Original Article

Malnutrition Prevalence in Lasa Xizang Children and Adolescents*

YIN Xiao Jian[1] and JI Cheng Ye[2,#]

1. Key Laboratory of Adolescent Health Assessment and Exercise Intervention, Ministry of Education, College of Physical Education & Health, East China Normal University, Shanghai 200241, China; 2. Institute of Child and Adolescent Health, Peking University Health Science Center, Beijing 100191, China

Abstract

Objective To assess the prevalence of malnutrition among children and adolescents in Xizang (Tibet).

Methods We analyzed data from the Chinese National Survey on Students' Constitution and Health for the years 1995, 2000, 2005, and 2010 pertaining to Tibetan children and adolescents in Lase (Lhasa), aged 7-18 years old. Numbers of survey subjects for these years were: 2 393, 2 754, 2 397, and 2 643, respectively.

Results Our results indicated that the rate of occurrence of stunting in Tibet has evidenced a gradual decline: for boys, from 26.8% in 2000 to 9.3% in 2010; and for girls, from 25.8% in 2000 to 10.8% in 2010. In general, the wasting rate for both boys and girls in Tibet has gradually decreased over time: for boys, from 17.7% in 1995 to 4.6% in 2005; and for girls from 12.5% in 1995 to 2.3% in 2005. The stunting rates of boys aged 7-13 years old and of girls aged 7-11 years old were 67.5% and 53.1%, respectively, while these rates for boys aged 14-18 years old and girls aged 12-18 years old were 32.5% and 46.9%, respectively.

Conclusion Stunting and wasting rates of Tibetan children and adolescents indicate a gradual declining trend over time. The stunting rates of both boys and girls during early puberty were significantly higher than those during late puberty.

Key words: Tibetan children and adolescents; Malnutrition; Stunting; Wasting

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INTRODUCTION

The growth and development of children and adolescents entails a complex process of change that is influenced by heredity, nutrition, hormones, work and sports, sleeping, as well as many other factors related to the natural environment. Of all the factors listed above, nutrition constitutes the most important physical foundation of children's growth[1]. Xizang (Tibet) is situated in China's Qinghai-Tibet Plateau and has a unique natural environment and widely divergent socialeconomic strata, life styles, and customs compared with other regions. Therefore, understanding the nutritional status of children and adolescents in this region and timely identification of existing nutritional issues is of great significance in improving children's nutrition, promoting their growth and development, and enhancing the quality of Tibet's population. In this regard, there have been a relatively large number of cross-sectional studies from across the world regarding malnutrition among Tibetan children and adolescents. A study by Harris et al.[2] on 2 078 Tibetan children aged 0-84 months old indicated that severe stunting in Tibetan children, caused by malnutrition, occurred in early life, and

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#Correspondence should be addressed to JI Cheng Ye, Tel: 86-10-82805109, Fax: 86-10-82805109, E-mail: jichengye@263.net

Biographical note of the first author: YIN Xiao Jian, male, bron in 1965, professor on child and adolescent health.

that their morbidity rate was high. Moreover, stunting was not associated with altitude after adjustment for the type of community. Dang et al.[3] have shown that the prevalence of malnutrition among children below 36 months old was 39.0% for stunting, 23.7% for underweight, and 5.6% for wasting. The prevalence of stunting and underweight among rural children was 41.4% and 24.7%, respectively, while for urban children, these figures were 25.3% and 18.1%, respectively. In this study, stunting and underweight were associated with altitude. A report by Ying et al.[4] indicated that the prevalence rates of stunting, underweight, and wasting for children under 3 years old in rural areas of Nyingchi and other Tibetan areas were 33.9%, 16.5%, and 3.4%, respectively, while the prevalence rates of stunting and underweight in places at altitudes higher than 4 500 m, were 36.5% and 19.1%, respectively. A study by Argnani et al.[5] on 131 Tibetan children aged between 8 and 14 years old found no evidence of wasting but did detect stunting (28.3%). It noted that children permanently exposed to a high-altitude environment above 4 000 m displayed a phenotypic form of adaptation and a moderate reduction in linear growth. A study by Tripathy et al.[6] on Indian Tibetans aged 2-40 years and living in three regions at different altitudes (3 521, 970, and 800 m) showed that the heights of Tibetans who migrated to low altitudes were slightly higher. This slight difference in height was largely attributed to greater leg length, which may be explained by differences in food and nutrition. Altitude may or may not be mediated by nutritional status. Rooze et al.[7] carried out a study on the growth of 688 Tibetan children aged between 0 and 5 years and living in rural areas where Kashin-Beck disease (KBD) was endemic. This showed that stunting and underweight were common phenomena and were probably associated with rickets. Research on malnutrition of children and adolescents in other countries also includes some longitudinal studies.

To sum up, studies on malnutrition among Tibetan children and adolescents were mostly cross-sectional and concentrated on children aged between 0 and 7 years old. Although there are a few studies and reports regarding malnutrition of children and adolescents in other countries, in China, there are hardly any longitudinal studies on malnutrition among Tibetan children and adolescents. Therefore, this study extracted cross-sectional data from national physical surveys conducted in 1995, 2000, 2005, and 2010 from the perspective of historical development. This data was used to analyze changes in the malnutrition status of children and adolescents aged 7-18 years old in Lasa Xizang (Lhasa Tibetan). This can provide a reference base for establishing and improving the standard system of screening growth, development, as well as nutrition among Tibetan children and adolescents.

