Implication of the WHO growth standards on estimation of malnutrition in young Chinese children: Two examples from rural western China and Tibet region

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Abstract

The aim of this study was to determine how malnutrition rates change in young Chinese children when 2006 WHO growth standards are used instead of 1978 WHO/NCHS reference. Cross-sectional survey data were used from rural western China and the Tibet region. The heights and weights of children <36 months of age were measured. The nutritional status of the children was assessed by two references. Using 2006 reference instead of 1978 reference, the prevalence of stunting increased significantly (17.9% vs.12.3% in rural western China and 37.5% vs. 28.1% in rural Tibet). The prevalence of underweight was lower in rural western China (7.7% vs.11.7%) than rural Tibet (13.1% vs.15.3%). For all ages, the prevalence of stunting increased and the greatest relative increase appeared in the first 6 months (102.9% in rural western China vs. 134.9% in rural Tibet). With respect to underweight, the relative increase only occurred during the first 6 months (314.3% in rural western China vs. 48.1% in rural Tibet); however, the reduction was observed in other age groups. For young Chinese Han and Tibetan children, the difference in estimation of malnutrition between two references differed in magnitude. The scale of change in the prevalence rates of stunting and underweight is much greater when 2006 reference was introduced.

Introduction

Height and weight are important indicators reflecting child growth or nutritional status, and are also commonly used to predict performance, health, and survival. A child growth reference, based on data of a well-nourished child population, is required for assessment of nutritional status of children (WHO 1995; WHO Working Group on the Growth Reference Protocol, Task Force on Methods for the Natural Regulation of Fertility 2000). The original National Center for Health Statistics (NCHS) growth curves were formulated in 1975 and adopted by WHO as the international reference in 1978 (Hamill *et al*. 1979) (*referred to as 1978 reference hereafter*). A revision was carried out by CDC in 1990 to correct some of the irregularities (WHO Working Group on Infant Growth 1995; de Onis & Yip 1996; Dibley *et al.* 1987; Yip, Scanlon & Torwbridge 1993). In 2006, WHO generated new growth standards through the Multicentre Growth Reference Study (MGRS) (de Onis *et al*. 2004; WHO Multicentre Growth Reference Study Group 2006). The standards were developed with a pooled sample of approximately 8,500 children from six countries (Brazil, Ghana, India, Oman, Norway, and United States) (*referred to as 2006 reference hereafter*).

The NCHS reference has been adopted by many national programs for growth monitoring or nutrition intervention and has allowed international comparisons (de Onis, Wijnhoven & Onyango 2004). Introduction of a new growth reference may interfere with the comparisons; consequently a striking misclassification of the nutritional status of children might affect adoption of a new reference. To date, some studies have shown inconsistent results when using the two references in some child populations. Onyango *et al*. (2007) reported good agreement between the two references. de Onis *et al.* (2006;

2007) suggested that a significant difference existed in the estimation of the prevalence of malnutrition derived from different references, but new standards provided a better tool for monitoring the rapid and changing rate of growth in early infancy. Two studies found that the 2006 reference resulted in a higher prevalence of acute malnutrition which could affect nutritional programs (Prost *et al*. 2008; Seal & Kerac 2007) but another study indicated reduction of prevalence of wasting (Orellana *et al*. 2009). Studies from the United Kingdom and Hong Kong suggested that new standards would not be suitable for all child populations, especially for East-Asian children (Wright *et al*. 2008; Hui *et al*. 2008). Therefore, further assessment on the difference between the two references is required in different child populations. However, few comparisons between the two references have been conducted among young Chinese children. To make use of new standards more rationally, we investigated how malnutrition rates change in young Chinese children when the 2006 reference was used instead of the 1978 reference. In the current study, two child samples with different environmental and cultural backgrounds, one from rural western China and the other from rural Tibet, were used for investigating such changes.

