HIGH ANEMIA PREVALENCE IN WESTERN CHINA

Renfu Luo[1], Xiaobing Wang[1], Linxiu Zhang[1], Chengfang Liu[1], Yaojiang Shi[2], Grant Miller[3], Scott Rozelle[3], Elaine Yu[4] and Reynaldo Martorell[4]

[1]Center for Chinese Agricultural Policy (CCAP), Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS);
[2]School of Economic Management, Northwest University of Xi'an, PR China;
[3]Freeman Spogli Institute for International Studies, Stanford University;
[4]Rollins School of Public Health, Emory University, USA

Abstract. We assessed the prevalence of anemia among schoolchildren in western China as determined by seven cross-sectional surveys involving 12,768 children aged 8-12 years. Subjects were selected randomly from 283 primary schools in 41 economically disadvantaged counties of Ningxia, Qinghai, Shaanxi and Sichuan Provinces. Data were collected through questionnaires and hemoglobin levels were measured. The anemia prevalence was 34% using the WHO hemoglobin cutoff of <120 g/l. Boarding students and girls were more likely to be anemic. The prevalence of anemia in schoolchildren was high. Iron deficiency is a significant nutrition issue in China.

Keywords: anemia, primary school students, rural China

INTRODUCTION

Iron deficiency anemia is the most common nutritional deficiency worldwide. This condition affects approximately a quarter of the global population, mostly in developing countries (Yip, 2001; de Benoist *et al*, 2008). Vital aspects of human health are affected adversely by anemia, including physical activity, temperature regulation, behavior and immune function (Dallman, 1986; de Benoist *et al*, 2008). Numerous studies have linked iron deficiency and anemia with cognitive impairment and altered brain function (Scrimshaw, 1990; Yip, 2001). Anemia can impair concentration, leading to poor learning. Literature over the past three decades links iron deficiency (particularly during early childhood) with poor cognitive performance and motor/psychomotor development (Walter *et al*, 1989; Grantham-McGregor and Ani, 2001; Iannotti *et al*, 2006). Childhood anemia is known to impair academic achievement, including grades, attendance and attainment (Halterman *et al*, 2001; Stoltzfus, 2001; Stoltzfus *et al*, 2001; Bobonis *et al*, 2006). Recognizing and treating anemia are important since the effects of anemia on development and behavior can last into adulthood (Lozoff *et al*, 2000; Algarin *et al*, 2003; Lozoff and Georgieff, 2006; Lozoff *et al*, 2006), hindering economic and social mobility (Bobonis *et al*, 2006).

Despite the unprecedented economic growth of China over the past few decades, the prevalence of anemia may

Correspondence: Reynaldo Martorell, Hubert Department of Global Health, Rollins School of Public Health, Emory University; 1599 Clifton Road, NE, Room 6.407; Atlanta, GA 30322, USA.
Tel: +404 727 9854; Fax: +404 727 9745
E-mail: rmart77@emory.edu

remain high in poor regions. According to the World Health Organization's "Global Database on Anemia" and other international studies the prevalence of anemia generally decreases as income increases (Gwatkin *et al*, 2007; de Benoist *et al*, 2008). In China, a number of indicators suggest many individuals, especially children, are not performing as well as expected. Literacy rates of rural students fall far short of their urban counterparts (World Bank, 2001; Zhang and Kanbur, 2005) and gaps in educational attainment across China further support this conjecture (Knight and Shi, 1996). Although China has made strides in nutrition and health in the cities, stunting and underweight in poor rural areas remain a significant public health problem (World Bank, 2001; Zhuo *et al*, 2009).

