

NUTRITIONAL AND HEALTH STATUS OF TIBETAN CHILDREN
LIVING AT HIGH ALTITUDESNANCY S. HARRIS, M.D., PATRICIA B. CRAWFORD, DR.P.H., YESHE YANGZOM, M.D., LOBSANG PINZO, M.D.,
PALDEN GYALTSEN, M.D., AND MARK HUDES, PH.D.**ABSTRACT**

Background Children living at high altitudes often have delayed growth, but whether growth retardation is related to altitude or to other factors is not known.

Methods A multicultural health care team assessed 2078 Tibetan children 0 to 84 months of age for anthropometric and clinical signs of malnutrition. The children lived in 11 counties, which contained more than 50 diverse urban and nonurban (nomadic, agricultural, or periurban) communities in the Tibet Autonomous Region of China. The height and weight of the children were compared with those of U.S. children. Height and weight were expressed as z scores (the number of standard deviations from the median of the age- and sex-specific reference group).

Results The mean z score for height fell from -0.5 to -1.6 in the first 12 months of life and generally ranged from -2.0 to -2.4 in older children. Overall, of 2078 children, 1067 (51 percent) had moderately or severely stunted growth, as defined by a z score of -2.0 or lower. Of the 1556 children 24 months of age or older, 871 (56 percent) had stunted growth, which was severe (z score, -3.0 or lower) in 380 (24 percent). Among the children in this age group, 787 of the 1313 nonurban children (60 percent) had stunting, as compared with 84 of the 243 urban children (35 percent). Stunting was associated with clinical conditions such as rickets, abdominal distention, hair depigmentation, and skin lesions and with a maternal history of hepatitis or goiter. Stunting was not associated with altitude, after adjustment for the type of community.

Conclusions In Tibetan children, severe stunting due to malnutrition occurs early in life, and morbidity is high. (N Engl J Med 2001;344:341-7.)

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MANY people who live at high altitudes are shorter than their lowland counterparts.¹⁻⁶ However, well-nourished children from diverse ethnic groups will attain a height within international reference ranges.^{7,8} Therefore, the short stature of children living at high altitudes should not be attributed to factors such as genetics and altitude when it may represent growth failure due to chronic undernutrition. Stunting of growth as a consequence of chronic malnutrition is often associated with irreversible neurodevelopmental delay and increased morbidity and mortality.⁹⁻¹⁷

The Tibet Autonomous Region of China is one such high-altitude area, and little is known about the

health status, growth, or nutritional status of children in this region. A 1986 study of 14,000 Tibetan children ranging in age from birth to seven years in Lhasa Prefecture concluded that the nutritional status of Tibetan children was "acceptable overall," and the data were used to generate reference ranges for the growth of Tibetan children.¹⁸⁻²⁰ However, in an unpublished 1989 survey conducted by the People's Republic of China in 16 Tibetan counties, the mortality rate among infants was 92 per 1000 in the Tibetan counties, as compared with 68 per 1000 in the rest of China; the mortality rate among children less than five years old was 127 per 1000, as compared with 84 per 1000; and the maternal mortality rate was 73 per 10,000, as compared with 20 per 10,000.²¹ We evaluated the health status of Tibetan children to determine whether their short stature is due to factors other than high altitude.

METHODS**Study Subjects**

During August through December of 1994 and 1995, we examined 2078 Tibetan children from birth to 84 months of age who were from 11 counties in five of the seven prefectures in the Tibet Autonomous Region. The 11 counties, which contained more than 50 townships, were representative of the wide range of regions (from urban to nomadic) in Tibet. For statistical purposes, the data were aggregated according to the type of region: urban (Lhasa and Chamdo), periurban (within 30 km of Lhasa or Chamdo), village, and nomadic. On the basis of census data provided by local health workers in each county, approximately 90 percent of the eligible children were surveyed. A map of the study sites and the distributions of the children according to age and location are shown in Figure 1.

Data Collection

A team of three Tibetan physicians (two pediatricians and one internist), one U.S. physician, a nutritional anthropologist, local representatives of the Tibetan Maternal and Child Health Department, and village health workers collected the data in all 11 counties, in accordance with protocols approved by the Tibetan health authorities. Informed consent was obtained from a parent or caretaker of each child.

