Original Article

Sociodemographic Factors Associated with Dietary Intake of Thiamine, Riboflavin, and Niacin among Chinese Adults in 2015*

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Abstract

Objective To estimate the association between three B-vitamin intakes and sociodemographic factors among adults in China.

Methods We derived our data from the China Health and Nutrition Survey (CHNS) among 12,241 individuals aged 18–64 years. Log binomial regression was used to estimate adjusted prevalence ratios for factors associated with the inadequate intake of B-vitamins.

Results Females with low incomes and living in the north had a higher prevalence of inadequate riboflavin intake than those with high incomes and living in the south. Both males and females living in a village had a higher prevalence of inadequate riboflavin intake than adults living in a city. Adults with low income, low education, and living in the north or in a village had a higher prevalence of inadequate niacin intake than adults with a high income, high education, and living in the south or in a city.

Conclusion We found that income, region, and area of residence were associated with riboflavin intake. Education, income, region, and area of residence were associated with niacin intake. Well-tailored strategies and policies are needed to improve nutritional status in China.

Key words: Thiamine; Riboflavin; Niacin; Vitamin B deficiency; Nutritional requirements; China

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INTRODUCTION

According to the 2016 Global Nutrition Report, malnutrition and poor diet are the leading cause of the global disease burden. Low body weight, stunted growth, and trace-element deficiency in children lead to an average annual gross domestic product loss of 11% in Asia and Africa[1]. B-vitamins play an important role in all stages of life, maintaining healthy skin and muscle tone and strengthening immune and nervous system functions[2,3]. They also play an important role in chronic disease prevention and control[4]. Thiamine, riboflavin, and niacin deficiencies have been shown to cause beriberi, mouth pain, anemia, even oral–genital disease, and pellagra, all of which have been important public health problems in some areas[5]. B-vitamin

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deficiency has been implicated as a risk factor for cardiovascular diseases and cancer and, if left untreated, can be fatal[5,6].

Rapid changes in the social and economic environment of China have brought a nutritional transition upon its citizens. The increasing intake of fats, sodium, vegetable oils and, animal-source foods are major contributors to this nutrient shift[7]. Though dietary patterns have improved over the past 10 years, the intake of some micronutrients remains deficient. The main sources of B-vitamins in China are grains, according to the report of the China National Nutrition and Health Survey from 2010 to 2013[8]. Excessive refining and polishing of grains, along with decreasing consumption of staple foods that contain coarse grains and refined grains[7], have maintained the deficient intakes of B-vitamins in China[9]. According to previous rounds of the China Health and Nutrition Survey (CHNS) by Wang et al., levels of thiamine and riboflavin that fall below the estimated average requirements (EAR) were found in 91.8% and 85.9% of Chinese residents aged 14–17 years old[10]. The China National Nutrition and Health Survey also showed that the prevalence of inadequate intake of thiamine and riboflavin was 85% across China in 2010 to 2012[8].

Many studies have examined B-vitamin intakes in special areas in China, or the association between diseases and B-vitamin intakes in China. However, limited prevalence data on thiamine, riboflavin and niacin related with risk factors are available. This has important information for nutritional policies and interventions to focus on populations who have inadequate intakes of B-vitamins in China. Therefore, the aim of this study is to examine the sociodemographic factors associated with the intakes of thiamine, riboflavin, and niacin among adults in China.

METHODS

CHNS and Individuals

The data used were from the 2015 survey of an ongoing longitudinal study, the CHNS, conducted by the Chinese CDC and University of North Carolina at Chapel Hill, USA. The survey was designed as a cohort study with multistage, cluster-randomized, stratified sampling in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. In 2015, the survey was carried out in 15 provinces: Beijing, Liaoning, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Shandong, Henan, Hubei, Hunan, Yunnan, Guangxi, Guizhou, Chongqing, and Shanxi. All individuals gave their written informed consent before participating in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was reviewed and approved by the Institutional Review Boards at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2015017, 18 August 2015).

The CHNS was designed to represent areas varying in geography, economic environments, and public resources, and provided information focusing on the dramatic changes in China. Detailed CHNS study design information is provided in previous publications[11,12]. Information on public health risk factors was collected *via* household surveys, individual surveys, nutritional assessments and physical examinations, and community surveys.

