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Multivariate Distance Analyses For Growth Characters During Adolescence Among Bhil Boys of Rajasthan

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ABSTRACT Results of growth data on number of body dimensions (23 measurements) among adolescent Bhil boys of Rajasthan (11+ years to 19+ years) have been subjected to multivariate distance analyses by applying four different formulations : (1) the mean percentage growth of all body dimensions in each yearly age as mean multivariate distance (MMD). (2) The average proportion of increment of all body dimensions between ages, called the co-efficient of proportion growth (CPG). (3) average ratio of mean differences of all body dimensions between ages, called the co-efficient of standardized growth (CSG). and (4) average value of the critical ratio or 't' for all measurements between all ages, called T-distance. The results of these multivariate distance analyses of all measurements among adolescent Bhil boys indicate an intermediate growth pattern between Linear (*e.g.* height) and transverse (bulk, *e.g.* weight and others) growth curves. Further, the combined effect of all the measurements exhibits a sharp adolescent spurt between 14+ and 15+ years followed by a sharp decline of growth rate and a final and slow increase indicating a continous growth of some body dimensions characterise the overall adolescent growth of Bhil boys. The use and application of multivariate distance analyses for growth is discussed.

INTRODUCTION

Study on growth involves body as a whole and also all external dimensions. It is usual practice to consider certain composite measurements, like, stature and weight, as a means to study the body as a whole and few others, like, sitting height vertex and certain girths for describing the growth of external dimensions (I.C.M.R., 1972; Singh, 1970; Kaul and Nyamongo, 1990). Some others have used large number of measurements to study the growth trends of various body segments or dimensions during the growth period or particular phase of growth, like, juvenile growth and adolescent growth (Sharma, 1970 and Reddy, 1980, 1989). It is noticed that there exists growth differentiation in body characters and also gradients of growth in attaining the maturity of growth characters (Krogman, 1972; Tanner, 1962, 1978). However, the general pattern of growth curve for all morphological dimensions is sigmoid in nature (Scammon, 1927). Further, considering the above, it is important to note that the magnitude of growth of a body character is important though it differs with others during the growth period. The combined effect of growth of all body dimensions is important to understand the process of growth further. This can only be studied by subjecting the measuremental values of all body dimensions to multivariate distance analyses (Reddy, 1980). The use and application of multivariate distance analyses to growth study has already been emphasised (Reddy, 1980; Reddy, and Mukherjee, 1981 and Mukherjee, 1989). This is an integrated measure of all body dimensions put together and see their changes during the growth period. The present paper is in this direction to design the method of multivariate distance to growth data and describe the use of such analyses for understanding the growth in its holistic perspective.

MATERIALS AND METHODS

The materials for the present study are Bhils, the largest tribal group in India, and the samples are drawn from Udaipur district in Rajasthan who have environmentally better-off over others. 900 boys spread over 9 yearly age-groups, *i.e.*, 100 boys in each age group, from 11+ years to 19+ years are considered. Thus, the data have been drawn cross-sectionally by using purpo-

sive sampling. The following measurements (growth characters) are taken on each boy and all measurements and definitions of landmarks are taken after Singh and Bhasin (1989) and Weiner and Lourie (1969).

1.	Composite measurements	:	1. Weight 2. Stature
2.	Vertical or linear measurements	:	1. Sitting Height Vertex 2. Trunk Height 3. Head and Neck Height 4. Upper Extremity Length 5. Lower Extremity Length
3.	Transverse measurements	:	1. Biacromial Breadth 2. Bi-iliocristal Breadth 3. Bi-trochanteric Breadth 4. Chest Breadth 5. Chest Depth
4.	Girth measurements	:	1. Upper Arm 2. Calf 3. Chest 4. Head
5.	Head and Face measurements	:	1. Head Length 2. Head Breadth 3. Minimum Frontal Breadth 4. Bizygomatic Breadth 5. Bigonial Breadth 6. Morphological Facial Height 7. Morphological Upper Facial Height

