Effects of Age, Community Location, and Illness on Nutritional Status of High Altitude Tibetan Children, 0-7 Years*

*Nancy S. Harris,*** *Yeshe Yangzom,****
*Lobsang Pinzo,**** *Palden Gyaltsen****
*and Patricia B. Crawford*****

Introduction

Approximately two million Tibetans reside in the Tibet Autonomous Region (TAR), a 1.2 million kilometer square plateau with an average altitude of 4000 meters.[1,2] Forty percent, or over 781,000 of the population, are children under the age of 14 years. Little has been published on the status of child or maternal health, child growth, nutrition, or the prevalence of disease in this historically isolated region.

Studies from other countries show that high altitude populations are shorter and lighter than their lowland counterparts, assuming both are adequately nourished.[3-6] Tibetans are perhaps the longest adapted high altitude population, with pulmonary and hematologic adaptations believed to differ from those characterizing other high altitude populations.[7,8] Growth of Tibetans outside Tibet has been studied,[5,9,10] but cannot necessarily be extrapolated to the growth patterns present on the high altitude plateau. Although specific growth reference standards for high altitude populations have not been developed, there is evidence to indicate that children from diverse ethnic and geographic locations grow within international growth references if well nourished, including those at high altitude.[11,12] While recognizing the limitations of the existing international growth reference standards in potentially overestimating malnutrition in developing countries,[13] it is equally important not to mistakenly attribute extreme shortness in a population of children to factors such as genetics and altitude.[14] Such shortness may represent growth failure due to chronic undernutrition. Chronically malnourished children are at greater risk of early mortality due to secondary disease[15-18] and may suffer irreversible neuro-developmental consequences.[19-22]

Background

Heights and weights of 14,272 Tibetan children, aged 0-7 years, within the Lhasa prefecture were surveyed in 1986 by the TAR Maternal and Child Health Bureau, in conjunction with UNICEF.[23] The survey found that Tibetan children fall behind Han Chinese children in both weight and height by age 3-6 months, according to WHO growth reference standards. The nutritional status of Tibetan children, however, was described as "acceptable overall."

In 1990, the *Save the Children Fund, UK*, analyzed data from the 1986 survey and gathered new data on an additional 479 Tibetan children.[23] Researchers concluded that the weight-for-age and the height-for-age of children in the entire survey area were "borderline unacceptable," and in certain counties "unacceptably low" by WHO references,

* Supported, in part, by grants from The Columbia Foundation, The Threshold Foundation, The Trace Foundation, and the Western Consortium for Public Health.

** Tibet Child Nutrition Project, Western Consortium for Public Health, Santa Cruz, California USA. Correspondence: Nancy S. Harris, M.D., Tibet Child Nutrition and Collaborative Health Project, International Health Programs, Western Consortium for Public Health, 210 High Street, Santa Cruz, California 94050 USA.

*** Tibet Autonomous Region, First People's Hospital, Department of Pediatrics and Medical Research, Lhasa, Tibet, PRC.

**** School of Public Health, University of California, Berkeley, California 94720 USA.

with a prevalence of stunting greater than 40%. These findings raised a number of questions regarding overall nutritional status, child feeding practices, sexual dimorphism, and the effects of disease and altitude. In the same year, a village survey of 48 Tibetan children, aged 0-4 years, documented a dramatic compromise in height-for-age by 12 months of age.[24] This study found a stunting prevalence of over 60%, suggesting that more severe chronic malnutrition might be found in rural children.

Micronutrient deficiency syndromes reported in Tibet include goiter,[23] endemic cretinism,[23] rickets,[25] anemia,[26] "Big Bone Disease" (Kershan's Disease, a crippling arthritic syndrome possibly related to selenium deficiency) and night blindness.[27] Infectious diseases included a high incidence of diarrheal illness, hepatitis, echinococcus, and tuberculosis.[23,24,27]

According to a 1990 Epidemiological Survey performed in the TAR, the prevalence of pulmonary tuberculosis is high: 1203/100,000 in the general population. The prevalence in children 0-5 years is 338/100,000, and in the children 5-10 years, 1490/100,000.[28]

This paper presents a pilot nutritional survey data collected in 1993 by the Tibet Child Nutrition and Collaborative Health Project (TCNCHP). The purpose of the study was to assess the nutritional status of Tibetan children living in diverse areas on the high altitude plateau. The following questions were addressed:

- Is there evidence of significant chronic malnutrition in Tibetan children?
- If so, which groups are at greatest risk, and for what reason?
- Which demographic and underlying disease factors contribute to undernutrition?
- What are the implications for future studies and eventual public health interventions in this region?

Subject and Methods

Sample Selection

This study surveyed 341 Tibetan subjects between 0 and 84 months from four community locations within the Tibet Autonomous Region. The survey was conducted during four weeks in November 1993, a post-harvest period which is associated with a relatively greater abundance of food than other months.

The four survey locations were representative of communities characteristic of contemporary Tibet: nomadic, agricultural, periurban, and urban.

Nomadic Community: The survey team visited Nagchu town and one nearby village (4500-4700 meters altitude) about 250 kilometers north of Lhasa, in northeast Tibet. In November, the community was situated in the usual winter encampment consisting of one-story mud and brick houses. Nomadic families are characterized as transhuman pastoralists, living by animal husbandry and raising sheep, yak, "dri" (female yak), and high altitude hybrid cattle. The nomads barter with sedentary farmers. Animal products and salt, collected from nearby salt lakes, are exchanged for barley.

Village Agricultural Community: Two villages in the Medrogonggar province (3900 meters altitude) within the Lhasa prefecture were surveyed. This province has been characterized as one of the poorest in the prefecture.[23] A segment of the community is considered semi-nomadic if they own high altitude animals. Agricultural crops are primarily barley, rapeseed, black beans, turnips, potatoes, and winter wheat. Barley is bartered with nomads for salt.

Periurban Community: Two communities — Radu and Nyangra (3650 meters altitude) — outside Lhasa but within 30 km of the city, were selected to represent the periurban settlements. Primary crops include barley, rapeseed, and beans. Of the agricultural communities studied, this area has potentially the best access to urban-based health care resources, and these villages have the same geographical characteristics as Lhasa.

Urban Community: Urban children within the city of Lhasa were sampled at a centrally located daycare center near the Potala Palace (3650 meters altitude). The daycare center served approximately 200 families, with one or both parents employed full time as small business owners, government workers, or wage laborers. Daycare was provided by a staff of Tibetan teachers; children received midday meals at the center.

A census sampling strategy was used in each of the four locations. Community health workers recruited all families with children between the ages of 0 and 84 months (7 years) to participate in the survey. Parents were enthusiastic about receiving supplemental medical care and presented themselves and their children at designated clinic sites. Distribution of children's ages and communities are given in Table 1.

Data Collection

Data were collected by a team of Tibetan physicians (two pediatrics; one internist), an American physician, and local Maternal and Child Health and village health workers. Questionnaire data were collected from each child's presenting parent or caretaker, using a standard instrument that was verbally administered by a Tibetan pediatrician in the Tibetan language. Additional Tibetan translators were required when local dialect differed significantly from central Lhasa dialect. The instrument, developed by the authors, assessed demographic, socioeconomic, and family health data, including residence, parental occupations, number of children in the family, and the incidence of sibling death. Clinical exams were performed by study clinicians (NH, YY, PG, and LP). Children were examined for signs of malnutrition: hair depigmentation, abdominal distention, skin abnormalities, eye findings, and sores, as well as rickets, goiter, caries, abnormal development, and Big Bone Disease. The presenting parent or caretaker provided the child's medical history. Childhood diseases included diarrhea, upper respiratory infections, parasites, hepatitis, tuberculosis, and seizures. Maternal health history was assessed for iodine deficiency, hepatitis, tuberculosis, as well as other chronic illnesses.