Eligible individuals were adults aged 18 to 64 years in 2015, whose dietary data on three consecutive days were recorded in this study. The final sample number was 12,241; due to missing data, the sample number for education level was 12,207.

Sociodemographic Variables

The key sociodemographic factors included education, income, area of residence, region, dietary intake, smoking and drinking data, and anthropometric data. These sociodemographic factors have been shown as important determinants of nutrient intakes in China[13-15]. Age was classified as 18–34, 35–49, and 50–64 years. Education was categorized as low (≤ 6 years of education), middle (7–12 years of education), and high (≥ 13 years of education). Region was grouped as the northern or southern part of China[14]. Areas of residence were defined as cities, suburbs, counties, and villages, according to administrative divisions[8,13]. Annual household income was collapsed into tertiles, as low (> 0 and < 2.69 thousand yuan/per capita), moderate (≥ 2.69 and < 11.60 thousand yuan/per capita), and high (≥ 11.60 thousand yuan/per capita). Smoking status was categorized as nonsmoker, former smoker and current smoker[16] and alcohol consumption was categorized as nondrinker and drinker ('drinker' included both current and former drinkers), according to the questionnaire set-up.

Method for Calculating the Intake of Three B-vitamins

Participants’ dietary data were collected on three consecutive days with 24-h recalls supplemented with a daily food inventory in the family. Food recalls were analyzed to assess nutrient intakes by use of the China Food Composition Table[17]. The EAR cut-point method was used to assess the adequacy of B-vitamins[18,19]. The consumption of food ingested by individuals in the survey was converted to vitamin intake and compared with the age-and sex-specific EAR recommended by the Chinese Nutrition Society[20]. In adults aged 18–64 years, the EAR of thiamine and riboflavin is 1.2 mg/d for males and 1.0 mg/d for females; the EAR of niacin is 12 mg/d for males and 10 mg/d for females.

Statistical Analyses

Means, medians of B-vitamin intakes, and the prevalence of inadequate dietary intakes of thiamine, riboflavin, and niacin were estimated. The EAR cut-point method was used to assess the prevalence of inadequate intake of the three B-vitamins. The EAR is defined as the average daily nutrient intake level estimated to meet the nutrient requirements of 50% of all healthy individuals within a group. The intakes of thiamine, riboflavin, and niacin were evaluated by comparison with the EAR of Chinese residents' dietary reference intakes. For our study, individuals with extremely high or low energy intake (< 500 kcal/d or > 5,000 kcal/d, respectively) were excluded[21]. General linear regression and quantile regression models were used to calculate adjusted means and adjusted medians of the respective intakes of the three vitamins. Covariates for the models included total energy intake, age, education, income, area of residence, and region. Adjusted medians of B-vitamin intake were compared using Kruskal–Wallis analysis or the Wilcoxon rank-sum test.

Due to the high percentage of inadequate intake of B-vitamins in the study, log binomial regression models were used to estimate the adjusted prevalence ratios and corresponding confidence intervals for the associations between sociodemographic variables and the risk of inadequate intake of the three vitamins, adjusting for total energy intake. When the log binomial model failed to converge, Poisson regression was used. Analyses were conducted separately for each of the vitamins by gender. Statistical analysis was performed using StataSE14.0. All P values reported are two-tailed; we defined statistical significance as $P < 0.05$.

RESULTS

In total, we included 12,241 individuals, comprised of 5,684 males (46.4%) and 6,557 females (53.6%). Only 14.1% male adults and 12.4% female adults were in the high-education group. In our study, 31.8% males and 34.7% females were in the low-income group (Table 1).

Table 2 presents the dietary intakes of thiamine, riboflavin, and niacin and the prevalence of inadequacy by age, education, area of residence, income, and region in both sexes. The prevalence of inadequate intake of thiamine and riboflavin was statistically significantly higher among males (77.4%, and 85.5%, respectively) than females (75.8% and 81.7%, respectively). Age, education, income, and area of residence were associated with the adjusted median intake of thiamine, riboflavin, and niacin among males and females. Region was associated with the adjusted median intake of thiamine among females, but not among males.

