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Growth and Nutritional Status of Tibetan Children at High Altitude

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A B S T R A C T

Growth and development are clearly affected by high-altitude exposure to hypoxia, nutritional stress, cold or a combination of these factors. Very little research has been conducted on the growth and nutritional status of children living on the Tibetan Plateau. The present study evaluated the environmental impact on human growth by analyzing anthropometric characteristics of Tibetan children aged 8–14, born and raised above 4000 m altitude on the Himalayan massif in the prefecture of Shegar in Tibet Autonomous Region. Data on anthropometric traits, never measured in this population, were collected and the nutritional status was assessed. A reference data set is provided for this population. There was no evidence of wasting but stunting was detected (28.3%). Children permanently exposed to the high-altitude environment above 4000 m present a phenotypic form of adaptation and a moderate reduction in linear growth. However, it is also necessary to consider the effects of socioeconomic deprivation.

Key words: *growth, children, nutritional status, high altitude, Tibet*

Introduction

People permanently exposed to hypoxia at >3000 m above sea level show a phenotypic form of adaptation[1]. Children living at high altitudes* often have delayed growth, but whether growth retardation is related to high altitude or to other factors is still not known[2]. In fact, the effects of hypoxia on growth are combined with the effects of low socioeconomic status, poor nutrition and disease. The few studies conducted in Tibet indicated that there is a high prevalence of malnutrition in preschool and school children (especially stunting), with values higher than the average in China. These studies also implied that there is some adaptation to high-altitude hypoxia in the growth pattern of Tibetan children[3,4].

However, it is difficult to interpret this information because of insufficient data due to limited samples and/or a small number of characters considered. This paper presents the results of a study designed to increase the amount of information available on Tibetan children. Its purpose is to assess the physical growth and nutritional status of Tibetan children living above 4000 m. on the Himalayan massif.

Materials and Methods

Study subjects

During the Italian scientific expedition on Mount Everest (Shegar, Tibet) as part of the *K2-2004* project (April-May 2004), we examined 131 Tibetan children (67 males and 64 females) from 8 to 14 years of age, with no manifested or suspected genetic or chronic disease of any kind. None of the girls had reached menarche. The community we studied are situated at an altitude higher than 4000 m (Shegar, at 4050 m; Tingri, at 4350 m; Qi, at 4380 m) within the Qomolangma (Tibetan name of Mount Everest) Nature Reserve in the prefecture of Shegar, Tibet Autonomous Region (TAR) (Figure 1). All participants were born and raised in one of these three villages

* Another research article on growth of Tibetans in India[2] was recently published when the present paper was in reviewing.

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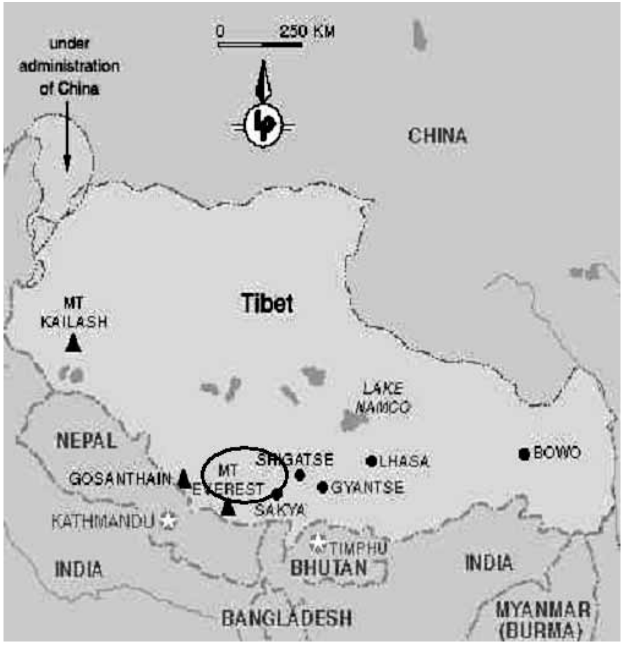

Fig. 1. Map of Tibet showing the location of the study area.

above 4000 m. with similar socioeconomic characteristics. This study is based on cross-sectional data collected at the local schools or at community centers.

