological variables under study show an increasing trend in their mean values from 11 to 21 years of age (Table 2).

I. Anthropometric Measures

1. Body Weight: A total increase of 29.78 kg is observed at the end of the growth period. The mean values of the 19 year age group and that of the highest age group (22-40 years) are almost similar (54.26 kg and 54.23 kg, respectively). A maximum rate of growth of 15.60 per cent is observed between the 14 and 15 years age groups.

A. Projective Height Measurement of the Body

2. Stature: The stature ranges between 128.37 cm (11 year age group) and 165 cm (21 year age group). The highest value of annual increment is observed in the 14+ year age group (7.69 cm). At the age of 20 years 100 per cent growth is acheived.

3. Sitting Height: The 11+ year age group shows that minimum mean value (68.37 cm) and the 20+ year age group the maximum one (88.08 cm). Maximum annual increment (4.4 cm) is achieved between 14 and 15 year.

4. Posterior Trunk Height: The mean range is between 47.22 cm (11+ years) and 63.61 cm (20+ year). Maximum rate of growth (3.70 cm) is observed in 16 and 17 year age groups.

B. Breadth of Trunk

5. Biacromial Breadth: Variation between a minimum mean value of 27.26 cm (11+ year) and a maximum of 37.33 cm (22-40 year) is observed. It becomes stable after 19 years.

6. Biiliocristal Breadth: The 11+ year age group shows the minimum mean value (20.30 cm), while the maximum is observed in the 21+ year age group (27.97 cm). A continues growth up to the 18+ years and a slight decline after 19 years is observed. The highest rate of growth (7.32 percent) in the 14 and 15 year age group corresponds with highest peak velocity.

C. Head Measurements

7. Head Length: Variation in mean value ranges between 18.29 cm (11+ years) and 19.15 cm (19+ years). The maximum increment is observed in the 13 and 14 year age group (18 cm, 0.97 per cent).

8. Head Breadth: Head breadth grows from a minimum of 13.93 cm (11 years) to 14.72 (19 years). A steep rise is observed in 14+ year age group (1.36 per cent increment).

D. Girths

9. Chest Circumference-Normal: Mean values vary from 63.89 cm (11+ years) to 83.65 cm (21+ years). The highest peak velocity is observed between 15+ and 16+ years (4.23 cm), 5.54 per cent).

10. Chest circumference-inspiration: This measure ranges from 68.34 cm (11+ years) to 89.72 cm (21+ years); other considerations are similar to those in normal state.

11. Chest Circumference-Expiration: Minimum mean value is observed in the 11+ year age group (61.69 cm) and maximum in the 20+ year age group (80.63 cm).

Table 2: The means and standard errors of various biological variables among Bodh males of Lahaul.

Age (Years)	Weight (kg.)		Height (cm)		Sitting height (cm)		Posterior trunk height (cm)		Biacromial breadth (cm)		Biiliocristal breadth (cm)		Head length (cm)		Head breadth (cm)		Chest circumference normal (cm)	
	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.
11+	24.5	±0.3	128.4	±0.4	68.4	±0.4	47.2	±0.2	27.3	±0.2	20.3	±0.1	18.3	±0.1	14.0	±0.1	63.9	±0.4
12+	27.8	±0.6	132.6	±0.7	71.0	±0.5	49.4	±0.2	29.2	±0.2	21.3	±0.2	18.5	±0.1	14.1	±0.1	65.4	±0.5
13+	29.2	±0.6	137.8	±0.8	72.8	±0.5	50.9	±0.4	29.7	±0.2	22.0	±0.2	18.6	±0.1	14.2	±0.1	67.8	±0.4
14+	32.3	±0.6	142.6	±0.9	74.5	±1.0	52.4	±0.4	30.6	±0.3	22.4	±0.2	18.8	±0.1	14.2	±0.1	69.8	±0.5
15+	38.3	±0.9	150.4	±1.2	78.9	±0.6	55.4	±0.5	32.3	±0.3	24.2	±0.2	18.8	±0.2	14.5	±0.1	72.2	±0.7
16+	40.6	±1.0	154.0	±1.1	79.7	±0.7	56.2	±0.6	33.6	±0.3	25.0	±0.5	18.8	±0.1	14.6	±0.1	76.4	±0.7
17+	46.3	±0.8	160.1	±1.0	84.1	±0.5	59.9	±0.5	34.7	±0.2	26.2	±0.2	18.9	±0.1	14.6	±0.1	78.5	±0.6
18+	52.0	±0.7	161.7	±0.9	87.3	±0.7	62.5	±0.7	36.5	±0.4	26.5	±0.2	19.1	±0.1	14.6	±0.1	80.7	±0.7
19+	54.3	±0.7	164.5	±1.2	87.7	±0.5	63.5	±0.5	37.1	±0.4	26.1	±0.1	19.2	±0.1	14.7	±0.1	82.8	±0.5
20+	54.2	±0.7	165.0	±0.9	88.1	±0.6	63.6	±0.4	37.0	±0.3	26.7	±0.3	19.1	±0.1	14.6	±0.1	83.6	±0.5
21+	53.5	±0.1	165.0	±0.6	88.1	±0.6	63.6	±0.5	37.3	±0.3	28.0	±0.4	19.1	±0.1	14.8	±0.1	83.7	±0.8
22-40	54.2	±0.4	164.5	±0.4	87.6	±0.4	63.5	±0.2	37.3	±0.1	27.4	±0.1	19.1	±0.1	14.7	±0.1	83.4	±0.3