METHODS

Subjects and Sampling

Data were obtained from the results of the Chinese National Survey on Students' Constitution and Health (CNSSCH) implemented in 1995, 2000, 2005, and 2010. Since 1985, the CNSSCH has been respectively administered by the Ministry of Education, National Health and Family Planning Commission of the People's Republic of China; the Ministry of Science and Technology; the State of National Affairs; and the State Sports General Administration in China every 5 years. This survey entails the largest nationally representative samples of school-aged children and adolescents in China. Data from these surveys have been widely used to produce prevalence estimates for a variety of health indicators of children and adolescents in China. The target groups of the CNSSCH are mainly divided into two categories: Chinese Han students from primary schools, secondary schools, and universities aged 7-22 years, and Chinese minority students from primary and secondary schools aged 7-18 years. Han students are sampled separately from Tibetans. Random samples of minority students are directly obtained from the selected survey regions and races. For example, Tibetan children and adolescents who have been living for a long period in Lhasa, the capital of the Tibet Autonomous Region, are directly chosen. However, only students, whose parents and grandparents are of the same ethnic group, can be included in the survey sample. Further, since the CNSSCH was first implemented in 1985, and subsequently every 5 years, surveys have had to strictly comply with the CNSSCH's requirements. It is mandatory that samples are selected from the same schools and that the same survey methods are implemented[8-13]. This study focuses on Tibetan children and adolescents aged 7-18 years old in Lhasa, Tibetan, who were subjects during the last four CNSSCH surveys. As mentioned above, the samples only included Tibetan students in Lhasa. To

ensure the validity of comparisons between samples, subjects in each group were selected randomly during the different periods. As a result, each period provided suitable subjects totaling 2 393 in 1995 (1 196 boys and 1 197 girls); 2 354 in 2000 (1 183 boys and 1 171 girls); 2 397 in 2005 (1 198 boys and 1 199 girls); and 2 643 in 2010 (1 318 boys and 1 325 girls). Ethical approval was obtained from Peking University's Medical Research Ethics Committee. Before using the data, it was explained to all of the subjects that the data would be used for statistical purposes only to further improve the administration of the students' health. When the data for this study were fed into the computer, the students' names were coded to ensure anonymity, and the original data were managed by Peking University.

Methods of Measurement

The subjects underwent a thorough medical examination before measurements were taken, and those with obvious diseases or physical/mental deformities were excluded. Their heights and weights were both measured by the same technicians who were required to participate in a week's rigorous training. All measurements were taken according to a standardized procedure and using uniformly recommended apparatus. The subjects were asked to use the restroom before being measured. Male students were measured wearing underpants only, and female students wore a t-shirt and a pair of light trousers. None wore shoes.

Subjects were weighed standing on platform scales, and the results were recorded to the nearest 0.1 kg. Their heights were measured against metal column bars and recorded to the nearest 0.1 cm. Rigid quality control measures were enforced in the field. After completing measurements each day, 3% of the subjects were requested to undergo a repeat set of measurements.

Definitions of Stunting and Wasting

Body mass index (BMI) was calculated using the formula: BMI equals weight (kg)/height $(m)^2$. Stunting and wasting rates of Tibetan children and adolescents across different generations in this study were calculated according to two criteria: height-for-age (height below the 3rd percentile was defined as stunted) and BMI-for-age (BMI below the minus 2Z-Score was defined as wasting). These two criteria are adopted in the WHO reference of 2007[14]. For this study, measurement of malnutrition was based on stunting and wasting rates. Stunting ratios were first calculated using the height-for-age criterion, and wasting ratios were subsequently calculated based on the BMI-for-age criterion, after excluding the previously defined stunted group.

Statistical Analysis

The 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles of height-for-age and BMI-for-age were computed using the LMS method for groups of Tibetan children and adolescents between the ages of 7 and 18 years old. LMS Developed by Cole (1990) is an internationally accepted method for establishing growth and development criteria[15]. The above-mentioned percentiles of the WHO-prescribed criteria of height-for-age and BMI-for-age were sourced from the WHO website.[14] The chi-square test was used to determine significant differences in stunting for one 5-year span (1995-2000) and one 10-year span (2000-2010). The *t*-test was used to determine significant differences of height, weight, and BMI for one 5-year span (1995-2000) and one 10-year span (2000-2010). For all analyses, the level of statistical significance was set at 0.05. Statistical analyses were carried out using the SPSS version 16.0 statistical software. Data input was performed using the Epidata 3.1 software.

RESULTS

As shown in Table 1, in general, the average height, weight, and BMI of boys and girls of all age groups in the survey sample showed a gradual increase over time. However, an exception was the average height of boys and girls of all age groups in 2000, which was relatively lower than the corresponding value in 1995. Height differences for boys aged 11-15 years old and girls aged 9-11 years old, and in children aged 14 years, were of statistic significance. In general, BMI were higher for successive years than the value in 1995. Despite the inclusion of several age groups, average height and weight values were significantly higher for a number age groups in 2010 compared with these values in 2000. Height and BMI values were significantly higher and of statistical significance.

Table 2 show that in general, the rates of occurrence of stunting for boys and girls, as defined

Table 1. The Height, Weight, and BMI of Tibetan Children and Adolescents During 1995-2010

