Anemia and associated factors among adolescent girls and boys at 10-14 years in rural western China

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Abstract

Background: Evidence on the anemia and associated factors among young adolescent girls and boys in rural western China is limited.

Methods: We used data from a follow-up study of adolescents (10-14 years) born to women who participated in a randomized trial of antenatal micronutrient supplementation in western China. Anemia was defined by World Health Organization standards. Logistic regression was used to examine the associated factors with anemia.

Results: The overall prevalence of anemia was 11.7% (178/1517). Female adolescents were 1.73 (95% CI 1.21, 2.48) times more likely to have anemia as compared to males. Adolescents whose mothers had completed high school were 65% (95% CI 7%, 87%) less likely to be anemic, compared with those of whom had <3 years. Household wealth was also inversely associated with anemia. The association of puberty status with anemia was modified by adolescent sex (p-value for interaction was 0.04): males with greater than mild puberty development had 65% (95% CI 17%, 85%) reduced odds of anemia while there was no association among females (OR: 0.72, 95% CI 0.29, 1.78). Consumption of flesh foods, eggs, and having a meal frequency of three times or more per day were associated with 42% (95% CI 11%, 62%), 40% (95% CI 7%, 62%) and 32% (95% CI 4%, 52%) reduced odds of anemia, respectively.

Conclusions: Anemia is a mild public health problem among young adolescents in rural western China. Nutritional and social determinants were identified as predictors, warranting interventions to reduce the risk of anemia among this critical age group.

Background

Adolescence is a critical period of growth, reproductive maturation, and developmental transitions which requires increased nutritional intake and makes individuals more vulnerable to nutritional deficiencies [1]. Nearly 90% of adolescents live in low- and middle-income countries (LMICs) where malnutrition is a major public health problem [2], including anemia. Anemia in adolescence may cause a wide range of functional consequences across the life course, including reduced resistance to infection, impaired physical performance and neurodevelopment, and suboptimal schooling outcomes such as school years, concentration/learning and achievements [3, 4].

Globally, many previous studies investigated the prevalence of anemia and its associated factors among adolescent girls [5], but the corresponding prevalence differed by countries or regions, ranging from 5.3% in developed settings to over 50.0% in LMICs [6, 7]. These results suggest that country-specific data is required for anemia-prevention strategies and programs. Further, limited evidence shows that anemia is also prevalent in boys. One study from India reported that the prevalence of anemia in boys was as high as in girls namely 50.0% and 56.5%, respectively [8], suggesting that both adolescent boys and girls are susceptible to anemia. In addition, although it may be reasonable to assume that developmental stages

of puberty are significantly associated with anemia, studies reported differential associations between puberty development and adolescent anemia among boys and girls [9].

Some studies reported that factors associated with anemia among adolescents were different from those in other populations and ages [10, 11]. Additionally, most of growth gained during adolescence occurs at early adolescence (age 10-14 years) defined by United Nations [12], which may be an important factor in the etiology of anemia given the higher nutritional demands during period [2]. Besides, existing literatures reported different prevalence of anemia among between early adolescents and older adolescents (age 15-19 years) [7, 13, 14], highlighting the essence of examining population-specific factors. Given that iron deficiency is a key factor contributing to anemia [15] and that early adolescence is a critical period of diet transition from childhood to adolescence [16, 17], improving adolescent dietary intake is likely a reasonable approach for preventing anemia among this special age group [18]. One study from South Africa reported that the consumption of red meat was likely to decrease the risk of iron deficiency but not anemia among adolescent girls ≥15 years old [11]. Inconsistent results on the associations of eggs, dairy products, and heme-iron containing food sources with anemia were also reported [13, 19-21].

As one of the largest countries in LMICs, China has been experiencing rapid development and urbanization with great changes in people's dietary patterns [22]. Recent data on Chinese adolescent anemia has been obtained from the National Nutrition and Health Survey [23, 24], providing for an incomplete examination of the epidemiology of anemia in this age group, e.g., missing to examine the population-specific influencing factors. Further evidence from the 2014 National Survey on Students' Constitution and Health, indicate that the prevalences of anemia in Chinese adolescents aged 12 and 14 years were 9.6% and 8.4%, respectively, with a range of risk by region, from 2.0% in Beijing to 24.1% in Hainan [25]. These results suggest that despite some improvement of wealth and dietary in China, adolescents across rural China still may face the burden of anemia due to the unmet needs of iron-rich foods, vitamins, and other micronutrients [26].

In this paper, we used recent data of adolescents from rural western China where rapid urbanization has been occurring to assess the associated factors of anemia among young adolescents aged 10-14 years, which will provide baseline data for guiding intervention strategies for this critical age group.

Methods

Study design and participants

The present study utilizes secondary analyses of data from a follow-up study of adolescents born to women who participated in a cluster-randomized controlled trial of prenatal micronutrient supplementation. The details of the original trial and the adolescent follow-up study were described elsewhere [27, 28].

Briefly, all pregnant women in villages from two counties in rural western China were randomly assigned to take a daily capsule of folic acid, folic acid plus iron, or multiple micronutrients between 2002 and

2006. A total of 4488 singleton live births were eligible for long-term follow-up. We followed 1517 adolescents aged 10 to 14 years between June and December 2016, with data on hemoglobin (Hb). Due to the rapid urbanization, moving out of study area was the primary reason for lost to follow-up.

Venous blood samples were collected from each participant by a nurse in a local hospital and were immediately tested for the hemoglobin concentration using an automated hematology analyzer (BC-3000Plus, mindray).