Table 3 presents the factors affecting inadequate intake of thiamine, riboflavin, and niacin in adults. Among males and females, no risk factors predicted inadequate thiamine intake in the final model. Controlling for all variables in the final model, significant factors for inadequate intake of riboflavin among males were area of residence and among females were income, region, and area of residence. The results showed a 2.7% reduction in the prevalence of inadequate intake of riboflavin for females in the high-income group compared with the low-income group. Females living in the southern region were associated with a 2.0% reduced prevalence of inadequate intake of riboflavin compared with those in northern region. Among males and females, living in a city was associated with a 6.6%–13.5% reduction in the prevalence of inadequate riboflavin intake compared with living in a village.

Significant factors associated with inadequate niacin intake were education, income, region, and area of residence for both sexes in the final model. Among males and females, the high-education group was associated with a 21.2%–23.4% reduction in the prevalence of inadequate niacin intake compared with the low-education group. The results showed a 22.0%–23.1% reduction in the prevalence of inadequate niacin intake for both sexes in the high-income group compared with the low-income group.

Among males and females, living in a city was associated with a 10.9%–16.6% reduction in the prevalence of inadequate of niacin intake compared with living in a village.

The lowest prevalence of inadequate riboflavin intake was observed among adults living in a city (PR: 0.934, 95% *CI*: 0.910, 0.958 for males; PR: 0.865, 95% *CI*: 0.839, 0.892 for females). The lowest prevalence of inadequate niacin intake was found among adults living in the southern region (PR: 0.433, 95% *CI*: 0.390, 0.481 for males; PR: 0.478, 95% *CI*: 0.443, 0.515 for females).

Table 4 presents the top 10 food sources of thiamine, riboflavin, and niacin intake in Chinese adults aged 18–64 years. The top three sources of thiamine, riboflavin, and niacin intake in both sexes are cereals, meat, and vegetables. The contribution of cereals to the intake of thiamine made up 41.2% for males and 40.8% for females, for riboflavin it was 23.9% for males and 22.5% for females, and for niacin, it was 39.4% for males and 38.7% for females.

DISCUSSION

The dietary intakes of thiamine and riboflavin among adults aged 18–64 are lower than the average requirement (EAR) in over 75% of residents in China, and insufficient when compared with other counties in the world[22-25]. The dietary intake of niacin is less than 27% of the average requirement (EAR) for both sexes. B-vitamins are derived from similar food sources; therefore, one form of B-vitamin deficiency often occurs in combination with others deficiencies[26]. Our findings demonstrate that the top three sources of thiamine, riboflavin, and niacin in Chinese adults are cereals, meat, and vegetables, respectively. The results show that the main source of thiamine intake is cereals (41% for both males and females), which is similar to trends found in other surveys in China[8,20]. The processing of foods by refining and polishing of grain removes most of the thiamine, riboflavin, and niacin[27-29]. In addition, the process of cleaning and cooking also results in the loss of B-complex vitamins[27].

Table 1. Characteristics of adults aged 18–64 years from 15 provinces of China, CHNS 2015

Characteristics		Males		Females		Total
		Cases	%	Cases	%	
Age (years)						
	18–34	1,050	18.5	1,311	20.0	2,361
	35–49	2,090	36.8	2,416	36.8	4,506
	50–64	2,544	44.8	2,830	43.2	5,374
Education						
	Low	1,033	18.2	1,870	28.6	2,903
	Medium	3,838	67.7	3,854	59.0	7,692
	High	798	14.1	814	12.4	1,612
Region						
	North	2,179	38.3	2,526	38.5	4,705
	South	3,505	61.7	4,031	61.5	7,536
Area						
	City	1,171	20.6	1,401	21.4	2,572
	Suburb	952	16.7	1,096	16.7	2,048
	County	1,033	18.2	1,168	17.8	2,201
	Village	2,528	44.5	2,,892	44.1	5,420
Income (1,000 yuan/per capita)						
	Low	1,806	31.8	2,272	34.7	4,078
	Medium	1,924	33.8	2,157	32.9	4,081
	High	1,954	34.4	2,128	32.4	4,082