Age	1995				2000				2005				2010			
	N	Height	Weight	BMI	*N*	Height	Weight	BMI	*N*	Height	Weight	BMI	*N*	Height	Weight	BMI
Boy																
7-	99	118.6±5.2	20.1±2.6	14.3±1.0	116	119.1±4.0	20.9±2.7$^{\triangle}$	14.7±1.3$^{\triangle}$	99	118.3±5.6	21.9±3.0	15.6±1.2	109	123.3±5.4*	23.9±3.8*	15.6±1.9*
8-	100	123.5±5.0	22.1±2.9	14.4±1.5	115	122.6±5.9	22.5±3.1	14.9±1.3$^{\triangle}$	100	126.2±6.5	25.8±4.5	16.2±2.0	107	127.1±5.5*	25.6±5.6*	15.7±2.5*
9-	100	127.4±5.4	23.6±3.0	14.5±1.3	119	127.0±6.0	24.3±3.7	15.0±1.3$^{\triangle}$	100	132.3±6.3	28.9±4.7	16.4±1.8	113	132.6±6.0*	28.9±6.0*	16.3±2.6*
10-	99	132.0±6.1	25.7±3.8	14.7±1.4	113	130.4±5.4	25.8±3.0	15.1±1.2$^{\triangle}$	100	133.6±5.1	29.7±5.3	16.6±2.2	112	137.8±5.6*	31.1±6.5*	16.3±2.4*
11-	100	135.8±6.2	28.1±4.9	15.1±1.6	110	134.9±6.7	28.1±4.2	15.4±1.3	100	139.2±6.7	32.3±5.5	16.6±1.8	124	142.3±6.3*	34.5±7.5*	16.9±2.8*
12-	100	142.4±8.5	31.1±6.1	15.3±1.6	132	143.6±7.2	34.4±6.4$^{\triangle}$	16.6±2.3$^{\triangle}$	100	143.3±7.8	35.4±6.3	17.1±1.9	117	146.0±8.8*	36.9±9.5*	17.1±3.0
13-	100	151.1±8.7	37.1±7.5	16.1±1.8	103	147.7±7.9$^{\triangle}$	35.9±6.3	16.4±1.6	100	146.0±8.9	39.3±9.1	18.4±3.6	110	153.8±8.4*	43.0±10.3*	18.0±3.3*
14-	100	157.5±8.4	41.1±6.2	16.5±1.5	113	155.3±7.5$^{\triangle}$	40.8±6.2	16.8±1.6	100	158.2±7.8	45.3±7.6	18.0±1.9	112	162.3±8.2*	49.5±9.5*	18.5±2.4*
15-	100	164.6±5.8	67.2±6.0	17.4±1.6	107	161.6±7.3$^{\triangle}$	44.8±6.3$^{\triangle}$	17.1±1.5	100	161.5±7.0	48.4±7.5	18.5±2.1	112	167.3±6.8*	53.3±10.0*	19.0±2.9*
16-	100	165.9±6.0	48.3±6.3	17.5±1.8	115	164.8±6.3	50.6±6.0$^{\triangle}$	18.6±1.5$^{\triangle}$	100	167.0±5.2	54.0±7.1	19.3±2.3	100	167.7±6.3*	53.8±8.3*	19.1±2.4
17-	98	168.0±6.0	51.3±5.6	18.1±1.5	118	167.6±6.3	51.2±5.0	18.2±1.6	100	168.7±5.1	55.7±5.5	19.6±1.8	102	169.4±5.6*	55.7±7.9*	19.4±2.5*
18-	100	168.0±5.4	52.2±5.5	18.5±1.7	122	168.6±5.9	54.1±6.4$^{\triangle}$	19.0±1.9$^{\triangle}$	99	168.8±4.9	56.7±5.5	19.9±2.0	100	169.1±5.8	58.5±7.2*	20.5±2.5*
Total	1196	146.3±18.9	35.7±12.7	16.0±2.1	1383	145.3±19.7	36.2±12.7	16.5±2.1$^{\triangle}$	1198	146.9±18.1	39.5±13.3	17.7±2.5	1318	149.5±17.7*	40.9±14.2*	17.7±3.0*
Girl																
7-	99	117.6±4.2	19.5±2.1	14.1±0.9	117	117.8±5.0	19.9±2.6$^{\triangle}$	14.3±1.4	100	116.7±6.6	21.0±3.5	15.3±1.3	110	122.2±5.7*	22.8±3.4*	15.2±1.7*
8-	100	122.4±5.4	21.5±2.6	14.3±1.3	110	121.5±5.2	21.9±3.1	14.8±1.3$^{\triangle}$	100	125.7±6.6	24.4±4.3	15.3±1.8	116	125.5±5.4*	23.9±3.7*	151.±1.7
9-	100	128.4±6.5	23.3±3.1	14.1±1.0	119	125.2±6.5$^{\triangle}$	23.3±4.3	14.8±1.8$^{\triangle}$	100	131.4±7.4	28.2±5.8	16.2±2.2	113	132.7±6.3*	26.8±4.9*	151.±1.8
10-	100	133.1±6.8	25.9±4.1	14.4±1.5	109	130.5±6.0$^{\triangle}$	25.9±3.9	15.1±1.4$^{\triangle}$	100	134.3±5.6	29.1±4.8	16.1±2.0	118	138.1±7.3*	29.9±6.1*	15.5±2.3
11-	100	138.4±7.3	28.7±5.0	14.9±1.5	121	136.4±6.6$^{\triangle}$	28.3±4.4	15.1±1.6	100	141.7±6.1	33.8±5.1	16.8±1.9	112	143.3±7.0*	34.3±7.2*	16.6±2.6*
12-	99	144.9±7.5	32.9±5.7	15.6±1.7	120	144.8±6.5	33.8±6.1	16.0±1.9	100	145.1±6.3	36.2±7.2	17.1±2.4	106	145.0±8.1	34.9±8.1	16.4±2.5
13-	100	150.4±6.3	37.5±5.6	16.5±1.8	122	149.2±6.0	38.6±7.0	17.3±2.3$^{\triangle}$	100	147.0±7.2	41.0±7.5	18.9±3.3	110	152.0±6.0*	42.2±7.4*	18.1±2.4*
14-	100	155.4±5.6	44.0±6.4	18.1±2.2	110	153.1±5.0$^{\triangle}$	42.1±6.6$^{\triangle}$	17.9±2.3	100	152.7±7.2	45.6±8.3	19.5±2.9	125	156.9±4.9*	47.4±7.5*	19.3±2.9*
15-	99	156.2±5.4	44.8±5.7	18.4±2.0	109	155.8±5.1	45.4±6.0	18.7±2.2	100	155.7±5.0	49.1±8.1	20.2±3.0	108	157.6±5.1*	48.5±6.5*	19.5±2.3*
16-	100	156.5±5.1	45.7±5.2	18.6±1.8	115	156.6±4.7	48.0±5.7$^{\triangle}$	19.5±2.1$^{\triangle}$	100	157.8±5.6	51.3±5.5	20.6±2.4	102	157.1±4.8	49.0±6.3*	20.1±2.3*
17-	100	156.9±5.3	47.4±5.8	19.2±2.0	114	157.6±5.2	50.2±6.8$^{\triangle}$	20.2±2.4$^{\triangle}$	100	157.5±4.8	51.7±6.4	20.8±2.4	105	157.6±5.4	50.16.1±	20.2±2.3
18-	100	157.3±5.3	48.2±5.6	19.4±2.1	105	156.8±4.8	59.9±5.5$^{\triangle}$	20.3±1.9$^{\triangle}$	99	157.5±4.8	51.3±5.8	20.7±2.4	100	158.4±4.6*	50.6±0.7	20.1±2.3
Total	1197	143.2±15.2	35.0±11.6	16.5±2.7	1371	141.9±15.4$^{\triangle}$	35.4±12.2	17.0±2.9$^{\triangle}$	1199	143.6±14.6	38.6±12.4	18.1±3.2	1325	145.3±14.0*	38.2±12.2*	17.6±3.1*

Note. $^{\triangle}P<0.05$, refers to the comparison between 2000 and 1995; $^{*}P<0.05$, refers to the comparison between 2010 and 2000; The statistical analyses are *t*-test.

