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Altitude and Growth Among the Sherpas of the Eastern Himalayas

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ABSTRACT The results of the anthropometric survey of Sherpa children of both sexes (n = 478) from high- and low-altitude areas in the eastern Himalayas are presented. The study reveals that growth is slower both more prolonged in the high-altitude Sherpas compared with growth at low altitude and that Sherpa children are the smallest of all the high-altitude populations considered here. Sexual dimorphism is not well defined during the earlier age periods. Our skinfold thickness data from the low-altitude Sherpas corroborate the centripetal distribution of fat found elsewhere.

Child growth is an important indicator for evaluating the extent of environmental quality and adaptation (Harrison and Brush, manuscript in preparation, 1990) and therefore the level of health, including nutritional status and well being, of populations. Among environmental factors affecting health and well being, physical environmental ones associated with high altitude have long been recognized.

The major thrust of the present paper is to evaluate the child growth patterns of the Sherpas inhabiting the harsh climatic conditions of high-altitude Nepal and their migrant low-altitude Kalimpong counterparts in India. The two altitude groups reside under dissimilar altitude-related ecological milieus but have a similar ethnic ancestry.

Pawson (1974, 1976, 1984), Frisancho (1978, 1981), Mueller et al. (1978, 1980), Beall (1981b), Gupta (1981), and Gupta et al. (1987) have made comprehensive reviews of the growth and development patterns of children in relation to altitude that are not repeated here, but the following salient findings should be noted. Most studies on the effects of hypoxia on growth and development of children have been done in the Andes. The available information to date shows, in general, that growth at high altitude is retarded, the processes of growth and pubescence are slow but protracted, a growth spurt is absent, sexual dimorphism appears late, and skeletal and sexual maturation are delayed; but growth of the organ system concerned with O_2 transport, e.g., the placenta, lung, and thorax, is accelerated (Frisancho, 1981). This general pattern of high-altitude effects on child growth and development, however, was not found consistently in subsequent studies. For instance, in some of the studies the high-altitude children are found to have smaller body dimensions (except for chest girth) as expected under some physiological considerations (Miklashevskaya, 1979; Frisancho and Baker, 1970; Malcolm, 1970; Miklashevskaya et al., 1973; Haas, 1973, 1976; Beall et al., 1977; Mueller et al., 1978; Stinson, 1980, 1982; Beall, 1981a; Singh, 1980, 1989); in others, high-altitude children are taller and heavier (Clegg et al., 1972; Frisancho et al., 1975; Singh and Malik, 1977; Malik and Singh, 1978); and in yet others the two altitudinal groups are similar (Hoff, 1974).

The review of the literature on high-altitude growth patterns indicates that a wide spectrum of variation exists in the responses of different high-altitude human populations in different regions of the world as well as among different high-altitude populations within the same region. Leonard (1989) opined that nutritional factors have significantly contributed to the extremely slow growth previously reported for the children of Nunoa.

Very little comprehensive study has been done on the high-altitude child growth pattern in the eastern Himalayas, despite the wide array of microphysical environmental, sociocultural, and ethnic variations occur-

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	4-7 Years						8-11 Years						12-15 Years						16-19 Years					
	High altitude			Low altitude			High altitude			Low altitude			High altitude			Low altitude			High altitude			Low altitude		
Measurements	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Weight (kg)	23	14.97	2.31	32	14.80	2.77	52	19.91	3.07	39	20.40	3.67	43	27.10	3.29	20	29.30	8.72	19	36.67	5.73	28	39.10	12.93
Stature (cm)	29	99.43	7.85	32	99.60	8.35	52	115.91	2.29	39	116.30	9.86	43	130.69	6.59	20	132.80	21.54	19	145.68	7.74	28	143.20	24.87
Sitting height (cm)	27	57.80	3.83	12	56.90	3.19	52	63.61	3.86	20	64.40	5.26	39	69.64	3.31	7	71.70	9.82	9	74.05	2.16	11	71.80	12.89
Biacromial diameter (cm)	27	19.98	2.08	12	22.50	1.62	52	22.16	2.10	20	25.40	2.08	39	24.91	1.82	7	28.40	4.40	9	25.83	1.52	16	31.50	6.23
Biceps girth (cm)	28	14.55	0.92	12	14.80	0.95	52	14.85	0.91	20	15.80	1.25	39	16.56	0.95	7	17.80	1.33	8	17.54	0.91	16	20.50	3.97
Calf girth (cm)	26	20.29	1.79	12	20.40	1.64	52	21.75	1.63	20	23.30	2.02	39	24.80	1.88	7	26.60	3.53	9	27.33	1.97	16	28.80	5.20
Triceps skinfold thickness (mm)	28	7.30	1.70	12	6.50	1.91	52	5.40	1.40	20	5.20	1.15	39	5.40	1.00	7	5.80	2.13	9	5.70	2.10	16	5.80	1.04
Subscapular skinfold thickness (mm)	28	4.50	3.90	12	4.90	1.54	52	4.00	0.80	20	4.70	0.88	39	4.50	2.60	7	5.70	0.94	9	4.70	1.60	16	7.20	1.88