Anemia is likely the result of poor diet, particularly in schools in poor rural areas, such as Shaanxi Province, where many students eat predominantly starch-based diets with minimal meat, vegetables and fruits (FAO, 1999; Kim *et al*, 2003; Luo *et al*, 2009). While some data are available from local Centers for Disease Control and Health Bureaus in China showing a high prevalence of iron deficiency (Chen *et al*, 2005; Li, 2009), the methods by which they obtained these data are unclear. There are few studies of the prevalence of anemia and iron deficiency among school-aged children, especially in poor rural areas. We found no studies from China during the past 10 years on the extent of anemia in China's schools. The main objective of this study was to assess the prevalence of anemia in school-aged children from China's poor, rural areas. We also attempted to determine if certain types of students had characteristics more likely to be associated with anemia. The results of this study are based on seven surveys of 12,768 third to fifth grade students, mostly aged 8 to 12 years, from 283 randomly chosen elementary schools in 41 of the poorest counties in Ningxia, Qinghai, Shaanxi, and Sichuan Provinces, located in China's poor western region. The same research team conducted all seven surveys with identical sampling (schools and students) and measurement approaches (testing for anemia, collecting information about structural correlates). These data can be considered representative of western China's poor areas and can be used to understand the nutritional status of more than 7 million children (ages 8 to 12 years). This study aims to assist in policy formulation to address large-scale nutritional deficiencies and overcome large health disparities between China's urban and rural areas.

MATERIALS AND METHODS

Definition of anemia

Normal hemoglobin (Hb) values vary by a number of factors, including age and altitude. The age range of our sample population results in some uncertainty about which Hb cutoff to use to report anemia. Since we focused on third to fifth graders, most students were between eight and twelve years old. The WHO recommends a cutoff of 115 g/l for children aged 5-11 years and 120 g/l for children aged 12-14 years (United Nations Children's Fund, World Health Organization, United Nations University, 2001). Although the WHO standards are widely used to define anemia, some studies have defined anemia levels using different hemoglobin cutoffs. For these reasons we set anemia cutoff levels at: 1) 120 g/l for ages 8-12 years (Table 3); and 2) 115 g/l for children under 12 years and 120 g/l for children 12 years and over (Table 4).

Given that borderline Hb levels and iron deficiency without anemia have also been shown to affect cognitive performance, we emphasized the use of 120 g/l as the cutoff point for anemia in the majority of the analyses (Halterman *et al*, 2001).

In order to compare the prevalence of anemia among populations living at varying elevations, the hemoglobin levels of populations at high altitudes must be adjusted downward using accepted algorithms (Hurtado and Merino, 1945; Nestel, 2002).

Many students in our population sample attend schools at altitudes well above 1,000 meters. For example, Qinghai students attend schools at a mean altitude of 2,344 meters above sea level. Thus, we adjusted hemoglobin levels for any altitude above 1,000 meters using a curvilinear equation (below) developed by the Centers for Disease Control and Prevention (CDC), Pediatric Nutrition Surveillance System (Nestel, 2002).

$Hb_{adjustment}$ = –0.32 (altitude in meters–0.0033) + 0.22 (altitude in meters–0.0033)^2

Data

Student and school data were collected from third, fourth and fifth grade elementary school students from 41 poor counties (defined below) in four provinces, Ningxia, Qinghai, Shaanxi and Sichuan, between October 2008 and April 2010. Conducting the study in four western Chinese provinces allowed us to identify anemia prevalence across broad regions of the rural west. Over 737 million people live in rural regions of China, accounting for 56% of the population (National Bureau of Statistics of China, 2008). Even if we only consider the rural populations of the poor counties in our four sample provinces, the results in this paper are relevant for nearly 38 million school aged children.

The four studied provinces are among the poorest in China based on per capita income. In Ningxia, the average per capita income was RMB 3,180 (RMB 7.62 = USD 1), 23% below the mean national income. Qinghai's average per capita income (RMB 2,683) was even lower, 35% below the mean national income. Shaanxi's per capita income was RMB 3,546, 14% below the mean national income. The lowest among our sampled provinces was Sichuan, with an average per capita income of RMB 2,644, 36% below the mean national income (National Bureau of Statistics of China, 2008).

In choosing our sample sites, we followed a uniform selection procedure. First, we obtained a list of all poor counties in each study region. In China a "poor county" is a designation given by the National Statistics Bureau as a way of identifying counties that contain significant concentrations of people that live under the poverty line. There are 592 poor counties in China, making up about one third of the total counties, in which live 20% of the population. There are 109 poor counties in the four studied provinces. From these poor counties we took a random sample of 41 counties.