Anthropometric measurements were assessed, including height and weight. After removal of shoes and heavy clothing, standing height was measured to the nearest 0.1 cm using a steel strip stadiometer (SZG-210, Shanghai JWFU Medical Apparatus Corporation), and body weight was measured to the nearest 0.1 kg using bioelectrical impedance (BC-420, Tanita Corporation, Tokyo, Japan) which was originally used to collect data on body composition. Two measurements for height were performed and if discrepancy occurred, repeated measures were taken until consensus obtained. Body mass index (BMI) for age Z-score (BAZ) and height for age Z-score (HAZ) were used to classify the nutritional status as thinness (BAZ<-2 SD) or stunting (HAZ<-2 SD), and overweight (BAZ>1 SD) or stature above average (HAZ>1 SD) according to the WHO growth standards [29]. BMI was calculated as body weight divided by height squared (kg/m^2).

Puberty was assessed by the Tanner scale including five-level developmental stages of scrotum and pubic hair in males and breasts and pubic hair in females, respectively [30, 31]. Specifically, among females, both pubic hair and breasts showing the characteristics of Stage 1 indicate the pre-puberty; both pubic hair and breasts showing the characteristics of Stage 2 indicate mild development; either pubic hair or breast that shows the characteristics of Stage 3 or beyond indicates above mild development (due to scarce data, Stage 3, 4 and 5 were merged in the present study. For boys, the frequencies of Tanner stage 1 to 5 were 182(21.0%), 420(48.5%), 182(21.0%), 78(9.0%) and 4(0.5%), respectively. As for girls, the corresponding frequencies were 78(12.2%), 226(35.2%), 286(44.6%), 52(8.1%) and 0(0.0%), respectively.). Similar cut-off criteria applied to the developmental stages of scrotum and pubic hair in males. All these measurements were completed by rigorously trained medical graduate students on standard procedures.

A structured questionnaire for information on socioeconomic status, adolescent disease history and dietary was administered by a trained public health graduate at the adolescence-stage visit. Adolescent's primary caregivers provided this information except for dietary intake which was directly collected from the adolescents. Adolescent dietary intake was collected using food group-based frequency questionnaire. For example, we asked every adolescent by "How often do you consume the flesh foods such as meat, poultry, and fish, i.e., almost never, almost 1/month, 1-3/month, 1/week, 2-4/week, 5-6/week, and ≥1/day?". Consumption of food groups including beans, dairy products and egg, and meal frequency in 24 hours were similarly collected. We then transformed the frequencies into times of consuming each food group per day, which were then classified into tertiles. Socioeconomic status was indicated by parental age, education, occupation, and household wealth. Adolescent disease history was defined as whether the adolescent had seen a doctor in the prior two weeks. Household wealth was

constructed by principal component analysis using 17 household assets or the ownership of goats, cattle, horses and poultry, and then categorized as an indicator of the low-, middle- and high-income households by its tertiles [32].

Statistical analysis

Anemia was defined and adjusted for age as recommended by World Health Organization (WHO) [33], i.e., hemoglobin concentration <115 g/L for adolescents who were 10–11 years old, and hemoglobin concentration <120 g/L for those who were 12–14 years old. In terms of severity, mild anemia was defined as a hemoglobin concentration between 110-114 g/L among adolescents aged 10-11 and 110-119 g/L among adolescents aged 12-14. Moderate and severe anemia was defined by a hemoglobin concentration of 80-109 and lower than 80 g/L, respectively.

Counts/percentages for categorical variables and means±SDs for continuous variables were used to describe characteristics of the study population. Bivariate and multivariate logistic regression models were performed to examine the factors associated anemia including socioeconomic status, randomized regimens during pregnancy, adolescent age, sex, nutrition status, disease history, puberty development and dietary intake. All potential factors were considered in the multivariate analysis. We also examined predictors of continuous hemoglobin concentrations using generalized linear models. Finally, we performed stratified analysis by sex of predictors of anemia with other variables included in the model. P values for interactions were estimated from likelihood ratio tests comparing models including and excluding interaction terms between sex and factors.

Data were analyzed using STATA 12.0 (StataCorp, College Station, TX, USA). A two-sided p value <0.05 was considered significant for all statistics.

Results

A total of 1517 adolescents were interviewed, had hemoglobin data, and were included in the analyses, with age ranging 10-14 years. Table 1 presents socioeconomic and nutritional characteristics of participants. The mean age of adolescents, their mothers and fathers were 11.8 (±0.9), 37.3 (±4.4) and 39.5 (±4.1) years, respectively. Of adolescents, 873 (57.6%) were female. Majority of mothers and fathers had secondary education or higher. More than half of mothers were farmers, but only 34.4% of fathers.

As shown in Table 1, the overall prevalence of thinness and stunting was 5.5% and 2.1%, while the prevalence of overweight and stature above average was 14.6% and 19.8%, respectively. The onset of puberty had already happened among 82.8% of participants with 42.8% in mild stage. Regarding dietary intake, the frequencies of consuming high protein-based foods including flesh foods, beans, dairy products, and eggs were fairly low, ranging from 0.23 to 0.38 times per day. Nearly half (44.2%) of the adolescents reported to have a meal frequency of two times per day.

Associated factors with adolescent Anemia

The average hemoglobin concentration was 133.0 (±14.9) g/L. In total, age-adjusted anemia was detected in 178 (11.73%) adolescents. Of these anemic adolescents, 93 (52.2%) were mild, 82 (46.1%) were moderate, while only 3 (1.7%) were severely anemic, respectively.

Univariate and multivariate analyses of associated factors for adolescent anemia are presented in Table 2. Adolescent girls were 1.73 (95% Confidence Interval [CI] 1.21, 2.48) times more likely to have anemia as compared to boys. We also found that the odds of anemia were 50% (95% CI 13%, 71%) lower in adolescents who experienced above mild development of puberty as compared to those in pre-puberty. Compared with adolescents whose mother had <3 years of education, those whose mother completed education beyond high school were 65% (95% CI 7%, 87%) less likely to be anemic. Besides, adolescents from high-income households relative to those from low-income households were also less likely to be anemic, with adjusted odds ratio (OR) of 0.55 (95% CI 0.34, 0.88).