Table 2. Rate of Malnutrition of Tibetan Children and Adolescents during 1995-2010 (By WHO Standard)

Age	1995				2000				2005				2010			
	N	Stunting (%)	Wasting (%)	Non-malnutrition (%)	*N*	Stunting (%)	Wasting (%)	Non-malnutrition (%)	*N*	Stunting (%)	Wasting (%)	Non-malnutrition (%)	*N*	Stunting (%)	Wasting (%)	Non-malnutrition (%)
Boy																
7-	99	23.2	12.1	64.6	116	17.2	3.4	79.3	99	27.3	1.0	71.7	109	5.5*	1.8	92.7
8-	100	15.0	16.0	69.0	115	33.0△	6.1	60.9	100	11.0	3.0	86.0	107	7.5*	6.5	86.0
9-	100	24.0	15.0	61.0	119	27.7	7.6	64.7	100	6.0	1.0	93.0	113	5.3*	4.4	90.3
10-	99	31.3	16.2	52.5	113	34.5	8.0	57.5	100	8.0	3.0	89.0	112	0.9*	11.6	87.5
11-	100	30.0	15.0	55.0	110	39.1	11.8	49.1	100	21.0	2.0	77.0	124	4.8*	7.3	87.9
12-	100	36.0	21.0	43.0	132	28.0	9.1	62.9	100	25.0	4.0	71.0	117	23.9	8.5	67.5
13-	100	28.0	13.0	59.0	103	42.7△	12.6	44.7	100	50.0	8.0	42.0	110	15.5*	10.0	74.5
14-	100	24.0	21.0	55.0	113	32.7	14.2	53.1	100	24.0	6.0	70.0	112	9.8*	3.6	86.6
15-	100	8.0	18.0	74.0	107	22.4△	23.4	54.2	100	24.0	9.0	67.0	112	7.1*	11.6	81.3
16-	100	16.0	25.0	59.0	115	18.3	5.2	76.5	100	5.0	7.0	88.0	100	11.0	10.0	79.0
17-	98	16.3	19.4	64.3	118	16.1	16.1	67.8	100	7.0	6.0	87.0	102	8.8	13.7	77.5
18-	100	19.0	21.0	60.0	122	13.1	17.2	69.7	99	8.1	5.1	86.9	100	12.0	5.0	83.0
Total	1196	22.6	17.7	59.7	1383	26.8△	11.1	62.1	1198	18.0	4.6	77.4	1318	9.3*	7.8	82.9
Girl																
7-	99	15.2	10.1	74.7	117	17.9	8.5	73.5	100	29.0	1.0	70.0	110	6.4*	1.8	91.8
8-	100	23.0	10.0	67.0	110	30.9	1.8	67.3	100	6.0	3.0	91.0	116	8.6*	4.3	87.1
9-	100	24.0	18.0	58.0	119	48.7△	6.7	44.5	100	11.0	1.0	88.0	113	8.8*	8.0	83.2
10-	100	28.0	26.0	46.0	109	42.2	7.3	50.5	100	22.0	3.0	75.0	118	13.6*	13.6	72.9
11-	100	35.0	20.0	45.0	121	48.8△	9.1	42.1	100	15.0	2.0	83.0	112	13.4*	13.4	73.2
12-	99	26.0	20.0	54.0	120	33.3	12.5	54.2	100	27.0	6.0	67.0	106	31.1	11.3	57.5
13-	100	18.0	15.0	67.0	122	23.8	9.0	67.2	100	39.0	3.0	58.0	110	10.9*	9.1	80.0
14-	100	8.1	9.1	82.8	110	18.2△	10.9	70.9	100	23.0	8.0	69.0	125	4.0*	6.4	89.6
15-	99	9.0	9.0	82.0	83	13.8	6.4	79.8	100	11.0	0.0	89.0	108	1.9*	1.9	86.3
16-	100	13.0	4.0	83.0	115	7.8	1.7	90.4	100	6.0	1.0	93.0	102	8.8	2.9	88.2
17-	100	9.1	4.0	86.9	114	7.0	1.8	91.2	100	8.0	0.0	92.0	105	7.6	5.7	86.7
18-	100	13.0	5.0	82.0	105	12.4	1.0	86.7	99	6.1	0.0	93.9	100	8.0	4.0	88.0
Total	1197	18.5	12.5	69.0	1371	25.8△	6.5	67.7	1199	16.9	2.3	80.8	1325	10.8*	6.9	82.3

Note. △P<0.05, refers to the comparison between 2000 and 1995 in stunting; *P<0.05, refers to the comparison between 2010 and 2000 in stunting; χ^2- test.

according to the WHO standards, have been gradually declining with the exception of the rate in 2000. Thus, the rate for boys decreased from 26.8% in 2000 to 9.3% in 2010. For girls, the rate decreased from 25.8% in 2000 to 10.8% in 2010. The stunting rate in 2000 was relatively high compared with the rate in 1995, with significant differences evident for both boys and girls. However, a significant difference did not exist for boys and girls aged 16-18 years old. Compared with the figure in 2000, the stunting rate of boys and girls decreased dramatically in 2010, and the difference was statistically significant. For both boys and girls, there was a considerable decrease in the 7-11 and 13-15 age groups, and the difference was statistically significant. However, differences for children in other age groups were not statistically significant. In general, the wasting rate, according to WHO standards, gradually decreased for both boys and girls. For boys, the rate decreased from 17.7% in 1995 to 4.6% in 2005. For girls, the rate decreased from 12.5% in 1995 to 2.3% in 2005. In addition, stunting ratios were generally higher than wasting ratios during the different times of the surveys. The non-malnutrition ratios correspondingly showed a gradual increase over time. For boys, the ratio increased from 59.7% in 1995 to 82.9% in 2010. For girls, the increase was from 69.0% in 1995 to 82.3% in 2010.