Medical histories of children and mothers were collected from parents with the use of a pretested questionnaire administered in Tibetan by the pediatricians. Translators were used when local dialects differed. Birth-date information was collected with the use

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No. of Children Examined

| AGE (mo) | NOMADIC | VILLAGE | PERIURBAN | URBAN | TOTAL |
|----------|---------|---------|-----------|-------|-------|
| 0-11 | 19 | 150 | 50 | 27 | 246 |
| 12-23 | 21 | 155 | 57 | 33 | 266 |
| 24-35 | 24 | 204 | 72 | 38 | 338 |
| 36-47 | 30 | 184 | 68 | 50 | 332 |
| 48-59 | 44 | 165 | 55 | 69 | 333 |
| 60-71 | 30 | 165 | 47 | 59 | 301 |
| ≥72 | 38 | 161 | 36 | 27 | 262 |
| Total | 206 | 1184 | 385 | 303 | 2078 |

Figure 1. Map of Tibet Autonomous Region Showing Study Sites and the Number of Children Examined According to Age and Location (1035 Boys and 1043 Girls).

The map is based on information from the Bureau of Survey of Tibet Autonomous Region²² and Dorje.²³

of the Tibetan lunar calendar and was subsequently converted to Gregorian calendar dates. For most children, parents or caretakers provided health booklets in which the birth dates were recorded; complete birth-date information was available for 85 percent of the children. For the 161 children for whom the year and month of birth were known but the day of birth was unknown, the 15th of the month was used as the estimated birthday. For 158 children, the month of birth could not be determined, and a midyear birth date was used. The questionnaire used for the child's history included specific questions about hepatitis (clinical jaundice), diarrhea or cough lasting longer than one month, night blindness, measles, and otitis. The questionnaire for the mother's history included questions about clinical jaundice and visible goiter.

Four of us performed the physical examinations. The children were examined for hair depigmentation, abdominal distention, skin abnormalities and sores,²⁴ rickets,^{24,25} goiter,²⁶ caries, and Kashin-Beck disease.²⁷⁻²⁹ A crippling arthropathy affecting large joints, Kashin-Beck disease is found in regions of Asia, primarily in China. Physical examination for the disease was confined to inspection of the wrist, a commonly involved site, for signs of deformity. Skin lesions included xerosis, intertriginous lesions, diffuse excoriations

and secondary infections, and angular stomatitis. Examination for rickets included inspection for all major and minor signs of rickets. The most common signs of rickets were craniotabes, frontal bossing, rachitic rosary, delayed fontanelle closure, delayed dentition, occipital alopecia, and thoracic deformities (Harrison's grooves and pigeon chest).

Anthropometric measurements, performed with the use of standard methods,²⁴ included measurements of height, weight, head circumference, chest circumference, and mid-upper-arm circumference. The children were weighed and measured with a calibrated, beam-balance scale and stadiometer (Panda Model TGT-50, Shanghai Bao Shen Measurement Factory, Shanghai, China) used by the United Nations Children's Fund Maternal and Child Health programs throughout China. Children less than two years of age and those two to three years of age who were unable to stand were measured while recumbent with the use of a standard calibrated board (Golden Lion Model WBI, Beijing Tractor Company No. 6 Measuring Factory, Beijing, China). All children were weighed while they were wearing one layer of undergarments, without shoes. All these measurements were performed by or in the presence of the same four researchers, with good interobserver correlation.

Statistical Analysis

The age in months was rounded down to the nearest integer and examined as a categorical variable as follows: 0 to 11 months, 12 to 23 months, 24 to 35 months, 36 to 47 months, 48 to 59 months, 60 to 71 months, and 72 months or more. Because some families included multiple siblings, the data were analyzed with the use of a generalized estimating equation program to adjust for correlation within households.³⁰ Height and weight were compared with normalized growth curves from the reference population of the U.S. National Center for Health Statistics.³¹ For each category of age, height for age, weight for age, and weight for height, z scores were computed by subtracting the age-specific median reference value from the measured value and dividing the difference by the age-specific standard deviation for the reference population.³²

Chi-square tests were performed to evaluate the relations of the categorical height-for-age z score and clinical conditions with urban or nonurban location. To compare height-for-age z scores among children with clinical conditions and those without clinical conditions, two independent sample t-tests were used. All statistical tests were two-tailed.