In terms of dietary intake, adolescents who daily consumed the highest tertile of egg had 40% (95% CI 7%, 62%) reduced odds of having anemia compared to those who daily consumed the lowest. We also observed that consuming moderate flesh foods relative to the lowest was associated with a 0.58 (95% CI 0.38, 0.89) times lower odds of anemia. Similarly, the results for dairy products approached significance with an adjusted OR 0.68 (95% CI 0.46, 1.01). In addition, having a meal frequency of three times or more compared with two times per day was also associated with 32% (95% CI 4%, 52%) reduced odds of having anemia.

We also examined the associations between factors aforementioned and hemoglobin concentrations in adolescents (table 3). Similar predictors of anemia were identified. Besides, mothers with non-farmer occupation, not experiencing diseases in prior two weeks and stature above average were significantly associated with higher hemoglobin concentrations in adolescents.

Stratified analysis by sex

In addition, we found that adolescent sex modified the associations of stages of puberty development and maternal education with anemia with a p value of 0.04 and 0.01, respectively (Table 4). The statistical association between higher stages of puberty development and reduced odds of anemia was achieved only among males (OR 0.35; 95% CI 0.15, 0.83) but not among females (OR 0.72; 95% CI 0.29, 1.78). Similar results for continuous hemoglobin concentrations were presented in Supplementary table 1 (see Additional file 1).

Discussion

We found that the overall prevalence of anemia in our study population of adolescents aged 10-14 years in rural western China was 11.7%, with 9.7% and 14.4% in males and females, respectively. Multivariate analysis identified lower maternal education, lower household wealth, female sex, pre-puberty development, lower consumption of flesh foods, eggs and dairy products, and lower meal frequency were associated with increased likelihood of anemia. In addition, we found that higher stage of puberty

development was statistically associated with reduced risk of anemia for male adolescents but not for females.

The prevalence of anemia in our study population (11.7%) would be classified as a mild public health problem according to the WHO [15], which was also lower than the prevalence of 25.5% from a cross-sectional survey on middle school students conducted in our study area in 2006 [34]. Similar decrements were also observed as compared with the prior prevalence from other western rural areas in China [35, 36]. These findings indicate that the prevalence of adolescent anemia in China has improved to some extent. Besides, the decreasing tendency was also observed among adolescents aged 12-17 in the 2002 and 2012 Chinese National Nutritional and Health Survey, which may be due to the great improvements in socioeconomic status, dietary diversity and/or availability of fortified foods such as soy sauce with NaFeEDTA [24]. Nevertheless, the prevalence of adolescent anemia in our study population was still higher than that in more developed areas of China such as 2.9% among adolescents aged 12-14 in Yiwu, a city in eastern China [37], which warrants further studies on determinants and developing intervention strategies for adolescent anemia in western China.

We found positive associations between being female and adolescent anemia which was in line with previous studies conducted in Indonesia and Turkey [9, 18]. This finding could be explained by the occurrence of menarche and associated regular blood loss [8]. Further, one study from India reported that adolescent girls tended to consume fewer protein- and vitamin-rich foods compared with boys [38].

In addition, our results show that adolescent sex significantly modifies the associations between stages of puberty development and anemia. We found that males with higher stages of puberty development had reduced odds of anemia while the statistical association was not achieved among females, which was similar to the results of one study from Indonesia [9]. Some studies reported that the hemoglobin concentration in adolescent boys could increase along with the puberty development, which was regulated by the testosterone and other androgen effects [39, 40]. However, we could not provide evidence for the causality between puberty development and anemia due to the cross-sectional design. Based on a cohort study in Pakistan, Campisi and colleagues reported that anemia and stunting in childhood can delay the adolescent puberty onset [41]. We hypothesized that among female adolescents, those who had puberty onset may have better nutrition status and lower risk of anemia, on the other hand the onset of puberty among those with better nutritional status was associated with regular blood loss and higher risk of anemia, which potentially resulted in the null associations between puberty development and anemia among females. That said, we could not rule out the possibility of chance finding given the wide confidence interval.

Some studies reported that the risk of having anemia increased with age among adolescents that may be explained by puberty development [13], however these studies did not adjust for stages of puberty development in the models. We noted significant associations between continuous adolescent ages and anemia even after adjusting for stages of puberty development. The models produced a condition index of 8.16 which indicated that the multicollinearity between age and stages of puberty was not a concern

(data not shown) [42]. We noted, in the same study population, that adolescent age was positively associated with prevalence of stunting. Taken together, these findings suggest that data on adolescent health outcomes e.g. anemia, should be reported by sex and age and that when possible development stages of puberty should be factored in the interpretation of the findings.