Statistical Analyses of Growth Data

The growth of each of the 23 physical measurements between subsequent years of age has been studied by obtaining the differences of arithmetical means between the successive age-groups. The basic growth curves known as distance curves are drawn by plotting the means of each age and connecting successive points by a straight line. The slopes of these curves between subsequent age-groups assess the relative rates or velocity of growth. The increment at each age from the previous age-group is also studied by drawing the increment curves. These have been again converted into percentages of the means of the lower age and plotted to indicate the velocity of growth. The standard errors of the means for each age-group have also been calculated. The significance of the increment between successive age groups is tested by using the modified t-test, as follows.

$$t = \frac{M_1 - M_2}{\sqrt{S.E_1^2 + S.E_2^2}} \quad \text{..... (A)}$$

Where, M_1 and $S.E_1$ are the mean standard error of mean of the higher age-group and M_2 and $S.E_2$ are the mean and standard error of the mean in the lower age-group. The t-test is assumed to be applicable in view of the non-significant differences between variances in successive ages and no apparent deviations of the distributions from normality in almost all measurements. The trends of age changes are also considered even when the differences are not large enough to show significance at 0.5 level of probability.

The increments in each year from the previous lower age-group have again been expressed as proportions of standard deviations of measurements in the lower age. These values of mean differences divided by standard deviations of the lower age-groups when multiplied by 100 become equivalent to Mollison's deviation index, DI (Mitra, 1951).

$$DI = \frac{M_1 - M_2}{SD_2} \times 100 \quad \text{..... (B)}$$

These values of deviation index are plotted for all the dimensions and Wagenxel's (1931) morphological profile for each age is obtained by joining adjacent points by straight lines.

The present data on growth of 23 different body dimensions displaying differential rhythm and time of peak velocities have been combined together to examine how far a pattern of overall growth in the adolescent Bhil boys and definite age of adolescent spurt etc., can be brought out. This can be considered as a preliminary attempt to study multivariate (multidimensional) growth by combining the univariate data. The averages of the rates of increment per year expressed as % (percents of means or as ratios of the standard deviations of lower age-groups have been used as measures of (multivariate combined or multi dimensional) growth between pairs of particular age-groups.

The average rates of growth of all measurements between any two years may serve as a measure of multivariate distance (of growth) between those years, in the same way as the Clarke's (1952) co-efficient of divergence (CD), derived from the following formula, measures multivariate distance between two populations.

$$C.D. = \frac{\Sigma \left(\frac{M_1 - M_2}{M_2} \right)^2}{v} \quad \text{..... (C)}$$

where, M_1 and M_2 are the means of the first and second populations respectively and 'v' is the number of variables or traits studied. Since in the comparison between populations $(M_1 - M_2)/M_2$ for some traits may be positive and for some others negative, it is necessary to square 'the mean differences expressed as a ratio of one of the means to give equal weight to both positive and negative differences. While applying the same concept of multivariate distance to growth data in the present study it has not been felt necessary to square the mean differences expressed as ratio of the lower mean. The formula, is found suitable. In the absence of negative value of $(M_1 - M_2)$ where M_1 is the mean of higher age-group and M_2 that of a lower age-group. The

'v' in the formula represents the number of variables or traits. Similarly, the formula,

$$\text{Coefficient of percent growth (CPG)} = \frac{\Sigma \frac{M_1 - M_2}{M_2} \times 100}{v} \quad \ldots\ldots\ldots (D)$$

gives a multivariate distance when the mean differences are expressed as ratios of the standard deviations of the lower age-group and 'v' the number of variables or traits. The differences of this formula with that of CRL (Pearson, 1926) is that the expression, $(M_1 - M_2)^2/S.D_2$ is replaced by $(M_1 - M_2)/S.D_2$. It is not found necessary to square the expression

$$\text{Coefficient of standardised growth (CSG)} = \frac{\Sigma \left(\frac{M_1 - M_2}{SD_2}\right)}{v} \quad \ldots\ldots\ldots (E)$$

since theoretically $M_1 > M_2$ in growth data. This measure is referred to as coefficient of standardised growth (CSG).

A third measure of distance is derived by the formula,

$$T = \Sigma t / v \quad \ldots\ldots\ldots (F)$$

where `t' is the critical ratio (refer to formula A) and `v' is the number of variables of traits. The `t' values give estimates of univariate distance also because the sample size of different age-groups are equal.