TABLE 2. Anthropometric measurements by age and altitude (females)

	4-7 Years						8-11 Years						12-15 Years						16-19 Years					
	High altitude			Low altitude			High altitude			Low altitude			High altitude			Low altitude			High altitude			Low altitude		
Measurements	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Weight (kg)	34	14.31	1.87	32	13.20	2.58	52	18.94	2.71	25	19.10	4.83	35	26.03	5.26	14	28.80	11.30	6	44.08	10.74	17	43.90	6.48
Stature (cm)	35	97.21	6.55	32	94.80	9.47	52	113.67	6.67	25	114.50	12.57	35	131.59	7.37	14	126.80	20.35	6	148.08	9.60	17	147.30	5.24
Sitting height (cm)	34	56.57	2.61	24	52.70	4.53	46	63.40	2.68	9	59.70	5.53	16	67.89	3.20	3	74.30	4.71				14	76.30	2.51
Biacromial diameter (cm)	34	19.70	2.06	24	20.80	1.69	46	22.18	1.80	9	24.00	3.03	16	23.72	1.62	3	31.10	1.71				16	32.60	1.87
Biceps girth (cm)	34	14.49	0.94	24	14.50	0.96	48	14.52	0.89	9	14.90	1.21	16	16.39	1.00	3	20.60	2.14				16	22.10	2.01
Calf girth (cm)	34	19.58	1.13	24	19.80	1.78	46	21.73	1.51	9	21.50	2.19	16	24.24	1.52	3	29.30	3.55				16	30.90	2.29
Triceps skinfold thickness (mm)	34	8.00	2.80	24	7.30	1.56	46	6.20	1.40	9	6.20	1.47	16	5.90	1.00	3	9.40	3.68				16	11.30	3.13
Subscapular skinfold thickness (mm)	34	4.90	2.40	24	5.60	1.06	46	4.40	1.00	9	5.60	1.43	16	4.50	1.00	3	9.50	3.27				15	12.70	3.77

TABLE 3. Quantitative assessment of sexual dimorphisms according to age (years) groups[1]

	High altitude				Low altitude			
Measurements	4-7	8-11	12-15	16-19	4-7	8-11	12-15	16-19
Weight	1.05	1.05	1.04	0.83	1.12	1.07	1.02	0.89
Stature	1.02	1.02	0.99	0.98	1.05	1.02	1.05	0.97
Sitting height	1.02	1.00	1.03	—	1.08	1.08	0.96	0.94
Biacromial diameter	1.01	0.99	1.05	—	1.08	1.06	0.91	0.97
Biceps girth	1.00	1.02	1.01	—	1.02	1.06	0.86	0.93
Calf girth	1.04	1.00	1.02	—	1.03	1.08	0.91	0.93
Triceps skinfold thickness	0.91	0.87	0.92	—	0.89	0.84	0.62	0.51
Subscapular skinfold thickness	0.92	0.91	1.00	—	0.87	0.84	0.60	0.57

[1]Sexual dimorphism = male measurement/female measurement.