Although dietary intake is an important contributor to adolescent nutrition, and early adolescence is a critical period in the dietary transition from mid-childhood through adolescence to adulthood [43, 44], related dietary data on anemia are limited. In the adjusted models, we found that higher consumption of egg, flesh foods and dairy products were associated with decreased odds of having anemia. A meta-analysis of randomized controlled trials from China also reported that dietary interventions such as consuming eggs before or after the meal once a day could significantly improve the iron deficiency in children with iron deficiency anemia [45]. Further, another study conducted in a refugee camp of Ethiopia found that adolescent girls who consumed more heme-iron containing food sources were less likely to have anemia [13]. These foods such as eggs, dairy products, and flesh foods, are important source of protein, vitamin B_{12}, bioavailable iron and other micronutrients, all of which are determinants of anemia [46]. In a recent study, it was estimated that less than half of adolescent girls consumed daily dairy products, flesh foods, or eggs (41%, 46%, and 19%, respectively) in LMICs, highlighting the essence of improving dietary intake to prevent anemia and other poor health outcomes among adolescents [47]. Subclinical micronutrient deficiency (including iron and vitamin B_{12}) can occur before the onset of anemia [48], warranting improved dietary intake as a preventive strategy. WHO recommended weekly iron and folic acid supplementation for menstruating adolescent girls in settings with 20% or higher levels of anemia prevalence [32], however whether this public health program had similar benefits on other settings or adolescent boys is inconclusive. In agreement with another study in southern Ethiopia [49], we also found that consuming three or more of meals per day was associated with reduced risk of developing anemia. We assumed that adolescents who ate more times per day would have higher likelihood of consuming iron-rich foods and meeting their nutritional requirements. It is notable that in our study area majority of families had only two times of meal per day and ate the first meal by noon, i.e., skipping the breakfast, which also might lead to poor health status for adolescents who are susceptible to nutrition deficiency. One study from China reported that skipping breakfast was associated with higher risk of stunting, wasting and malnutrition among children aged 6-17 years [50].

In addition to biomedical influences, we also found that adolescents from higher-income households or whose mothers had higher educations were less likely to be anemic, which is in accord with other studies [6, 11]. Similar results were observed when using the continuous Hb as the outcome. Individuals from higher socioeconomic status consume more iron- and vitamin C-rich food [6]. Tur and colleagues also reported that maternal education was positively associated with the quality of dietary mineral and vitamin intakes among adolescents [51]. In the stratified analysis by sex, although the significant association of maternal education with adolescent anemia was only found in females but not in males, we could not identify similar finding in the literature for explaining this result. We hypothesized that adolescent girls were more likely than boys to follow mothers' advice on healthy behaviors [52], which

warrants further study. However, these findings suggest that programmes that only emphasized biomedical factors might not sufficient to prevent adolescent anemia, and that integrated interventions addressing biomedical determinants and targeting at high-risk subpopulations are essential to improve adolescent health.

This study has some limitations that should be noted. First, we obtained the sample from follow-up of offspring born by women who participated in an antenatal micronutrient supplementation trial, and this population may not be a truly representative sample of our target population. However, our prior data had shown that the background characteristics between participants followed and those lost to follow-up at adolescence were balanced [28]. Besides, the cluster-randomized trial included all pregnant women in villages, representing the community to some extent. Second, due to no available data on older adolescents in the present study, we were not able to compare the differences of prevalence and/or associated factors between early adolescence and older adolescence like other study where statistical differences were reported [13]. Third, we focused on high protein-, vitamin-, and mineral-based foods, but some studies reported that regular consumptions of fruits and green leafy vegetables were also associated with reduced odds of having anemia in adolescent girls [53], and this is an area to pursue in further research. Besides, other factors associated with anaemia were not accounted in the present study such as parasite infection, thalassemia, and maternal nutritional status. Finally, owing to the cross-sectional study design used, prospective study with careful control of potential confounders are needed to verify the relationships between identified factors and anemia among adolescents. The presented results provide, however, basic evidence that could help develop intervention strategies and target at high-risk subpopulations in this vulnerable population group, as adolescence is a critical window in life for achieving human potential.

Conclusions

Anemia is a mild public health problem among young adolescents in rural western China. Integrated interventions addressing biomedical determinants and targeting at high-risk subpopulations are essential to reduce the risk of anemia and improve health among this critical age group.

Abbreviations

Body mass index for-age z score, BAZ; Confidence interval, CI; Height for-age z score, HAZ; Hemoglobin, Hb; Low- and middle-income countries, LMICs; Odds ratio, OR; Standard deviation, SD; World Health Organization, WHO

Declarations

Ethics approval and consent to participate

This study was conducted according to the principles laid down in the Declaration of Helsinki, and approved by the Ethics Committee of Xi'an Jiaotong University. Written and verbal informed consent were obtained from each parent or legal guardian of participants and adolescent, respectively.

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files. Data sharing is available from the corresponding author on reasonable request.

Competing interests

Dr. Suying Chang is a nutrition specialist of UNICEF China Office. The other authors declare that they have no competing interests.

Authors' contributions

ZZ, YC, WY, MJD, and LZ: planned and designed the study; ZZ, YC, QQ, SL and ME: conducted the study; ZZ, CS, and WF: analyzed data and interpreted results; ZZ: wrote the paper; LZ: had primary responsibility for final content; and all authors: reviewed, revised and approved the final manuscript.

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Tables

Table 1 Background characteristics and anemia status among adolescents in rural Western China, 2016[1]