Participants were asked to identify their ethnicity, birthplaces, birth dates, and birthplaces of both parents. Statements regarding the birth dates of participants were verified by checking school records or by questioning the parents. The ages of the subjects were computed at 2-year intervals. The children are all from peasant families and are not related to each other. The children were classified as Tibetans only if both parents were identified as ethnic Tibetans. The children's families were adequately informed about the project and participation in the study was voluntary.

The project was approved by the scientific board of the IMONT (Italian Institute for the Mountain).

Data collection

A standard set of anthropometric measurements was taken on each participant at fixed measurement stations, following the guidelines of Weiner and Lourie[5]. The anthropometric measurements were: height; weight; skinfolds measured at the biceps, triceps, subscapular, supraspinale and medial calf sites; upper arm (relaxed and flexed), wrist, waist, gluteal and calf circumferences; chest circumferences (normal, minimum and maximum) and elbow breadth. All children were weighed with a digital balance (Sohenle, reading accuracy ± 0.1 kg) while wearing one layer of undergarments. The other instruments were: Lange caliper (reading accuracy ± 1 mm) for skinfold thicknesses, portable anthropometer for height, anelastic tape for circumferences and a sliding caliper for elbow breadth.

Statistical analysis

Means and standard deviations of all characters were calculated.

Body mass index (BMI) was calculated as kilograms divided by height in meters squared. Waist to hip ratio (WHR) was calculated as the ratio of waist girth and hip girth. Cross-sectional muscle (UMA) and fat (AFA) areas of the upper arm and the Arm Fat Index (AFI) were calculated on the basis of measurements of the relaxed upper arm circumference and triceps skinfold[6]. Percentage of Fat (%Fat), Fat Mass (FM) and Fat Free Mass (FFM) were calculated following Slaughter's formulas[7].

The raw measurements were converted to z-scores using the means and standard deviations of the data from the Global Database on Child Growth and Malnutrition, NCHS/WHO international reference population[8,9]: weight-for-height (WHZ), weight-for-age (WAZ) and height-for-age (HAZ) were computed. To evaluate the nutritional status, a cut-off point of –2 SD from the mean value of the reference population[10] was used to separate the undernourished population from the well-nourished one. Undernourished children (Z-score = –2 SD) were considered wasted (low weight-for-height), underweight (low weight-for-age) or stunted (low height-for-age)[11].

Student's t-test was calculated for comparisons between groups. Statistically significant differences are labeled with * ($p<5\%$). Analyses of variance (ANOVA) and Tukey's post hoc tests were conducted to determine whether there were significant differences in anthropometric characteristics among groups.

The statistical analyses were performed with Statistica software (StatSoft Inc., 2000).

Results and Discussion

Table 1 shows the means and standard deviations of the anthropometric variables in the Tibetan children (males and females). At the same age, boys and girls do not differ in thorax circumferences (normal, minimum and maximum) or fat free components (FFM and UMA). However, there is sexual dimorphism in the fat component: skinfold thicknesses, FM, %Fat, AFA and AFI. In females, there are significant changes in skinfold thicknesses during growth (ANOVA), while males do not show significant differences through time (subscapular skinfold excepted). Student's t-test and ANOVA results indicated a significant effect for sex and age in almost all characters ($p<0.05$). Post hoc Tukey's test confirmed age pair-wise differences. Comparisons within age-groups by this test indicated significant differences especially for 14-yr group vs the others: it seems that 14 years is a critical age for changes in almost all the anthropometric characters.