Table 2: Contd....

Age (year)	Chest circumference inspiration (cm)		Chest circumference expiration (cm)		Upper Arm circumference (cm)		Calf circumference (cm)		Head circumference (cm)		Haemoglobin gm/100cc		Red Blood cells million/cu mm		Forced vital capacity (FVC ml)		Forced expiratory volume 1st 2nd (FEV_1) ml		Maximum voluntary ventilation (MVV) litre/min.	
	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.	X	S.E.
11+	68.3	±0.4	61.9	±0.6	15.4	±0.2	23.3	±0.2	52.6	±0.4	13.9	±0.2	2.96	±0.07	1734	±90	1712	±86	78.2	±2.5
12+	69.4	±0.5	63.7	±0.4	15.9	±0.2	25.0	±0.5	53.0	±0.4	14.1	±0.2	3.39	±0.10	2123	±98	2048	±89	85.8	±3.0
13+	72.2	±0.4	65.8	±0.4	16.6	±0.2	25.5	±0.6	53.7	±0.3	14.1	±0.2	3.62	±0.12	2244	±88	2123	±86	94.6	±2.3
14+	74.6	±0.6	67.3	±0.5	17.1	±0.2	25.9	±0.3	54.4	±0.5	14.7	±0.2	4.06	±0.10	2724	±81	2526	±80	104.2	±2.3
15+	72.2	±0.7	69.8	±0.7	18.0	±0.2	27.3	±0.4	54.7	±0.5	15.1	±0.1	4.55	±0.10	3418	±93	3098	±88	121.9	±1.8
16+	82.1	±0.8	73.5	±0.7	18.8	±0.2	28.1	±0.4	55.0	±0.5	15.5	±0.2	4.76	±0.11	3505	±88	3191	±83	132.3	±1.6
17+	84.8	±0.6	75.8	±0.6	20.3	±0.2	29.4	±0.3	54.8	±0.4	14.9	±0.2	4.74	±0.13	3817	±86	3421	±58	139.2	±0.9
18+	86.1	±0.7	78.0	±0.7	22.4	±0.3	31.7	±0.4	55.7	±0.5	14.6	±0.2	4.85	±0.14	4593	±65	4005	±84	142.5	±3.8
19+	88.4	±0.6	79.8	±0.6	22.8	±0.2	31.8	±0.4	56.1	±0.3	14.9	±0.2	4.83	±0.09	4806	±103	4249	±79	152.5	±3.7
20+	88.9	±0.5	80.7	±0.7	22.5	±0.2	32.1	±0.5	55.5	±0.2	14.7	±0.2	4.90	±0.11	4800	±92	4020	±91	114.6	±3.7
21+	89.7	±0.9	80.3	±0.8	22.5	±0.2	31.7	±0.4	55.7	±0.4	15.0	±0.1	5.11	±0.09	4852	±98	4245	±71	150.9	±3.5
22-40	89.7	±0.3	79.9	±0.3	22.5	±0.1	31.6	±0.1	56.0	±0.1	14.5	±0.1	4.96	±0.05	4711	±42	4031	±38	157.0	±10.8

12. Upper Arm Circumference: The 11+ year age group shows the minimum mean value (15.33 cm) and the 19+ year age group the maximum (22.77 cm). A steep growth (9.30 per cent) is observed in the age group of 17 and 18 years.