Parental characteristics	Total/n(%)	Adolescent Characteristics	Total/n(%)
N	1517(100.0)	N	1517(100.0)
Maternal age/years[2]		Adolescent age/years (Mean±SD)	11.8(0.9)
Mean (SD)	37.3(4.4)	10	73(4.8)
Q1: ≤35	642(42.3)	11	538(35.5)
Q2: 36-39	408(26.9)	12	547(36.1)
Q3: ≥40	467(30.8)	13-14 (only two children were 14)	359(23.7)
Maternal education		Sex	
< 3 years	87(5.8)	Male	873(57.6)
Primary	433(28.6)	Female	644(42.5)
Secondary	757(50.1)	Hemoglobin concentrations (g/L, Mean±SD)	133.0(14.9)
High school+	235(15.5)	BMI for age z score	
Maternal occupation		Thinness (<-2SD)	82(5.5)
Farmer	923(60.9)	Normal weight	1202(80.0)
Others	593(39.1)	Overweight (>1SD)	219(14.6)
Paternal age/years[2]		Height for age z score	
Mean (SD)	39.5(4.1)	Stunting (<-2SD)	32(2.1)
Q1: ≤37	571(37.8)	-2 to 1 SD	1184(78.1)
Q2: 38-41	477(31.6)	Stature above average (>1SD)	300(19.8)
Q3: ≥42	464(30.7)	Whether having illness in last two weeks	
Paternal education		Yes	590(39.0)
< 3 years	19(1.3)	No	923(61.0)
Primary	218(14.4)	Puberty development[3]	
Secondary	894(59.1)	Pre-puberty	260(17.2)
High school+	383(25.3)	Mild	646(42.8)
Paternal occupation		Above mild	602(39.9)
Farmer	507(34.4)	Times of consuming flesh foods per day/Mean (SD)[4]	0.23(0.28)
Others	968(65.6)	Q1 (<0.03)	374(24.7)
Household wealth		Q2 (0.03-0.14)	523(34.5)
Low	525(34.6)	Q3 (>0.14)	620(40.9)
Medium	446(29.4)	Times of consuming beans per day/Mean (SD)[4]	0.29(0.33)
High	546(36.0)	Q1 (<0.03)	512(34.0)
Randomized regimens		Q2 (0.03-0.43)	723(48.0)
Folic acid	529(34.9)	Q3 (>0.43)	270(17.9)
Iron/folic acid	502(33.1)	Times of consuming dairy products per day/Mean(SD)[4]	0.33(0.38)
Multiple micronutrients	486(32.0)	Q1 (<0.03)	583(38.7)
		Q2 (0.03-0.43)	54(30.5)
		Q3 (>0.43)	36(20.3)
		Times of consuming egg per day/Mean(SD)[4]	0.38(0.37)
		Q1 (<0.07)	526(34.9)
		Q2 (0.07-0.43)	564(37.4)
		Q3 (>0.43)	419(27.8)
		Meal frequency in 24 hours	
		Two times	663(44.2)
		Three times and four times[5]	836(55.8)

[1]Data are missing for maternal education (n=5), maternal occupation (n=1), paternal education (n=3), paternal occupation (n=42), BMI for age z score (n=14), height for age z score (n=1), high protein-based food (n=4), puberty development (n=9), beans (n=2), dairy products (n=2), egg (n=8), and meal frequency (n=18).

[2]Parents' age was categorized by its tertiles.

[3]Puberty development was defined by the Tanner stages.

[4]The frequency of consuming foods was converted into continuous variables, namely times per day, which were then categorized by its tertiles. Flesh foods included meat, poultry and fish.

[5]Only 14 (0.9%) adolescents had a meal frequency of four times per day.

Table 2 Factors associated with adolescent anemia in rural western China, 2016 (N=1517)

	Anemia/n(%)	Unadjusted			Adjusted[1]			P values for trend[1]
		OR	95% CI	p values	OR	95% CI	p values	
Maternal age/years[2]								0.50
Q1: ≤35	84(13.1)	1.00			1.00			
Q2: 36-39	45(11.0)	0.82	0.56, 1.21	0.32	0.85	0.53, 1.34	0.47	
Q3: ≥40	49(10.5)	0.78	0.54, 1.13	0.19	0.89	0.46, 1.69	0.71	
Maternal education								0.07
< 3 years	17(19.5)	1.00			1.00			
Primary	61(14.1)	0.68	0.37, 1.22	0.20	0.60	0.31, 1.15	0.13	
Secondary	89(11.8)	0.55	0.31, 0.97	0.04	0.56	0.28, 1.12	0.10	
High school+	11(4.7)	0.20	0.09, 0.45	<0.001	0.35	0.13, 0.93	0.04	
Maternal occupation								-
Farmer	130(14.1)	1.00			1.00			
Others	48(8.1)	0.54	0.38, 0.76	<0.001	0.81	0.53, 1.22	0.31	
Paternal age/year[2]								0.42
Q1: ≤37	71(12.4)	1.00			1.00			
Q2: 38-41	58(12.2)	0.97	0.67, 1.41	0.89	0.97	0.62, 1.51	0.89	
Q3: ≥42	49(10.6)	0.83	0.56, 1.22	0.35	0.71	0.36, 1.43	0.34	
Paternal education								0.88
< 3 years	4(21.1)	1.00			1.00			
Primary	32(14.7)	0.65	0.20, 2.07	0.46	0.57	0.16, 1.97	0.37	
Secondary	114(12.8)	0.55	0.18, 1.68	0.29	0.63	0.18, 2.13	0.45	
High school+	28(7.3)	0.30	0.09, 0.95	0.04	0.60	0.16, 2.20	0.44	
Paternal occupation								
Farmer	72(14.2)	1.00			1.00			
Others	98(10.1)	0.68	0.49, 0.94	0.02	0.87	0.59, 1.27	0.46	
Household wealth					0.78	0.63, 0.98		0.03
Low	75(14.3)	1.00			1.00			
Medium	70(15.7)	1.12	0.78, 1.59	0.54	1.17	0.80, 1.72	0.38	
High	33(6.0)	0.39	0.25, 0.59	<0.001	0.55	0.34, 0.88	0.01	
Randomized regimens								
Folic acid	55(10.4)	1.00			1.00			
Iron/folic acid	62(12.4)	1.21	0.83, 1.79	0.32	1.10	0.72, 1.66	0.68	
Multiple micronutrients	61(12.6)	1.24	0.84, 1.82	0.28	1.27	0.85, 1.91	0.25	
Adolescent age					1.28	1.02, 1.62		0.04
10	6(8.2)	1.00			1.00			
11	55(10.2)	1.27	0.53, 3.07	0.59	1.01	0.40, 2.54	0.98	
12	71(13.0)	1.67	0.70, 3.98	0.25	1.48	0.58, 3.77	0.41	
13-14	46(12.8)	1.64	0.67, 4.00	0.28	1.64	0.61, 4.42	0.33	