Inside each sampled poor county, the survey team obtained a list of all townships and for each township we obtained a list of all *wanxiao* (rural elementary schools with six full grades, grades 1-6). Sampled schools had over 400 students and at least 50 boarding students. With the implementation of school merger programs in rural China, more and more *jiaoxuedian* (small branch schools that still offer teaching services to younger first or second grade students in remote villages)

Table 1
Description of sample population.

	Sample province	Number of sampled counties	Per capita income of sample area (PPP-adjusted, in USD)[a]	Number of sampled schools	Number of sampled students	Survey date
Dataset 1	Shaanxi	9	683.48	70	4,151	October 2008
Dataset 2	Shaanxi	8	660.20	24	1,476	June 2009
Dataset 3	Shaanxi	10	769.14	66	2,066	October 2009
Dataset 4	Qinghai	5	813.91	37	1,474	October 2009
Dataset 5	Ningxia	5	794.21	37	2,658	October 2009
Dataset 6	Sichuan	3	1,085.81	21	516	April 2010
Dataset 7	Shaanxi	1	579.02	28	427	April 2010
Total/ Avg	-	41	769.44	283	12,768	-

Data sources: Authors' surveys.
[a] All values are reported in US dollars in real purchase power parity (PPP) terms by dividing all figures that were initially reported in yuan (Chinese currency) by the official exchange rate (7.62 yuan = USD 1 in 2007) and multiplying by the PPP multiplier (1:2.27543) (International Monetary Fund, 2007; World Bank,2009).

are disappearing. Across rural areas, jiaoxuedian students are moving to dormitories at wanxiao. Many townships now have only one or two primary schools. Since boarding schools are becoming the main providers of educational services in rural China, we specifically used the criteria of including only wanxiao and schools with at least a certain number of total students in addition to the boarding students in this study. The students in our sampling cohort accounted for most of the grade three, four and five students in the study areas. In total, 368 schools met our criteria; we randomly chose 283 schools for inclusion in our study. The location, size, date and other information about the surveys are summarized and grouped by province and study year in Table 1.

Data were collected by eight enumerator teams. In each team one person collected data regarding the school from the principal, third, fourth and fifth grade homeroom teachers, and others collected individual and household socioeconomic information obtained from students. Trained nurses from the Xi'an Jiaotong University School of Medicine measured hemoglobin levels on-site using a Hemocue Hb 201+ system. The age of each student was obtained from the birth records in each student's matriculation folder, which is considered an accurate source. The teams used surveys to collect simple socioeconomic information about each student, including gender, residence (home or boarding school) and their parents' levels of education, residence, and occupation. We examined the relationship between these variables and anemia.

Approval to perform the study was obtained from the "Administrative Panel on Human Subjects in Medical Research" of Stanford University.

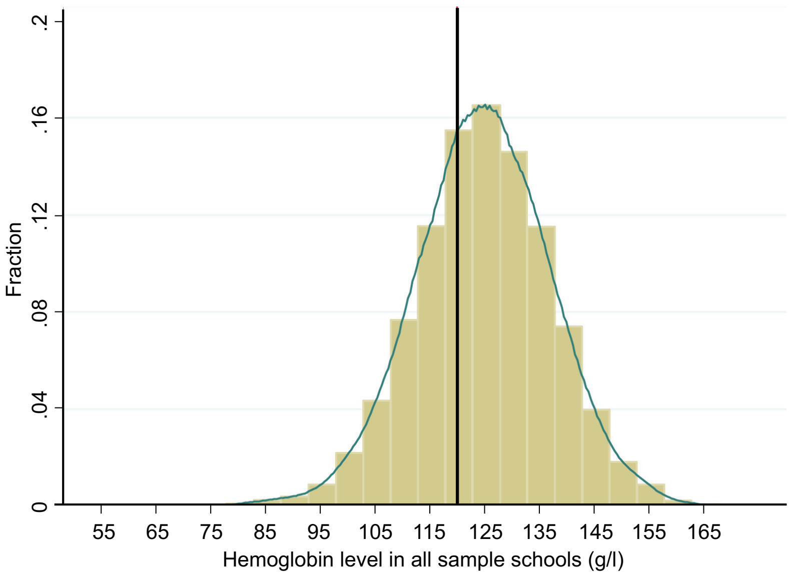

Fig 1–Hemoglobin distribution in total sampled population.