Anthropometric measurements were performed according to standard methodology[29] and included height, weight, head circumference, chest circumference, mid-arm circumference, and triceps skinfold. Children were weighed and measured

Table 1. NUMBER OF STUDY PARTICIPANTS BY AGE AND LOCATION

Age (Years)	*Community Location*				*Total*
	Nomad	*Village*	*Periurban*	*Urban*	
0 - 0.9	14	10	17	1	42
1.0 - 1.9	10	13	16	1	40
2.0 - 2.9	12	12	16	2	42
3.0 - 3.9	15	19	16	10	60
4.0 - 4.9	13	21	12	18	64
5.0 - 5.9	13	14	15	12	54
6.0 +	8	8	17	4	37
Total	85	97	109	48	339

using a beam balance scale and attached stadiometer ("Panda" Model TGT-50, Shanghai Bao Shen Measurement Factory), used by UNICEF/MCH programs throughout China. The scale was calibrated before each set of measurements. Children unable to stand were measured for recumbent length, using another standard model recumbent length board ("Golden Lion" Model WB1, Beijing Tractor Company #6 Measuring Factory). Head, chest, and arm circumference were measured with a nylon centimeter tape. Lafayette skinfold calipers (Model #01127) were used for triceps skinfold measurements. All children were measured in undergarments and without shoes.

Birthdate information was collected using the Tibetan lunar calendar, with subsequent conversion to Gregorian calendar dates. Date of birth was subtracted from date of exam to provide calculated biologic age. In two instances, no date of birth could be determined, and the data were deleted from analysis. In 15 cases, a specific birth month could not be identified, and the field staff used historical events, season, and period within season to estimate age. It was decided to include data from these subjects since most were four or more years old (one at 22 months, two at 2 years, two at 3 years, three at 4 years, and seven at 5 years and above). Over half the parents could identify the month of birth but not the day of the month. In these cases, the 15th of the month was used. In instances when birthdates were estimated, ages were always rounded down. These methods provide a conservative estimate of age.[30]

Data Analysis

Age was examined both as a continuous and a categorical variable: 0-11 months, 12-23 months, 24-35 months, 36-47 months, 48-59 months, 60-71 months, and 72+ months. The log transformation of age was used in the analyses, which included age as a covariate.

The sample included 72 subjects who were siblings. As multiple observations from the same family are not statistically independent, data were analyzed adjusting for complex cluster design effects, with household as the cluster, using the *SAS macro GEE* statistical program.

Height and weight were examined in relation to the U.S. National Center for Health Statistics (NCHS) reference population,[31] using normalized growth curves in the calculation of Z-scores for height-for-age (H/A), weight-for-age (W/A), and weight-for-height (W/H).[32]

Z-scores were evaluated by age and community location groups using a one-way analysis of variance (ANOVA). Differences among groups were followed up using Tukey's HSD test, with a 5% procedure-wise error rate to determine differences between pairs. Given the association between age and community location, analyses using location were age-adjusted through analysis of covariance techniques.

In order to unravel associations among highly correlated medical variables (mother's illness history, child's illness history, and child's clinical signs), three dichotomous variables were created. The variable was defined as either the absence or presence of one or more of the clinical conditions. Stepwise multiple regression techniques were used to examine the relative contributions of each of these three variables to predict Z-scores. Regressions included log age and indicator variables for location of residence.

All analyses were performed at the University of California, Berkeley, using *SPSS* statistical software.

Results

Characteristics of Sample

Data were obtained from 341 children between ages 1 month and 84 months from four distinct communities (see Table 1). Two subjects were deleted for missing data. Highly significant ($p<.01$) associations between age and location were found, in large part due to the virtual absence of children under three years of age at the urban daycare center. For this reason, associations involving community location variables were adjusted for age.

The sample was nearly equally divided by sex when examined by age and location of residence. The total sample was 49% male and 51% female. No association tested was found to be significant by sex.

Occupation of parents was reported as farmer, nomad, or steady income/business (Table 2). Parental occupation was highly correlated with community location. All parents in the urban group reported their occupation as steady income/business. All villagers reported their occupation as farmer, and virtually all periurban families also reported their occupation as farmer. Nomads classified their occupations as either nomad or steady income/ business.

Family Size and Z-Score

Ninety-six percent of the families reported having both a mother and a father present in the household (Table 2). Sixteen percent of the sample were single children; 34% had one sibling, and 18% had five or more siblings. Urban families were the smallest, while village families were the largest (Table 2). Families with as many as ten siblings were reported. Twenty-nine percent of the families reported that one or more of their children had died. The number of living siblings correlated negatively with the H/A Z-score ($p<.05$), i.e., the larger the number of living siblings, the lower the H/A Z-score. However, there was no association between the number of dead siblings and H/A Z-scores.

Table 2. DEMOGRAPHIC CHARACTERISTICS AND EARLY FEEDING PRACTICES OF SAMPLE, BY LOCATION

	Location			
	Nomad	*Village*	*Periurban*	*Urban*
Occupation (Percent)				
Farmer	0	100	97	0
Nomad	57	0	0	0
Steady Income/Business	43	0	3	100
Family Composition (Percent)				
Families with 2 Parents in Home	92	97	97	100
Families with 1 Child	20	8	8	42
Families with 2 Children	39	12	46	44
Families with 3 Children	15	21	17	6
Families with 4 Children	13	10	7	4
Families with 5 Children	4	14	5	2
Families with 6+ Children	9	34	17	2
Early Feeding Practices (In Months)				
Average Length of Breastfeeding	22	28	21	13
Average Age at Introduction of Additional Foods	8	8	*	12

* Data on additional foods were not collected in the periurban location.

Table 3. MEAN HEIGHT-FOR-AGE, WEIGHT-FOR-AGE, AND WEIGHT-FOR HEIGHT Z-SCORES, BY LOCATION*

	Z-Scores		
Location	*Mean Height-for-Age*	*Mean Weight-for-Age*	*Mean Weight-for-Height*
Nomad	–2.13	–1.51	–0.38
Village	–3.01	–2.21	–0.58
Periurban	–2.79	–1.49	–0.33
Urban	–0.35	–0.02	–0.38

* Adjusted for age.

Observed Mortality Percent

Our data can provide a crude estimate of mortality within the households sampled, by dividing total deaths reported in the households (which includes stillbirths and abortions) over total births in the households (including the subjects). Since the age of death of the siblings is not always clear, this is not comparable to the infant mortality rate, under-5 mortality rate, or crude death rate. In our study of 269 families reporting 865 children, there were 156 reported deaths. The observed mortality was 15.3%.

Z-Scores and Age

Z-scores were calculated for three anthropometric indices: height-for-age, weight-for-age, and weight-for-height. Z-scores for all three indices were closer to WHO norms during infancy than at any other subsequent age.