Methods

Study setting and the samples

Western China consists of 12 provinces including the Tibet region. The area in western China accounts for 71.6% of China's land area, and > 70% of people live in rural areas. The Tibet region is located on the Qinghai-Tibet plateau, where 86% of the areas is at an altitude > 4000 m; the area is hypoxic and the climate is cold. The rural population account for 87% of the total population and > 95% of people belong to the Tibetan ethnic group (National Bureau of Statistics of China 2004; Liu 1988). Hence, Tibetan children live in a different environment compared with their Chinese Han counterparts living in other areas of western China. In the current study we present the results of rural Tibetan children and children from rural western China (not including rural Tibet) separately.

Data from two surveys were used in our analysis, which were conducted in rural western China and the rural Tibet region in 2005. The purpose of both surveys involved maternal and child healthcare and children < 36 months of age were investigated. The same stratified multistage random sampling method was adopted. In the sample from the rural western China survey, most of the children were of the Chinese Han ethnic group. The survey covered 45 counties, which were selected in terms of social and economic development. Sixteen households with children <36 months of age were selected randomly in each sample village of the sampled township. A sample of 14,000 children was estimated to detect a 20% malnutrition rate and 30% acceptable variability in each specific gender-age group, assuming $\alpha=0.05$ and $1-\beta=90\%$ and accounting for an expected 20% non-response rate.

In the sample from the rural Tibet survey, all children belonged to the Tibetan ethnic group. Fifteen counties were selected from four districts of Tibet, which were located at elevations from 3,000-5,000 m. Due to the small size of these counties, there were five townships randomly selected instead of villages in each county. Sixteen households with children < 36 months of age were selected randomly from each selected township. The sample size of 1300 was estimated assuming a malnutrition rate of 20%, an error of 10%, $\alpha=0.05$, and $1-\beta = 90\%$ and accounting for an expected 20% non-response rate.

Anthropometry and definition of malnutrition

Anthropometric measurements were obtained from the investigated children using standard measurement techniques. Body weight without shoes, but while wearing underwear, was measured using an electronic scale (Tanita HD-305, Tanita Corporation, Shanghai, China) with precision to the nearest 100 g. Body length without shoes was measured to the nearest millimeter using a portable measuring board with a fixed head piece (Model WB-II, Xi'an Teaching Instrument Company, Xi'an, China). Weight-for-age Z scores (WAZ), height-for-age Z scores (HAZ) and weight-for-height Z scores (WHZ) were derived from the observational data based on the 1978 and 2006 references. Underweight, stunting, and wasting were defined as WAZ, HAZ, and WHZ less than - 2, respectively (WHO 1995).

A face-to-face interview was conducted in households using a household questionnaire and anthropometric tools. Verbal informed consent was obtained from all of the children's mothers. The accurate age of each child was collected from the permanent residence registration and/or immunization records. When necessary, Chinese Han or Tibetan lunar calendar dates were converted to Gregorian calendar dates. The anthropometric measurements were collected by trained staff. This study was approved by the Ethical Committee of Xi'an Jiaotong University (China).

Data analysis

A database was established by duplicate entries using EpiData 3.02. Prior to data analysis, data cleaning and quality check were performed. Software of WHO Anthro (version 3.2.2;

WHO) was used for calculation of Z scores based on the 1978 and 2006 references. A flexible exclusion range was used to exclude the unreasonable anthropometric data (WHO 1995). The data analysis was adjusted for the stratified multistage cluster random sampling used in the surveys to ensure an appropriate width of the confidence intervals. In the adjustments, the county was regarded as a strata variable. The village for the western China survey was used as a cluster variable, while the township as a cluster variable for the Tibet survey. Weights were obtained based on the proportion of investigated households in the counties to overall households of the counties. Then, the weighted prevalence of malnutrition with 95% confidence intervals (CI) was calculated. McNemar test was used for comparison of prevalence rates from the two references. Distributions of Z scores from the two references were made for the description of the overall nutritional status. Comparison of Z-score means from the two references in the two surveys was carried out using a mixed model. In this model, gender, age, economic status, mother's education and altitudes were treated as co-variables, and survey, reference, and interaction between survey and reference were treated as fixed effects, whereas the subject was treated as a random effect. The estimated Z-score mean differences between the two references in the two surveys from the model were reported together with 95% CI. A two-sided P-value < 0.05 was considered statistically significant. Stata/SE (version 9.0; StataCorp) was used for all analyses.