Table 3 shows that for both the shortness and thinness criteria, wasting rates in stunting of boys and girls in 1995 were 36.1% and 23.1% respectively, decreasing to 18.7% and 18.5%, respectively in 2010. This finding implies that a short and thin stature among Tibetan children and adolescents has gradually disappeared. Table 4 shows that both the stunting and wasting rates of boys were higher than those of girls. The stunting rate for boys in the age groups of 7-13 years (early puberty) and 14-18 years (later puberty) were 67.5% and 32.5%, respectively. The stunting rate for girls in the age groups of 7-11 years (early puberty) and 12-18 years (later puberty) were 53.1% and 46.9%, respectively. It is evident from the above findings that the stunting rate of was higher during the early puberty phase of the children compared with their later puberty phase, and that the stunting difference was statistically significant.

Table 3. Wasting Rate in the Stunting of Tibetan Children and Adolescents during 1995-2010 (Both the Short and the Thin, By the WHO Standard)

Items	1995	2000	2005	2010
Boy				
Stunting and wasting (Both the short and the thin)	97 (36.1)	75 (20.2)	19 (8.8)	23 (18.7)
General stunting (Just the Short)	172 (63.9)	296 (79.8)	197 (98.1)	100 (81.3)
Total	269	371	216	123
Girl				
Stunting and wasting (Both the short and the thin)	51 (23.1)	77 (21.9)	25 (12.3)	25 (18.5)
General stunting (Just the short)	170 (76.9)	275 (78.1)	178 (87.7)	110 (81.5)
Total	221	352	203	135

Note. '( )' should be filled with %.

Table 4. The Rate of Stunting and Wasting in Early and Late Puberty of Tibetan Children and Adolescents (By the WHO Standard)

Sex	Age	Height Category		BMI Category	
		Stunting	Normal	Wasting	Normal
Boy	7-13	661 (67.5)*	2 336 (56.8)	254 (48.5)*	2 082 (58)
	14-18	318 (32.5)	1 779 (43.2)	270 (51.5)	1 509 (42)
	Total	979	4115	524	3 591
Girl	7-11	484 (53.1)*	1 660 (39.7)	180 (50.1)*	1 480 (38.7)
	12-18	427 (46.9)	2 521 (60.3)	179 (49.9)	2 342 (61.3)
	Total	911	4 181	359	3 822

Note. *$P<0.05$, '( )' should be filled with %; χ^2 test.

Figure 1 shows the 25th, 50th, 75th, and 95th percentiles of height-for-age of Tibetan children and adolescents from 1995-2010, along with the WHO stunting standard. They show that compared with data for the years 1995, 2000, and 2005, the heights of boys and girls in 2010 were closest to the WHO height values. Almost all the percentiles of boys below 13-14 years old and of girl below 10-11 years old were close to the WHO height values. However, they then gradually deviated from the WHO reference values. At high percentiles, this gap increased. For example, the heights of children aged 18 years old were comparable to the WHO reference value. In 2010, percentile differences of boys for P25, P50, P75, and P95 were 5.55, 6.31, 7.33, and 8.9 cm, respectively. Comparable percentile differences for girls were 3.66, 4.86, 5.93, and 7.48 cm, respectively. These differences indicate that the gap between the taller Tibetan adolescents and the WHO reference heights was greater than the gap between the shorter Tibetan adolescents and the WHO reference heights. Moreover, although the heights of boys and girls for each age group in 2010 were generally greater than those measured in 2005, 2000, and 1995,