Table 2. Dietary intake and prevalence of inadequate intake (% of the population below the EAR) of thiamine, riboflavin, and niacin among adults aged 18–64 years, CHNS 2015

Variables	*n*	Thiamine (mg/d)			Riboflavin (mg/d)			Niacin (mg/d)		
		Mean (95% *CI*)	Median (95% *CI*)	< EAR%	Mean (95% *CI*)	Median (95% *CI*)	< EAR%	Mean (95% *CI*)	Median (95% *CI*)	< EAR%
Males										
Total	5,684	0.96 (0.95, 0.96)	0.88 (0.87, 0.89)	77.4	0.86 (0.85, 0.86)	0.78 (0.78, 0.79)	85.5	17.11 (16.98, 17.23)	15.83 (15.70,15.99)	25.6
Age (years)										
18–34	1,050	0.95 (0.93, 0.97)	0.87 (0.85, 0.90) [a]	77.7	0.85 (0.84, 0.86)	0.78 (0.76, 0.79) [a]	86.4	17.44 (17.14, 17.74)	16.36 (16.00, 16.64) [a]	23.0
35–49	2,090	0.98 (0.97, 1.00)	0.90 (0.89,0.92) [a]	75.7	0.87 (0.86, 0.88)	0.80 (0.79, 0.81) [a]	84.8	17.65 (17.44, 17.87)	16.27 (16.01, 16.52) [a]	24.1
50–64	2,544	0.94 (0.93, 0.95)	0.86 (0.84, 0.87) [a]	78.7	0.85 (0.84, 0.86)	0.77 (0.77, 0.78) [a]	85.7	16.53 (16.33, 16.72)	15.34 (15.12, 15.53) [a]	28.0
Education										
Low	1,033	0.92 (0.90, 0.94)	0.85 (0.83, 0.87) [a]	77.7	0.79 (0.78, 0.80)	0.72 (0.71, 0.74) [a]	90.8	16.54 (16.23,16.85)	15.38 (15.00, 15.68) [a]	27.2
Medium	3,838	0.97 (0.96, 0.98)	0.88 (0.87, 0.90) [a]	77.3	0.86 (0.85, 0.87)	0.78 (0.77, 0.79) [a]	85.0	17.04 (16.88,17.20)	15.76 (15.60, 15.94) [a]	26.3
High	798	0.95 (0.93, 0.97)	0.87 (0.86, 0.90) [a]	77.6	0.94 (0.92, 0.95)	0.87 (0.86, 0.89) [a]	80.7	18.19 (17.87,18.52)	16.72 (16.49, 17.16) [a]	20.3
Region										
North	2,179	0.96 (0.95, 0.97)	0.87 (0.86, 0.89)	76.6	0.84 (0.83, 0.85)	0.76 (0.75, 0.77) [a]	86.7	15.02 (14.82,15.22)	13.54 (13.33, 13.76) [a]	39.4
South	3,505	0.95 (0.94, 0.96)	0.87 (0.87, 0.89)	77.9	0.87 (0.86, 0.88)	0.80 (0.79, 0.81) [a]	84.8	18.41 (18.25,18.56)	17.10 (16.91, 17.26) [a]	17.0
Area										
City	1,171	0.97 (0.95, 0.99)	0.90 (0.88, 0.93) [a]	76.5	0.97 (0.96, 0.98)	0.90 (0.88, 0.91) [a]	78.6	18.07 (17.79,18.33)	16.53 (16.21, 16.81) [a]	20.5
Suburb	952	0.96 (0.94, 0.98)	0.86 (0.84, 0.88) [a]	78.7	0.87 (0.86, 0.88)	0.79 (0.77, 0.81) [a]	86.2	17.89 (17.57,18.21)	16.44 (16.21, 16.78) [a]	22.8
County	1,033	0.94 (0.92, 0.96)	0.88 (0.85, 0.90) [a]	76.8	0.84 (0.83, 0.85)	0.76 (0.74, 0.77) [a]	86.3	16.88 (16.58,17.18)	15.78 (15.49, 16.13) [a]	27.9
Village	2,528	0.95 (0.94, 0.96)	0.87 (0.86, 0.89) [a]	77.6	0.81 (0.80, 0.82)	0.76 (0.74, 0.77) [a]	88.1	16.47 (16.27,16.67)	15.36 (15.14, 15.51) [a]	28.1
Income (1,000 yuan/per capita)										
Low	1,806	0.95 (0.94, 0.97)	0.87 (0.86, 0.89) [a]	76.8	0.83 (0.82, 0.84)	0.75 (0.73, 0.76) [a]	87.7	16.72 (16.48,16.94)	15.52 (15.31, 15.70) [a]	27.8
Medium	1,924	0.94 (0.93, 0.95)	0.86 (0.85, 0.88) [a]	79.2	0.83 (0.82, 0.84)	0.75 (0.74, 0.77) [a]	87.9	16.53 (16.32,16.76)	15.29 (15.05, 15.50) [a]	28.6
High	1,954	0.98 (0.96, 0.99)	0.89 (0.88, 0.91) [a]	76.2	0.91 (0.90, 0.92)	0.84 (0.83, 0.85) [a]	81.1	18.03 (17.81,18.24)	16.68 (16.52, 17.03) [a]	20.6
Females										