13. Calf Circumference: Minimum and maximum mean values are 23.32 cm (11 years) and 32.08 cm (20 years), respectively. The maximum mean annual increment of 2.20 cm (4.09 per cent) is observed in the 17 and 18 year age groups.

14. Head Circumference: The mean values vary between 52.63 cm (11 years) and 56.05 cm (19 years) with a maximum growth (1.51 per cent) in the 17 and 18 year age groups.

II. Physiolqgical Measures

a) Haematological Measures

1. Haemoglobin: In the age group of 16 years a maximum of 15.47 gm/100ml, and in the 11+ year age group a minimum (13.85 gm/100 ml) is found. The maximum increment (0.56 gm/100 ml) occurs in the 13 and 14 year age groups.

2. Red Blood Cells: The red blood cell count ranges between 2.96 million/mm^3 (11+ year age group) and 5.11 million/mm^3 (21+ years age group). Maximum increment and maximum rate of growth is observed in 14 and 15 year age groups (0.49 million/mm^3, 1.88 per cent respectively).

b) Respiratory Functions

3. Forced Vital Capacity (FVC): This measure/ ranges between 1733.70 ml (11+ year age group) and 4851.82 ml (21+ year age group). A maximum increment of 775.99 ml is observed in the 17 and 18 year age groups.

4. Forced Expiratory Volume First Second (FEV_1): In the age group of 11+ years a minimum mean value of 1712.33 ml, and in the 19+ year age group the maximum value of 4248.78 ml are observed. Two high peaks are seen, one in the 17 - 18, and a second in 14 - 15 year age groups (584.61 ml and 571.60 ml, respectively).

5. Maximum Voluntary Ventilation (MVV): The minimum value is observed in the 11+ year age group (78.20 1/min), and the maximum (157.00 1/min) in 22-40 year age group. A steep increment of 17.64 1/min is present between 14 and 15 age groups.

Distance and Velocity Curves

The distance curves plotted for the 19 biological variables of the Bodhs under study show, by and large, a mixed trend in the advancement of growth from 11 to 21 years. Among the anthropometric variables the head length is the only measure, which shows a steep rise between 11 and 14 years of age. It is significant that all the three respiratory functions show a steep rise twice in the progression of the variables.

The velocity curve plotted for each biological variable for the Bodhs reveals more than one peak, indicating multimodality, which could be attributed to the cross-sectional nature of the data. Such has been emphasized by Tanner (1962). However, Frisancho (1969), Baker et al. (1966) and Baker (1971) show a high degree of multimodality revealing poorly defined adolescent spurt among high altitude Peruvian Quechua boys.

Adolescent Spurt

The highest peak velocity (HPV) corresponding to the occurrence of adolescent spurt spread over between 11 and 12 years and 17 and 18 years, shows that the various biological variables of the body among the Bodhs of Lahaul Tehsil show a wide variation in the occurrence of adolescent spurt. This indicates the early and late maturity of the various parts of the body and confirms the basic contention that the adolescent spurt occurs for all the body measures between 13 and 17 years of age (Tanner, 1962; Krogman, 1972; Johnson, 1972; Marshall, 1977).

Growth Gradients

The growth gradient of a biological variable expresses the percentage of growth achieved at any age in relation to its "final" value as seen in a fully grown adult. Among the various anthropometric variables, the measurements of the head show more than 90 per cent of growth in the 11 year age group. Among the linear measures, the stature shows 78.02 per cent of growth, followed by sitting height (77.26 per cent) and posterior trunk height (74.40 per cent) at 11 years of age. Both the trunk breadth measures (biacromial breadth and biiliocristal breadth) show 73.02 per cent and 73.99 per cent growth at 11 years of age, respectively. Circumferential measures, excluding head circumference, show above 70 per cent of growth at 11 years of age, except upper arm circumference (68.12 per cent). Among the physiological variables, the haemoglobin level shows the least per cent of growth achieved, and

among the respiratory functions, the forced vital capacity (FVC) shows 36.79 per cent growth, indicating that this variable is highly affected by age changes.