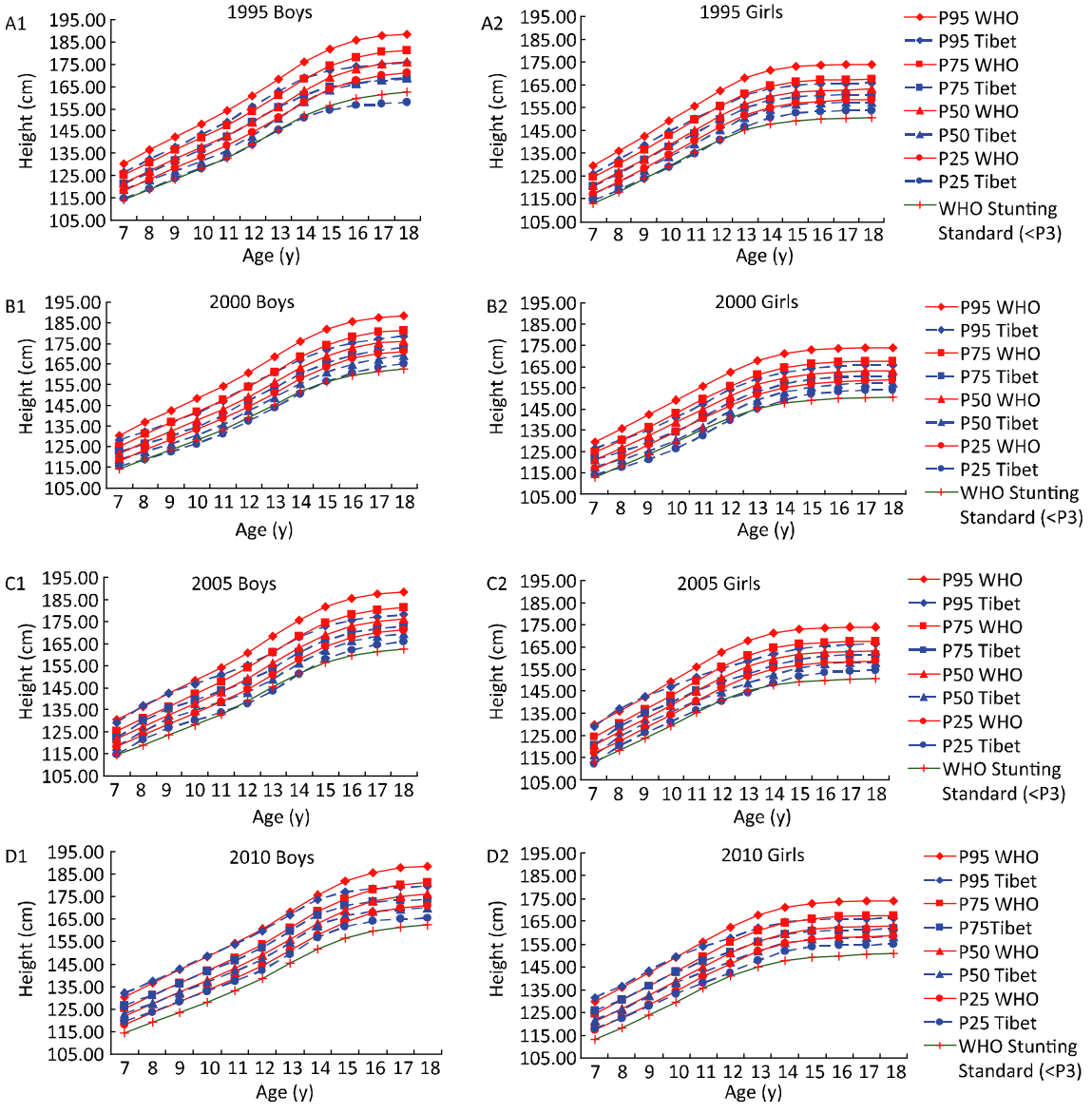

Figure 1. The Height of Tibetan Children and Adolescents from 1995 to 2010 and the WHO Height Reference and the WHO Stunting Standard. A1, B1, C1, and D1 are boys; A2, B2, C2, and D2 are grils.

the heights tended to be almost the same when they had grown up at the age of 18 years for each year of the survey at these 5-year intervals (see Table 1). Moreover, the P25 heights of Tibetan boys and girls in all of the age groups in 1995 were less than or in proximity to the WHO stunting standard, and the P25 heights of Tibetan adolescents in all age groups in 2010 exceeded the WHO stunting standard.

Figure 2 shows the 25th, 50th, 75th, and 95th percentiles of the BMI-for-age of Tibetan children and adolescents from 1995 to 2010, along with the WHO wasting standard. It is evident that the BMI percentiles of boys aged around 7-10 years old in 2005 and 2010 were close to the WHO reference values, but that they then gradually deviated from these values. Although over time, the values of BMI percentiles of girls have gradually approached the WHO reference values, they are still lower than the reference values. In addition, the P25 BMIs of all the age groups of Tibetan boys were in proximity to the WHO wasting standard in 1995 and 2000, but were higher than this standard for all age groups of Tibetan children and adolescents in 2000 and 2010.

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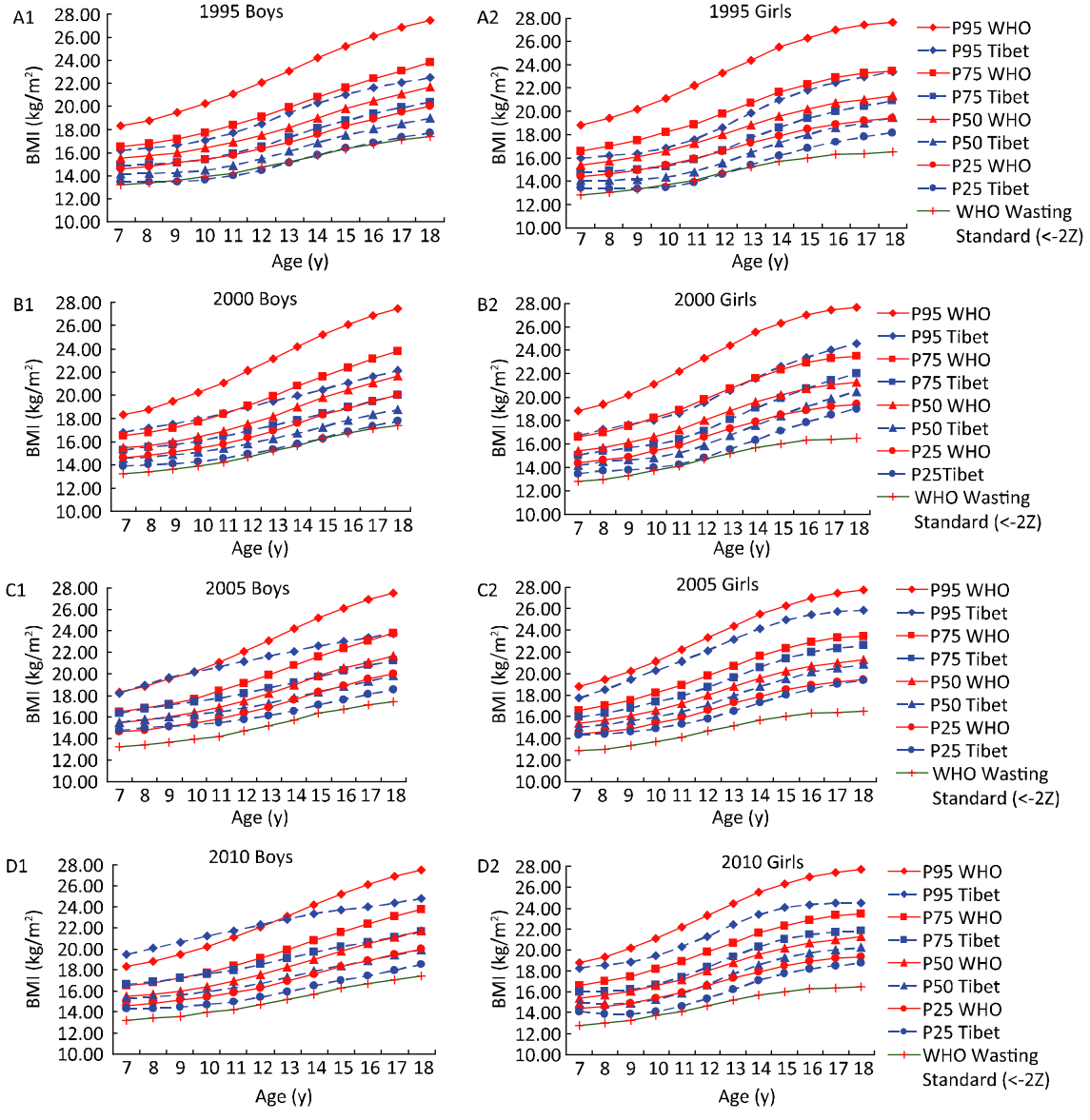