Results

Characteristics of the two samples

For the sample from rural western China, anthropometric data was obtained from 13,371 children. Approximately 4.4% of data had flagged errors and excluded from the analyses. Data available for this study were 12,783 children and the weighted counts were 12,222. Among the children, 58% were boys and 96% were breast-fed. Of the children's families, 85% earned a living mainly by farming. Of the children's mothers, 61% had 6-9 years of schooling. For the sample from rural Tibetan, anthropometric data was gathered from 1455 children. Approximately 6.7% of the data had flagged errors and excluded from the analyses. Data available for this study were 1357 children and the weighted counts were 1344. Among them, 56% were boys and 61% had exclusive breastfeeding within 4 months after birth. Greater than one-half (54%) of the children's families earned a living by farming. Of the children's mothers, 58% had no schooling and only 14% had > 6 years of schooling. All Tibetan children surveyed lived at an altitude > 3,500 m.

Distributions of Z scores based on the two references

The distribution of Z scores was shifted to the left compared with the reference distribution, especially for the HAZ and WAZ, irrespective of which reference was used. However, the magnitude of the shift varied depending on the reference used, indicators, and child population. In rural western China, the distribution of the HAZ from the 2006 reference was shifted downward much more than the 1978 reference. The mean HAZ was -0.83 from the 2006 reference, which was significantly lower than -0.65 from the 1978 reference. The reverse situation existed for the WAZ. The mean WAZ was -0.49 from the 2006 reference significantly higher than -0.66 from the 1978 reference. With respect to WHZ, the magnitude of the shift was greater than for that of the HAZ and WAZ when using the 2006 reference (Figure 1 and Table 1).

In rural Tibet, the same shifting trend was observed as in rural western China. However, when the 2006 reference was used, the HAZ shifted more than the WAZ, but in an inverse direction. In comparison of rural Tibet with rural western China, the mean difference between the two references was statistically significant in the HAZ (-0.226 vs. -0.186) and the WAZ (0.145 vs. 0.158) ($P<0.05$) but similar to the WHZ (0.226 vs. 0.229; $P>0.05$) after controlling for potential factors (Figure 1 and Table 1).

General prevalence of malnutrition based on the two references

In rural western China, the prevalence of stunting increased from 12.3% using the 1978 reference to 17.9% using the 2006 reference, or a relative increase of 45.5%. The prevalence of underweight based on the 2006 reference was lower than the 1978 reference (7.7% vs. 11.7%). For the prevalence of wasting, a relative reduction of 14.8% was observed (Table 1).

In rural Tibet, the prevalence of stunting using the 2006 reference was higher compared with the 1978 reference and the relative increase was 33.5%, which was lower than rural western China. The prevalence of underweight decreased from 15.3% using the 2006 reference to 13.1% using the 1978 reference, or a relative reduction of 14.4%, which was less than rural western China. The prevalence of wasting was 3.4% for the 1978 reference and 2.6% for the 2006 reference. The relative reduction was 23.5% (Table 1).

Prevalence of malnutrition by age based on the two references

Table 2 shows the prevalence and variation by age derived from the two references. In rural western China, the prevalence of stunting from the 2006 reference was higher than the 1978 reference for all age groups. During the first 6 months, greatest relative increase in stunting occurred (102.9%), i.e., the prevalence assessed by the 2006 reference was about 1-fold greater than that derived from the 1978 reference. Another significant relative increase occurred after 24 months, ranging from 80.1-85%. With respect to underweight, during the first 6 months the prevalence derived from the 2006 reference was 3.14-fold greater that from the 1978 reference. The prevalence rates derived from the 2006 reference during the 2nd year after birth were reduced and relative reduction was between 47.4% and 43.1%. The variation for wasting by age was similar to the underweight. During the first 6 months the prevalence derived from the 2006 reference was 1.81-fold greater than that from the 1978 reference. Thereafter, the prevalence rates derived from the 2006 reference were lower than or similar to that derived from 1978 reference.