Continued

Variables	n	Thiamine (mg/d)			Riboflavin (mg/d)			Niacin (mg/d)		
		Mean (95% *CI*)	Median (95% *CI*)	< EAR%	Mean (95% *CI*)	Median (95% *CI*)	< EAR%	Mean (95% *CI*)	Median (95% *CI*)	< EAR%
Total	6,557	0.82 (0.81, 0.82)	0.75 (0.74, 0.76)	75.8	0.76 (0.75, 0.76)	0.69 (0.68, 0.79)	81.7	14.25 (14.14, 14.35)	13.13 (13.02, 13.24)	26.5
Age (years)										
18–34	1,311	0.81 (0.79, 0.82)	0.75 (0.73, 0.76) [a]	77.4	0.76 (0.75, 0.77)	0.69 (0.67, 0.71) [a]	81.5	14.43 (14.19, 14.67)	13.24 (13.06, 13.59) [a]	24.6
35–49	2,416	0.84 (0.83, 0.85)	0.76 (0.75, 0.77) [a]	74.5	0.76 (0.76, 0.77)	0.69 (0.69, 0.71) [a]	80.7	14.60 (14.43, 14.78)	13.42 (13.23, 13.58) [a]	24.8
50–64	2,830	0.80 (0.79, 0.81)	0.74 (0.73, 0.75) [a]	76.3	0.75 (0.74, 0.75)	0.67 (0.67, 0.69) [a]	82.7	13.86 (13.70, 14.02)	12.81 (12.63, 12.99) [a]	28.8
Education										
Low	1,870	0.80 (0.79, 0.81)	0.73 (0.72, 0.75) [a]	77.3	0.69 (0.68, 0.70)	0.63 (0.62, 0.64) [a]	87.4	13.77 (13.58, 13.97)	12.80 (12.60, 13.02) [a]	28.1
Medium	3,854	0.83 (0.82, 0.83)	0.75 (0.75, 0.77) [a]	74.9	0.77 (0.76, 0.77)	0.70 (0.69, 0.70) [a]	80.8	14.31 (14.18, 14.46)	13.13 (12.96, 13.27) [a]	26.9
High	814	0.81 (0.80, 0.83)	0.74 (0.73, 0.77) [a]	77.2	0.84 (0.83, 0.86)	0.77 (0.75, 0.79) [a]	73.5	15.01 (14.72, 15.29)	13.76 (13.44, 14.02) [a]	21.0
Region										
North	2,526	0.81 (0.80, 0.82)	0.73 (0.73, 0.75) [a]	76.3	0.73 (0.72, 0.74)	0.65 (0.65, 0.66) [a]	84.2	12.36 (12.20, 12.51)	11.10 (10.97, 11.25) [a]	40.3
South	4,031	0.82 (0.81, 0.83)	0.76 (0.75, 0.77) [a]	75.6	0.77 (0.76, 0.77)	0.71 (0.70, 0.71) [a]	80.2	15.43 (15.31, 15.56)	14.18 (14.03, 14.31) [a]	17.9
Area										
City	1,401	0.84 (0.83, 0.85)	0.77 (0.76,0.79) [a]	73.4	0.87 (0.86, 0.89)	0.80 (0.79, 0.81) [a]	70.5	15.08 (14.86, 15.30)	13.91 (13.66, 14.09) [a]	22.6
Suburb	1,096	0.82 (0.81, 0.84)	0.74 (0.73,0.76) [a]	77.2	0.77 (0.75, 0.79)	0.69 (0.68, 0.70) [a]	81.6	14.75 (14.47, 15.02)	13.50 (13.18, 13.80) [a]	23.4
County	1,168	0.81 (0.79, 0.82)	0.75 (0.73,0.76) [a]	77.1	0.75 (0.74, 0.76)	0.66 (0.65, 0.68) [a]	82.5	14.10 (13.86, 14.33)	12.92 (12.66, 13.24) [a]	26.4
Village	2,892	0.81 (0.80, 0.82)	0.74 (0.72,0.75) [a]	76.0	0.69 (0.69, 0.70)	0.63 (0.62, 0.64) [a]	86.9	13.72 (13.56, 13.88)	12.92 (12.66, 13.24) [a]	29.6
Income (1,000 yuan/per capita)										
Low	2,272	0.82 (0.81, 0.84)	0.76 (0.74,0.77) [a]	75.3	0.73 (0.72, 0.74)	0.66 (0.65, 0.67) [a]	83.7	14.17 (13.98, 14.36)	12.94 (12.76, 13.16) [a]	28.0
Medium	2,157	0.80 (0.79, 0.81)	0.74 (0.73,0.75) [a]	76.8	0.72 (0.72, 0.74)	0.66 (0.65, 0.67) [a]	84.6	13.79 (13.61, 13.96)	12.76 (12.52, 12.95) [a]	29.5
High	2,128	0.82 (0.81, 0.99)	0.75 (0.74,0.76) [a]	75.5	0.81 (0.80, 0.82)	0.73 (0.73, 0.74) [a]	76.7	14.80 (14.63, 14.98)	13.68 (13.46, 13.88) [a]	21.8