Figure 2. The BMI of Tibetan Children and Adolescents in from 1995 to 2010 and the WHO BMI References and the WHO Wasting Standard. A1, B1, C1, and D1 are boys; A2, B2, C2, and D2 are grils.

DISCUSSION

The survey subjects examined in this study were all from the Lhasa region along the southwestern periphery of the Qinghai-Tibet Plateau at an average altitude of 3 658 m. Lhasa, which is the capital city of the Tibet Autonomous Region, is an important city in terms of its economy, education, and culture. The annual average temperature and rainfall are 7.4 degrees Celsius and 500 mm, respectively, with an annual average of 3 000 h of sunshine. Statistics show that there were 515 300 registered permanent residents in Lhasa in 2009, composed of an urban (nonagricultural) registered population of 211 400 residents and an agricultural population of 303 900 residents. The entire city covers an area of 29 518 square kilometers, and contains eight county districts, 64 counties, and 269 villagers committees. Although Lhasa was formally designated as a city in 1960, it still, in fact, has farming and pastoral areas[16].

This study found a trend of gradually declining occurrence rates of stunting and wasting among Tibetan children and adolescents over time. This result is primarily and closely correlated to availability of education, medical care, and health, as well as economic development in Tibet. Regarding education, during the period from 2000 to 2010, the proportion of Tibet's illiterate population over the age of 15 years was reduced from 47.25% to 32.29%, and the number of college students per 100 thousand people increased from 1 262 to 5 507. Thus, the education level has significantly improved during the study period[17-18]. Pan[19] has shown that from 1999 to 2002, gross enrollment rates at elementary schools, junior high schools, and high schools in Tibet increased to 88.3%, 52.3%, and 42.1%, respectively. Moreover, the number of high schools increased by 266%, close to the national average. The education level of rural Tibetan women has also been greatly enhanced, with the progressive weakening of gender inequality within society and families in the allocation of educational resources. Investment in children's education has increasingly become a kind of family development strategy[17-22]. Since 1985, the Chinese government has implemented a 'Free Food, Free Lodging, and Free Tuition' policy regarding rural Tibetan children receiving compulsory education. Consequently, over 98% of Tibetan students benefit from this favorable policy[23]. In 2007, Tibet became the first province in China to implement free compulsory education, and, subsequently, China's 15 years of free education program in 2012. Various education-aid policies cover education at each level across the whole region, and the right to education of Tibetan people has been fully protected[24].

With respect to medical care, Tibetans did not have any modern medical care institutions prior to 1951. In 2008, Tibet had 1 039 health institutions. With the improvement of medical care, the average life expectancy of Tibetans increased from 35.5 years in 1951 to 67 years in 2008, and further to 72.99 years in 2010[17]. By the end of 2010, there were 1 352 medical institutions of all types and at all levels in Tibet, with 8 838 hospital beds and 9 983 medical workers. A healthcare system has been established in farming and pastoral areas, with government funds comprising the major portion, supplemented by family accounts, and comprehensive arrangements for serious diseases and medical relief. A medical and healthcare network covering all counties and townships, with Lhasa as the center, has taken shape. Now, all Tibetan townships have health centers and all villages have clinics. The mortality rate of women in childbirth has dropped from 5 000 per 100 000 women in 1959 to 174.78 per 100 000 women in 2010, and the infant mortality rate from 430 per thousand before 1951 to 20.69 per thousand in 2010[24-25]. Regarding the economy, Gyesang[26] reports that the gross value of production increased from RMB 10 561 billion in 1999 to RMB 60 583 billion in 2011.

The data for this study were sourced from a cross-sectional survey. Therefore, Tibetan children and adolescents aged between 7 and 18 years in 1995, 2000, 2005, and 2010 were from four respective birth cohorts for the following time periods: 1977-1988, 1982-1993, 1987-1998, and 1992-2003. The period from 1977 to 1988 was one of rapid economic growth in Lhasa, commencing from 1984. The average income of Tibetan peasants and herdsmen increased from RMB 353 in 1985 to RMB 1 200.31 in 1995[27]. In 1996, the average income of urban Tibetan citizens was RMB 6 566.62, which was higher than the national average of RMB 4 844.78. The latter further rose to RMB 8 765.45 in 2003, remaining higher than the national average of RMB 8 472.20 at this time[28]. A study by Yin et al.[29] showed that the physical constitutions of city-born college students were stonger than those of college students born in rural areas. This was mainly attributed to average family income, with an

improved physical constitution corresponding to a higher average family income. Some studies have argued that the education level of women is the main factor for predicting the risk of stunting in children, because the higher the education level of mothers, the stronger their influence on their children's nutrition[30-32]. Yang et al. found[33] that a lower level of maternal education and low family income significantly increased the risk for infant anemia and malnutrition. Wang et al.[34] further found that the subgroup with the highest level of education demonstrated significantly higher intakes of vitamins A and C than the subgroup with the lowest level of education. In 1995, total numbers of high school and college graduates in Tibet were 7 155 and 525 persons, respectively. Corresponding figures for 1998 were 11 322 and 1 151 persons, respectively, and for 2003, they were 21 290 and 1 745 persons, respectively[35]. It is evident that there is a trend of annually increasing numbers of educated Tibetan citizens. In 1995, women accounted for 51% of the total Tibetan population, as shown in a 1% sample survey of the population[36], and there were 2 145 women with various levels of education per 10 thousand Tibetan women. This can be attributed to the government's implementation of various policies encouraging Tibetan citizens to receive education, such as that of providing free food, lodging, and tuition[37]. The percentage of female students enrolled at various Tibetan schools has continued to increase, with figures for the years 2000, 2007, 2009, 2010, and 2011 being 46.1%, 49.8%, 44.1%, 48.7%, and 48.7%, respectively[38]. Therefore, it appears that continuous enhancement of education levels among Tibetan women has further affected the nutritional status of their children. Moreover, ongoing development of the Tibetan economy has contributed to the current trend of a gradual decline in occurrence rates of stunting and wasting of Tibetan children and adolescents over time.