In rural Tibet, compared with the 1978 reference, the greatest increase (134.9%) for stunting occurred during the first 6 months when using the 2006 reference, which was slightly higher compared with rural western China. The prevalence of stunting was reduced in other age groups, but the magnitude of the reduction was less than rural western China. With respect to underweight, a relative increase of 48.1% during the first 6 months was observed, which was much lower than rural western China. From 6-30 months, the prevalence rates of underweight derived from the 2006 reference were reduced compared with the 1978 reference but the relative reductions were lower than western China. After 30 months there was a slight increase in the prevalence of underweight when using the 2006 reference. The variation in the prevalence of wasting assessed by the two references was similar to western China, except for the reduced prevalence of wasting during the first 6 months when using the 2006 reference.

Our sample might present specific changes in malnutrition rates using the 2006 reference instead of the 1978 reference. Compared with Bangladeshi children, our sample children had a higher increase in prevalence rates of stunting for each age group, especially during the first 6 months (102.9% in rural western China vs. 134.9% in rural Tibet vs. 56% in Bangladesh). The prevalence of wasting was complex, and different variations in the prevalence of wasting by age were observed in the three child populations (Table 2).

Discussion

In this study, we used two larger samples, one with a lower prevalence of malnutrition and the other with a relatively higher prevalence, to explore the impact of new WHO growth standards on the assessment of the nutritional status of young Chinese children. Both child populations were quite different based on culture and natural environment where they lived, and they might have specific growth patterns (Liu 1988; Harris *et al*. 2001; Dang, Yan & Yamamoto 2008). As expected, there was an important difference found between the 1978 and 2006 references in assessing the nutritional status of younger Chinese children. This difference varied by index population, growth indicator, and age group.

The current study showed that rural Chinese children tended to be smaller in height-for-age but greater in weight-for-age or weight-for-height when the 2006 reference was used. Stunting became an outstanding malnutrition of rural children in western China, which was consistent with other Chinese studies (Chen *et al*. 2011; Mak & Tan 2012). The prevalence of stunting and underweight was higher in our samples compared with overall rural China (16.3% for stunting and 6.1% for underweight). Specifically rural Tibetan children had a much higher prevalence of stunting because higher altitude may account for the reduction of height of Tibetan children (Dang, Yan & Yamamoto 2008). Childhood malnutrition may yield adverse outcomes in the adolescence. About 6-10% of Chinese adolescents remained underweight (Zhang & Wang 2011), which may partly due to maintenance of childhood underweight because 33% of underweight children in childhood were still underweight in their adolescence (Wang *et al.* 2000). Early childhood stunting also might be associated with disadvantages in late adolescence, including deficits in cognition, school achievement, and even psychological functioning (Walker *et al.* 2007). Thus, it is crucial to prevent early childhood malnutrition or the adverse effects will persist, even in such a country experiencing improvement in nutrition as China.

We found that an additional one-third of children could be classified as stunted, but 1/6-1/3 of children who was underweight could not be classified when using the 2006 reference, compared to the 1978 reference. This feature seemed more evident in the child population with a lower prevalence of malnutrition as rural western Chinese children (Prost *et al*. 2008; Duggan 2010; Prinja, Thakur & Bhatia 2009). On a population scale, using the 2006 reference could give the impression of an improvement in nutritional status of Chinese children if previous data are not reanalyzed, especially when underweight was used as an indicator. The results strongly suggested that a comparison of period monitoring data on nutritional status of Chinese children should be cautious because different references were possibly used.