Note. EAR: Estimated Average Requirements. The EAR were used as cutoffs to estimate the prevalence of inadequate intakes of three *B-vitamins*. Values were adjusted means (95% *CI*) and adjusted medians (95% *CI*). The adjusted medians of each B-vitamin intake across subgroups of age (18–34, 35–49, or 50–64), education (low, ≤ 6 years of education; middle, 7–12 years of education; high, ≥ 13 years of education), region (north or south), area (city, suburb, country, or village), and income (tertiles of annual household income) in each gender were compared by analysis or Wilcoxon rank-sum test ($P < 0.05$). [a]Significantly different from other groups by an overall test ($P < 0.05$).

Moreover, people are consuming less of the staple foods that contain these B-vitamins. All those factors likely contribute to insufficient intakes of thiamine, riboflavin, and niacin in Chinese adults. Priority should be placed on guiding these subpopulations who have insufficient intake of these three B-

Table 3. Log binomial regression for the association of sociodemographic variables with the risk of inadequate intake of thiamine, riboflavin, and niacin among adults aged 18–64 years, CHNS 2015

Variables	Riboflavin		Niacin	
	PR[b] (95% *CI*)	*P*	PR[b] (95% *CI*)	*P*
Males				
Education				
Low[a]	1		1	
Medium	0.947 (0.877, 1.021)	0.155	0.946 (0.826, 1.083)	0.418
High	0.930 (0.829, 1.044)	0.218	0.766 (0.619, 0.947)	0.014
Income				
Low[a]	1		1	
Medium	1.004 (0.990, 1.018)	0.564	0.988 (0.875,1.115)	0.841
High	0.984 (0.967, 1.002)	0.085	0.780 (0.681,0.894)	< 0.001
Region				
North[a]	1		1	
South	0.994 (0.982, 1.006)	0.354	0.433 (0.390,0.481)	< 0.001
Area				
Village[a]	1		1	
County	0.996 (0.980, 1.013)	0.641	1.068 (0.925, 1.233)	0.368
Suburb	0.987 (0.969, 1.005)	0.168	0.841 (0.721, 0.981)	0.027
City	0.934 (0.910, 0.958)	< 0.001	0.834 (0.712, 0.978)	0.025
Females				
Education				
Low[a]	1		1	
Medium	0.951 (0.890, 1.016)	0.134	0.973 (0.899, 1.052)	0.372
High	0.901 (0.804, 1.010)	0.073	0.788 (0.680, 0.914)	< 0.001
Income				
Low[a]	1		1	
Medium	0.999 (0.983, 1.015)	0.884	0.966 (0.894, 1.043)	0.372
High	0.973 (0.953, 0.993)	0.010	0.769 (0.700, 0.846)	< 0.001
Region				
North[a]	1		1	
South	0.980 (0.966, 0.994)	< 0.001	0.478 (0.443, 0.515)	< 0.001
Area				
Village[a]	1		1	
County	0.963 (0.942, 0.985)	0.001	0.999 (0.907, 1.101)	0.990
Suburb	0.964 (0.943, 0.986)	0.001	0.853 (0.768, 0.948)	0.003
City	0.865 (0.839, 0.892)	< 0.001	0.891 (0.801, 0.992)	0.036

Note. [a]Reference category.[b]Adjusted PR from log binomial regression.

vitamins to change their eating behaviors and improve their methods of cleaning and cooking food to reduce the loss of B-vitamins.