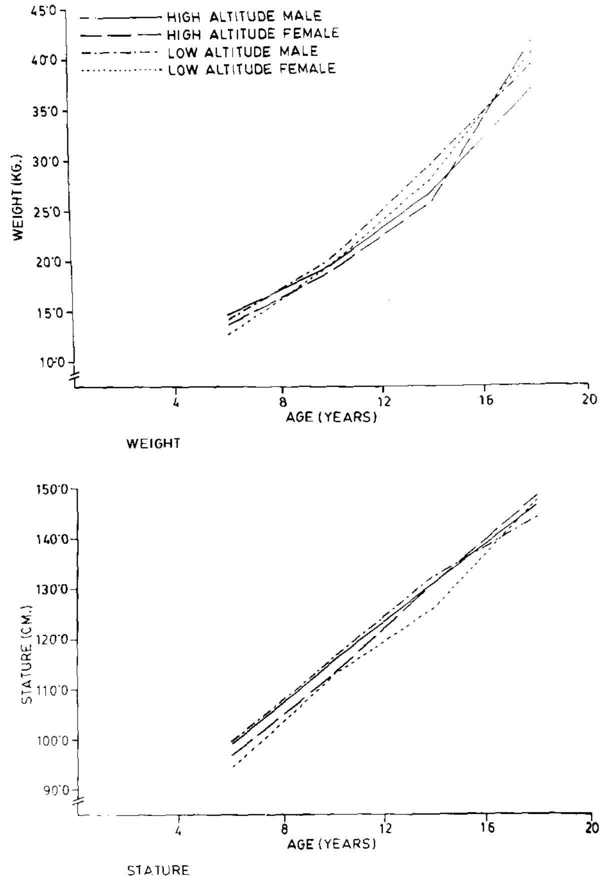

Fig. 1. Distance curves for weight and stature: high- and low-altitude Sherpa males and females.

ring within this region. In view of this, multidisciplinary biomedical surveys have been carried out on some populations of the eastern Himalayas since 1976, in the course of which demographic, anthropometric (both adult and child), dietary, intestinal parasitic, blood pressure, blood polymorphic, haematologic, and medical-ophthalmological data were collected. The data on child growth are presented here.

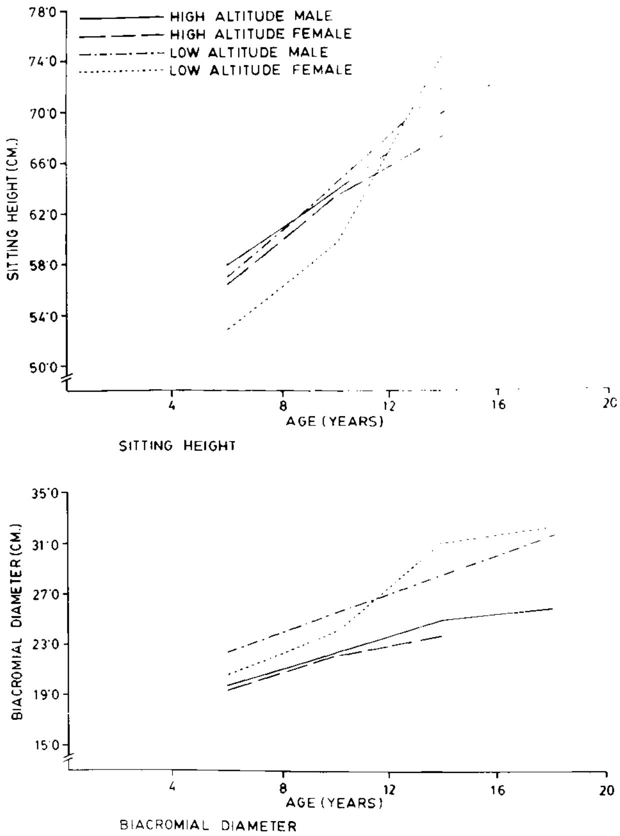

Fig. 2. Distance curves for sitting height and biacromial diameter: high- and low-altitude Sherpa males and females.

MATERIALS AND METHODS

The present study was conducted among the Sherpas of Upper Khumbu (altitude, 3,500–4,050 m) in Nepal and of Kalimpong (altitude, 1,000–1,500 m) in India. The Sherpas presumably migrated from eastern Tibet to northeastern Nepal about 450 years ago (Oppitz, 1974) and from there to the Kalimpong area in India about 200 years ago, most of them directly and some via Sikkim (Gupta, 1981). The diet of the Upper Khumbu Sherpas is mainly cereal based, while that of the Kalimpong Sherpas include, in addition to cereals, greater quantities of green vegetables and animal proteins (for further details on the Sherpas' environment and life style, see Gupta, 1981).