The three multivariate distance curves of growth using (1) CPG, (2) CSG, which takes account of the variability of the traits, and (3) T-distance, which considers the standard errors of means, are studied to observe the trends of combined growth of measurements showing difference patterns and gradients of growth. These multivariate measures are used to estimate the overall patterns of growth and the period of overall adolescent spurt, assuming that the measurements studied fairly represent the dimensional changes in the human body in the period of adolescent growth.

RESULTS AND DISCUSSION

The means, SDs, SEs and `t' values for 23 body measurements are given in table 1 to 4 and the distance and increment curves for stature and weight are given in figure 1 and 2 for better understanding and interpretation of various multivariate distance curves. The growth of other body dimensions has been discussed elsewhere. An attempt has been made to bring out the combined growth patterns of different body dimensions in view of some general similarity in the pattern of growth among linear, transverse, and girth measurements and in the time of adolescent spurt of all body characters. A multivariate distance curve (Fig. 3) has been obtained by plotting the percentage of growth in each yearly age from all the dimensions attained at 11+ year of age (Table 5). The growth curve thus appear to resemble the curves obtained for growth of weight and transverse measurements as expected. It is a sigmoid curve and the upper end shows an upward trend instead of an asymptote. The velocity curves of multidimensional (total) growth are also obtained by averaging : (1) the t-values for mean differences of different traits between successive years (Fig. 4); (2) the per cent rates of growth (CPG) of different traits between successive ages (Fig. 5) and also (3) the standardised increments or CSG (Fig. 6) (*i.e.*, the increments of different traits expressed in terms of the respective standard deviations of the measurements of the previous years of age) of different traits between specific pairs of successive ages. The velocity curves obtained by using these formulae show a general resemblance with that for weight and height. The trend of rising growth rate in the last year of the age-range resembles the growth pattern of weight and the sharp adolescent spurt between 14+ and 15+ years is obtained similar to that in height. There is also a small peak of velocity betwen 16+ and 17+ years as noted for most of the traits in this sample.

The use of multivariate distance method for the dynamic processes like human growth bears fruit as these analyses bring out sharply the combined growth of various body dimensions between several age-groups though there exists growth differentiation and growth gradients among body characters. Further, the `distance curve' of growth is merely a representation of mean differences of a specific measurement between a series of successive age groups which cannot be compared between different measurements or between different periods for the same measurement. This difficulty can be removed by dividing the mean differences by the mean or variance of the early age and this has been successfully deviced and used in the

Table 1 : Means of growth characteristics in each year of age

Growth Characteristics	*Age in years*								
	11+	*12+*	*13+*	*14+*	*15+*	*16+*	*17+*	*18+*	*19+*
Height vertex	131.33	134.77	139.84	146.74	155.20	159.52	162.85	163.53	163.97
Sitting height vertex	68.28	69.94	71.80	75.41	79.51	81.63	82.98	83.51	83.87
Trunk height	43.49	44.08	44.80	47.41	51.47	53.02	54.29	54.56	54.59
Upper extremity length	61.35	62.68	65.20	68.62	72.10	74.24	75.79	75.84	76.14
Lower extremity length	63.05	64.85	68.76	71.33	75.69	78.50	79.87	80.02	80.11
Head and neck height	24.67	25.35	25.77	26.49	27.67	28.47	28.82	29.17	29.64
Weight	24.31	25.45	27.83	32.16	38.97	41.82	44.77	46.84	49.23
Biacromial breadth	27.82	28.38	29.44	30.95	33.14	33.55	34.79	35.31	36.33
Biiliocristal breadth	19.74	20.36	21.41	22.84	24.25	24.89	25.44	25.73	26.16
Bitrochanteric breadth	21.38	22.07	23.14	24.70	26.90	27.46	28.02	28.36	28.98
Chest breadth	18.90	19.46	20.61	21.43	23.10	23.75	24.46	24.74	25.77
Chest depth	13.92	14.35	14.74	15.53	16.79	17.13	17.60	17.82	18.35
Chest circumference	16.14	62.49	64.55	67.76	72.84	74.83	76.66	77.81	79.69
Upper arm girth	16.99	17.11	17.53	18.63	20.17	21.02	21.70	22.02	22.72
Calf girth	23.71	23.93	24.68	25.97	27.98	28.65	29.49	29.93	30.94
Head length	16.86	16.95	17.05	17.19	17.40	17.44	17.46	17.65	17.88
Head breadth	13.06	13.18	13.27	13.34	13.42	13.49	13.58	13.69	13.80
Head circumference	50.41	50.59	50.76	51.32	52.01	52.44	52.68	53.00	53.16
Minimum frontal breadth	9.91	9.98	10.01	10.18	10.25	10.33	10.35	10.43	10.44
Bizygomatic breadth	11.89	12.09	12.13	12.37	12.63	12.78	12.95	12.99	13.10
Bigonial breadth	9.01	9.17	9.23	9.38	9.58	9.73	9.89	10.11	10.23
Total facial height	9.89	10.03	10.65	10.17	10.54	10.67	10.85	10.90	10.96
Upper facial height	6.22	6.39	6.39	6.40	6.54	6.69	6.76	6.82	6.85