The growth of our sample was also characterized by enlarged chest and smaller body size, as previously reported in the literature[12–14]. In humans exposed to high altitude, the effect of suboptimal nutrition may contribute to the altered pattern of growth, although poor nutri-

TABLE 1
MEAN AND STANDARD DEVIATION'S VALUES OF THE ANTHROPOMETRIC MEASUREMENTS. ANOVA COMPARING THE FOUR AGE-GROUPS FOR EACH SEX AND STUDENT'S TEST BETWEEN SEXES WERE REPORTED (* denotes p<0.05)

Age	8–9 years			10–11 years			12–13 years			14 years			Among	age-groups
Sex (n)	M (18)		F (13)	M (10)		F (25)	M (16)		F (17)	M (23)		F (9)	M (67)	F (64)
Characteristics	X(SD)	*t*	X(SD)	X(SD)	*t*	X(SD)	X(SD)	*t*	X(SD)	X(SD)	*t*	X(SD)	ANOVA[a]	ANOVA[b]
Height (cm)	115.6(4.1)	*	114.6(4.2)	130.6(10.1)	*	131.3(8.3)	133.8(5.3)		136.5(7.2)	150.2(11.4)		146.2(5.0)	73,206*	45.452*
Weight (kg)	20.7(1.9)		20.7(1.5)	28.1(5.9)		28.1(5.1)	28.4(2.2)		29.9(4.7)	39.4(9.3)		38.1(4.3)	46.991*	27.201*
BMI (kg/m²)	15.5(1.0)	*	13.1(1.0)	16.3(1.2)		16.1(1.3)	15.9(0.9)		16.0(1.1)	17.8(1.7)		17.8(1.5)	11.291*	6.327*
Arm, relaxed (cm)	15.3(0.9)	*	15.5(0.9)	16.9(1.5)	*	16.8(1.3)	16.6(1.0)		17.0(1.3)	19.4(2.4)		19.8(1.8)	28.705*	16.117*
Arm, flexed (cm)	16.5(0.9)	*	16.6(0.8)	18.2(1.2)		18.2(1.2)	18.2(1.1)		18.5(1.6)	21.9(3.1)		21.6(2.4)	32.026*	19.020*
Wrist girth (cm)	11.6(0.4)		11.5(0.3)	12.5(0.8)	*	12.6(0.7)	12.7(0.6)		12.9(0.8)	14.6(1.1)		14.3(0.8)	49.085*	25.959*
Chest, normal (cm)	58.0(2.0)		58.6(1.7)	64.6(3.3)		63.7(3.8)	65.5(2.8)		66.1(3.0)	74.3(6.7)		72.9(4.7)	42.203*	28.676*
Chest, max (cm)	61.1(2.0)		61.5(1.4)	68.1(4.7)		67.3(4.4)	68.2(2.2)		68.7(3.4)	78.7(6.9)		76.8(4.8)	45.989*	26.392*
Chest, min (cm)	57.3(2.0)		57.9(1.6)	63.0(4.8)		61.9(4.1)	63.5(2.5)		63.6(3.1)	72.9(6.6)		70.6(4.2)	40.819*	22.361*
Waist girth (cm)	52.2(2.2)		52.8(2.0)	56.5(3.4)		55.0(3.2)	56.9(2.0)		57.3(2.7)	65.2(5.0)	*	59.7(3.5)	41.315*	11.551*
Gluteal girth (cm)	63.2(3.4)		62.7(1.8)	70.2(6.0)	*	71.0(4.9)	69.7(3.0)	*	72.5(6.2)	80.1(5.7)		78.7(4.0)	43.461*	21.420*
Calf girth (cm)	21.8(1.1)	*	22.4(1.1)	24.7(2.2)		24.7(1.9)	24.5(1.2)	*	25.1(1.8)	29.4(2.8)		27.7(1.1)	47.691*	17.286*
Biceps skinfold (mm)	3.1(1.0)	*	3.1(0.9)	2.6(0.7)		2.6(0.6)	2.5(0.6)		2.9(0.8)	2.4(0.5)	*	5.1(1.4)	0.575	28.082*
Triceps skinfold (mm)	6.2(1.5)	*	6.8(1.3)	7.1(2.7)	*	6.9(2.4)	5.7(1.5)	*	7.3(1.3)	5.1(1.1)	*	9.9(3.2)	0.205	6.502*
Subscapular skinfold (mm)	4.5(0.8)		4.4(0.8)	6.2(2.4)		5.7(2.2)	5.0(1.3)	*	6.3(1.5)	5.7(1.8)	*	9.1(2.1)	5.286*	12.553*
Supraspinale skinfold (mm)	4.7(1.5)		4.4(0.9)	5.0(2.1)		4.8(2.1)	4.4(1.3)	*	5.6(1.8)	4.6(1.6)	*	7.4(1.4)	0.967	4.603
Medial calf skinfold (mm)	8.9(2.4)		8.6(1.9)	9.6(3.2)	*	9.4(2.8)	8.8(3.2)	*	11.4(2.5)	6.6(2.3)	*	13.4(2.5)	2.182	8.837*
Humerus breadth (mm)	45.5(2.8)		45.3(1.9)	50.8(4.8)		50.8(4.0)	51.5(2.5)		51.9(2.5)	58.2(5.6)		55.7(3.3)	31.503*	20.432*
% FAT	9.4(4.1)	*	9.8(4.3)	9.2(2.6)	*	11.0(3.0)	8.2(2.0)	*	11.7(4.1)	8.7(2.6)	*	12.0(4.0)	1.676	0.464
Fat Mass (kg)	1.9(0.8)	*	2.0(0.9)	2.6(1.0)	*	3.1(0.9)	2.3(0.6)	*	3.6(1.5)	3.9(1.9)		4.6(1.7)	14.912*	7.531*
Fat Free Mass (kg)	18.8(2.0)		18.7(1.7)	25.5(5.2)		25.0(4.7)	26.1(2.0)		26.3(3.9)	38.9(7.8)		33.5(3.9)	51.359*	24.808*
Total Upper Arm Area (cm²)	18.8(2.3)	*	19.1(2.2)	22.8(4.2)	*	22.7(3.7)	21.9(2.7)		23.1(3.8)	30.4(7.5)		31.5(5.3)	24.515*	17.365*
Upper arm muscle area (cm²)	14.3(1.3)		14.2(1.2)	17.1(1.9)		17.3(2.4)	17.4(2.0)		17.3(2.6)	25.6(6.7)		22.3(2.6)	26.061*	19.586*
Arm Fat Area (cm²)	4.5(1.2)	*	4.9(1.1)	5.7(2.6)	*	5.5(2.2)	4.5(1.3)	*	5.8(1.4)	4.7(1.4)	*	9.2(3.3)	3.412	9.783*
Arm Fat Index	23.6(4.2)	*	25.5(3.7)	24.2(6.7)		23.6(6.5)	20.5(4.5)	*	25.0(2.9)	15.9(3.5)	*	28.3(6.9)	7.230*	4.565