We document that the main sources of B-vitamins are cereals and vegetables for both sexes, accounting for 39.7%–40.5% of riboflavin and 47.9% of niacin of intake. Milk and dairy products contribute only 3.3% of riboflavin intake for males and 4.8% for females. Nuts and seeds contribute 2.5% of niacin intake for males, and 2.4% for females. In our study, plant foods make up almost half of the sources of riboflavin and niacin, not meat, milk, and eggs, which are rich in riboflavin, or liver, kidney, lean poultry, and nuts, which are rich in niacin. According to previous studies, riboflavin deficiency occurs in populations with diets lacking dairy products and meats, both major contributors of riboflavin in western diets[6]. The main sources of thiamine, riboflavin, and niacin in our study participants may reflect the dietary habits of Chinese adults. The 2016 edition of China's dietary guidelines for residents recommended improving dietary adequacy by increasing food diversity and eating more than 25 kinds of food each week. Food diversity is one of the safest and most effective measures to improve nutrient deficiencies[28,30,31]. All these trends suggest that promoting specific and varied foods, dairy products, some plant-based sources, and a moderate amount of meats, which are rich in thiamine, riboflavin, and niacin for subpopulations with inadequate intakes can result in diets with higher nutrient quality.

Our findings show that higher income and education levels and living in the south or living in a city is associated with higher niacin intakes among adults. Higher income is associated with higher riboflavin among females. It is recognized that micronutrient deficiencies are found more often in the lower and lower-middle income populations or countries[32-34], consistent with our results. Previous reports demonstrated that populations with higher education, incomes, and socio-economic status tended to consume higher-quality diets in America, Australian adolescents and adults, Belgian males, and Germans aged 14–80 years[35-40]. We observed that people of both sexes living in cities had higher intakes of riboflavin compared with those living in villages. The trend was similar for the intake of niacin. Both males and females living in a cities or suburbs had higher intakes of niacin than those living in villages, but we saw no disadvantage of adults living in villages vs. counties. Studies have shown that the intakes of riboflavin and niacin were

Table 4. Top 10 food sources of thiamine, riboflavin, and niacin among adults aged 18–64 years, CHNS 2015