Table 2 : Standard errors of growth characteristics in each year of age

Growth Characteristics	*Age in years*								
	11+	*12+*	*13+*	*14+*	*15+*	*16+*	*17+*	*18+*	*19+*
Height vertex	0.35	0.31	0.35	0.38	0.38	0.30	0.42	0.53	0.50
Sitting height vertex	0.20	0.20	0.19	0.26	0.19	0.20	0.21	0.23	0.22
Trunk height	0.18	0.16	0.18	0.18	0.26	0.19	0.18	0.16	0.20
Upper extremity length	0.21	0.18	0.22	0.21	0.24	0.19	0.25	0.30	0.31
Lower extremity length	0.18	0.27	0.33	0.24	0.29	0.20	0.33	0.36	0.35
Head and neck height	0.08	0.12	0.09	0.11	0.10	0.11	0.11	0.12	0.13
Weight	0.11	0.15	0.25	0.33	0.42	0.40	0.31	0.30	0.33
Biacromial breadth	0.10	0.12	0.14	0.23	0.20	0.20	0.19	0.19	0.18
Biiliocristal breadth	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.13
Bitrochanteric breadth	0.13	0.10	0.12	0.12	0.15	0.13	0.12	0.11	0.13
Chest breadth	0.12	0.11	0.09	0.10	0.16	0.15	0.16	0.15	0.17
Chest depth	0.08	0.09	0.09	0.08	0.10	0.10	0.12	0.08	0.09
Chest circumference	0.24	0.23	0.26	0.32	0.42	0.39	0.29	0.25	0.25
Upper arm girth	0.11	0.10	0.20	0.14	0.17	0.15	0.13	0.12	0.14
Calf girth	0.14	0.12	0.13	0.16	0.19	0.16	0.14	0.15	0.13
Head length	0.05	0.04	0.05	0.06	0.06	0.07	0.05	0.05	0.05
Head breadth	0.04	0.03	0.03	0.04	0.04	0.05	0.04	0.04	0.04
Head circumference	0.12	0.10	0.12	0.13	0.11	0.12	0.10	0.09	0.10
Minimum frontal breadth	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Bizygomatic breadth	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Bigonial breadth	0.03	0.03	0.03	0.02	0.04	0.03	0.03	0.03	0.03
Total facial height	0.05	0.03	0.04	0.04	0.05	0.04	0.05	0.06	0.05
Upper facial height	0.04	0.03	0.03	0.02	0.04	0.03	0.03	0.04	0.03