The difference between the two references varied with age group. Irrespective of rural children of western China or rural Tibetan children, such a changing pattern with age was similar to that of Bangladeshi children, but the magnitude of change was quite different (de Onis *et al*. 2006). Although our study also showed that the greatest difference in malnutrition rates appeared during the first 6 months (de Onis *et al*. 2006; Prost et al. 2008; Prinja, Thakur & Bhatia 2009), the differences in our samples were much greater than those in Bangladesh children (de Onis *et al*. 2006) but less compared with Malawian children (Prost *et al*. 2008). Moreover, Tibetan children also presented a different changing pattern with age compared with children of western China. It suggested the impact of the 2006 reference on nutritional assessment varied markedly by index populations. Tibetan children are a unique population who live at high altitudes > 3,000 m and have a unique traditional culture (Liu 1988). Previous studies in Tibet have shown that high altitude might be an important and independent factor affecting the growth of Tibetan children and could take effect before birth (Dang, Yan & Yamamoto 2008; Yip 1987; Moore *et al*. 2001). Thus, Tibetan children might have their own growth pattern, which caused a different response to the two references. A comparative study also showed that using two references resulted in different prevalence of malnutrition for India, Peru and Vietnam (Fenn *et al*. 2008). The three countries have significant differences in population characteristics and environmental and social measures, which might bring about specific child growth patterns; such could also be true for China. A study among a Hong Kong Chinese birth cohort suggested that such growth standards would not be appropriate for Hong Kong Chinese children, or even the child population in East Asia (Hui et al. 2008). A similar situation also was observed in UK child cohort (Wright et al.

2008). A previous study conducted among breastfed children from seven countries found that growth patterns were “strikingly similar”, except for India and China (WHO Working Group on the Growth Reference Protocol, Task Force on Methods for the Natural Regulation of Fertility 2000); however, the MGRS did not include any infants from China (de Onis et al. 2004). Therefore, we suggest that Chinese children might have a specific growth pattern.

The prevalence of wasting was about 5%, suggesting that there are few children at risk of acute malnutrition in rural western China. However, the introduction of the 2006 reference could further reduce identification of wasted children in our samples. In addition to improvement of the food environment and child health, a possible reason that must be considered is that the 2006 reference tends to underestimate height-for-age and overestimate weight-for-age of rural children of China because our comparison between two references was based on the same child population. In view of population-based growth monitoring, using the 2006 reference could underestimate the level of acute malnutrition of Chinese children, especially in poor areas.

The other implication was that the introduction of the 2006 reference could bring about considerable differences in determination of malnutrition for rural Chinese children, which would probably affect the formulation of nutritional intervention strategies in rural China. Caution must be exercised when interpreting malnutrition rates derived from the international growth reference for Chinese children. Perhaps a local growth reference may be required.

The strength of this study was the application of random sampling and weighted analysis adjusting for possible bias from the stratified multistage cluster random sampling but some limitations have to be considered. The sample was from western China and could not be representative of the entire Chinese child population. A smaller sample size in younger age group, especially for Tibetan sample, may weaken the power of the study because the first 6 months is a key time in growth trajectory. Anthropometric methods were used in this study for estimating nutritional status of children at the population level. They cannot determine completely whether an individual was really malnourished so misclassification may arise. These methods may be inferior to a direct measurement of body density as body fat percentage or skinfold thickness but are much more convenient in population screening and some of them are correlated well with the body fat percentage (WHO 1995; Mak *et al.* 2013). Despite these limitations, we believe that the results are valuable because our study covered the key child growth phase (0-24 months) and few studies have been conducted for a comparison of the two references in assessment of malnutrition rates among young Chinese children.

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Conflicts of interest

The authors declared no conflicts of interest.

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Table 1 Mean Z scores and percentage of children under 3 years of age who were stunted (height-for-age <-2 Z) underweight (weight-for-age <-2 Z), wasted (weight-for-height <-2 Z) by two growth references in rural western China and rural Tibet region*