[a] Tukey test. Height: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Weight: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. BMI: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Arm, rel.: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Arm, fle.: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Wrist g.: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Chest,n.: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Chest,mx: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Chest,mn: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Waist g.: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Gluteal g.: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Calf g.: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Subscap.skin.: 8–9 yrs* vs 14; 12–13 yrs* vs 14. Humerus b.: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Fat Mass: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. FFM: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. T.Up.Arm: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.AFA: 8–9 yrs* vs 14. AFI: 8–9 yrs* vs 14. [b] Tukey test. Height: 8–9 yrs* vs 10–11, 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Weight: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. BMI: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Arm, rel.: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Arm, fle.: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Wrist g.: 8–9 yrs* vs 10–11, 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Chest,n.: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Chest,mx: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Chest,mn: 8–9 yrs* vs 10–11, 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Waist g.: 8–9 yrs* vs 12–13, 14; 10–11 yrs* vs 14. Gluteal g.: 8–9 yrs* vs 10–11;12–13, 14; 10–11 yrs* vs 14. Calf g.: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Biceps sk.: 8–9 yrs* vs 10–11, 12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Triceps skin.: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.Subscap.skin.: 8–9 yrs* vs 10–11, 14; 10–11 * vs 14;12–13 yrs* vs 14. Supraspin.skin.: 8–9 yrs* vs 14; 10–11 yrs* vs 14. Medial calf skin.: 8–9 yrs* vs 14; 10–11 yrs* vs 12–13,14. Humerus b.: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. Fat Mass: 8–9 yrs* vs 12–13,14; 10–11 yrs* vs 14. FFM: 8–9 yrs* vs 10–11,12–13, 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. T.Up.Arm: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14.AFA: 8–9 yrs* vs 14. AFI: 8–9 yrs* vs 14; 10–11 yrs* vs 14; 12–13 yrs* vs 14. AFI: 8–9 yrs* vs 10–11; 10–11 yrs* vs 14.