H/A, W/A, and W/H Z-scores declined with increasing age between the first and sixth years of life (Figure 1). Conventionally, stunting is defined as a H/A Z-score less than or equal to -2.0. For all children of both sexes, 60.7% fell below -2.0 for H/A Z-score, 32.5% fell below -3.0, and another 14% fell between -4.0 and -6.0 H/A Z-scores. If the period of infancy were excluded from the analysis, the H/A Z-score remained inversely associated with age, as indicated by a regression of log linear age on H/A Z-scores ($p<-.05$). However, similar trends were not observed for W/A or W/H Z-scores. The age at which the lowest W/H Z-score occurred was 1 to 1.9 years. Turkey's HSD test showed this age group to be the only group with W/H Z-scores significantly different than those in infancy (0-0.9 years).

Z-Scores and Location

Children in urban settings were significantly heavier and taller than their counterparts in village, nomad, and periurban areas (Table 3). Age-adjusted H/A Z-scores and W/A Z-scores were significantly higher in urban children than in children from the other three areas. Age-adjusted W/H Z-scores were not significantly different among children from different geographic areas.

As a result of the large differences in H/A and W/A Z-scores between the urban children and the children in the other locations, Z-score frequencies were calculated separately for urban and non-urban children (Table 4). Prevalence of stunting was 65% in the non-urban group, as compared with 33% in the urban group. H/A Z-scores $\leq$ -3.0 were found in more than one-third of the non-urban children and one-sixth of the urban children.

W/A Z-scores of <-2.0 were observed in 37% of the non-urban children and 8% of the urban. W/A Z-scores of <3.0 were observed for 7% and 2% of non-urban and urban children, respectively. Few children in any location had wasting (W/H Z-scores $\leq$ -2.0).

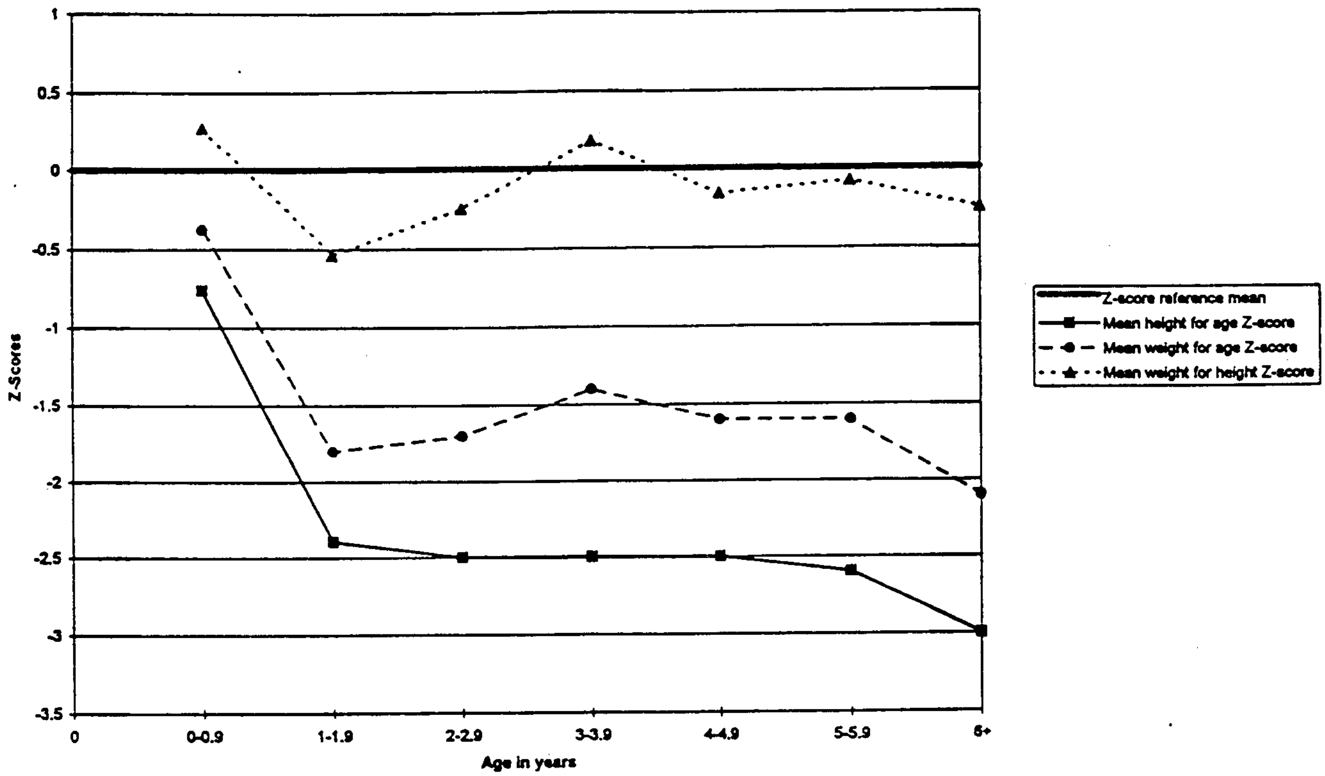

Fig.1. Mean height-for-age, weight-for-age and weight-for-height Z-scores by age.

Z-Scores and Occupation

Given the nearly perfect association between occupation and location, it was not unexpected that parental occupation was significantly associated with Z-scores for H/A and W/A. For both indices, children with parents who had steady income demonstrated significantly higher scores than those whose parents classified themselves as farmers. Children with parents classified as nomads had Z-scores similar to other non-urban children.

Z-scores and Early Feeding Practices

The Tibetan children surveyed were breastfed an average of 22 months, with a range of 0-64 months (Table 2). Village children were breastfed on average the longest at 28 months, while urban children were breastfed on average only 13 months. Three percent of the children were never breastfed due to reported lactation failure. Most Tibetan children were given mixtures of tsampa (toasted barley flour), black tea, and butter within the first days of life and throughout infancy. Virtually no children were exclusively breastfed in the first six months. Children with prolonged periods of breastfeeding tended to have lower H/A Z-scores ($p<.05$).

The average age at which additional foods (eggs, meat, wheat, rice, yogurt, or vegetables) were added to the infant diet was 9 months (Table 2). Nomad and village children received at least one of these additional foods at an average of 8 months, as compared with urban children who received additional food at an average 12 months. In our sample, H/A Z-scores did not correlate with the time of the introduction of "additional infant foods."

Z-Scores and Clinical Assessment

The data demonstrated a clear association between clinical assessment and Z-scores (Table 5).

Table 4. FREQUENCY OF Z-SCORES FOR HEIGHT-FOR-AGE, WEIGHT-FOR-AGE, AND WEIGHT-FOR-HEIGHT FOR URBAN (n=48) AND NON-URBAN (n=290) CHILDREN BETWEEN 3 AND 6 YEARS OF AGE*

Z-Score Category	*Height-for-Age Z-Score*		*Weight-for-Age Z-Score*		*Weight-for-Height Z-Score*	
	Urban	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*
≤ −3	16.7	35.5	2.1	7.2	0	0.7
≤ −2	16.7	29.3	6.3	29.7	0	1.7
≤ −1	27.1	24.1	43.8	36.9	6.3	13.8
−1 to 0	27.1	7.2	27.1	19.0	43.8	39.0
0 & Above	12.5	3.8	20.8	7.2	50.0	44.8

* Non-urban included children living in village, nomad, and periurban areas.