The z scores were compared according to community location with one-way analysis of variance. After adjustments for correlation among siblings, Bonferroni techniques were used to determine the overall type I error rates for all follow-up procedures.³³

RESULTS

Prevalence of Malnutrition

Overall, the prevalence of stunted growth (z score, -2.0 or lower) was 51 percent (1067 of 2078 children). The patterns of stunting according to age were similar in girls and boys; however, girls had higher z scores after 12 months of age (Fig. 2). Growth failure was most pronounced during the first 12 months of life and was almost as pronounced from 12 through 23 months, after which time z scores remained fairly sta-

ble up to 84 months of age. Thus, age would have confounded any analysis of a relation between the height-for-age z score and other variables related to age. For this reason, data from children from birth to 24 months of age were not included in further analyses.

Anthropometric measures of malnutrition were evaluated according to location. The mean height-for-age z score was lower than -2.0 for all groups of children except those living in urban areas. Nearly twice as many children in nonurban areas (village, nomadic, or periurban) as children in urban areas had z scores of -2.0 or lower (60 percent vs. 34 percent), and more than three times as many children in nonurban areas had z scores of -3.0 or lower (Table 1). The prevalence of wasting, as indicated by the mean weight-for-height z score, was low (Table 2). This finding is not uncommon in malnourished populations with high levels of stunting,³⁴ since wasting is a result of short-term nutritional deprivation.

Fourteen percent of children less than 24 months of age had a mid-upper-arm circumference of less than 11.5 cm. This value has been used as a predictor of a significantly increased risk of death in young children.³⁵ Furthermore, 75 percent of children 12 to 23 months of age had a chest-to-head circumference ratio of less than 1.0, which indicates undernutrition.²⁴

Children's z Scores and Location

Of the children 24 months of age or older, 56 percent had a height-for-age z score that was at least 2 SD below the reference value (Table 1). Children in ur-

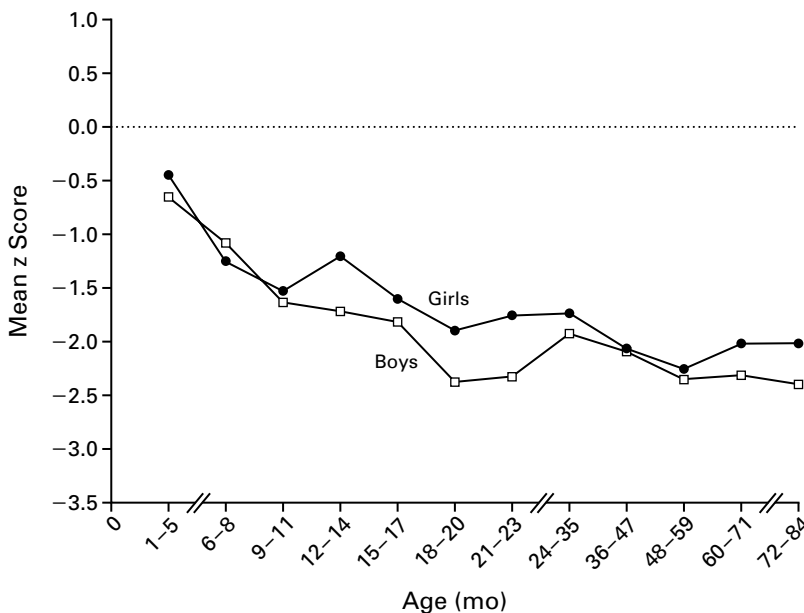


Figure 2. Mean Height-for-Age z Score According to Age and Sex. A z score of zero indicates the mean of the reference group.