TABLE 2
COMPARISONS WITH LHASA BOYS

Characteristics	8–9 years					10–11 years					12–13 years					14–15 years				
	Shegar (n=18)			Lhasa (n=15)		Shegar (n=10)			Lhasa (n=11)		Shegar (n=16)			Lhasa (n=24)		Shegar (n=23)			Lhasa (n=28)	
	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)
Stature (cm)	115.6	(4.1)	*	121.6	(5.8)	130.6	(10.1)		131.1	(5.7)	133.8	(5.3)	*	142.3	(6.6)	150.2	(11.4)		153.1	(8.7)
Weight (kg)	20.7	(1.9)		22.6	(3.1)	28.1	(5.9)		27.1	(3.6)	28.4	(2.2)	*	33.2	(5.1)	39.4	(9.3)		41.5	(6.9)
BMI (kg/m^2)	15.5	(1.0)		15.2	(1.3)	16.3	(1.2)		15.8	(2.1)	15.9	(0.9)		16.3	(1.6)	17.8	(1.7)		17.6	(1.7)
Upper arm muscle area (cm^2)	14.3	(1.3)		15.7	(1.8)	17.1	(1.9)		16.8	(2.6)	17.4	(2.0)		20.2	(3.0)	25.6	(6.7)		25.0	(4.9)
Chest circumference (cm)	58.0	(2.0)		58.7	(1.9)	64.6	(3.3)		61.6	(2.6)	65.5	(2.8)		66.5	(2.6)	74.3	(6.7)		73.0	(2.6)
Sum of skinfolds (mm)	9.6	(1.6)		9.9	(1.9)	9.9	(1.9)		11.4	(3.2)	9.7	(1.7)		12.7	(4.8)	10.1	(2.3)		13.9	(3.8)

* denotes $p<0.05$, statistical significance of t Student's test between samples.

TABLE 3
COMPARISONS WITH LHASA GIRLS

Characteristics	8–9 years					10–11 years					12–13 years					14–15 years				
	Shegar (n=13)			Lhasa (n=27)		Shegar (n=25)			Lhasa (n=21)		Shegar (n=17)			Lhasa (n=24)		Shegar (n=9)			Lhasa (n=23)	
	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)	X	(SD)	p	X	(SD)
Stature (cm)	114.6	(4.2)	*	122.9	(5.5)	131.3	(8.3)		132.9	(8.4)	136.5	(7.2)	*	144.5	(7.6)	146.2	(5.0)		150.7	(5.1)
Weight (kg)	20.7	(1.5)		21.7	(2.5)	28.1	(5.1)		26.7	(4.7)	29.9	(4.7)	*	34.4	(6.2)	38.1	(4.3)		41.6	(5.4)
BMI (kg/m^2)	13.1	(1.0)		14.4	(1.0)	16.1	(1.3)		15.1	(1.9)	16.0	(1.1)		16.3	(1.8)	17.8	(1.5)		18.3	(1.8)
Upper arm muscle area (cm^2)	14.2	(1.2)		14.7	(2.2)	17.3	(2.4)		15.6	(2.1)	17.3	(2.6)		18.8	(2.8)	22.3	(2.6)		21.3	(4.1)
Chest circumference (cm)	58.6	(1.7)		57.0	(2.6)	63.7	(3.8)	*	60.7	(2.6)	66.1	(3.0)		66.1	(3.9)	72.9	(4.7)		72.2	(3.9)
Sum of skinfolds (mm)	12.2	(1.0)		11.4	(3.6)	12.9	(4.6)		13.4	(3.8)	14.3	(2.5)		15.9	(6.9)	19.0	(4.9)		22.3	(9.0)

*denotes $p<0.05$, statistical significance of t Student's test between samples.

tion would not cause the increased chest circumference observed in high-altitude populations.