Indicator	Rural western China			Rural Tibet region		
	1978 Reference	2006 Reference	Difference	1978 Reference	2006 Reference	Difference
Height-for-age						
Mean	-0.65	-0.83	-0.186	-1.21	-1.59	-0.226†
95% CI	[-0.681, -0.627]	[-0.861, -0.801]	[-0.191,-0.182]	[-1.312, -1.106]	[-1.701, -1.484]	[-0.233,-0.219]
Stunting(%)	12.3	17.9		28.1	37.5	
95% CI	[11.50, 13.00]	[17.05, 18.78]		[25.10, 31.20]	[34.05, 41.03]	
Weight-for-age						
Mean	-0.66	-0.49	0.158	-0.85	-0.72	0.145†
95% CI	[-0.691, -0.637]	[-0.512, -0.462]	[0.152,0.163]	[-0.933, -0.775]	[-0.791, -0.651]	[0.137,0.151]
Underweight(%)	11.7	7.7		15.3	13.1	
95% CI	[11.00, 12.30]	[7.19, 8.31]		[13.30, 17.60]	[11.16, 15.27]	
Weight-for-height						
Mean	-0.29	-0.06	0.229	-0.07	0.21	0.226
95% CI	[-0.324, -0.265]	[-0.093, -0.033]	[0.223,0.235]	[-0.154, 0.009]	[0.120, 0.294]	[0.217,0.235]
Wasting(%)	5.4	4.6		3.4	2.6	
95% CI	[4.90, 5.90]	[4.15, 5.01]		[2.50, 4.50]	[1.75, 3.88]	

* Weighted counts: n=12222 for rural western China, n=1344 for rural Tibet region

† Z-score mean differences between two reference in rural Tibet region was different significantly from those in rural western China by a mixed model controlling for sex, age, economic status, mother's education and altitudes ($P<0.05$).

Table 2 Percentage of children under 3 years who were stunted (height-for-age <-2 Z), underweight (weight-for-age <-2 Z), wasted (weight-for-height <-2 Z) by two growth references by age in rural western China and rural Tibet region

Age in months	Rural western China				Rural Tibet region				Difference from Bangladesh % §
	n	1978 Reference	2006 Reference	Difference (%)	n	1978 Reference	2006 Reference	Difference (%)	
Stunting									
0-5	1612	3.4	6.9	3.5(+102.9)*	157	10.9	25.6	14.7(+134.9)*	+56.0
6-11	2700	8.7	11.0	2.3(+26.4)*	270	23.9	28.3	4.4(+18.4)*	+16.7
12-17	2312	14.4	17.7	3.3(+22.9)*	262	41.5	47.4	5.9(+14.2)*	+5.0†
18-23	2230	18.5	23.3	4.8(+25.9)*	229	32.7	41.3	8.6(+26.3)*	
24-29	1615	13.6	24.5	10.9(+80.1)*	236	25.8	38.9	13.1(+50.8)*	+16.7‡
30-35	1753	14.0	25.9	11.9(+85.0)*	190	26.8	40.1	13.3(+49.6)*	
Underweight									
0-5	1612	0.7	2.9	2.2(+314.3)*	157	2.7	4.0	1.3(+48.1)*	+135.3
6-11	2700	8.2	6.8	-1.4(-17.1)*	270	9.2	8.9	-0.3(-3.3)	-6.1
12-17	2312	15.6	8.2	-7.4(-47.4)*	262	23.3	14.5	-8.8(-37.8)*	-17.2†
18-23	2230	13.7	7.8	-5.9(-43.1)*	229	18.0	13.6	-4.4(-24.4)*	
24-29	1615	17.4	10.8	-6.6(-37.9)*	236	19.6	17.7	-1.9(-9.7)*	-14.5‡
30-35	1753	14.0	10.2	-3.8(-27.1)*	190	15.4	18.2	2.8(+18.2)	
Wasting									
0-5	1612	1.6	4.5	2.9(+181.3)*	157	2.1	1.0	-1.1(-52.4)*	+155.5
6-11	2700	4.2	4.7	0.5(+11.9)*	270	2.1	3.3	1.2(+57.1)*	+41.7
12-17	2312	9.1	5.9	-3.2(-35.2)*	262	5.6	3.0	-2.6(-46.4)*	-6.5†
18-23	2230	7.2	3.5	-3.7(-51.4)*	229	3.9	2.0	-1.9(-48.7)*	
24-29	1615	4.8	4.4	-0.4(-8.3)	236	3.3	3.2	-0.1(-3.0)	+13.3‡
30-35	1753	4.1	4.1	0(0)	190	2.5	2.4	-0.1(-4.0)	