	n(%)	OR	95% CI	p	OR	95% CI	p	p trend
Sex								
Male	85(9.7)	1.00			1.00			
Female	93(14.4)	1.56	1.14, 2.14	0.01	1.73	1.21, 2.48	0.003	
Height for age z score								0.23
Stunting (<-2SD)	7(21.9)	1.89	0.80, 4.44	0.68	1.20	0.46, 3.13	0.71	
-2 to 1 SD	153(12.9)	1.00			1.00			
Above average (>1SD)	18(6.0)	0.43	0.26, 0.71	0.43	0.71	0.40, 1.24	0.22	
Whether having illness in last two weeks								
Yes	81(13.7)	1.00			1.00			
No	95(10.3)	0.72	0.53, 0.99	0.04	0.76	0.54, 1.06	0.10	
Puberty development[2]					0.70	0.53, 0.93		0.01
Pre-puberty	40(15.4)	1.00			1.00			
Mild	71(11.0)	0.68	0.45, 1.03	0.07	0.64	0.40, 1.01	0.06	
Above mild	66(11.0)	0.68	0.44, 1.03	0.07	0.50	0.29, 0.87	0.01	
Times of consuming flesh foods per day (Mean/SD)[4]								0.11
Q1 (Lowest)	62(16.6)	1.00			1.00			
Q2	54(10.3)	0.58	0.39, 0.86	0.01	0.58	0.38, 0.89	0.01	
Q3 (Highest)	62(10.0)	0.56	0.38, 0.82	0.003	0.72	0.48, 1.08	0.11	
Times of consuming beans per day (Mean/SD)[4]								0.48
Q1 (Lowest)	62(12.1)	1.00			1.00			
Q2	94(13.0)	1.08	0.77, 1.53	0.64	1.20	0.83, 1.73	0.34	
Q3 (Highest)	22(8.2)	0.64	0.39, 1.07	0.09	0.75	0.44, 1.31	0.31	
Times of consuming dairy products per day (Mean/SD)[4]					0.79	0.64, 0.99		0.04
Q1 (Lowest)	87(14.9)	1.00			1.00			
Q2	54(10.2)	0.64	0.45, 0.93	0.02	0.68	0.46, 1.01	0.06	
Q3 (Highest)	36(9.2)	0.58	0.38, 0.88	0.01	0.70	0.45, 1.09	0.11	
Times of consuming egg per day (Mean/SD)[4]					0.76	0.62, 0.95		0.01
Q1 (Lowest)	76(14.5)	1.00			1.00			
Q2	63(11.2)	0.74	0.52, 1.06	0.11	0.79	0.54, 1.15	0.22	
Q3 (Highest)	39(9.3)	0.61	0.40, 0.92	0.02	0.60	0.38, 0.93	0.02	
Meal frequency in 24 hours								-
Two times	100(15.1)	1.00			1.00			
Three times and four times	76(9.1)	0.56	0.41, 0.77	<0.001	0.68	0.48, 0.96	0.03	

[1]The adjusted model included all the variables in the table except for dietary variables. And then, each of the dietary variables were put in the adjusted model above one at a time. The p values for trend were calculated by treating the factors as ordinal variables in the adjusted models above.

[2]Parents' age was categorized by its tertiles.

[3]Puberty development was defined by the Tanner stages.

[4]The frequency of consuming foods was converted into continuous variables, namely times per day, which were then categorized by its tertiles. Flesh foods included meat, poultry and fish.

Table 3 Factors associated with hemoglobin concentrations (g/L) in adolescents from rural Western China, 2016 (N=1517)

	Mean (SD)	Unadjusted			Adjusted[1]		
		Mean differences	95% CI	p values	Mean differences	95% CI	p values
Maternal age/years[2]							
Q1: ≤35	131.9(15.1)	Ref.			Ref.		
Q2: 36-39	133.6(14.1)	1.65	-0.20, 3.49	0.08	0.54	-1.48, 2.56	0.60
Q3: ≥40	134.0(15.3)	2.06	0.29, 3.83	0.02	1.63	-1.26, 4.52	0.27
Maternal education							
< 3 years	129.3(15.9)	Ref.			Ref.		
Primary	131.9(15.5)	2.58	-0.84, 6.00	0.14	3.28	-0.24, 6.79	0.07
Secondary	133.2(15.1)	3.86	0.56, 7.15	0.02	4.34	0.68, 8.01	0.02
High school+	135.8(12.1)	6.49	2.83, 10.14	0.001	4.83	0.44, 9.22	0.03
Maternal occupation							
Farmer	135.0(14.1)	Ref.			Ref.		
Others	131.8(15.3)	3.21	1.68, 4.74	<0.001	2.44	0.62, 4.27	0.01
Paternal age/year[2]							
Q1: ≤37	132.0(13.9)	Ref.			Ref.		
Q2: 38-41	133.6(15.7)	1.60	-0.21, 3.41	0.08	0.84	-1.16, 2.83	0.41
Q3: ≥42	133.6(15.3)	1.68	-0.14, 3.51	0.07	0.57	-2.46, 3.59	0.71
Paternal education							
< 3 years	126.9(14.9)	Ref.			Ref.		
Primary	132.3(16.8)	5.41	-1.56, 12.39	0.13	6.05	-0.94, 13.03	0.09
Secondary	132.6(15.3)	5.70	-1.06, 12.46	0.10	4.98	-1.92, 11.88	0.16
High school+	134.6(12.6)	7.73	0.88, 14.59	0.03	4.25	-2.89, 11.39	0.24
Paternal occupation							
Farmer	133.3(13.50	Ref.			Ref.		
Others	132.9(17.3)	0.39	-1.22, 1.99	0.64	-1.50	-3.29, 0.29	0.10
Household wealth							
Low	131.6(15.7)	Ref.			Ref.		
Medium	131.9(16.0)	0.37	-1.50, 2.24	0.70	0.46	-1.42, 2.35	0.63
High	135.3(12.8)	3.71	1.93, 5.48	<0.001	2.52	0.53, 4.50	0.01
Randomized regimens							
Folic acid	133.4(15.7)	Ref.			Ref.		
Iron/folic acid	132.4(13.7)	-0.96	-2.78, 0.86	0.30	-0.78	-2.59, 1.02	0.39
Multiple micronutrients	133.2(15.3)	-0.22	-2.05, 1.62	0.82	-0.28	-2.10, 1.53	0.76
Adolescent age							
10	131.2(14.5)	Ref.			Ref.		
11	131.0(15.7)	-0.24	-3.86, 3.81	0.90	1.08	-2.59, 4.76	0.56
12	134.0(13.9)	2.75	-0.87, 6.37	0.14	3.05	-0.74, 6.84	0.12
13-14	135.0(14.7)	3.78	0.06, 7.51	0.05	3.01	-1.05, 7.08	0.15
Sex							
Male	134.9(15.2)	Ref.			Ref.		