The results were compared with data for a sample of Tibetans of the same age range living above 3800 m altitude (Tables 2 and 3) in Lhasa Municipal district, TAR[15]. They lived in similar environmental conditions but had a better economic situation and health care than the children from the prefecture of Shegar. Weitz's sample consisted of females born and raised at 3800 m and males born and living at 4300 m. Our sample is shorter at all the considered ages and lighter, except at 10–11 years. The lower values of stature observed among Tibetans from Shegar may be explained by their poorer nutritional status than in Lhasa.The males have a higher BMI value (except at 12–13 years), while females have a lower BMI (except at 10–11 years). For both sexes, Student's t-test is significant at 8–9 and 12–13 years for height.

Skinfold thicknesses are lower in both sexes: only the 8-year-old females have higher skinfold values. The boys have comparable or higher chest circumference values until 11 years and lower values thereafter, while the girls always have higher values. In fact, Weitz's female sample lived at 3800 m, i.e. at lower altitudes than those of our sample. This suggests that indigenous higher-altitude populations have a different genetic potential for thorax growth with respect to lower-altitude populations and that chest circumference increases at higher altitudes[12,16]. Student's t-test is significant for chest circumference at 10–11 years in females (Table 3).

International growth standards based on well-nourished, healthy children vary little among countries throughout the world[9]. Therefore, the mean values of the Tibetan children were compared with the values reported by Frisancho[6], Fernandez et al.[17] and NHANES III. Waist circumferences of the Tibetan sample are below the 10th percentile for age and gender of the US standard[17], except for the 14-yr-old boys (10–25th percentile). Mean standing heights and BMI values are below the 15th percentile of the US standard for both sexes. Since being shorter than average may not be an important clinical problem, we compared the cross-sectional muscle area of the upper arm and triceps skinfold with the Frisancho standards by age: the values of Tibetan children are between the 5th and 25th percentiles. However, if we compare the values of arm circumference with the standards by height, the Tibetan values rise to the 50th percentile.

To assess the nutritional status, we compared the z-scores of the Tibetan sample for height and weight with NCHS/WHO international data (Global Database on Child Growth and Malnutrition) (Figures 2, 3 and 4). A 5% prevalence of wasted children in a population is considered alarming (WHO). The Tibetan sample has 2.1% of wasted males (< –2 SD) and 0% of wasted females. Nevertheless, a lack of evidence of wasting in a population does not imply the absence of nutritional problems; indeed, stunting and other deficiencies are present in this sample. The percentage of stunted children is 29.9 for males and 26.6 for females. Severe stunting (< –3 SD) is present only in males (6%), while the prevalence of underweight (< –2 SD) is 0% for both sexes.

Males show a positive trend with age, as the percentage of stunting decreases up to 14 years. The trend is

Fig. 2. Height for age of Tibetan boys (8 yrs: n=9; 9 yrs: n=9; 10 yrs: n=6; 11 yrs: n=4; 12 yrs: n=11; 13 yrs: n=5; 14 yrs; n=23) and girls (8 yrs: n=5; 9 yrs: n=8; 10 yrs: n=16; 11 yrs: n=9; 12 yrs: n=12; 13 yrs: n=5; 14 yrs; n=9) compared to international reference population.