Table 5. MEAN HEIGHT-FOR-AGE, WEIGHT-FOR-AGE, AND WEIGHT-FOR-HEIGHT Z-SCORES BY CHILDREN'S CLINICAL SIGNS, CHILDREN'S MEDICAL HISTORY, AND MATERNAL MEDICAL HISTORY

	% of Sample	*H/A Z-Score*	*W/A Z-Score*	*W/H Z-Score*
Clinical Condition				
Overall Rating:				
Good	31.7	−1.68[a]	−0.89[a]	0.17[a]
Fair	49.0	−2.41[b]	−1.59[b]	−0.15[b]
Poor	19.4	−3.21[c]	−2.23[c]	−0.42[b]
Rickets	45.7	−2.66**	−1.73***	−0.18
Hair Depigmentation	41.1	−2.56*	−1.75**	−0.26
Abdominal Distention	31.4	−2.69**	−1.74**	−0.15
Skin Signs	6.7	−2.76*	−2.00*	−0.47
Caries	25.2	−2.51	−1.60	−0.11
Medical History				
Hepatitis	6.5	−3.19**	−1.88	0.06
Diarrhea > 1 Month	15.6	−2.85*	−1.95**	−0.37*
Cough > 1 Month	15.6	−2.97**	−2.02**	−0.32
Parasites	5.3	−2.90	−2.11*	−0.53
Tuberculosis	1.8	−2.36	−1.31	0.16
Seizures	3.2	−3.25*	−2.40**	−0.61
Maternal Medical History				
Hepatitis	7.7	−2.75	−1.83	−0.22
Iodine	8.3	−3.02**	−1.92*	−0.11
Tuberculosis	6.8	2.72	−1.87	−0.29

* $p < .05$
** $p < .01$
*** $p < .001$

a,b,c Groups sharing a common superscript are not statistically different from each other at a procedure-wise error rate of 5%.

H/A and W/A Z-scores were significantly associated with clinical status: good, fair, and poor. W/H Z-scores were significantly different for children assessed as good versus those assessed as fair or poor. Physicians' subjective clinical assessment rated 32% of the children in good clinical condition, 49% as fair, and 19% as poor. Two cases of frank clinical marasmus were noted in lethargic children with severely depigmented hair, obvious muscle wasting, and weakness. No edematous states were seen. Rickets, indicated by cranial bossing, deformed costo-chondral development, or enlargement of the distal wrist, was noted in 46% of the children. Hair depigmentation, with both thinness and blonding of the hair, was noted in 41% of the children. Abdominal distention was observed in 31% of the cases. Caries were found in 25% of the cases, and skin findings, which were confined to multiple sores of impetiginous nature, were found in 7% of the children. Eye findings included bluish scleral discolorations, probably normal variants, without evident Bitot's spots or keratomalacia in 4% of the subjects. No goiter was found in children, although this was observed in adults. None of the children studied had arthropathic changes of Big Bone Disease. Extremity deformities noted were post-traumatic. No frank cretinism was identified, though 1% of children had uncharacterized abnormal physiognomies, which could include Fetal Alcohol Syndrome, genetic dysmorphism, and iodine deficiency as possible diagnoses.

There was a high concordance of lower H/A and W/A Z-scores with the presence of clinical rickets ($p < .01$ and $p < .001$, respectively), hair depigmentation ($p < .05$ and $p < .01$) and abdominal distention ($p < .01$ and $p < .01$).

Z-Scores and Child and Maternal Disease History

From their medical histories, hepatitis was reported in 7% of children, chronic diarrheal disease (loose stools lasting more than one month) in 16%, chronic cough (lasting more than one month) in 16%, visible parasites in 5%, diagnosed tuberculosis in 2%, and seizures of an unknown etiology in 3%. Significant associations were found between H/A Z-scores and history of hepatitis ($p < .01$), history of diarrhea for longer than one month ($p < .01$), and cough longer than one month ($p < .001$). W/A Z-scores were associated with the history of diarrhea for longer than one month ($p < .01$), history of cough longer than one month ($p < .01$), and parasites ($p < .05$). W/H Z-scores were associated with diarrhea greater than one month ($p < .05$).

Mothers' history of hepatitis was also associated with the H/A Z-scores of their children ($p < .002$). Eight percent of the mothers reported a history of hepatitis. All disease variables were associated with lower Z-scores.

Children's clinical signs, children's history of disease, and maternal disease history were all highly correlated with each other. For this reason, each of these three types of clinical data were recorded as binary variables, and regression techniques were used to examine the relative contribution of these new variables. Parents reported that 34% of children had a history of disease (at least one of five diseases listed); 77% of the children had clinical signs at the time of examination, and 19% of the mothers reported having a history of chronic disease. All pair-wise comparisons of the binary illness variables were significant at $p < .01$. A step-wise multiple regression was employed to unravel the effects of the three variables, while controlling for the effects of log age and location. When regressed against H/A Z-scores, the effect of mother's history of disease and clinical signs were not significant when the child's medical history of disease was included in the model. Since infants have a lower probability of having a disease history, the model was rerun with only those over one year of age. The results were unchanged. The child's history of disease explains more of the variation in H/A Z-scores than the other two variables. When the same procedure was employed to predict W/A Z-scores, mother's history of disease was the only variable to remain in the equation. The presence of clinical signs was the only variable to remain in the regression to predict W/H Z-scores. Therefore, it appears that a positive child's medical history is most predictive of stunting, the maternal medical history most predictive for W/A, and the child's clinical findings most predictive of wasting. However, as all three variables are highly related, the significance of the presence of a specific variable for the prediction of each Z-score must be viewed with caution.

Skinfold and Circumference Findings

Results of the other anthropometric measurements are presented for Tibetan children with comparative values from NHANES II, based on American children[33] (Figures 2-6). Sex-specific means are compared with NHANES values. Values are not compared in infancy since NHANES presented data for a 6-11 months interval, while this study aggregated data from 0-12 months.

Triceps skinfold data differences between Tibetan and American children generally ranged between 0 and 3 mm (Figure 2). Tibetan children have smaller skinfold values, and differences appeared to increase for female children after three years of age. For boys, the pattern is less clear.

Mid-upper arm circumferences are smaller for Tibetan children by a magnitude of about 4 cm (Figure 3). There appeared to be no difference in pattern for male and female children. Arm circumference values for NHANES reference children increase at each successive age, while those for Tibetan children level off after three years of age. Fifteen percent of Tibetan children under two years of age were found to have arm circumferences less than 11.5 cms., a value below which has been found to correlate with increased risk of mortality within the next four months of life.[34]

Mean chest circumference values were consistently lower for Tibetan children (Figure 4). While the increase in chest circumference is steady in NHANES children, there is a period of rapid increase for Tibetan children in the early years — males between ages 2 and 3 years and females between ages 1 and 2 years.