An attempt has been made to determine at which particular age the highest per cent growth is attained by various biological variables. It could be observed that among the anthropometric variables, except calf circumference (93.03 per cent) at the age of 16 years all the variables show a substantial growth varying from 97.90 per cent to 99.99 per cent.

Relative Variability

The values of minimum and maximum variability are 1.45 per cent and 29.98 per cent for stature and forced vital capacity (FVC), respectively, at 11 years of age.

Among all the anthropometric variables, except for body weight, the variability is less than 10 per cent in the different age groups, whereas in physiological variables it is more than 10 per cent, with the exception of the haemoglobin level. The maximum values of variability (25 to 30 per cent) are observed for two respiratory functions (forced vital capacity and forced expiratory volume - First Second).

It has been observed furthermore that of the 19 biological variables, none shows a minimum variability in the age groups 14, 15, 16 and 22-40 years, and a maximum variability in the 18, 20 and 21 year age groups.

Percentiles

To study age changes, percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) were calculated so as to represent the standards of the population.

Certain anthropometric and physiological variables are selected and a uniform trend observable with regard to all the variables chosen. The 50th centile seems to be representing the maximum number of individuals in all the age groups, whereas the frequency of individuals in all the variables above 75th centile is very low.

Correlation and Regression

Coefficient of Correlation Between Different Biological Variables Along with Age: The correlation coefficient has been applied to all biological variables and age groups for the Bodh population in order to assess linear relationship between two concerned variables. It has been observed that all the values of 'r' are positive (11 to 21 years), which indicates that there is a direct relationship between different biological variables along with age. However, in the pooled age group of 22-40 years negative values of 'r' with age and a few biological variables are seen. For explanatory convenience, the values of 'r' have been classified into three categories (A, B and C). Category "A" (value of r close to 0 and upto ± 0.149) showing almost independence or no relationship between the variables, has been confined to head circumference, haemoglobin level, head length (11 to 21 year age groups), and in the 22-40 years age group negative values have been observed with age, maximum voluntary ventilation (MVV), haemoglobin level, head circumference and forced expiratory volume-First Second (FEV_1). Category "B" (value of r ranging from ± 0.150 to ± 0.499) exhibiting only moderate degree of positive relationships, includes head length, head circumference, haemoglobin, red blood cells in 11-21 year age groups, sitting height, biacromial breadth, biiliocristal breadth, head measurements and calf circumference. Category 'C' (value of r ranging from ± 0.500 to 1.000) showing a higher degree of positive relationship, includes all the other biological variables.

Relationship of Physiological Variables with Anthropometric Variables: From the detailed statistical analysis emerged that all the anthropometric variables and ages shows a significant, correlation for the value of 'r' with forced vital capacity (FVC), forced expiratory volume - First Second (FEV_1) and maximum voluntary ventilation (MVV) in the 11-21 year of age groups. It has been observed furthermore that FVC, FEV_1 and MVV are best correlated with body weight and stature. In the adult age group (22-40 year) FVC and FEV_1 exhibit the best correlation with stature and body weight and MVV with stature.

Simple Linear Regression of Different Biological Variables on Age

New simple linear regression equations have been formulated for the prediction of different biological variables from age in the Bodhs of Lahaul Tehsil. It could be demonstrated that in the age group of 11-21 years among the anthropometric variables the stature shows the highest value with age (R=0.897) and among the

physiological variables FVC shows the highest value (R = 0.18), whereas in the adult group (22-40 years) among the anthropometric variables the body weight shows a high value with age (R = 0.16). Among the physiological measures, FEV_1 shows the maximum value (R = 0.25). It is significant to note here that the values of age related with different biological variables are not dependent upon the level of coefficient of correlation.

Simple Linear Regression of Respiratory Functions on Anthropometric and Haematological Variables

New simple linear regression equations have been formulated to predict FVC, FEV_1 and MVV for the Bodh population group. The following are the best simple linear regression equations showing maximum regression coefficient of estimate for this population.