Using multiple regression of county dummies for anemia levels, the *p*-value for the test (an *F*-test of the joint significance of the dummies) showed a significant difference by county ($p < 0.001$) within province.

Beyond variation by province and county, we also observed significant variation by school. The prevalence of anemia varied widely by school. More than 90% of 165 students from the four sampled schools in Qinghai Province were anemic and 10% of 203 students from the four sampled schools in Ningxia Province were anemic. The differences in anemia prevalence among the different schools was statistically significant.

According to the WHO, anemia is considered a serious public health problem in populations when the anemia prevalence in greater than 5% (United Nations Children's Fund, World Health Organization, United Nations University, 2001). Of the 283 schools we sampled only 4 had an anemia prevalence less than 5%. Although there was significant variation across the samples, all 41 counties contained schools with anemia levels above this cutoff.

RESULTS

Anemia in Qinghai, Ningxia, Shaanxi, and Sichuan

Of all the schools surveyed (41 counties), we found the overall mean hemoglobin was 124.6 g/l. Hemoglobin levels were normally distributed across all seven datasets, with a standard deviation of 12.5 (Table 2). In our sample, 4,303 of the 12,768 students surveyed had hemoglobin levels lower than 120 g/l, resulting in a population anemia prevalence of 34% (Table 2). The proportion of students with hemoglobin levels between 115 g/l and 120 g/l was high (Fig 1). If we used an anemia cutoff of 115 g/l for children less than 12 years old and 120 g/l for those 12 and older, the anemia prevalence would be lower but still significantly high at 21% (Table 4).

There was considerable variation in anemia prevalence (<120 g/l) across the sample, ranging from 25.4% in Ningxia (Dataset 5) to 51.1% in Qinghai (Dataset 4).

Structural correlations with anemia

We did not find a significant difference in anemia rates between children older than 12 years and children younger than 12 years when using the 120 g/l cutoff (Table 2). However, using the two cutoff points for anemia in children of this age, as recommended by the WHO, resulted

Table 2
Hemoglobin levels and anemia (Hb < 120 g/l) prevalence of sample students.

	Below12 years old	Above 12 years old	Total
Hemoglobin (g/l)			
Total[a]	124.5 (12.3)	125.4 (14.3)	124.6 (12.5)
Shaanxi-2008 (Dataset 1)	122.8	124.6	122.9
Shaanxi-2009a (Dataset 2)	124.7	125.1	124.8
Shaanxi-2009b (Dataset 3)	126.7	131.0	126.9
Qinghai-2009 (Dataset 4)	119.2	118.0	118.9
Ningxia-2009 (Dataset 5)	128.2	131.7	128.7
Sichuan-2010 (Dataset 6)	126.1	N.A.	126.1
Shaanxi-2010 (Dataset 7)	125.2	124.6	125.2
Anemia (%)			
Total	33.8	33.2	33.7
Shaanxi-2008 (Dataset 1)	37.7	33.0	37.5
Shaanxi-2009a (Dataset 2)	31.6	31.3	31.6
Shaanxi-2009b (Dataset 3)	26.8	15.5	26.2
Qinghai-2009 (Dataset 4)	50.3	53.1	51.1
Ningxia-2009 (Dataset 5)	26.3	19.8	25.4
Sichuan-2010 (Dataset 6)	24.8	N.A.	24.8
Shaanxi-2010 (Dataset 7)	33.2	32.1	33.1

Data source: Authors' survey
[a]The numbers in parentheses indicate the standard deviation of hemoglobin count distribution.
NA, not available

Table 3
Structural correlates of anemia (Hb < 120 g/l).