Mean head circumference data for Tibetan children is similar to that of NHANES children (Figure 5). Chest/head ratios for Tibetan children are graphed in Figure 6. The mean chest/head ratio for Tibetan males exceeds 1.0 after three years of life, and for Tibetan females after two years. The chest/head ratio in well-nourished populations should reach 1.0 by age six months. Ratios less than 1.0 are considered to suggest early childhood undernutrition.[29]

Discussion

Our study has found evidence of significant malnutrition in Tibetan children. Over 60% of the children examined had H/A Z-scores of -2 or less. No sexual dimorphism was observed for any of the Z-scores calculated. Some have speculated that delayed or depressed growth achievement in high altitude children could be attributed to genetic factors or to the effects of high altitude living.[11,35,36] Our data suggest otherwise for Tibetan children in our sample. We found significantly more cases of low H/A and low W/A Z-scores in the non-urban children (i.e., those living in nomad, village, or periurban locations). Urban children living at the same altitude as their periurban peers were significantly taller and heavier.

H/A Z-scores, or stunting, provided the most compelling evidence for malnutrition, while W/H Z-scores, wasting, were less dramatic (Figure 1). Trowbridge made the same observation in his study of Peruvian children, stating: "Weight for height may not provide a constant index of nutritional status in populations having different dietary, environmental, and/or genetic backgrounds that lead to a different mix of body composition, body size, and proportions."[37] Our data do not allow examination of issues of body proportion and composition.

In our series of bivariate analyses, after controlling for age and complex cluster design effects, a low H/A Z-score was significantly associated with (1) a history of childhood illness, particularly respiratory or diarrhea; (2) clinical presence of rickets, abdominal distention, hair depigmentation; (3) maternal illness history; (4) non-urban location, particularly agricultural, (5) prolonged period of breastfeeding, and (6) a greater number of living siblings. Of importance, there was no association with numbers of dead siblings or with the child's gender.

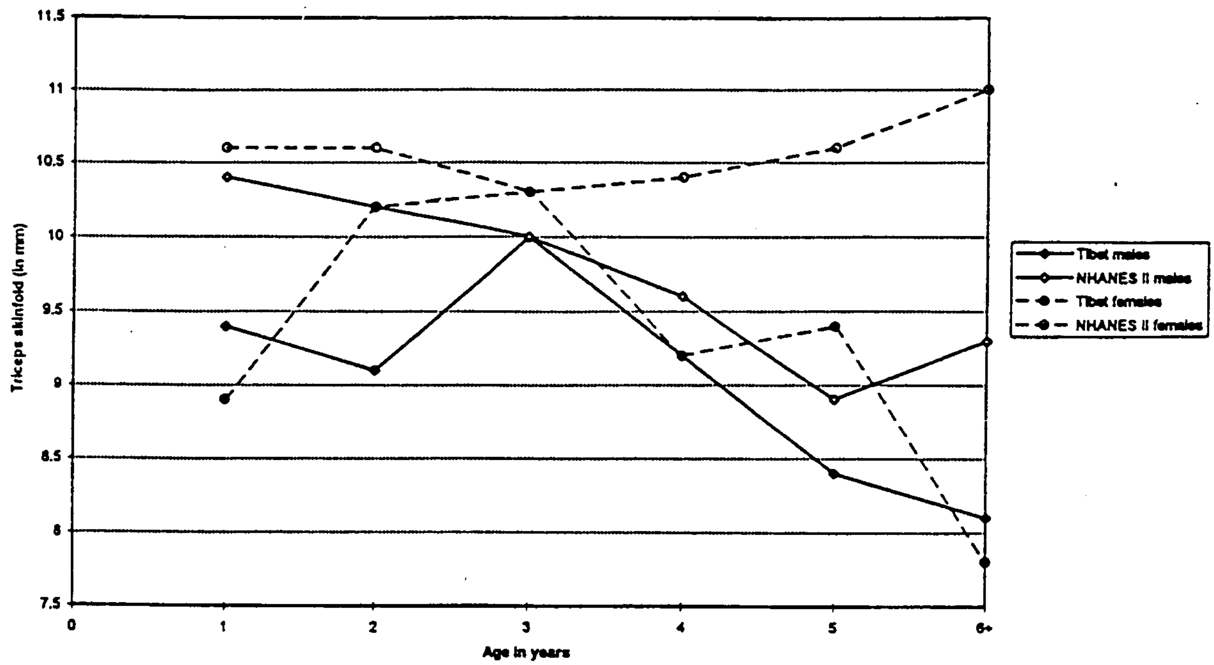

Fig. 2. Mean triceps skinfold (in mm) for male & female Tibetan children compared with NHANES II values by age.

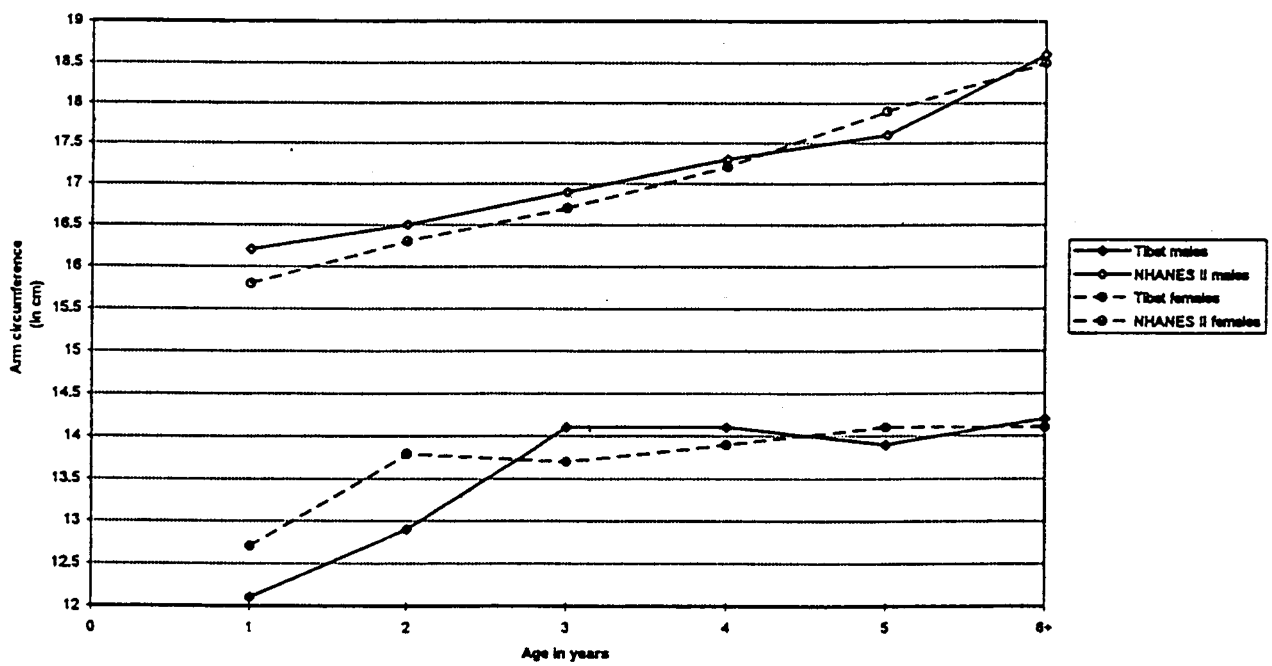

Fig. 3. Mean mid-arm circumference (in cm) for male & female Tibetan children compared with NHANES II values by age.