Age group 11-21 year	*Value of 'R'*
FVC = -8904.50 ± 8.19 stature	0.937
FEV_1 = -6998.05 ± 26.13 stature	0.925
MVV = -156.60 ± 0.18 stature	0.884
Age group 22-40 year	
FVC = -5765.42 ± 6.36 stature	0.633
FEV_1 = -4078.97 ± 4.93 stature	0.511
MVV = -10.28 ± 0.42 biacromial breadth	0.324

Multilinear Regression of Respiratory Functions on Anthropometric and Haematological Variables and Age (Taken as Forced Variable)

New multilinear regression equations have been formulated for the prediction of FVC, FEV_1 and MVV on the basis of age taken as forced variable and one of the anthropometric variables as independent variable for the Bodh population. The following are the best multilinear regression equations with age as forced variable.

Age group 11-21 years	*Value of 'R'*
FVC = -7794.42 + 78.63 age + 6.63 stature	0.941
FEV_1 = -5863.28 + 37.09 age + 68.32 body weight	0.921
-5559.10 + 42.78 age + 6.43 stature	0.921
MVV = -126.60 + 2.12 age + 0.14 stature	0.890
Age group 22-40 years	
FVC = -5116.24 - 13.74 age + 6.21 stature	0.647
FEV_1 = -3265.07 - 17.23 age + 4.78 stature	0.582
MVV = -7.44 - 0.92 age + 0.11 stature	0.405

Stepwise Multilinear Regression of Respiratory Functions on Anthropometric and Haematological Variables with Age (Taken as Independent Variable)

It is difficult to assess, which of the body measures contributes to what extent, with age taken as independent variables, in the different respiratory functions. Therefore, stepwise multilinear regression equations have been formulated, in which variables add stepwise in order of their correlation coefficient value in the regression equation. Further addition of variable stops as soon as there is not further increase in the value of multiple coefficient of correlation.

The following are the best regression equations computed stepwise, showing the maximum value of multiple regression coefficient estimate on the basis of anthropometric variables and age taken as independent variables or the Bodh population.

Age group 11-21 year	*Value of 'R'*
	(al 0.001 per cent significance level)
With a set of seven variables	
FVC = - 6766.39 + 3.21 stature + 34.16 body weight + 103.92 haemoglobin + 10.53 red blood cells + 3.066 posterior trunk height = 2.827 biacromial breadth + 45.80 age.	0.954
With a set of four variables	
FEV1 = -5604.85 + 2.722 stature + 27.63 body weight 108.57 haemoglobin + 3.650 posterior trunk height	+ 0.940
With a set of four variables	
MVV = -111.75 + 0.094 stature + 1.78 age + 0.04 red blood cells + 0.074 posterior trunk *height*	0.897
Age group 11-21 years	*Value of 'R'*
	(at 0.01 per cent significance level)
With a set of two variables	
FVC = -5526.437+4.783 stature + 43.394 body weight	0.947
With a set of two variables	
FEV_1 = -4515. 023 + 4.18 stature + 31.895 body weight	
With a set of two variables	0.890
MVV = -126.60 + 0.14 stature + 2.12 age	
Age group 22-40 years	
With a set of four variables	
FVC = -9214.73 + 4.688 stature +4.946 chest circumference +3.794 head circumference -10.46 age	0.740

With a set of six variables

FEV_1 = -4052.04 + 3.493 stature + 5.125 biacormial breadth - 16.09 + age + 3.188 chest circumference - 4.030 biiliocristal breadth - 5.093 upper arm circumference 0.641

With a set of five variables

MVV = -94.72 + 0.090 stature -0.86 age +0.280 biacromial breadth - 0.275 biiliocristal breadth + 0.424 head length 0.498

From the various regression equations it may be observed that of all the anthropometric and haematological measures and age, stature and body weight show highly positive correlations with all the respiratory functions (FVC, FEV_1, and MVV), indicating thereby that these can be best predicted by stature and body weight. Similar findings have been reported by (Bhattacharya, 1963; Abromowitz et al., 1965; Ferris et al., 1965; Damon, 1966, Jain and Gupta, 1967; Pyzuk et al., 1967; Jain and Rainiah, 1968a, 1968b, 1969; Harrison et al., 1969; Kopetzky et al., 1974).