The basic design comprised a comparison between two subunits of a population, one native to high altitude, i.e., the Sherpas of Upper Khumbu (3,500–4,050 m), and another migrant to a lower altitude, i.e., the Sherpas of Kalimpong subdivision (1,000–1,500 m). The two study areas were selected purposely to include the highest and lowest altitude Sherpa settlements in order to maximize altitudinal differences and their effects, if any.

This study of child growth is based on a cross-sectional sample of 478 Sherpa children of both sexes in the age range of 4 to 19 years from the two areas. The usual difficulties involved in such communities were encountered in the assessment of age, as there was no tradition of keeping birth registration or any written record of age among them, but the reported age was cross-checked with the "Tibetan animal element calendar." This calender makes possible age

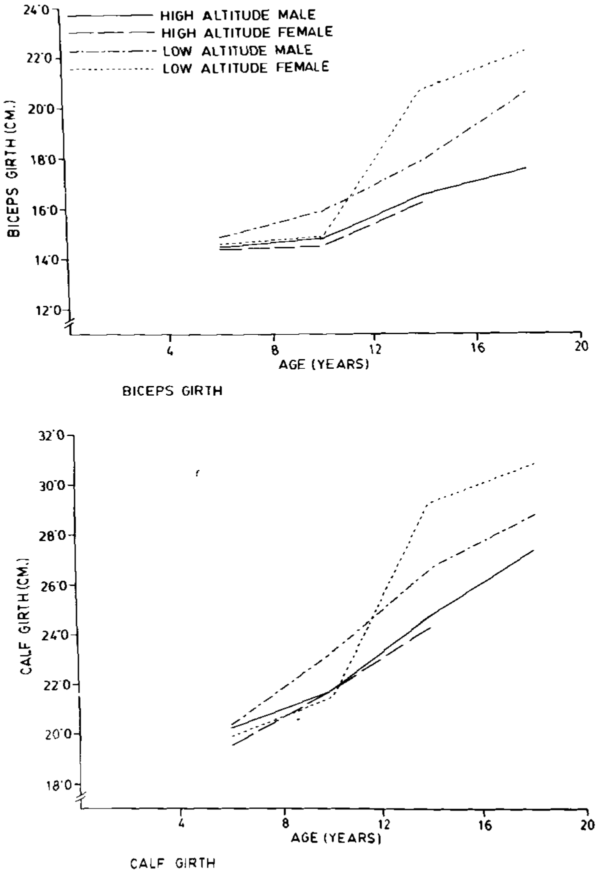

Fig. 3. Distance curves for biceps girth and calf girth: high- and low-altitude Sherpa males and females.

ascertainment with an error range not exceeding 1 year.

Eight measurements, shown in Tables 1 and 2, taken by author R.G., utilized the standard techniques (Weiner and Lourie, 1969). Biceps and calf girths as well as triceps and subscapular skinfold thicknesses were taken on the left side of the subject. The data are presented in 4-year age groups.

RESULTS

The means and standard deviations for anthropometric measurements for males and females are presented in Tables 1 and 2, respectively. The quantitative data on sexual dimorphisms are presented in Table 3. Figure 1 shows that the high- and low-altitude curves are very close and run pari passu and that there is an increasing trend. Figure 2 shows that for sitting height the curves generally overlap in the males and that low-altitude females surpass males from the 8–11-year age group onward, whereas for biacromial diameter the low-altitude group has higher values in all age groups in both sexes.

It appears from Figure 3 that the low-altitude group has increasingly higher biceps girth values, and, by and large, a similar trend is observed with respect to calf girth. Figure 4 shows that the high-altitude children have consistently higher values for triceps than do those at low-altitude in both sexes, while at the subscapular site the low-altitude group has increasingly higher values in both sexes. Overall, the distribution of