Table 3 : Standard deviations of growth characteristics in each year of age

Growth Characteristics	*Age in years*								
	11+	*12+*	*13+*	*14+*	*15+*	*16+*	*17+*	*18+*	*19+*
Height vertex	3.45	3.13	3.45	3.79	3.77	2.99	4.22	5.33	5.01
Sitting height vertex	2.02	1.98	1.87	2.57	1.88	2.00	2.09	2.28	2.24
Trunk height	1.78	1.59	1.83	1.83	2.62	1.89	1.78	1.61	1.95
Upper extremity length	2.14	1.80	2.15	2.07	2.43	1.85	2.54	3.01	3.06
Lower extremity length	1.84	2.66	3.29	2.42	2.90	1.97	3.30	3.64	3.50
Head and neck height	0.72	1.17	0.85	1.05	0.99	1.14	1.10	1.19	1.27
Weight	1.09	1.52	2.51	3.32	4.24	3.97	3.14	3.03	3.25
Biacromiai breadth	1.02	0.80	1.44	2.34	2.00	1.99	1.90	1.87	1.78
Biiliocristal breadth	1.40	1.26	1.26	1.19	1.24	1.15	1.13	1.08	1.30
Bitrochanteric breadth	1.25	1.01	1.20	1.18	1.45	1.26	1.18	1.12	1.29
Chest breadth	1.16	1.05	0.94	0.97	1.60	1.51	1.56	1.50	1.73
Chest depth	0.79	0.92	0.85	0.78	1.04	1.00	1.16	0.79	0.85
Chest circumference	2.37	2.33	2.57	3.24	4.19	3.88	2.94	2.54	2.46
Upper arm girth	1.07	0.97	1.99	1.40	1.66	1.52	1.30	1.20	1.41
Calf girth	1.42	1.22	1.26	1.61	1.88	1.64	1.42	1.50	1.34
Head length	0.52	0.43	0.46	0.56	0.57	0.65	0.54	0.53	0.50
Head breadth	0.48	0.30	0.31	0.37	0.39	0.48	0.37	0.36	0.41
Head circumference	1.22	0.98	1.18	1.28	1.09	1.19	1.04	0.93	1.02
Minimum frontal breadth	0.28	0.26	0.27	0.28	0.26	0.28	0.29	0.29	0.33
Bizygomatic breadth	0.39	0.39	0.30	0.30	0.39	0.39	0.42	0.40	0.43
Bigonial breadth	0.32	0.28	0.28	0.24	0.35	0.33	0.32	0.28	0.28
Total facial height	0.50	0.34	0.37	0 36	0.46	0.40	0.49	0.55	0.54
Upper facial height	0.38	0.29	0.31	0.24	0.41	0.32	0.39	0.36	0.32

Table 4 : Values of 't' test of significance for growth characteristics between successive age-groups

Growth Characteristics	*Age in years*							
	11-12	*12-13*	*13-14*	*14-15*	*15-16*	*16-17*	*17-18*	*18-19*
Height vertex	9.83	16.35	19.71	22.26	11.37	11.10	1.62	0.83
Sitting height vertex	8.30	9.30	19.00	15.77	11.16	6.75	3.48	1.57
Trunk height	3.28	4.50	14.50	22.56	5.96	7.74	0.39	0.19
Upper extremity length	6.30	14.00	15.55	16.57	8.92	8.16	0.20	1.00
Lower extremity length	10.00	14.48	7.79	18.17	9.69	6.85	0.45	0.25
Head and neck height	9.71	3.50	8.00	10.73	8.00	3.18	3.18	3.92
Weight	10.00	15.87	17.32	20.64	6.79	7.38	6.68	7.97
Biacromial breadth	5.60	13.25	10.79	9.52	2.05	6.20	2.74	5.37
Biiliocristal breadth	4.43	8.08	11.00	11.75	5.33	4.58	2.64	3.91
Bitrochanteric breadth	5.31	10.70	13.00	18.33	3.73	4.31	2.58	5.91
Chest breadth	4.67	10.45	9.11	16.70	4.06	4.73	1.75	6.87
Chest depth	5.38	4.33	8.78	14.75	4.20	4.70	1.83	6.63
Chest circumference	5.63	8.96	12.35	15.88	4.74	4.69	3.97	7.52
Upper arm girth	1.09	4.20	5.50	11.00	5.00	4.53	2.46	5.83
Calf girth	1.57	6.25	9.92	12.56	3.53	5.25	3.14	6.73
Head length	1.80	3.25	2.02	3.50	0.67	0.29	3.80	4.60
Head breadth	3.00	3.00	2.33	2.00	1.75	1.80	2.75	2.75
Head circumference	1.50	1.70	4.67	5.31	3.91	2.00	3.20	1.78
Minimum frontal breadth	2.33	1.00	5.67	2.33	2.67	0.67	2.67	0.33
Bizygomatic breadth	5.00	1.00	8.00	8.67	3.75	4.25	1.00	2.75
Bigonial breadth	5.33	2.00	5.00	10.00	3.75	5.33	7.33	4.00
Total facial height	2.80	0.67	3.00	9.25	2.60	4.50	1.00	1.00
Upper facial height	4.25	0.00	0.33	7.00	3.75	2.33	2.00	0.75