DISCUSSION

The Bodhs of Lahaul Tehsil have been compared with high altitude Bods of Ladakh Malik and Singh, 1978, Bhasin et al., 2008a), Transhumant and Settled Gaddis from the Bharmour Sub Tehsil, Chamba District, and Kangra District, Himachal Pradesh (Singh, 1980) and sea-level Indian Rural Boys (ICMR, 1972) to assess differences in such biological variables as body weight, stature and respiratory functions. All these populations are rural in their origin.

Comparing the results of these studies one can see that the Bodhs of Lahaul Tehsil and the Bodhs of Ladakh exhibit a faster rate of growth. This is in conformity with the findings of Malcom (1970), Garutto (1973), but in contrast with the results of Frisancho (1969, 1970, 1973 and 1975), McClung (1969); Frisancho and Baker (1970) and Boyce et al. (1974), who reported a slowed and prolonged growth among high altitude natives.

The Bods under study exhibit also a faster growth in body weight than Indian Rural boys. This difference may be attributed to altitude rather than to geographic or genetic factors, as also reported by Rothammier and Spielman (1972).

The Bods of Ladakh and the Bodhs of Lahaul are characterized by a larger chest size, which is a pronounced characteristic of high altitude populations as emphasized by Pawson (1976) and Frisancho et al. (1975).

The Bodhs of Lahaul as well as the Bods of Ladakh exhibit, too higher values of FVC, FEV_1 and MVV. Similar high values have been reported by Singh (1980) for the Transhumant Gaddis from the Bharmour Sub Tehsil, Chamba District (Mid Himalayan Zone) and for the Settled Gaddis from the Kangra District (Outer Himalayan Zone). Cotes et al. (1973) concluded that this may be attributed to the high level of habitual activity as these population groups inhabit steep terrained mountaneous region. The same has been suggested by Jones et al. (1977), Miller et al. (1977), Anderson et al. (1978), and Singh (1980).

Thus, it may be inferred from the analysis of the patterns of body growth and respiratory functions among the Bodhs of Lahaul Tehsil, Lahaul-Spiti District (Inner Himalayan Zone), that they exhibit more similarities with the high altitude Bods of Ladakh than with Indian Rural Boys at sea level, whereas the Transhumant and Settled Gaddis (Mid Himalayan Zone and Outer Himalayan Zone) are intermediately placed.

ACKNOWLEDGEMENT

Financial Aid for this study was provided by Anthropological Survey of India, Govt. of India, Calcutta and Indian Council of Medical Research, New Delhi.

REFERENCES

Abromowitz, S., Leiner, G.C. Lewis, W.A. and Small, M.J.: Vital capacity in the Negro. *Amer. Rev. Resp. Dis.,* **92:** 287 (1965).

Anderson, H.R., Anderson, J.A., King, H.O.M. and Cotes J.E.: Variation in the lung size of children in Papua New Guinea: Genetic and enviromental factors, *Ann. Hum. Biol.,* **5:** 209 (1979).

Baker, P.T.: Adaptation problems in Andean human populations. In: F. Salzano (Ed.): *Opening Evaluation of Latin American Populations*. Charles C. Thomas, Springfield (1971).

Baker, P.T., Frisancho, A.R. and Thomas, R.B.: A preliminary analysis of human growth in the Peruvian Andes. In: M.S. Malhotra (Ed.): *Human Adaptability to Environment and Physical Fitness.* Defence Inst. Physiol. Allied Sciences, Madras (1966).

Bhasin, M. K., Singh, L.P., Walter, H. and Bhardwaj, V.: Genetic study of five populations groups of Lahaul-Spiti and Kulu districts. Himachal Pradesh. *Z. Morph, Anthropol.,* **74:** 13 (1983).

Bhasin, M.K. Singh, L.P. and Kaur, B.: Biology of the People of Jammu and Kashmir: 1. The growth patterns and physiological variables of various population groups of the state. *Anthropologist,* **10(2):** 89-118 (2008)

Bhattacharya, D.K.: Vital capacity of the Jat males of Punjab: A modification of the formula existing for its computation. *Ind. J. Med. Res.*, **51:** 361 (1963).