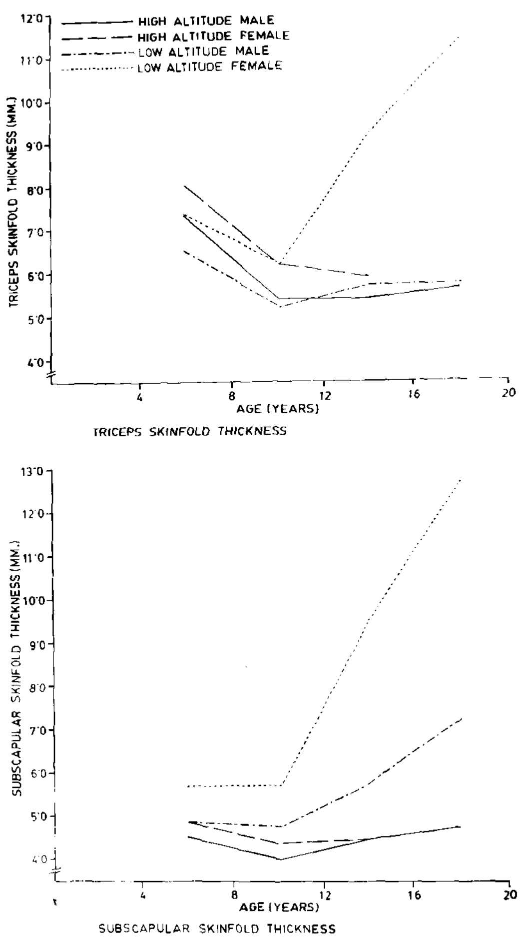

Fig. 4. Distance curves for triceps and subscapular skinfold thicknesses: high- and low-altitude Sherpa males and females.

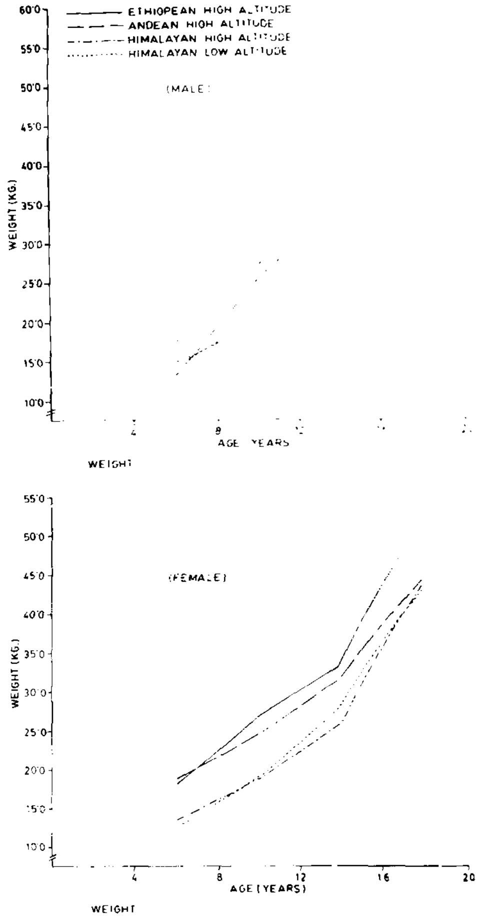

Fig. 5. Distance curves for weight: high- and low-altitude (Himalayan) Sherpas and high-altitude Andean and Ethiopian males and females.

subcutaneous fat during growth follows a centripetal pattern.

Often data are lacking for the last age group in the high-altitude Sherpa females. Thus in many cases the degree of sexual dimorphism is difficult to ascertain in the higher age group(s), but an attempt has nevertheless been made to consider this interesting phenomenon to the extent possible.

Furthermore, an attempt has been made to compare the growth curves of the Himalayan high- and low-altitude Sherpa children with those of high-altitude Ethiopian (Clegg et al., 1972) and high-altitude Andean (Frisancho and Baker, 1970) children. The data on stature and weight were used after recalculating these data into 4-year cohorts for comparability. It appears that both high- and low-altitude Sherpa children are consistently smaller than Ethiopian and Andean children, in both sexes, in all the age groups (Figs. 5 and 6). The Andean curves lie between the Ethiopian and Himalayan curves.

DISCUSSION

Despite a large number of studies, the magnitude of hypoxic effect on growth is still far from clear. The growth process at high altitude represents responses to a myriad of physical environmental as well as sociocultural factors which cannot at present be separated.