	Mean(SD)	β	95% CI	P	β	95% CI	P
Female	130.5(14.1)	-4.44	-5.94, -2.94	<0.001	-5.04	-6.64, -3.45	<0.001
Height for age z score							
Stunting (<-2SD)	127.7(13.5)	-4.31	-9.48, 0.86	0.10	-2.21	-7.51, 3.08	0.41
-2 to 1 SD	132.0(14.5)	Ref.			Ref.		
Above average (>1SD)	137.6(15.7)	5.55	3.69, 7.42	<0.001	2.96	0.92, 5.00	0.004
Whether having illness in last two weeks							
Yes	131.7(13.8)	Ref.			Ref.		
No	133.9(15.4)	2.14	0.61, 3.67	0.01	1.58	0.06, 3.10	0.04
Puberty development[2]							
Pre-puberty	128.7(14.2)	Ref.			Ref.		
Mild	132.7(14.8)	3.95	1.83, 6.08	<0.001	3.26	1.07, 5.44	0.004
Above mild	135.3(14.9)	6.53	4.39, 8.68	<0.001	5.83	3.27, 8.39	<0.001
Times of consuming flesh foods per day (Mean/SD)[4]							
Q1 (Lowest)	130.9(15.7)	Ref.			Ref.		
Q2	133.7(13.5)	2.79	0.82, 4.76	0.01	2.28	0.31, 4.24	0.02
Q3 (Highest)	133.7(15.4)	2.73	0.83, 4.64	0.01	1.31	-0.64, 3.26	0.19
Times of consuming beans per day (Mean/SD)[4]							
Q1 (Lowest)	132.7(15.3)	Ref.			Ref.		
Q2	132.6(14.9)	-0.04	-1.73, 1.64	0.96	-0.87	-2.56, 0.82	0.31
Q3 (Highest)	134.3(14.2)	1.64	0.56, 3.84	0.14	0.27	-1.93, 2.47	0.81
Times of consuming dairy products per day (Mean/SD)[4]							
Q1 (Lowest)	132.2(15.6)	Ref.			Ref.		
Q2	133.3(14.2)	1.13	-0.62, 2.87	0.21	0.81	-0.94, 2.56	0.37
Q3 (Highest)	133.7(14.7)	1.50	-0.41, 3.41	0.12	0.85	-1.06, 2.77	0.38
Times of consuming egg per day (Mean/SD)[4]							
Q1 (Lowest)	131.3(14.2)	Ref.			Ref.		
Q2	134.2(14.7)	2.86	1.14, 4.58	0.001	2.64	0.94, 4.34	0.002
Q3 (Highest)	133.4(14.5)	2.11	0.25, 3.97	0.03	2.45	0.62, 4.29	0.01
Meal frequency in 24 hours							
Two times	131.1(15.7)	Ref.			Ref.		
Three times and four times	134.5(14.1)	3.39	1.88, 4.90	<0.001	1.69	0.13, 3.25	0.03

[1]The adjusted model included all the variables in the table except for dietary variables. And then, each of the dietary variables were put in the adjusted model above one at a time.

[2]Parents' age was categorized by its tertiles.

[3]Puberty development was defined by the Tanner stages.

[4]The frequency of consuming foods was converted into continuous variables namely times per day, which were then categorized by its tertiles. Flesh foods included meat, poultry and fish.

Table 4 Factors associated with adolescent anemia stratified by adolescent sex in rural western China, 2016