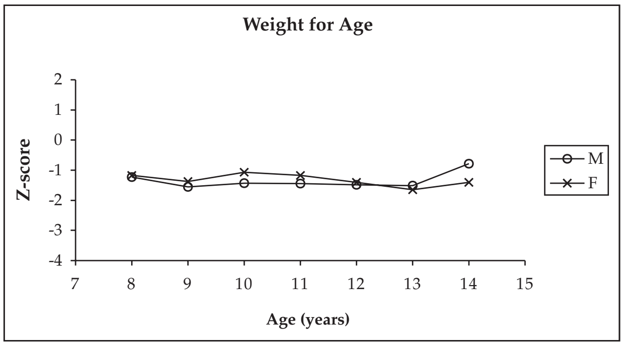

Fig. 3. Weight for age of Tibetan boys (8 yrs: n=9; 9 yrs: n=9; 10 yrs: n=6; 11 yrs: n=4; 12 yrs: n=11; 13 yrs: n=5; 14 yrs; n=23) and girls (8 yrs: n=5; 9 yrs: n=8; 10 yrs: n=16; 11 yrs: n=9; 12 yrs: n=12; 13 yrs: n=5; 14 yrs; n=9) compared to international reference population.

Fig. 4. Weight for height of Tibetan boys (8 yrs: n=9; 9 yrs: n=9; 10 yrs: n=6; 11 yrs: n=4; 12 yrs: n=11; 13 yrs: n=5; 14 yrs; n=23) and girls (8 yrs: n=5; 9 yrs: n=8; 10 yrs: n=16; 11 yrs: n=9; 12 yrs: n=12; 13 yrs: n=5; 14 yrs; n=9) compared to international reference population.

more fluctuating in females but the lowest value is also at 14 years (Figure 2).

Weight-for-age (Figure 3) shows a more linear trend, ranging from –2 to –1 SD. Once again, the percentage of undernourished children is lowest at 14 years. The weight--for-height indicator has a similar pattern in both sexes from 10 years and the values are always within a healthy range (Figure 4). ANOVA for age and sex is not significant both for HAZ (F=0.64, p=0,42) and WAZ (F=1.18, p=0.27). According to the theories of Dang et al.[4], a significant left shift of the distribution of HAZ and WAZ in our sample implies that the nutritional status of the entire population of Tibetan children, and not just some individuals, is adversely affected. Since there is no evidence of wasting (low weight-for-height), the stunted height of our sample indicates a sufficient energy intake but chronic low-quality nutrition[10] and/or a likely negative effect of altitude. A chronic malnutrition at high altitude may also be due to the influence of cold and hypoxia on metabolism.

Males have a higher prevalence of stunting than females at all ages, presumably related to the more resistant growth processes of girls in response to malnutrition[18]. Although it is impossible to assess growth velocity (and the eventual catch-up growth in body dimensions) on the basis of a cross-sectional study, the values at 14 years might be considered an indicator of late compensatory growth.

Although based on a small sample, our study provides useful information on the anthropometric characters and nutritional status of Tibetan children, allowing an extensive anthropometric profile of a previously poorly documented group. The magnitude of the effect of altitude on the growth of Tibetan children can only be determined by further studies based on larger sample sizes, preferably a longitudinal design and the control of other risk factors influencing growth.

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RAST I PREHRAMBENI STATUS TIBETANSKE DJECE NA VEĆOJ NADMORSKOJ VISINI

SAŽETAK

Na rast i razvoj na većim nadmorskim visinama utječu okolišni uvjeti karakterizirani hipoksijom, prehrambenim stresom, hladnoćom ili kombinacijom ovih čimbenika. Do sada je provedeno vrlo malo istraživanja o rastu i prehrambenom statusu djece koja žive na Tibetanskoj visoravni. U ovom istraživanju procijenjen je okolišni utjecaj na ljudski rast pomoću analize antropometrijskih mjera tibetanske djece starosti 8-14 godina, rođenih i odraslih na nadmorskoj visini od 4000 m na Himalajskom masivu u regiji Shegar autonomne pokrajine Tibet. Po prvi puta su u ovoj populaciji mjerena antropometrijska svojstva, te je procijenjen prehrambeni status. Osigurani su referentni podaci za ovu populaciju. Nije primijećena pothranjenost, ali je primijećeno zaostajanje u rastu (28,3%). Djeca konstantno izložena okolišu nadmorske visine iznad 4000 m predstavljaju fenotipski oblik adaptacije i umjerenu redukciju linearnog rasta. Međutim, također je nužno uzeti u obzir utjecaj socioekonomskog statusa.