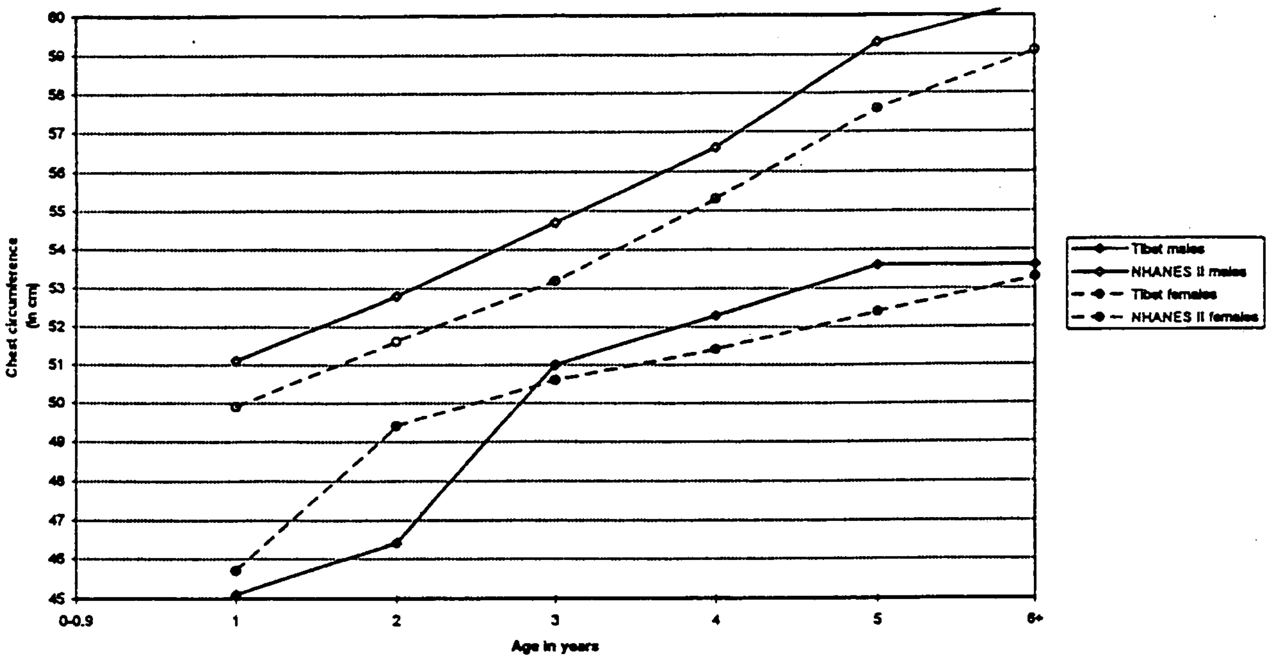

Fig. 4. Mean chest circumference (in cm) for male & female Tibetan children compared with NHANES II values by age.

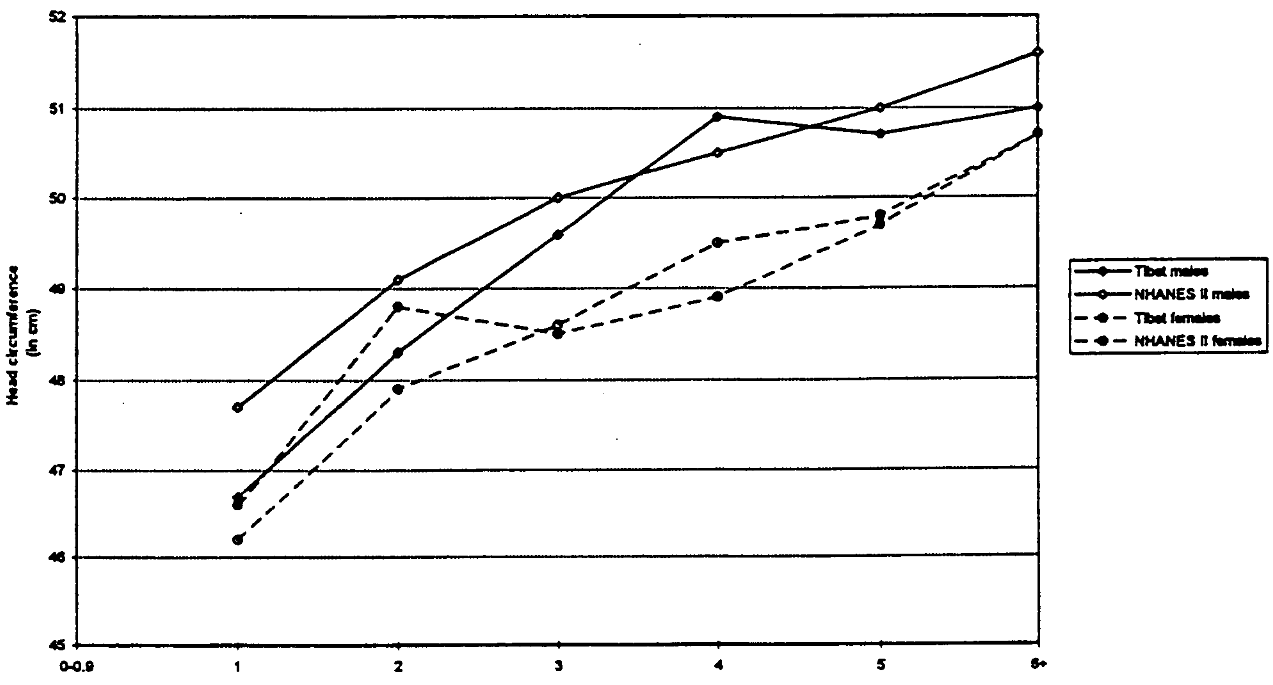

Fig. 5. Mean head circumference (in cm) for male & female Tibetan children compared with NHANES II values by age.