Table 5 : Values of indices of various multivariate distance analyses

S. No.	Name of the multivariate analysis	Age in years and index values								
		11+	*12+*	*13+*	*14+*	*15+*	*16+*	*17+*	*18+*	*19+*
1.	Mean Multivariate Distance (MMD)	0.00	2.00	4.65	9.81	16.63	18.71	20.65	21.80	23.62
2.	Co-efficient of per cent growth (CPG)		2.00	2.60	4.72	6.45	2.20	1.88	1.02	1.44
3.	Co-efficient of Standardised growth (CSG)		0.50	0.63	0.96	1.28	0.51	0.48	0.36	0.40
4.	T-Distance (T-D)		4.82	6.83	9.21	13.00	4.78	4.50	3.22	4.00

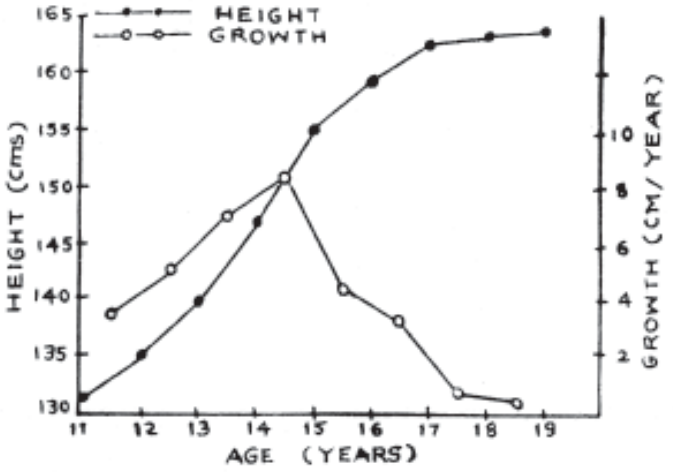

Fig. 1. Distance and velocity curves of height

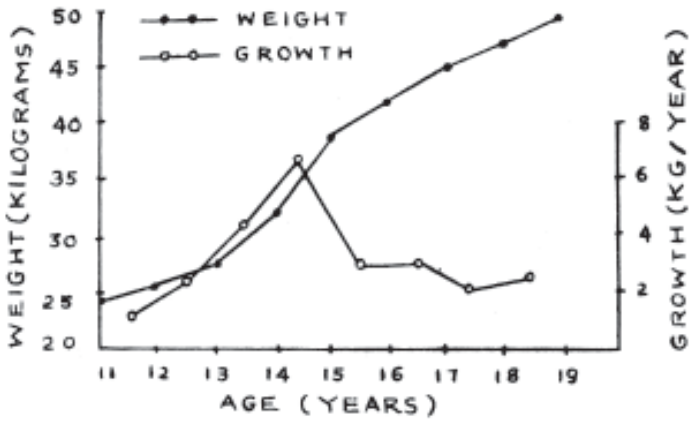

Fig. 2. Distance and velocity curves of weight (kilograms)

