

A STUDY OF HUMAN GROWTH AMONG HIGH ALTITUDE FEMALE BODS OF LADAKH WITH REMARKS ON MORPHOLOGICAL ADAPTATION

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The researches in the Andes have shown that high altitude populations have slower and prolonged growth in stature, moreover, the adolescent spurt, as indicated by biennial increment, is not well defined in either sex (FRISANCHO 1966, 1968, BAKER et al. 1966, FRISANCHO and BAKER 1970, BAKER 1969, 1971, FRISANCHO 1975). Later, a further probing into the growth and development of these high altitude populations, led to the opinion that retarded growth seems to be genetic in nature and is not associated with the altitude of residence (HOFF 1972, FRISANCHO et al. 1975). PAWSON (1971), on the basis of his study on Ethiopian highlanders, concluded that females from Debarek (3,048 m. altitude) are significantly taller and heavier than their genetic counterparts at Adi Arkai (1,524 m.). PAWSON (1974) reported further that the highlanders from Nepal show clear adolescent spurt in stature.

The pattern of human growth among highlander Bods have been examined to find out whether they follow the "growth norms" of the highlanders from the Andes, Ethiopia, Nepal or are different from all of them. We shall emphasize here only the female Bods of Ladakh in the age range of 10 to 18 years.

Material and methods

This investigation is based on a cross-sectional sample of 148 apparently healthy Bod females of Ladakh (3,354 m. altitude) — a district in the Jammu and Kashmir (India), in the age range of 10 to 18 years.

Body measurements, viz. stature and body weight have been taken following the standard techniques as described by WEINER and LOURIE (1969). It needs mention that body weight has not been taken in nude, as suggested, but has been taken with minimum clothings and the respective weight of the garments has been subtracted from the observed weight. Body surface area has been calculated using the formula given for India populations by BANERJEE and SEN (1954) which is given below:

$$\text{Surface area} = (\text{weight})^{0.425} \times (\text{height})^{0.725} \times 74.66$$

Age has been recorded by following the I.B.P. Code No. 1 (WEINER and LOURIE 1969) and converted into decimals following decimal age system (TANNER et al. 1966). The mean values, annual increments and subsequently standard errors have been corrected by linear interpolation as advocated by TANNER (1959).

Results and Discussion

(A) Human growth (with emphasis on sexual dimorphism)

The mean values shown in Table 1 indicate that stature and body weight vary with increase in age from 10 to 18 years. Female Bods of Ladakh attain adolescent spurt between 12 and 13 years as assessed by maximum annual increment and rate of growth (Table 2) corresponding to the highest peak

Table 1

Age-changes in stature and body weight among Bods of Ladakh and Indian girls (ICMR, 1972) from 10 through 18 years

1. táblázat. Ladakhi bod leányok és indiai leányok termetének és testsúlyának életkori változásai 10–18 év között

Age groups Korcsoportok	Bods of Ladakh Ladakhi bod leányok					Indian girls Indiai leányok				
	N	Stature (mm) Termet		Body weight (kg) Testsúly		N	Stature (mm) Termet		Body weight (kg) Testsúly	
		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.
9.5–10.5	13	1275.92	41.21	23.70	6.29	3646	1284	80.2	23.6	5.74
10.5–11.5	10	1342.96	57.04	27.16	5.30	3442	1336	94.9	26.4	5.53
11.5–12.5	11	1407.85	72.21	29.98	11.29	3426	1392	102.4	29.8	6.63
12.5–13.5	16	1487.34	62.46	36.67	13.31	3168	1439	92.3	33.3	7.26
13.5–14.5	23	1489.18	57.19	38.12	13.27	2900	1475	97.2	36.8	7.23
14.5–15.5	23	1499.72	47.14	40.74	12.98	2644	1496	83.1	36.8	7.12
15.5–16.5	27	1503.29	47.70	43.56	11.99	2534	1510	71.1	41.1	6.80
16.5–17.5	15	1537.59	55.09	44.62	9.60	2115	1515	75.1	42.4	6.76
17.5–18.5	10	1565.06	36.72	46.16	8.65	1712	1517	58.9	42.4	7.17