Bose, S.C.: *Geography of the Himalaya.* National Book Trust, Delhi (1972).

Boyce, A.J., Haighl, J.S.J., Rimmer. D.B. and Harrison, G.A.: Respiratory function in Peruvian Quechua Indians. *Ann. Hum. Biol.*, **1:** 137 (1974).

Consolazio, C.F., Johnsen, R.E. and Pecora, L.T.: *The Physiological Measurements of Metabolic Functions in Man.* McGraw Hill, New York (1963).

Cotes, J.E., Saunders, M.J., Adam, J.E.R., Andersen. H.R. and Hall, A.M.: Lung function in coastal and highland New Guineans, comparison with Europeans. *Thorax*, **28:** 320 (1973).

Damon, A.: Negreo-White differences in pulmonary functions. *Hum. Biol.*, **38:** 380 (1966).

District Gazetteer Himachal Pradesh: *Lahaul and Spiti*. Government of Himachal Pradesh, Shimla (1975).

Dutt, J.S.: Population movement and gene flow. In: P.T. Baker and M.A. Little (Eds.): *Man in the Andes: A Multidisciplinary Study of High Altitutde Quechua.* Hutchinson and Rose, Inc. Stroudsburg, Pa. (1976).

Ferris, B.G. Jr., Anderson, D.O. and Zickmantal, R.: Prediction value for screening tests of pulmonary function. *Amer. Rev. Resp. Dis.*, **91:** 252 (1965).

Frisancho, A.R.: Human growth and pulmonary function of a high altitude Peruvain Quechua population. *Hum. Biol.*, **41:** 365 (1969).

Frisancho, A.R.: Developmental responses to high altitude hypoxia. *Amer J. Phys. Anthrop.*, **32:** 401 (1970).

Frisancho, A.R.: Adaptive significance of small body size under poor socio-economic conditions. Abstract. *Amer. J. Phys. Anthrop.*, **40:** 136 (1973).

Frisancho, A.R.: Functional adaptation to high altitude hypoxiza. *Science*, **187:** 313 (1975).

Frisancho, A.R. and Baker, P.T.: Altitude and growth: A study of the patterns of physical growth of a high altitude Peruvian Quechua population. *Amer. J. Phys. Anthrop.*, **32:** 279 (1970).

Frisancho, A.R., Velasquez, T. and Sanchez, J.: Possible adaptive significance of small body size in the attainment of aerobic capacity among high altitude Quechua natives, pp. 55-64. In: S. Watts, E. Johnston and G.W. Lasker (Eds.): *Biological Interrelations on Population Adaptability.* Mouton Publishers, The Hague (1975).

Garutto, R.M.: *Polycythemia as an Adaptive Response to Hypoxic Stress.* Ph. D. Thesis. Pennsylvania State University, Pennsylvania (unpublished) (1973).

Garruto, R.M. and Ho, C.J.: Genetic history and affinities. In: P.T. Baker and M A Little. (Eds.): *Man in the Andes: A Multidisciplinciry Study of High Altitude Quechua.* Hutchinson and Ross Inc. Slroudsburg (1976).

Harcourt A.E.P.: *The Himalayan Districts of Kooloo, Lahoul and Spiti.* Vivek Publishing House, Delhi (Reprint) 1870.

Harrison, G.A., Kucheman, C.F., Moore, M.A.S., Boyce, A.J., Baju, T., Mourant, A.E., Godber, M.J., Glasgow, B.G., Kopec, A.G., Tills, D. and Clegg, E.J.: The effects of altitudinal variations in Ethiopian populations. *Philos. Trans, Roy Soc. Lond.*, **256:** 147(1969).

Hiernaux, J.: Heredity and environment. Their influence. on human morphology. *Amer. J. Phys. Anthrop.*, **21:** 575 (1963).

Indian Council of Medical Research - ICMR: Growth and physical development of Indian infants and children. *ICMR Tech. Report Series No.* 18 (l972).

Jain, S.K. and Gupta, G.K.: Age height and body weight as determinants of ventilatory "norms" in healthy man above fifty years of age. *Ind. J. Med. Res.*, **55:** 599 (1967).