	Percent anemic	Percent of sample
Gender		
Male	32.4	54.1
Female	35.3	45.9
	-2.9[a]	
Maternal education		
Primary school or below	34.2	61.2
Junior high or above	32.9	38.8
	1.3	
Left behind		
Mother lives with child	33.1	82.5
Mother does not live with child	34.3	17.5
	1.2	
Boarding status		
Lives at home	32.5	60.7
Lives at school	35.6	39.3
	3.1[a]	

Data source: Authors' survey
[a] Significance at 1%

Table 4
Hemoglobin levels and anemia (Hb < 115 g/l for children <12 years; Hb < 120 g/l for children ≥12 years) rates for sampled students.

	Below 12 years old	Above 12 years old	Total
Anemia (%)			
Total	19.5	31.8	20.7
Shaanxi-2008 (Dataset 1)	22.0	33.0	22.5
Shaanxi-2009a (Dataset 2)	18.0	31.3	19.2
Shaanxi-2009b (Dataset 3)	14.3	15.5	14.3
Qinghai-2009 (Dataset 4)	34.9	50.8	38.7
Ningxia-2009 (Dataset 5)	13.4	17.9	14.1
Sichuan-2010 (Dataset 6)	14.5	N.A.	14.5
Shaanxi-2010 (Dataset 7)	18.6	32.1	19.5

Data source: Authors' survey

in a significant difference in anemia: 19.5% in children younger than 12 years and 31.8% in children 12 years and older (Table 4). Females were significantly more likely than males to be anemic (Table 3). Maternal education was not associated with anemia (Table 3). Since it is common in many rural areas in China for one or both parents to migrate to the city to find better employment opportunities, we investigated a possible association between anemia and whether the child's mother lives at home or not. The maternal place of residence was not associated with anemia. However, students who lived in school dormitories were significantly more likely to be anemic than students who lived at home (Table 3).

DISCUSSION

We found the prevalence of anemia was high among elementary schoolchildren in all sampled poor counties of the four study provinces, Ningxia, Qinghai, Shaanxi, and Sichuan. Since the four studied provinces are similar to other poor provinces in western China, we believe these results may be applied to other poor counties in western China. The overall anemia prevalence was 34% using a blood hemoglobin cutoff of 120 g/l. Using this cutoff level, we estimate an additional 30-50% of students were iron deficient but not anemic (United Nations Children's Fund, World Health Organization, United Nations University, 2001). We did not study students in grades three, four and five from smaller schools that did not meet our sampling criteria; therefore, it is likely those students were even poorer than the students in our sampled schools. Since anemia is correlated with poverty, the results of our study may be considered the lower bound on the estimate of prevalence.

The use of a single cutoff of 120 g/l for the entire sample of children 8 to 12 years was justified in our analysis. Hemoglobin levels for children younger than 12 years were 124.5 g/l, nearly the same as for children 12 years and older of 125.4 g/l (pooled SD = 12.5 g/l; Table 2). This suggests iron status was similar in these two age groups; when using the single cutoff of 120 g/l, the anemia prevalence was similar for the two groups (33.8% and 33.2% for younger and older children, respectively). Applying the recommended age-specific cutoff points of 115 g/l for the younger group and 120 g/l for the older group resulted in different anemia prevalence figures: 19.5% for students younger than 12 years and 31.8% for students older than 12 years. This difference reflects the use of two cutoff points over this narrow age range. We could have used a cutoff point of 115 g/l for all children sampled, which would have resulted in a total prevalence of 20%. The conclusions and implications of the findings would remain the same: the prevalence of anemia is high.

Applying our results using a cutoff hemoglobin level of 120 g/l for all poor counties in all eight poor provinces of western China (our four studied provinces plus Yunnan, Guizhou, Gansu and Xinjiang) we estimate nearly 2.5 million 8 to 12 year old schoolchildren in these areas are anemic. This number is estimated from China's national census data to approximate the number of children aged 8 to 12 years from rural areas of poor counties in the eight western provinces and multiplying by 34%.