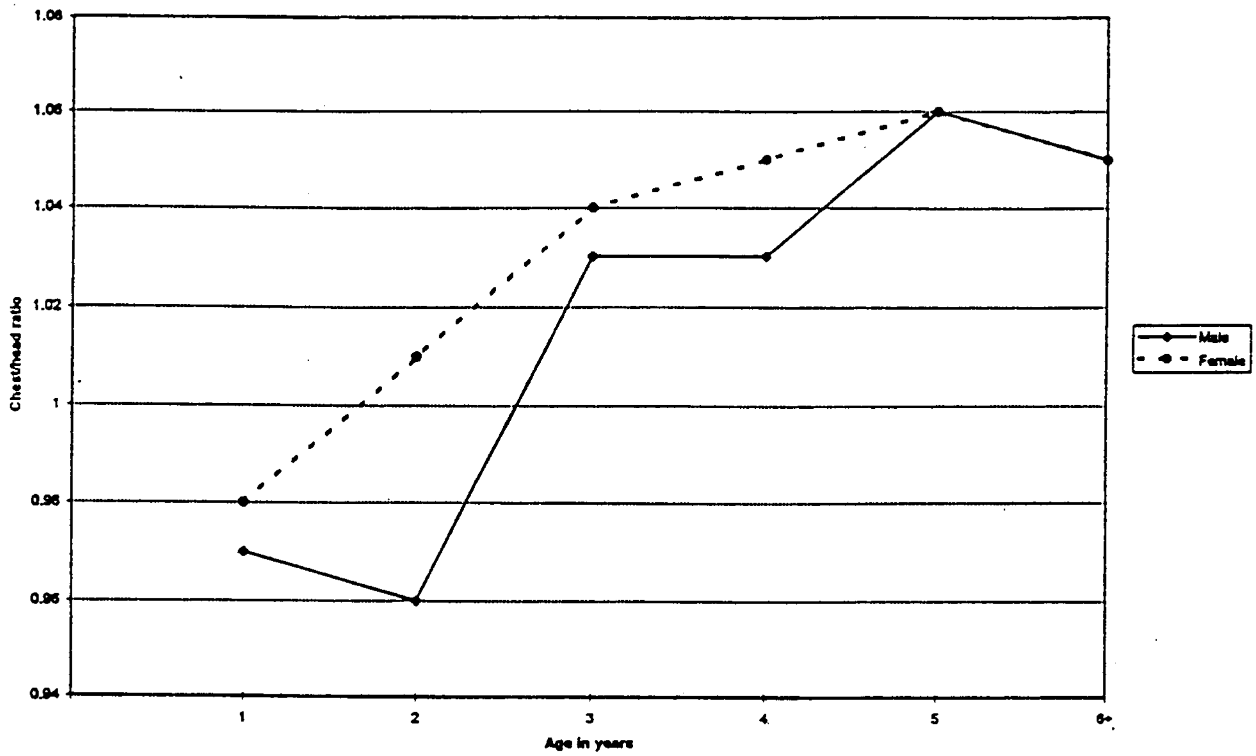

Fig. 6. Mean chest/head ratio of male & female Tibetan children.

Mid-upper arm circumference data suggest that perhaps as many as 15% of the under-two year olds are at increased risk of mortality. Delayed development, as indicated by low chest/head circumference ratios, is further evidence of growth failure within this population.

The high prevalence of rickets was a surprising finding in a dairy-consuming culture with a sunny climate of over 3400 hours of sunlight a year.[38] Possibly our clinical findings may reflect "scorbutiform" rickets, with codeficiencies of vitamin C. Other factors may be adversely affecting calcium absorption, such as the zinc Xphytase ratio of the current diet.[39] Swaddling practices, in which children are wrapped in multiple layers of clothing and not exposed to sunlight throughout the first years of life, are likely implicated.

Clinical signs or symptoms of vitamin A deficiency were not observed. Consultation with elder Tibetan traditional physicians reveals there is a recognized traditional syndrome, translated as "blindness at midnight," but is considered rare.

Iodine deficiency is reported throughout the Himalayas and mountainous areas of China.[40] Adult goiter was prevalent in parents of subjects. Frank myxedematous cretinism was not identified in this population of children, though subclinical hypothyroidism may be a factor in growth retardation. Future studies will examine thyroid status.

Our data identify potential periods of high risk. H/A Z-scores plummeted between the first and second years of life. This was also the age period with the lowest W/H Z-scores. Although this study is cross-sectional and direct causality cannot be determined, it appears that a period of insult between the first and second years of life may be influential in determination of subsequent H/A Z-scores.

We also observed different early feeding patterns between the lower risk urban children and the higher risk non-urban children. Urban children were breastfed significantly fewer months (13 versus 25 months), and urban children received added supplemental food later than non-urban children (12 versus 8 months). Extended breastfeeding was negatively associated with growth achievement. This may be due to tandem breastfeeding, compromised maternal nutrition, and lack of appropriately timed introduction of complementary foods. Reassuring is the importance placed by all groups on breastfeeding, which is not yet being significantly supplanted by bottle feeding. It should be noted that nearly all infants received supplemental feedings of tea, barley, and butter in the first days of life and throughout the first six months. This widespread feeding practice may play an important role in early diarrheal illness and nutritional compromise. More information on breastfeeding techniques and supplementation practices in this population are being addressed in a concurrent study.

The principal causes of growth stunting in the developing world are often attributable to a cycle of nutritional inadequacies and disease. Maladaptive selections of foods or food behaviors based on shifts away from traditional staples may be occurring in this traditional society undergoing socio-ecologic change. In the agricultural communities, the infrequent consumption of high quality protein is a factor which may be influenced by changes in traditional barter patterns of meat and dairy products for grains.

In planning for future nutritional intervention, further investigation of Tibetan traditional food preferences is necessary. The common perception that Tibetans "don't eat vegetables" was not borne out by our observation. Wild greens, nettles, fennel, carrots, turnips, radish, legumes, cabbage, scallions, and mushrooms were either sown or collected. Although hot-house vegetables are grown and abundantly available in Lhasa, vegetables recently introduced to the plateau may never achieve wide acceptance. Of great concern, however, is ready acceptance of recently introduced sugar products, such as candy and soda-pop. The "droma," or high altitude legume, may be an example of a traditional high status food whose consumption could be encouraged for mothers and children at risk.

Conclusions

Tibetan children achieve linear growth consistent with NCHS growth references until about 12 months of age, at which time they fall off dramatically and do not recover over the next six years.

Elite urban and nomad children are growing better than their agricultural counterparts, which suggests that all small stature on the Tibetan plateau cannot be ascribed to altitude. Moreover, these children exhibit signs of frank malnutrition and nutritional deficiency syndromes, which underscores the fact that they are not "small but healthy,"[41–43] — that this degree of stunting is adaptive.

This pilot study identifies several areas for future study and reveals several alarming areas of concern. It emphasizes the need for treatment and prevention of childhood disease in this population, particularly in the at-risk 0-3 age group. Future areas for intervention include prevention of rickets and enhancement of infant feeding behaviors in the at-risk age categories. A further study is planned to examine potential micronutrient deficiencies; to further define the contribution of concurrent disease, socioeconomic factors, and changes in agricultural practices; and to identify and implement specific intervention strategies based on these findings.

Acknowledgment

We gratefully acknowledge our Tibetan colleagues:

Dr. Zhu Shi Mei
Director, First People's Hospital

Madame Wang Yu Shu
Vice Director, First People's Hospital

Dr. Kelsang
Training, First People's Hospital

The Health Department, Medrogonggar

The Maternal and Child Health Department, Medrogonggar

Staff of the Shue Day Care Center, MCH Department, Nagchu.

Further acknowledgment is given to Dr. Mark Hudes, Nicole Lordi, Robert Minnis, Dr. Sheldon Margen, Dr. Frank Falkner, Nancy Nielsen, R.N., Ephrosine Daniggelis, Dr. Margaret Meites, Dr. Jean Humphrey, Dr. Robert Livingston, Dr. Elizabeth Hartka, Megan Tucker, and Carol Guion for their assistance during the fieldwork and preparation of this manuscript.

References

1. Census Office of the Tibet Autonomous Region. *1990 Census of the Tibet Autonomous Region*. Lhasa: Tibet People's Press, 1990.

2. *China-feasibility study for an integrated rural development project in Pa Nam Country, Tibet*. A report of the Commission of the European Communities Directorate-General External Relations. Commission of European Communities, September 1994.

3. Haas JD, Moreno-Black G, Frongillo Jr. EA, et al. Altitude and infant growth in Bolivia: A longitudinal study. *American Journal of Physical Anthropology* 1982; 59: 251-62.

4. Frisancho AR. Perspectives on functional adaptation of the high altitude native. *Progress in Clinical and Biological Research* 1983; 136: 383-407.

5. Singh SP. Growth patterns of children of Tibetan origin living at moderate altitudes, India. *Zeitschrift fur Morphologie und Anthropologie* 1980; 71(2): 187-95.

6. Leonard WR. Nutritional determinants of high altitude growth in Nunoa, Peru. *American Journal of Physical Anthropology* 1989; 80: 341-52.