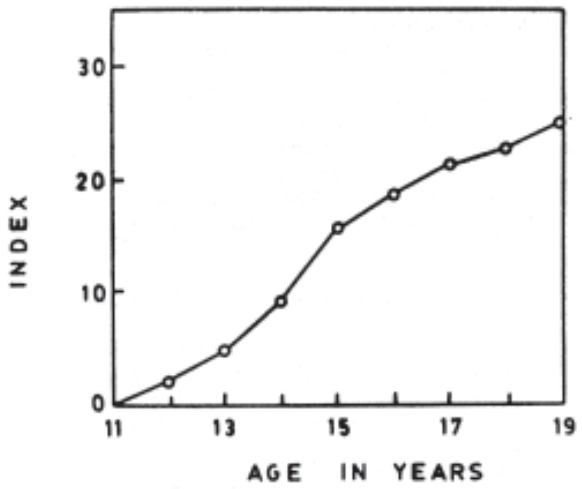

Fig. 3. Mean curve of multivariate distance

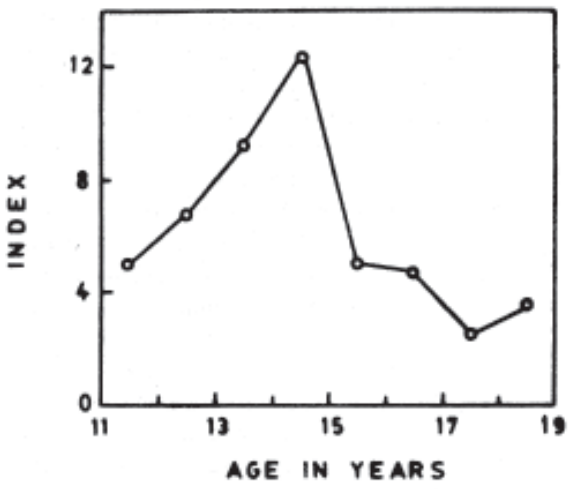

Fig. 5. Velocity curve of coefficient of percent growth

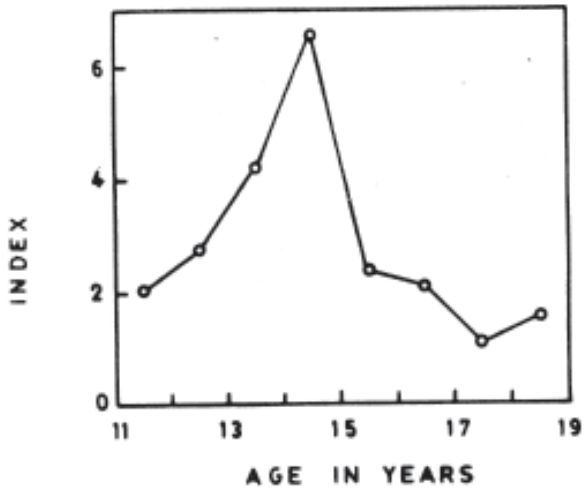

Fig. 4. Velocity curve of T-distance

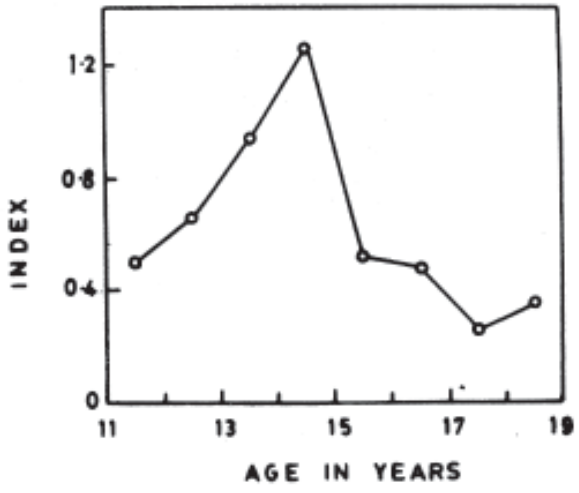

Fig. 6. Velocity curve of coefficient of standardised growth

present analyses of growth among adolescent Bhil boys. The basic element for multivariate distance, thus obtained, may remain directional when the study is limited to the period of rapid development. Thus, the composite multivariate distances based on these elements should display the pattern of total growth strain of the individuals instead of that for characters. The same elements can be used for a comparative study of differential or allometric growth.

The analyses of distance statistics bear fruit only if it is widely understood and that distance formulae are not merely computer tools but for using effectively in population differences both quantitatively and qualitatively and to use them for exploratory research of biological variation in man. With sharpening and simplification of the techniques broadly used here, multivariate distances may turn out to be most appropriate method for comprehensive holistic studies like growth and development and other subject matters of physical anthropology.

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