Factors	Male			Female			P values for interaction between sex and factors[2]
	No. (%) of anemia	Adjusted OR[1]	95% CI	No. (%) of anemia	Adjusted OR[1]	95% CI	
Maternal age/years[3]							0.01
Q1: ≤35	37(11.4)	1.00		47(14.9)	1.00		
Q2: 36-39	15(6.3)	0.54	0.24, 1.19	30(17.9)	1.17	0.64, 2.14	
Q3: ≥40	33(10.8)	1.01	0.39, 2.64	16(10.0)	0.54	0.20, 1.48	
Maternal education							0.008
< 3 years	5(8.9)	1.96	0.37, 10.44	12(38.7)	5.84	1.51, 22.54	
Primary	39(14.5)	3.14	0.87, 11.31	22(13.4)	0.90	0.30, 2.70	
Secondary	37(8.9)	1.89	0.56, 6.38	52(15.3)	1.44	0.56, 3.68	
High school+	4(3.1)	1.00		7(6.7)	1.00		
Maternal occupation							0.61
Farmer	25(7.2)	1.00		23(9.4)	1.00		
Others	60(11.4)	1.03	0.56, 1.90	70(17.6)	0.58	0.33, 1.06	
Paternal age/years[3]							0.35
Q1: ≤37	30(10.5)	1.00		41(14.3)	1.00		
Q2: 38-41	23(8.4)	0.83	0.40, 1.74	35(17.2)	1.02	0.57, 1.84	
Q3: ≥42	32(10.3)	0.73	0.26, 2.07	17(11.2)	0.72	0.25, 2.04	
Paternal education							0.48
< 3 years	2(16.7)	1.00		2(28.6)	1.00		
Primary	14(10.1)	0.32	0.05, 2.01	18(22.5)	0.79	0.12, 5.38	
Secondary	55(10.6)	0.52	0.09, 3.18	59(15.7)	0.56	0.08, 3.68	
High school+	14(6.9)	0.68	0.10, 4.65	14(7.8)	0.43	0.06, 3.17	
Paternal occupation							0.09
Farmer	42(7.6)	1.00		56(13.6)	1.00		
Others	40(13.5)	0.58	0.33, 1.02	32(15.2)	1.22	0.71, 2.12	
Household wealth							0.40
Low	39(12.6)	1.00		36(16.7)	1.00		
Medium	30(11.7)	0.92	0.53, 1.61	40(21.2)	1.62	0.93, 2.85	
High	16(5.2)	0.56	0.27, 1.13	17(7.1)	0.61	0.30, 1.23	
Randomized regimens							0.09
Folic acid	30(9.6)	1.00		25(11.6)	1.00		
Iron/folic acid	32(11.4)	1.16	0.65, 2.07	30(13.6)	1.10	0.59, 2.08	
Multiple micronutrients	23(8.2)	0.95	0.52, 1.73	38(18.4)	1.92	1.06, 3.47	
Adolescent age							0.39
10	4(11.1)	1.00		2(5.4)	1.00		
11	31(10.0)	0.62	0.19, 2.02	24(10.5)	1.61	0.35, 7.54	
12	29(9.4)	0.75	0.23, 2.51	42(17.6)	2.53	0.53, 12.08	
13-14	21(9.6)	0.97	0.27, 3.52	25(17.9)	2.67	0.52, 13.79	
Height for age z score							0.56

	n(%)	OR	95% CI	n(%)	OR	95% CI	p[2]
Stunting (<-2SD)	3(18.8)	1.00	0.20, 5.06	4(25.0)	2.14	0.58, 7.94	
-2 to 1 SD	73(11.1)	1.00		80(15.2)	1.00		
Above average (>1SD)	9(4.5)	0.57	0.25, 1.30	9(9.1)	0.98	0.43, 2.23	
Whether having illness in last two weeks							0.27
Yes	41(12.2)	1.00		40(15.8)	1.00		
No	42(7.9)	0.63	0.39, 1.02	53(13.6)	0.92	0.56, 1.50	
Puberty development[4]							0.04
Pre-puberty	29(15.9)	1.00		11(14.1)	1.00		
Mild	40(9.5)	0.59	0.33, 1.06	31(13.7)	0.92	0.39, 2.13	
Above mild	15(5.7)	0.35	0.15, 0.83	51(15.1)	0.72	0.29, 1.78	
Times of consuming flesh foods per day (Mean/SD)[5]							0.57
Q1 (Lowest)	31(14.8)	1.00		31(18.8)	1.00		
Q2	22(7.9)	0.51	0.27, 0.97	32(13.2)	0.68	0.37, 1.24	
Q3 (Highest)	32(8.3)	0.58	0.33, 1.05	30(12.7)	0.96	0.52, 1.77	
Times of consuming beans per day (Mean/SD)[5]							0.36
Q1 (Lowest)	33(11.5)	1.00		29(12.9)	1.00		
Q2	42(10.2)	0.94	0.56, 1.59	52(16.7)	1.55	0.90, 2.68	
Q3 (Highest)	10(6.0)	0.54	0.24, 1.21	12(11.8)	0.94	0.42, 2.10	
Times of consuming dairy products per day (Mean/SD)[5]							0.63
Q1 (Lowest)	44(13.0)	1.00		43(17.6)	1.00		
Q2	20(6.9)	0.56	0.31, 1.02	34(14.1)	0.80	0.46, 1.39	
Q3 (Highest)	20(8.4)	0.70	0.38, 1.28	16(10.5)	0.67	0.34, 1.32	
Times of consuming egg per day (Mean/SD)[5]							0.22
Q1 (Lowest)	34(11.6)	1.00		42(18.1)	1.00		
Q2	26(8.3)	0.70	0.39, 1.26	37(14.9)	0.87	0.52, 1.51	
Q3 (Highest)	25(9.5)	0.75	0.41, 1.37	14(8.9)	0.46	0.23, 0.92	
Meal frequency in 24 hours							0.80
Two times	50(13.1)	1.52	0.91, 2.54	50(17.7)	1.53	0.91, 2.55	
Three times and four times	33(6.9)	1.00		43(12.1)	1.00		

[1]The adjusted model included all the variables in the table except for dietary variables. And then, each of the dietary variables were put in the adjusted model above one at a time.

[2]The p values for interaction between sex and factors were calculated using likelihood-ratio test between including interaction terms and not including in the models.

[3]Parents' age was categorized by its tertiles.

[4]Puberty development was defined by the Tanner stages.

[5]The frequency of consuming foods was converted into continuous variables namely times per day, which were then categorized by its tertiles. Flesh foods included meat, poultry and fish.

Supplementary Files

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- 2020.11.3BPHsupplementarymaterials.docx
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