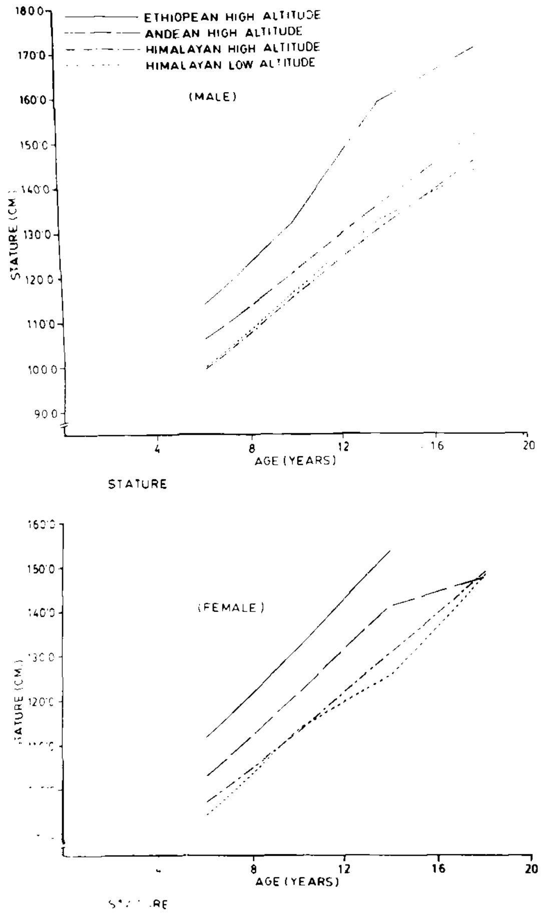

Fig. 6. Distance curves for stature: high- and low-altitude (Himalayan) Sherpas and high-altitude Andean and Ethiopian males and females.

The review of existing literature on altitudinal differences in child growth shows that all three theoretical possibilities have been realized in different study areas: 1) the high-altitude children have smaller measurements than do those at low altitude; 2) the high-altitude children have larger measurements than do those at low altitude, and 3) the high- and low-altitude differences are inconsistent. It appears that the effects of altitude on child growth are neither as clear-cut nor as marked among the Sherpas as among certain Andean and other populations studies, particularly in the case of stature and weight, in either sex. The general characteristics of absence of growth spurt in high-altitude children as found in Andean and other studies (e.g., Frisancho, 1976, 1978; Frisancho and Baker, 1970; Pawson, 1974) is also confirmed by our data. Furthermore, because the low-altitude Sherpas, particularly the females, have relatively bigger body dimensions in the lower age groups and smaller dimensions in the higher age groups, the high-altitude children presumably continue to grow after those at low altitude cease to do so, suggesting that growth is slower but more protracted at high altitude, as has been reported by others (Frisancho, 1981). It is plausible that because of the slower and relatively more protracted growth, high-altitude adults attain larger body dimensions compared with low-altitude adults, as has been shown for the Sherpa high- and low-altitude adults by Gupta and Basu (1981). Age changes among adults have been dealt with in an another paper (Ghosh Dastider and Gupta, 1988). With respect to sexual dimorphism, it is generally not well defined, particularly at high altitude, as has also been reported by Frisancho (1981). Basu et al. (1987) report that the Kalimpong Lepchas are only slightly taller and heavier than the Kalimpong Sherpas, except in the 12–15-year age group in males, and that the Lepcha curves lie within the range of 1 SE unit from the data points of the Kalimpong Sherpa curves in general, indicating that the nutrient intake differences between the two populations may not seem to exert any impact on growth pattern.

Unlike Andean studies (Frisancho, 1976, 1978; Frisancho and Baker, 1970), the skinfold thickness data of the high-altitude Sherpas show that in both males and females triceps and subscapular skinfold thicknesses decrease up to the age of 8–11 years. Our low-altitude skinfold data corroborate the centripetal distribution of fat, which is a general phenomenon and not restricted to the high-altitude niche alone.

The comparisons between Himalayan high- and low-altitude Sherpa growth curves, as well as between the Sherpa curves and high-altitude Ethiopian and Andean curves, were made visually following the common practice and also because even such visual comparisons yield interesting findings.

Thus our findings, which only partly conform with those obtained from Andean studies, may suggest that different populations respond differentially to altitude stress and different traits respond differentially in different mountainous zones. Furthermore, high-altitude Sherpa children are the smallest of all the high-altitude children samples studied thus far, which is in discordance with the findings of Greksa (1986). (This statement is subject to the limitations of the cross-sectional data.)

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