TABLE 1. HEIGHT-FOR-AGE Z SCORE FOR CHILDREN 24 MONTHS OF AGE OR OLDER, ACCORDING TO LOCATION.*

| z SCORE | URBAN (N=243) | NONURBAN (N=1313)† |
|----------------------------------|---------------------|-----------------------|
| | no. of children (%) | |
| ≤-3.0 (Severe stunting) | 18 (7) | 362 (28) |
| -2.9 to -2.0 (Moderate stunting) | 66 (27) | 425 (32) |
| -1.9 to -1.0 | 86 (35) | 349 (27) |
| -0.9 to 0.0 | 48 (20) | 127 (10) |
| >0.0 | 25 (10) | 50 (4) |

*The z score is the number of standard deviations from the median value for the reference group. The height-for-age distribution differed significantly according to urban or nonurban status (P<0.001 by the chi-square test). Because of rounding, percentages do not total 100.

†The nonurban group included children living in village, nomadic, and periurban areas.

ban areas had the lowest risk of stunting, which differed significantly from the risk for those in village and periurban areas (Table 2). Nomadic children had a significantly greater risk of stunting than did all other children.

Both children in urban areas and nomadic children had a significantly lower prevalence of rickets than did children in village and periurban areas (Table 2), suggesting that factors other than rickets play a part in the stunted growth of nomadic children.

Prevalence of Clinical Conditions

The prevalence of clinical conditions and details of the medical histories of urban and nonurban children 24 months of age or older are shown in Table 3. Clinical signs of rickets were detected in 66 percent of the children, most of whom were in nonurban areas. The serum concentration of 25-hydroxyvitamin D, which was measured in 130 children from all locations, was less than 10 ng per milliliter (25 nmol per liter) in 110 children (85 percent).

Children in nonurban areas were significantly more likely than those in urban areas to have depigmented hair, abdominal distention, skin lesions, goiter, and a maternal history of goiter. Children in urban areas were significantly more likely to have caries and a history of measles (Table 3).

Goiter was found in 3 percent of the children. Although Kashin–Beck disease is known to occur in several of the areas studied, early signs of this disease were found in only 1 percent of the children. The arthropathy that characterizes the disease usually becomes clinically evident after five years of age. Deformity of the limbs in the children we studied was usually post-traumatic. Stunting was associated with signs of rickets, hair depigmentation, abdominal distention, and skin lesions and with a maternal history of hepatitis or goiter (Table 4).

Association between Altitude and Stunting

There was no linear association between height-for-age z scores and altitude. The children 24 months

TABLE 2. MEAN ANTHROPOMETRIC MEASUREMENTS AND THE PREVALENCE OF RICKETS ACCORDING TO LOCATION.*

| LOCATION | NO. OF CHILDREN | AGE ≥24 Mo | | | RICKETS†‡§¶** | AGE <24 Mo | | AGE 12 TO 23 Mo | |
|-----------|-----------------|--------------------|-----------------------|----------------------|---------------|-----------------|---------------------------------------|-----------------|---|
| | | HEIGHT FOR AGE†‡§¶ | WEIGHT FOR HEIGHT‡¶** | WEIGHT FOR AGE†‡§¶** | | NO. OF CHILDREN | MID-UPPER-ARM CIRCUMFERENCE <11.5 CM† | NO. OF CHILDREN | RATIO OF CHEST-TO-HEAD CIRCUMFERENCE <1.0 |
| | | z score | | | % | % | | % | |
| Nomadic | 165 | -2.8 | -0.1 | -1.8 | 44 | 40 | 32 | 21 | 80 |
| Village | 871 | -2.2 | 0.02 | -1.4 | 78 | 305 | 11 | 155 | 77 |
| Periurban | 277 | -2.1 | 0.3 | -1.1 | 63 | 107 | 15 | 57 | 72 |
| Urban | 243 | -1.5 | -0.1 | -1.1 | 38 | 60 | 15 | 33 | 70 |
| Total | 1556 | -2.2 | 0.03 | -1.3 | 66 | 512 | 14 | 266 | 75 |

*Height for age, weight for height, weight for age, and the presence or absence of rickets were determined in children 24 months of age or older. Mid-upper-arm circumference was measured in children less than 24 months of age, and the ratio of chest-to-head circumference was determined for children between 12 and 23 months. Multiple comparisons were made with the use of Bonferroni techniques at a significance level of 0.05. Therefore, differences between any two groups were considered statistically significant at P<0.008 (P<0.05 divided by 6, the number of comparisons).