Table 2

Mean annual differences and rate of growth in stature and body weight among Bods and Indian girls (ICMR, 1972)

2. táblázat A bod és az indiai leányok termetének és testsúlyának koreltérései és becsült növekedési rátái

Age (yr) Életkor (év)	Bods of Ladakh Ladakhi bod leányok				Indian girls Indiai leányok			
	Stature (mm) Termet		Weight (kg) Testsúly		Stature (mm) Termet		Weight (kg) Testsúly	
	Annual difference Koreltérés	Rate of growth Becsült növekedési ráta	Annual difference Koreltérés	Rate of growth Becsült növekedési ráta	Annual difference Koreltérés	Rate of growth Becsült növekedési ráta	Annual difference Koreltérés	Rate of growth Becsült növekedési ráta
10–11	67.04	4.99	7.61	12.74	52.00	3.89	2.80	10.61
11–12	64.89	4.61	6.20	9.41	56.00	4.02	3.40	11.41
12–13	79.49	5.34	14.94	18.24	47.00	3.27	3.50	10.51
13–14	1.84	0.12	2.96	3.80	36.00	2.44	3.50	9.51
14–15	10.54	0.70	5.73	6.43	21.00	1.40	0.00	0.00
15–16	3.59	0.24	6.20	6.47	14.00	0.93	4.30	10.46
16–17	34.29	2.23	2.33	2.38	5.00	0.33	1.30	3.07
17–18	27.48	1.76	3.38	3.34	2.00	0.13	0.00	0.00

velocity (Fig. 1), which is attained between 12 and 13 years for both stature and body weight.

It may however, be interesting to note that the male Bods of Ladakh, a sample extracted from the same population as that of present study, do not have clear adolescent spurt in stature (MALIK 1976). Similarly, while making a depth analysis of the sexual dimorphism in human growth, especially adolescent spurt among Nuñoa, BAKER (1969) reported "Lack of well defined adolescent growth spurt for males, and a late and poorly defined spurt for females" which delineates that the adolescent spurt among females is much clearer than in males (Fig. 2; BAKER 1972). Thus, it remains still unexplained how the adolescent spurt among the females is clear but not so in males in the two ethnically distinct high altitute populations of the world, viz. Nuñoa