7. Beall CM, Goldstein MC. Hemoglobin concentration of pastoral nomads permanently resident at 4850-5450 meters in Tibet. *American Journal of Physical Anthropology* 1987; 73(4): 433-8.

8. Zhuang J, Droma T, Sun S, et al. Hypoxic ventilatory responsiveness in Tibetan compared with Han residents of 3658 m. *Journal of Applied Physiology* 1993; 74(1): 303-11.

9. Martorell R, Lechtig A, Yarbrough C, et al. Small stature in developing nations: Its causes and implications. In: Margen S, Ogar RA, editors. *Symposium on the biological and cultural sources of variability in human nutrition*. (Series title: Progress in human nutrition, v. 2). Westport, Connecticut: AVI Publishing Co., 1978 (pp 142-56).

10. Habicht JP, Martorell R, Yarbrough C, et al. Height and weight standards for preschool children. How relevant are ethnic differences in growth potential? *The Lancet* 1974; 1: 611-5.

11. Pawson IG. Growth characteristics of populations of Tibetan origin in Nepal. *American Journal of Physical Anthropology* 1997; 47(3): 473-82.

12. Majumder PP, Gupta R, Mukhopadhyay B, et al. Effects of altitude, ethnicity-religion, geographical distance and occupation on adult anthropometric characteristics of Eastern Himalayan populations. *American Journal of Physical Anthropology* 1986; 70(3): 377-93.

13. Garn SM. Stature norms and nutritional surveys. *Ecology of Food and Nutrition* 1973; 2: 79-81.

14. Smith T, Earland J, Bhatia K, et al. Linear growth of children in Papua New Guinea in relation to dietary, environmental and genetic factors. *Ecology of Food and Nutrition* 1993; 3: 1-25.

15. Chen LC, Chowdhury A, Huffman SL. Anthropometric assessment of energy-protein malnutrition and subsequent risk of mortality among preschool-aged children. *American Journal of Clinical Nutrition* 1980; 33: 1836-45.

16. Pelletier DL. The potentiating effects of malnutrition on child mortality: Epidemiologic evidence and policy implications. *Nutrition Reviews* 1994; 52(12): 409-15.

17. Victora CG, Barros FC, Kirkwood BR, et al. Pneumonia, diarrhea, and growth in the first 4 years of life: A longitudinal study of 5914 urban Brazilian children. *American Journal of Clinical Nutrition* 1990; 52: 391-6.

18. Victora CG. The association between wasting and stunting: An international perspective. *Journal of Nutrition* 1992; 122(5): 1105-10.

19. Allen LH. The nutrition CRSP: What is marginal malnutrition, and does it affect human function? *Nutrition Reviews* 1993; 51(9): 255-67.

20. Grantham-McGregor SM. Assessments of the effects of nutrition on mental development and behavior in Jamaican studies. *American Journal of Clinical Nutrition* 1993; 57 (Suppl.): 303S-309S.

21. Burger SE, Haas JD, Habicht JP. Testing the effects of nutrient deficiencies on behavioral performance. *American Journal of Clinical Nutrition* 1993; 57 (Suppl.): 295S-302S.

22. DeLong GR. Effects of nutrition and brain development in humans. *American Journal of Clinical Nutrition* 1993; 57 (Suppl.): 286S-290S.

23. Kolsteren P, Atkinson S, Maskall K. *Nutrition, health, water and sanitation assessment in the Lhasa Valley.* Report of Save the Children and the Lhasa Health Bureau. Lhasa: Save the Children, May-June 1990.

24. Chin N. *Child growth in three Tibetan villages: An assessment of environmental, biological and social determinants.* Master's essay. Rochester: University of Rochester, 1992.

25. Zhor AH, Huo SY, Wu ZWM, et al. *Report of Spring, 1987 rickets survey.* Lhasa Municipality, December 1987.

26. Zhang XR, Dawa, Gesang ZM, et al. *Survey of the rate of anemia in children 0-7 in the Lhasa area.* Lhasa, Tibet: Women and Children's Health Department, MCH, June 1989.

27. Taylor CE, Chin N, Leaf A, et al. Health survey of Tibetan villages north of Mount Everest. *National Geographic Research and Exploration* 1992; 8(3): 374-7.

28. Ping, XH, editor. *Epidemic survey results on TB performed in T.A.R. during 1990.* Chengdu: Sichuan Science and Technology Press, 1991.

29. Jelliffe DB. *The assessment of the nutritional status of the community.* Geneva: WHO, 1996.

30. Gorstein J. Assessment of nutritional status: Effects of different methods to determine age on the classification of undernutrition. *Bulletin of the World Health Organization* 1989; 67(2): 143-50.

31. Dibley MJ, Goldsby JB, Staehling NW, et al. Development of normalized curves for the international growth reference: Historical and technical considerations. *American Journal of Clinical Nutrition* 1987; 46(5): 736-48.

32. Dibley MJ, Staehling N, Nieburg P, et al. Interpretation of Z-score anthropometric indicators derived from the International Growth Reference. *American Journal of Clinical Nutrition* 1987; 46(5): 749-62.

33. Anthropometric reference data and prevalence of overweight, United States, 1976-1980. *Vital & Health Statistics Series 11* (No. 238). DHHS Publication No. (PHS) 87-1688. Washington, DC: National Center for Health Statistics, October 1987.

34. Trowbridge FL, Sommer A. Nutritional anthropometry and mortality risk [letter]. *American Journal of Clinical Nutrition* 1981; 34(11): 2591-2.

35. Haas JD, Frongillo Jr. EA, Stepick CD, et al. Altitude, ethnic and sex difference in birth weight and length in Bolivia. *Human Biology* 1980; 52(3): 459-77.

36. Beall CM. Growth in a population of Tibetan origin at high altitude. *Annals of Human Biology* 1981; 8(1): 31-8.

37. Trowbridge FL, Marks JS, Lopez de Romana G, et al. Body composition of Peruvian children with short stature and high weight-for-height. II. Implications for the interpretation for weight-for-height as an indicator of nutritional status. *American Journal of Clinical Nutrition* 1987; 46(3): 411-8.

38. Goldstein M, Beall C. *Nomads of Western Tibet: The survival of a way of life.* Berkeley, California: University of California Press, 1990.

39. Fitzgerald SL, Gibson RS, Quan de Serranan J, et al. Trace element intakes and dietary phytate/Zn and Ca X phytate/Zn millimolar ratios of periurban Guatemalan women during the third trimester of pregnancy. *American Journal of Clinical Nutrition* 1993; 57: 195-201.

40. Ma T, Guo J, Wang F. The epidemiology of iodine-deficiency diseases in China. *American Journal of Clinical Nutrition* 1993; 57 (Suppl.): 264S-266S.

41. Seckler D. The "small but healthy" hypothesis: A basic hypothesis in the theory, measurement and policy of malnutrition. In: Sukhatme M, editor. *Newer concepts in nutrition and their implication for policy.* India: Association for the Calibration of Science Research Institute, 1982 (p 127).

42. Gopalan C. "Small is healthy"? For the poor, not for the rich! *Nutrition Foundation of India*, October 1983.

43. Beaton, GH. Small but healthy? Are we asking the right question? *European Journal of Clinical Nutrition* 1989; 43: 863-75.