†Values for nomadic locations were significantly different from those for villages.

‡Values for nomadic locations were significantly different from those for periurban locations.

§Values for nomadic locations were significantly different from those for urban locations.

¶Values for villages were significantly different from those for urban locations.

||Values for periurban locations were significantly different from those for urban locations.

**Values for villages were significantly different from those for periurban locations.

TABLE 3. CLINICAL STATUS OF CHILDREN 24 MONTHS OR OLDER ACCORDING TO LOCATION.

| CLINICAL STATUS | TOTAL (N=1556) | URBAN (N=243) | NONURBAN (N=1313) | P VALUE* |
|-------------------------------|-------------------|------------------|----------------------|-------------|
| | | | | |
| Condition | | | | |
| Rickets | 1024 (66) | 93 (38) | 931 (71) | <0.001 |
| Hair depigmentation | 672 (43) | 37 (15) | 635 (48) | <0.001 |
| Abdominal distention | 855 (55) | 44 (18) | 811 (62) | <0.001 |
| Skin lesions† | 134 (9) | 13 (5) | 121 (9) | 0.02 |
| Caries | 615 (40) | 111 (46) | 504 (38) | 0.04 |
| Kashin-Beck disease | 15 (1) | 0 | 15 (1) | 0.15‡ |
| Goiter | 49 (3) | 1 (<1) | 48 (4) | 0.007 |
| Medical history | | | | |
| Hepatitis | 77 (5) | 12 (5) | 65 (5) | 0.88 |
| Maternal history of hepatitis | 72 (5) | 10 (4) | 62 (5) | 0.82 |
| Maternal history of goiter | 225 (14) | 4 (2) | 221 (17) | <0.001 |
| Diarrhea for >1 mo | 146 (9) | 17 (7) | 129 (10) | 0.20 |
| Cough for >1 mo | 171 (11) | 35 (14) | 136 (10) | 0.06 |
| Night blindness | 11 (1) | 0 | 11 (1) | 0.39‡ |
| Measles | 77 (5) | 26 (11) | 51 (4) | 0.001 |
| Otitis | 214 (14) | 29 (12) | 185 (14) | 0.52 |

*P values were calculated by chi-square tests for independence unless otherwise noted.

†Skin lesions included xerosis, sores, and intertriginous lesions.

‡The P values were calculated by Fisher's exact test.

of age or older who lived at the highest altitude (greater than 4000 m) and those who lived at the lowest altitude (less than 3000 m) had the lowest mean z scores (-2.6 and -2.2, respectively). The children who lived at an altitude of 3000 to 4000 m had the highest mean z score (-1.9). Within each category of altitude, urban children had higher height-for-age z scores than did nonurban children living at the same altitude.

Trends in Stunting

With the use of the technique described by Shen et al.,³⁶ sex-specific z scores were calculated and compared with those from a regional survey conducted in 1986.¹⁹ The z scores for children 24 months of age or older in the 1986 survey and in ours were pooled and weighted to reflect the distribution of ages in each survey. The mean z scores were then converted back to reflect a hypothetical, statistically standardized case of a boy 42 months old and 99.1 cm tall. A comparison of the results of the earlier survey with the present data is not ideal because of possible unknown differences in methodology. Although neither large survey is technically representative of Tibetan children because of the sampling methods, together they allow an approximate comparison of growth trends among children in Tibet. In 1986 the average height of a 42-month-old boy was 94.7 cm if he lived

TABLE 4. HEIGHT-FOR-AGE Z SCORE FOR CHILDREN 24 MONTHS OF AGE OR OLDER ACCORDING TO CLINICAL STATUS.