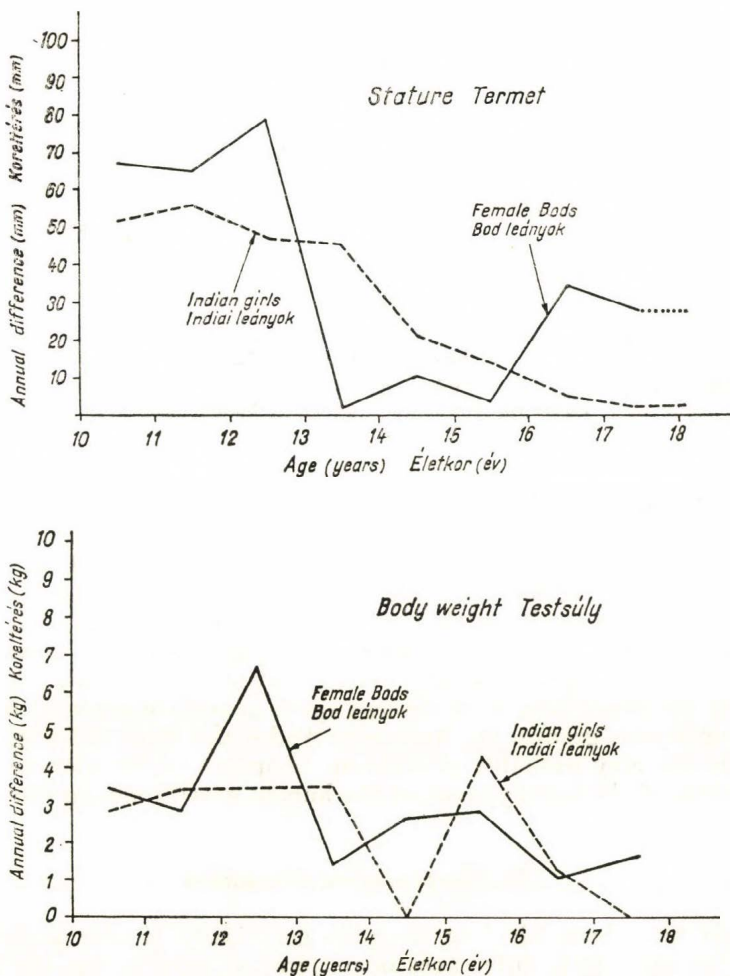


Fig. 1. Velocity curves of stature and body weight among Bods of Ladakh and Indian girls
 I. ábra. Ladakhi bod, valamint indiai leányok termetének és testsúlyának koreltérés-görbéi

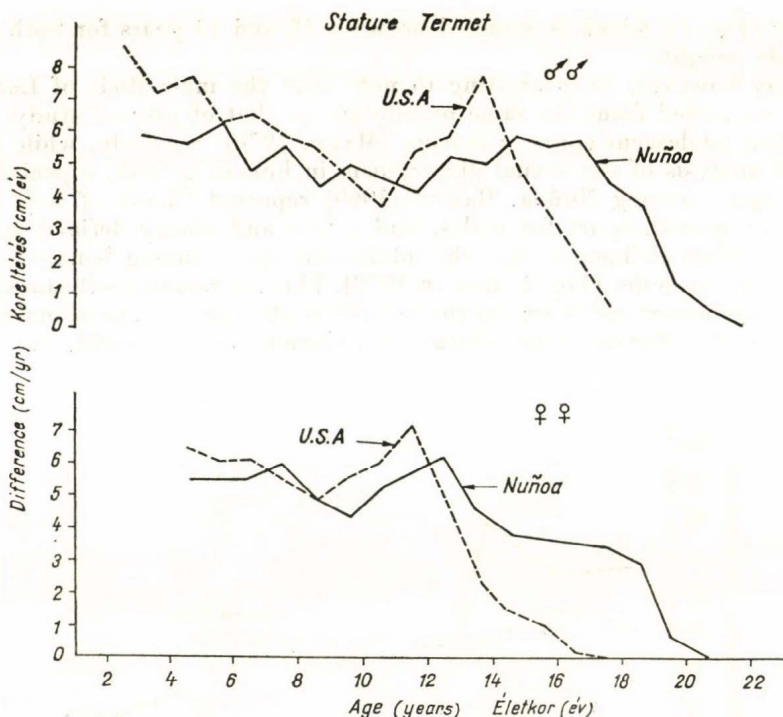


Fig. 2. Adolescent growth rates in Nuñoa (4000 m altitude) children compared to U. S. children (cf. BAKER 1972)

2. ábra. 4000 m magasságban élő nuñoai gyermekek serdülési növekedési rátája Amerikai Egyesült Államokbeli gyermekekéhez hasonlítva

and Bods. If this depression in adolescent spurt is associated to the altitude hypoxia as suggested earlier, how do we explain the clearer adolescent spurt among females? Are there any enzymatic factors involved? Is it due to the genetic 'superiority' of females (XX chromosome)? Or are there some other factors which enhance the adolescent spurt in females? While on the other hand, if we say that depression in adolescent spurt, as stated above, is not as a consequence of oxygen deficient environment of high altitude, then how do we explain the depression in adolescent spurt in stature amongst males from the two highlander groups, i.e. Nuñoas of Andes and Bods of Ladakh. Future research works may probably provide an adequate explanation to the differential effects of altitude hypoxia on the human growth among the two sexes.