The results of this study indicate that the rates of stunting and wasting of boys across different generations were higher than those of girls. Argnani et al.[5] have reported a higher prevalence of stunting among boys than among girls of all ages. This may be related to the greater resistance to malnutrition among girls during their growth compared with boys. A study by Yin et al.[39] indicated that the gender difference in physique that is associated with socioeconomic factors is greater than the difference associated with factors related to the natural environment. This is because socioeconomic conditions affect students' physiques primarily through nutrition and diseases, while conditions associated with the natural environment affect students' physiques by stimulating the body's response. Malina et al.[40] noted that socioeconomic conditions exerted a greater influence on the body weights of boys, but that they exerted almost no influence on girls' body weights. Therefore, because of the different effects of social and economic factors on the physical constitutions of males and females, rates of stunting and wasting are higher among males than among females.

The results of this study indicate that the height in 2010 were close to the WHO reference figures during the early stage of the children's development, but eventually lagged behind the WHO reference figures for the later stage of their development. Moreover, although Tibetan children's heights at differing times deviated during their early development phase, they more or less reached the same average value by the age of 18. As mentioned above, height and BMI values of Tibetan children and adolescents have gradually approached the WHO reference value for the early stage of adolescence because of rapid economic development and continually enhanced education levels and medical care in Tibet. However, although economic and education levels in Tibet have shown a rapid increase in recent years, the gap in relation to other Chinese provinces and developed nations is still relatively large[21-25]. Moreover, differences in race and the characteristics of adolescent growth may widen the gap between the height and BMI values measured for Tibetan adolescents and the WHO reference values during the later stage of their adolescence. Gilsanz et al.[41] found that the difference in spine BMD (bone mineral density) between Afro-American and Caucasian females emerged during puberty. In a comparative study across different races and times on growth and development, Salsberry et al.[42] reported evident differences in BMI and height, and the greater likelihood of Afro-American girls experiencing accelerated growth and early menarche compared with Caucasian girls. In another study, Weaver et al.[43] showed that Asian girls have a smaller skeleton than white or Hispanic girls during early puberty. Similarly, a study by Sampei et al.[44] demonstrated lower weights and heights among Japanese pre- and post-menarcheal girls compared with Caucasian girls. Cole[45-46] suggests that the trend in adult height

matches the trend evidenced at the age of 2 years. This implies that an increment in adult height has already been achieved by the age of 2 years. To identify factors relating to this trend, increased height gain during late infancy might be equivalent to a reduction in stunting. Stunting is thought to be caused by impaired growth of the long bones of the legs during later infancy. Leg growth may be regulated by the expression of growth-hormone receptors at the growth plates. As mentioned earlier, Harris et al.[2] found that severe stunting owing to malnutrition occurred early in life among Tibetan children (0-84 months old). Dang et al.[3] found that the prevalence of malnutrition of children below 36 months old, as indicated by stunting, was 39.0%. Rooze et al.[7] found that stunting and underweight were frequent for Tibetan children (0-5 years old), and were probably associated with rickets. Therefore, whereas Tibetan children and adolescents may display some improvement in their lagged heights during the short puberty period, because of the cumulative result of elementary stunting before the school-going age, their period of growth during puberty is naturally shortened. This results in a marginal contribution to adult height, whereas the mechanism that actually determines the entire height growth process during puberty is related to the adjustment mechanism created during the period of infancy[47]. We can, therefore, speculate that although the heights of different generations of Tibetan children and adolescents gradually approached the WHO reference values during the initial period of puberty, their heights during the later phase of puberty (nearly 18 years old) will still be lower than the WHO reference values Therefore, comprehensive enhancement of the health care levels for infants in the Tibetan Region is the key to eliminating stunting.

In China, two types of malnutrition screening standards are currently used: 1) the WHO (2007) 'Children Growth Standard'[48] and 2) the China GB/T School Sanitation Standard. The WHO standard mainly considers European and American children as the reference group. Thus, the point of height transition after puberty is evidently higher than the actual height of Chinese adolescents, as confirmed by the results of this study. This may result in a significant artificial increase in the stunting rate of adolescents aged 16-18 years[47]. The results of this study also indicate that the height and BMI values of Tibetan children during the early stage of puberty gradually approached the WHO reference values over time, but that they eventually lagged behind the WHO reference values during the later stage of adolescence. Therefore, we need further research to understand which evaluation criteria can be used to more effectively evaluate the prevalence of malnutrition among Tibetan children.

CONCLUSION

This study extracted cross-sectional data from national physical constitution surveys conducted in 1995, 2000, 2005, and 2010 from the perspective of historical development. Its aim in doing so was to analyze and discuss changes in the occurrence of malnutrition among children and adolescents aged 7-18 years old in Lhasa, Tibet. The following conclusions can be drawn from the study.

1) The rates of occurrence of stunting and wasting of Tibetan children and adolescents indicate a gradual declining trend over time. In general, rates of stunting and wasting of boys across each 5 year time span were higher than those of girls. Rates of stunting of both boys and girls during early puberty were significantly higher than those during late puberty.

2) The height and BMI values of Tibetan children during early puberty gradually approached the WHO reference values over time. However, they eventually lagged behind the WHO reference values during the later stage of adolescence.

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