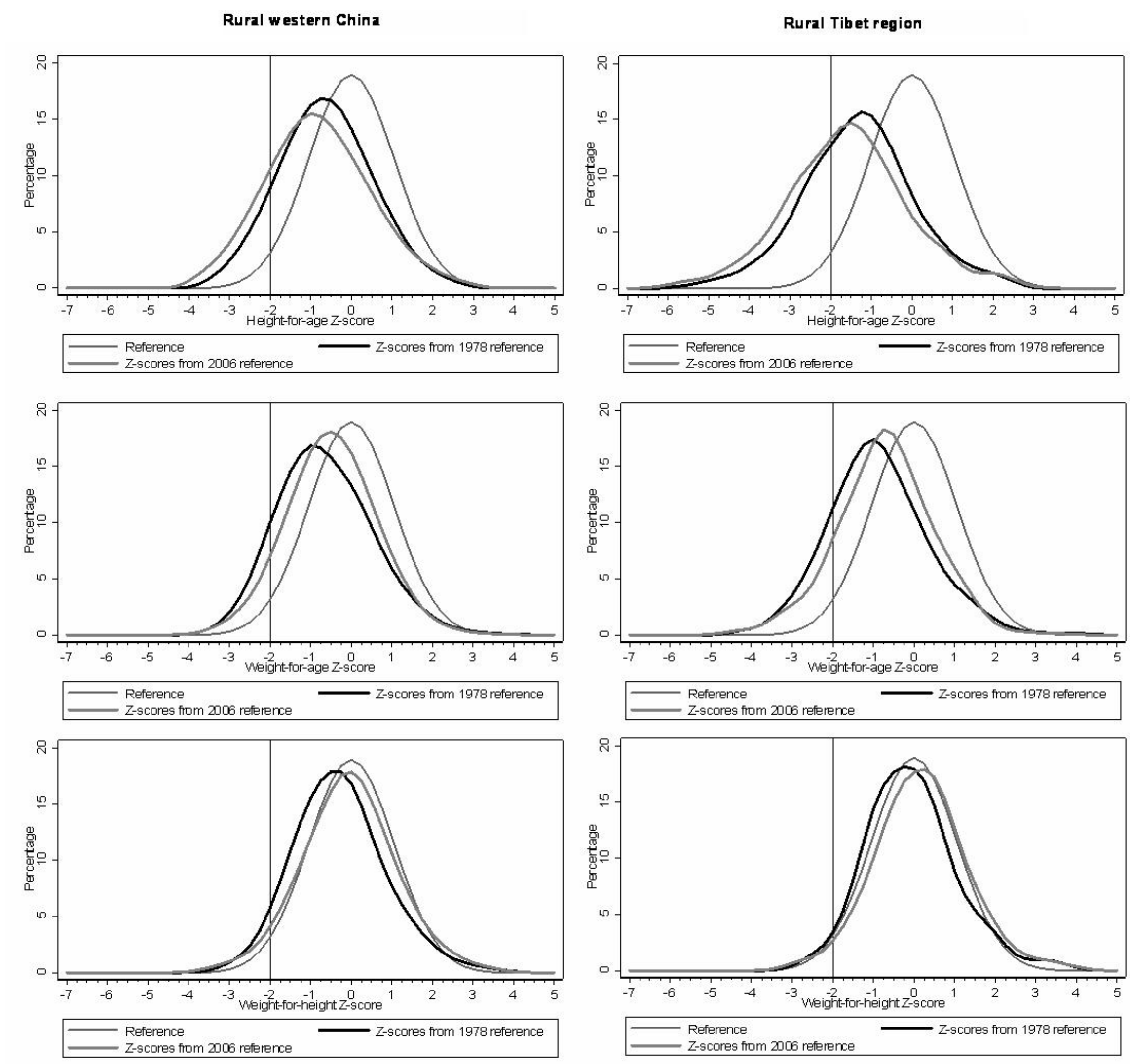

Figure 1 Distribution of Z scores from two growth references in rural western China and rural Tibet region (Reference here refers to standard distribution of Z score)