Rank	Thiamine				Riboflavin				Niacin			
	Males		Females		Males		Females		Males		Females	
	Food group	%	Food group	%	Food group	%	Food group	%	Food group	%	Food group	%
1	Cereals and products	41.2	Cereals and products	40.8	Cereals and products	23.9	Cereals and products	22.5	Cereals and products	39.4	Cereals and products	38.7
2	Meat and products	24.9	Meat and products	23.2	Meat and products	19.4	Meat and products	17.2	Meat and products	22.9	Meat and products	21.5
3	Vegetables and products	11.0	Vegetables and products	11.6	Vegetables and products	16.6	Vegetables and products	17.2	Vegetables and products	8.5	Vegetables and products	9.2
4	Legumes and product	4.7	Legumes and product	5.0	Eggs and products	9.4	Eggs and products	10.2	Poultry and product	6.9	Poultry and product	6.7
5	Tubers, starches, and products	3.0	Tubers, starches, and products	3.3	Legumes and product	4.7	Milk and products	4.8	Fish, shellfish, and mollusks	4.5	Fish, shellfish, and mollusks	4.4
6	Eggs and products	2.9	Eggs and products	3.2	Fungi and algae	3.9	Legumes and product	4.8	Fast foods	3.0	Fast foods	3.3
7	Fast foods	2.3	Fruit and products	2.8	Condiments	3.5	Fungi and algae	4.3	Condiments	2.6	Fungi and algae	2.9
8	Fruit and products	1.7	Fast foods	2.6	Poultry and product	3.3	Condiments	3.5	Nuts and seeds	2.5	Condiments	2.6
9	Liquor and alcoholic beverages	1.5	Nuts and seeds	1.2	Milk and products	3.3	Poultry and product	2.9	Fungi and algae	2.5	Tubers, starches, and products	2.5
10	Poultry and product	1.2	Poultry and product	1.1	Fish, shellfish, and mollusks	3.1	Fish, shellfish, and mollusks	2.9	Tubers, starches, and products	2.2	Nuts and seeds	2.4

significantly higher in urban than in rural areas in Mexico, and the intake of riboflavin was similarly varied among women of childbearing age in Cambodia, consistent with our results[22,41]. These results suggest that the wealthier, better-educated groups are better positioned to consume more nutritious diets[35-42]. Our findings show that southern females had higher riboflavin compared with those living in the north, and southern adults had higher niacin intakes compared with those living in the north. This may be explained by southern adults having access to a greater diversity of foods, including riboflavin- and niacin-rich foods, than northern adults, due to the warmer weather in south. More studies are needed to identify the specific reasons. All these results emphasize the need for effective strategies for these disadvantaged subpopulations.

However, our results were complicated when it came to the association between the prevalence and B-vitamin intakes in both sexes. No risk factors were found in males and females in terms of the dietary intake of thiamine. Females with low income and living in the north are the disadvantaged group in terms of riboflavin intake, but there was no difference in males. Furthermore, the prevalence of inadequate thiamine and riboflavin intake was higher in males than in females, but the prevalence of inadequate niacin intake was higher in females than in males in this study. Studies in Australia and England show that diet quality is higher in women than in men, and women are more likely to choose healthier diets aligned with dietary guidelines than men[43,44]. In contrast, other studies demonstrate that women are thought to be the most disadvantaged groups in nutrient intakes[34]. It is not clear why differences were observed between males and females in our study. These disparate findings highlight that further studies should be conducted seek the reasons for this nutritional inequality in China.

Supplements and fortification, the fastest tools, will be an effective choice to control B-vitamin inadequacies in disadvantaged populations[28,45]. Studies show that the main dietary sources of thiamine, riboflavin, and niacin are fortified foods in the United States, Canada, and other industrialized countries[24,46-48]. Fortified foods have proven successful in the past in reducing clinical forms of thiamine and niacin deficiency and can be a powerful tool to prevent or correct inadequacies of a number of micronutrients[30,31,49]. All this evidence provides information to facilitate food fortification research and policies in China.

This study had several limitations. We did not collect information about losses of the three B-vitamins in the cleaning and cooking process. We only estimated the prevalence of those three vitamins based on dietary intake data and did not gather information on clinical measures of deficiency. Future surveys will study these aspects and can be used to better understand the nutrient intake of this population.

CONCLUSIONS

The study found variations in the intake of thiamine, riboflavin, and niacin by education, region, area of residence and income group. Findings from this study provide useful information on these three vitamins and suggest that further intervention programs and studies should focus on promoting healthful eating, micronutrient supplements, and fortified foods to improve the adequacy of intake of these three vitamins in disadvantaged subpopulations.

ETHICS APPROVAL

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was reviewed and approved by the Institutional Review Boards at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2015017, 18 August 2015).

COMPETING INTERESTS

None declared.

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