Jain, S.K. and Ramiah, T.J.: Lung volumes and mechanisms of breathing in healthy boys 7-14 years old. *Ind. J. Chest Dis.*, **10:** 63 (1968a).

Jain, S.K. and Ramiah, T.J.: Prediction of ventilatory "norms" in healthy boys 7-14 years of age. *Ind. J. Chest Dis.*, **10:** 67 (1968b),

Jain, S.K. and Ramiah, T.J. : Normal standards of pulmonary function tests for healthy Indian man 15-40 years old. Comparison of different regression equations (Prediction formulae). *Ind. J. Med. Res.*, **57:** 1453 (1969).

Johnson, T.O.: The physique of Urban Nigerians in Adolescent period. *Environ. Child Health*, **18:** 134 (1972).

Jones, P.R.M., Baber, P.M., Heywood, C. and Cotes, J.E.: Ventilatory capacity in healthy Chinese children: Relation to habitual activity. *Ann Hum. Biol.*, **4:** 155 (1977).

Kopetzky, M. T., Maselii, R. and Elliot, E.F.: Pulmonary function studies with simple equipment in 323 normal children. *J. Allerg Clin. Immunol.*, **53:** 1 (1974).

Krogman, W.W.: *Child Growth.* University of Michigan Press, Michigan (1974).

Malcolm, L.A.: Growth and development of the Bundi children of the New Guinea highlands. *Hum. Biol.*, **42:** 293 (1970).

Malik, S.L. and Singh, I.P.: Growth trends among male Bods of Ladakh - A high altitude population. *Amer. J. Phys. Anthrop.*, **48:** 171 (1978).

Marshall, W.A.: *Human Growth and its Disorders*. Academic Press, London (1977).

Martin, R. and Saller, K.: *Lehrbuch der Anthropologie in Systemalischer Darstellung.* 4 Bde. Gustav Fisher Verlag Stuttgart (1957).

McClung, I.: *Effects of High Altitude on Human Birth.* Harvard University Press, Cambridge (1969).

Miller, G.J. Saunders, M.J., Gilson, R.J.C. and Ashcroft, M.T.: Lung function of healthy boys and girls in Jamaica in relation to ethnic composition, test exercise performance, and habitual physical activity. *Thorax*, **32:** 486 (1977).

Monge, C.: *Acclimatization in the Andes.* Baltimore O (1948).

O'Brian, E. and Bailey, T. G.: *District Gazetteer, Kangra.* Punjab Government Press, Lahore (1904).

Pawson, I.G.: Growth and development in high altitude populations: A review of Ethiopian, Peruvian and Nepalese studies. *Proc. R. Soc. Land. B.*, **194:** 83 (1976).

Pyzuk, M., Turusbekow, B.T. and Briancewa, L.: Certain properties of the respiratory systems in school children in various altitude and climatic conditions. *Hum. Biol.*, **39:** 35 (1967).

Rothammier, F. and Spielman, R.S.: Anthropometric variation in Aymara: Genetic geographic and topographic contributions. *Amer. J. Hum. Genet.*, **24:** 371 (1972).

Seivard, C.E.: *Hematology for Medical Technologists.* Lea and Febiger, Philadelphia (1975).

Singh, Indera P. and Bhasin, M. K.: *Anthropometry.* Bharti Bhawan, Delhi (1968).

Singh, Kanwaljit: *Age Changes in Biological Variables among a High Altitude Population, Bodh Males of Lahaul Tehsil, Lahaul-Spiti District, Himachal Pradesh*, Ph. D. Thesis (Unpublished) University of Delhi, Delhi (1981).

Singh, R.J.: *Age Changes in Biological Variables in Transhumant and Settled Populations: A Comparative Study of Gaddi Rajputs and Brahamans of Sub-Tehsil Bharmour, District Chamba and District Kangra, Himachal Pradesh.* Ph. D. Thesis, University Delhi, Delhi (unpublished) (1980).

Tanner, J.M.: *Growth at Adolescence.* Blackwell Scientific Publication. Oxford 2nd Ed. (1962).

Weiner, J.S. and Lourie, J.A.: *Human Biology: A Guide to Field Methods.* I B P Handbook No. 9, Oxford Blackwell Scientific Publication, Oxford (1969).