(B) Morphological adaptation

It would have been ideal to compare genetically similar populations to examine the altitudinal differences in patterns of growth, but the limitation of the present study do not permit this, instead they have been compared with the Indian pooled data (ICMR, 1972). It is explicit from growth rate index

($GRI = \bar{x}_F - \bar{x}_I/\bar{x}_F$) that Bod females grow faster than Indian girls both in stature ($GRI = 18.47$ and 15.36 , respectively) and weight ($GRI = 48.66$ and 44.34 , respectively) which is different from earlier observations on Peruvian highlanders where slower growth in stature has been recorded (FRISANCHO 1968, 1969). Furthermore, Bods are taller and heavier than the Indian girls at the age of 18 years which is in support of earlier findings from the highlands of Ethiopia and Nepal (PAWSON 1971, 1974). The greater body size among Bod highlanders reminds one of a pioneer study of BERGMANN (1847) which purports that in the single species of warm-blooded animals the population in colder climate attains greater body size than in the warmer climate. Later on, ROBERTS (1953) confirmed the above findings and reported that the body weight decreases with increase in mean annual temperature of its biotope.

The higher body weight/body surface area ratio among Bod females (Table 3)

Table 3

Body weight/body surface area among Bods and Indian girls
in the age range of 10 to 18 years

3. táblázat. A bod és az indiai leányok testsúly/testfelület hányadosának életkori változásai
10–18 év között

Age (yr) Életkor (év)	Body weight/surface area* Testsúly/Testfelület*	
	Bods of Ladakh Ladakhi bod leányok	Indian girls Indiai leányok
10	24.61	24.42
11	25.74	25.30
12	26.21	25.58
13	28.27	27.41
14	28.90	28.50
15	29.85	28.21
16	30.98	29.86
17	30.90	30.55
18	31.11	30.30

* Surface area calculated by the formula of Banerjee and Sen (1954).
A testfelületet BANERJEE és SEN (1954) képlete szerint számították.

seems to be of thermolytic utility in adapting to the cold climate of the area. It is well known that the production of body heat is proportional to its mass and loss of heat by radiation, to its body surface and organism with bigger body size and higher ratio between body weight/body surface cannot only produce more heat but also may resist better than the organism with smaller size (SCHREIDER 1951; NEWMAN 1953, 1955; SCHOLANDER 1955; GARN 1961; WALTER 1971). Therefore, it seems that bigger size and higher weight/surface area ratio contribute in adapting to the stress of cold climate.

Summary and conclusion

The findings in human growth and development at high altitude are somewhat controversial. Female Peruvian Quechua are shown not to have clear adolescent spurt with slower rate of growth in stature, whereas, females from

the highlands of Ethiopia and Nepal show clear adolescent spurt and are taller and heavier than their genetic counterparts at low altitude. The following conclusions appear justified from this survey conducted on female Bods of Ladakh — a high altitude population:

1. Female Bods at high altitude show clear adolescent spurt in stature; the males of the same population do not show clear adolescent spurt (MALIK 1976). This finding is similar to the case of the female Peruvian highlanders who have comparatively clearer adolescent spurt than the males (BAKER 1969).

2. Female Bods of Ladakh grow faster and are taller and heavier at the age of eighteen years than the Indian girls are at the same age.

3. Higher body size and weight/surface area ratio among female Bods than among Indian girls in the plains may be significant as adaptivity to the cold climate of Ladakh.

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NAGY MAGASSÁGBAN ÉLŐ LADAKHI BOD LEÁNYOK NÖVEKEDÉSE,
KÜLÖNÖS TEKINTETTEL A MORFOLÓGIAI ADAPTÁCIÓRA

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(Összefoglalás)

Szerzők keresztmetszeti növekedésvizsgálatot végeztek Ladakhban, 148 egészséges, a bod etnikai csoporthoz tartozó, 10—18 éves leányon.

A nagy magasságban (3354 m) élő bod leányok természetbeli növekedése határozott serdülési növekedési lökést mutat; a fiúknál ez nem észlelhető (MALIK 1976). Ez az eredmény hasonló a perui Andokban élő leányoknál talált jelenséghez; ők szintén viszonylag határozottabb serdülési növekedési lökést mutatnak, mint a fiúk (BAKER 1969).

A ladakhi bod leányok gyorsabban nőnek, magasabbak és súlyosabbak 18 éves korukban, mint az indiai leányok hasonló életkorban.

A síkságon élő indiai leányokhoz hasonlítva a bod leányokat, azok nagyobb termete és testsúly/testfelület hányadosa a ladakhi hideg éghajlathoz történő adaptáció jele lehet.

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