| CLINICAL STATUS | TOTAL (N=1556) | HEIGHT-FOR-AGE Z SCORE | | |
|-------------------------------|-------------------|------------------------|----------------------|-------------|
| | | WITH CONDITION | WITHOUT CONDITION | P VALUE* |
| | | no. (%) | | |
| Condition | | | | |
| Rickets | 1024 (66) | -2.3 | -2.0 | <0.001 |
| Hair depigmentation | 672 (43) | -2.4 | -2.0 | <0.001 |
| Abdominal distention | 855 (55) | -2.3 | -2.0 | <0.001 |
| Skin lesions | 134 (9) | -2.4 | -2.2 | 0.04 |
| Caries | 615 (40) | -2.1 | -2.2 | 0.07 |
| Kashin-Beck disease | 15 (1) | -2.5 | -2.2 | 0.27 |
| Goiter | 49 (3) | -2.3 | -2.2 | 0.47 |
| Medical history | | | | |
| Hepatitis | 77 (5) | -2.4 | -2.2 | 0.08 |
| Maternal history of hepatitis | 72 (5) | -2.6 | -2.2 | 0.002 |
| Maternal history of goiter | 225 (14) | -2.4 | -2.1 | <0.001 |
| Diarrhea for >1 mo | 146 (9) | -2.3 | -2.2 | 0.08 |
| Cough for >1 mo | 171 (11) | -2.2 | -2.2 | 0.86 |
| Night blindness | 11 (1) | -2.5 | -2.2 | 0.33 |
| Measles | 77 (5) | -2.2 | -2.2 | 0.78 |
| Otitis | 214 (14) | -2.3 | -2.2 | 0.07 |

*P values were calculated from two independent-sample t-tests with adjustment for interclass correlation within households.

in an urban area and 91.5 cm if he lived in a nonurban area. For the 1994-1995 period, the respective values were 93.0 cm and 89.8 cm. Thus, over the nine-year period from 1986 to 1995, the average height of a 42-month-old boy declined by 1.7 cm (P<0.001) in both urban and nonurban areas.

Death Rate among Children

Although the death rates for children could not be obtained, mothers were asked how many times they had given birth and how many of their children were still living. The age of a child at death could not always be determined. A mean of 3.2 children were born to each of the 1499 women surveyed; a mean of 2.8 children were still living and a mean of 0.4 had died. The mortality rate among all children born to all women surveyed was 13.2 percent.

DISCUSSION

We found evidence of substantial malnutrition among Tibetan children. Over 50 percent of the children we examined had moderate-to-severe stunting of growth. The proportion of children with stunted growth was greater in nonurban areas than in urban areas. The association between community location, altitude, and stunting was partially confounded by the fact that all the nomadic children were in the highest-altitude group and all urban and periurban children

were in the middle altitude group. However, children who lived in villages were represented in all three altitude groups, and for them we found no association between altitude and stunting, indicating that the effect of altitude is not the determining factor in growth failure.

Our data show that Tibetan children are not "small but healthy."³⁷⁻³⁹ They have clinical signs of malnutrition as well as high morbidity and mortality. Measurements of mid-upper-arm circumference alone suggest that up to 14 percent of children less than 24 months of age have a level of malnutrition that has been associated with a significantly increased risk of death in young children.³⁴ Delayed development, as indicated by a low ratio of chest-to-head circumference, is further evidence of growth failure in these children early in life. Although standard mortality rates could not be calculated, the mortality rate among all children born to all the women surveyed can be compared with similar rates in other developing countries. For example, in India the comparable mortality rate is 15 percent.⁴⁰

The decline in the average height of children between 1986 and 1995 is similar to trends in other poor regions in China,^{36,41,42} which may be masked in aggregated data by the increase in the average height of children in more affluent regions of the country. A 1991 study of 7-to-18-year-old children in Lhasa revealed that these urban children were taller than children in that group in 1985.⁴³ This finding may support the hypothesis that, with adequate nutrition, Tibetan children who live past the vulnerable early ages are reaching their growth potential.

This study was cross-sectional, and therefore direct causality cannot be determined, but it appears that malnutrition and illness between 12 and 24 months of age are important determinants of subsequent height-for-age z scores. This information is useful for those planning health interventions for children.

Generalizations about the growth of children living at high altitudes may deflect attention from the urgent need for maternal and child health programs in Tibet.^{44,45} Malnutrition and common childhood illnesses can be modified by changes in health education and health care. Culturally specific programs should be implemented to address the constellation of physiologic, socioeconomic, agricultural, and environmental factors that affect the health of children on the Tibetan plateau.

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