Our findings show anemia should be a concern for education officials who have a mandate to keep students healthy. It should be pointed out these studies only measured hemoglobin. Had we extended our analysis to other nutrients, we could have found other deficiencies, such as in zinc, vitamin A and vitamin C. School principals are the legal guardians of students while they are in school. During an earlier survey, over 90% of principals stated anemia and other micro-nutrient deficiencies were not a problem among their students (but they had no way of knowing the true levels of iron deficiency), or they did not know what iron deficiency was (Luo *et al*, 2010). This is especially concerning since boarding school students were more likely to be anemic. These findings support the results of our previous study which found boarding schools in rural Shaanxi Province are ill equipped to deliver sufficient nutritional content in school lunches to their students (Luo *et al*, 2009).

An important aspect of our data is that unlike certain impoverished populations of children in India and the African continent, we did not observe many cases of severe anemia characterized by hemoglobin levels less than 70 g/l (United Nations Children's Fund, World Health Organization; United Nations University, 2001). There were only four students in our sample that met this criterion.

Although we were unable to study the etiology of anemia, the main point of these results is that anemia remains a serious public health problem among children in rural western China, undermining their potential. Studies of anemia in China's large cities (*eg*, Shanghai) show anemia prevalence rates below 5%, suggesting a large disparity in health outcomes within China despite the nation's rapid growth (Shi *et al*, 2005). Our findings should alert national health officials to take action by conducing further research and to develop concrete measures to prevent anemia in vulnerable populations.

ACKNOWLEDGEMENTS

We thank the Stanford Presidential Fund for Innovation in International Studies (PFIIS), the Stanford Asia Health Initiative, the China Data Center at Tsinghua University, the International Initiative for Impact Evaluation (3ie), the National

Natural Science Foundation of China (71033003), the Institute of Geographic Sciences and Natural Resources Research (200905007), Pfizer, the Stanford Center for International Development (SCID), the LICOS Centre for Institutions and Economic Performance, the Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO), Eric Hemel, and Bowei Lee for their support. We also acknowledge the work of Michelle Lee, Wang Weiqing, Yingdan Chen (Center for Disease Control, China), and Qiran Zhao.

REFERENCES

Algarin C, Peirano P, Garrido M, Pizarro F, Lozoff B. Iron deficiency anemia in infancy: long-lasting effects on auditory and visual system functioning. *Pediatr Res* 2003; 53: 217-23.

Bobonis G, Miguel E, Puri-Sharma C. Anemia and school participation. *J Hum Resources* 2006; 41: 692-721.

Chen J, Zhao X, Zhang X, *et al*. Studies on the effectiveness of NaFeEDTA-fortified soy sauce in controlling iron deficiency: a population-based intervention trial. *Food Nutr Bull* 2005; 26: 177-86.

Dallman PR. Biochemical basis for the manifestations of iron deficiency. *Annu Rev Nutr* 1986; 6: 13-40.

de Benoist B, McLean E, Egli I, Cogswell M. Global prevalence of anemia 1993-2005: WHO global database on anemia. Geneva: World Health Organization Press, 2008.

Food and Agriculture Organization of the United Nations (FAO). Nutrition country frofiles (China). Rome: FAO, 1999. [Cited 2011 Feb 17]. Available from: URL: http://www.fao.org/ag/agn/nutrition/chn_en.stm

Grantham-McGregor S, Ani C. Iron-deficiency anemia: reexamining the nature and magnitude of the public health problem. *J Nutr* 2001; 131: 649-68.

Gwatkin D, Rutstein S, Johnson K, Suliman E, Wagstaff A, Amouzou A. Socio-economic differences in health, nutrition, and population within developing countries. Washington, DC: World Bank, 2007.

Halterman J, Kaczorowski J, Aligne C, Auinger P, Szilagyi P. Iron deficiency and cognitive achievement among school-aged children and adolescents in the United States. *Pediatrics* 2001; 107: 1381-6.

Hurtado A, Merino C. Influence of anoxemia on the hemopoietic activity. *Arch Intern Med* 1945; 75: 284-323.

Iannotti LL, Tielsch JM, Black MM, Black RE. Iron supplementation in early childhood: health benefits and risks. *Am J Clin Nutr* 2006; 84: 1261-76.

International Monetary Fund (IMF). Exchange rate archives. Washington DC: IMF, 2007. [Cited 2011 Feb 17]. Available from: URL: http://www.imf.org/external/np/fin/data/rms_mth.aspx?SelectDate=2007-06-30&reportType=REP

Kim S, Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. *J Nutr* 2003; 133: 3476-84.

Knight J, Shi L. Educational attainment and the urban-rural divide in China. *Oxford Bull Eco Stat* 1996; 58: 83-117.

Li Y. Iron deficiency and its impact on academic achievement. *Chin Agric Econ Rev* 2009; 1: 245-59.

Lozoff B, Georgieff MK. Iron deficiency and brain development. *Semin Pediatr Neurol* 2006; 13: 158-65.

Lozoff B, Jimenez E, Smith JB. Double burden of iron deficiency in infancy and low socioeconomic status: a longitudinal analysis of cognitive test scores. *Arch. Pediatr Adolesc Med* 2006; 160: 1108-13.

Lozoff B, Jimenez E, Hagen J, Mollen E, Wolf A. Poorer behavioral and developmental outcome more than 10 years after treatment for iron deficiency in infancy. *Pediatrics* 2000; 105: e51.

Luo R, Shi Y, Zhang L, Liu C, Rozelle S, Sharbono B. Malnutrition in China's rural boarding schools: the case of primary schools in Shaanxi Province. *Asia Pac J Educ* 2009; 29: 481-501.

Luo R, Kleiman-Weiner M, Rozelle S, *et al*. Anemia in rural China's elementary schools: prevalence and correlates in Shaanxi Province's poor counties. *Ecol Food Nutr* 2010; 49: 357-72.

National Bureau of Statistics of China. China statistical yearbook. Beijing: China Statistics Press, 2008.

Nestel P. Adjusting hemoglobin values in program surveys. Washington, DC: International Nutritional Anemia Consultative Group, ILSI Human Nutrition Institute, 2002: 2-4.

Scrimshaw NS. Functional significance of iron deficiency: an overview. In: Enwonwu CO, ed. Annual Nutrition Workshop Series, Vol. III. Functional significance of iron deficiency. Nashville, TN: Meharry Medical College, 1990: 1-13.

Shi A, Liu H, Zou S, Jiang P, Song J. Anemia survey of elementary and middle school students and women in Shanghai. *Shanghai J Prev Med* 2005; 17: 229-9 (in Chinese).

Stoltzfus R. Defining iron-deficiency anemia in public health terms: a time for reflection. *J Nutr* 2001; 131: 565-7.

Stoltzfus R, Kvalsvig J, Chwaya H, *et al*. Effects of iron supplementation and anthelmintic treatment on motor and language development of preschool children in Zanzibar: double blind, placebo controlled study. *Br Med J* 2001; 323: 1389.

United Nations Children's Fund, World Health Organization, United Nations University. Iron deficiency anemia: assessment, prevention, and control. A guide for programme managers. Geneva: World Health Organization, 2001.

Walter T, De Andraca I, Chadud P, Perales CG. Iron deficiency anemia: adverse effects on infant psychomotor development. *Pediatrics* 1989; 84: 7-17.

World Bank. China: Overcoming rural poverty. Report no. 21105-CHA. Washington, DC: World Bank, 2001.

World Bank. World development report 2009: reshaping economic geography. Washington DC: World Bank, 2009.

Yip R. Iron deficiency and anemia. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries, New York: Humana Press, 2001: 327-42.

Zhang X, Kanbur R. Spatial inequality in education and health care in China. *China Econ Rev* 2005; 16: 189-204.

Zhuo Q, Wang Z, Piao J, *et al*. Geographic variation in the prevalence of overweight and economic status in Chinese adults. *Br J Nutr* 2009; 102: 413-8.