Original Article

Malnutrition in Relation with Dietary, Geographical, and Socioeconomic Factors among Older Chinese*

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Abstract

Objective Nutrition is closely related to the health of the elderly population. This study aimed to provide a comprehensive picture of the nutrition status of elderly Chinese and its related dietary, geographical, and socioeconomic factors.

Methods A total of 13,987 ≥ 60-year-old persons from the 2010–2013 Chinese National Nutrition and Health Survey were included to evaluate various aspects of malnutrition, including underweight, overweight or obesity, and micronutrient inadequacy.

Results Overall, the prevalence of obesity, overweight, and underweight was 12.4%, 34.8%, and 5.7%, respectively, with disparities both geographically and socioeconomically. The prevalence of underweight was higher among the older old (≥ 75 years), rural residents and those with low income, with low education status, and residing in undeveloped West areas. More than 75% of the elderly do not meet the Dietary Reference Intakes for vitamins A, B_1, B_2, and E, folate, calcium, selenium, potassium, biotin, and choline, with the prevalence of inadequate intake increasing with age for most nutrients. At the population level, the mean intakes of numerous food groups did not meet the recommendations by the Chinese Dietary Guideline.

Conclusions Obesity epidemic, inadequacy of micronutrient intake, and high prevalence of underweight and anemia in susceptible older people are the major nutrition challenges for the rapidly aging population in China.

Key words: Malnutrition; Older Chinese; Food intake; Nutrients; National survey

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INTRODUCTION

Malnutrition affects billions of people worldwide with a substantial economic burden related to risk of diseases and complications[1]. Certain types of malnutrition more likely depend on the local environment, lifestyle, and resources. Undernutrition leads to low weight-for-height (wasting), height-for-age (stunting), and weight-for-age (underweight). The opposite side of

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the malnutrition spectrum shows overweight or obesity occurs with the overconsumption of energy and certain nutrients and sometimes specific nutrient deficiencies despite excess intake, which is common in patients before bariatric surgery[2]. Malnutrition leads to serious physical and health issues, increasing the risk of death and particularly noncommunicable diseases in adults[3]. According to the last reports from the Global Burden of Disease Study 2017 (GBD2017), poor dietary habits alone accounted for nearly one in every five deaths[4]. Considering the importance of proper nutrition and healthy diets on public health, the elimination of all forms of malnutrition has been adopted as a primary objective in the United Nation Decade of Action on Nutrition 2016–2025. Among adults, those living in poverty, those with specific medical conditions, and older individuals have a high risk of malnutrition.

The elderly is mentioned as the population group requiring 'particular attention to their special needs'. In 2015, nearly one in four persons ≥ 60 years old in the world lived in China, and the proportion of ≥ 60-year-old Chinese in the total population is increasing from 17.9% (249 million) in 2018 to 25.3% (358 million) in 2030[5]. The rapid aging population with increasing life expectancy leads to a growing burden of disease for the country. Dietary risks are the leading risk factor of disease burden, accounting for 21.3% of disability-adjusted life years and 30.2% of deaths in 2017[4]. Considering the importance of diet and nutrition for public health, the China National Nutrition Plan 2017–2030, the first ever nutrition plan issued by the State Council of the People's Republic of China, has included 'senior nutrition improvement action' as one of the major initiatives of the country[6]. Up-to-date and reliable nationwide information on elderly dietary and nutritional status are required for relevant preventive actions against malnutrition.

Herein, we took advantage of more recent information collected by the Chinese Center for Disease Control and Prevention (CCDC) to provide for the first time a nationwide coverage of elderly malnutrition attributes, showing a comprehensive picture of the nutrition landscape, including undernutrition, overweight or obesity, micronutrient inadequacy, and food patterns. Our findings may help in refining nutrition challenges for the aging population and designing evidence-based policies and intervention to promote a healthy diet, which supports the reduction of all forms of malnutrition in China.

METHODS

Study Sample and Survey Design

This study's sample was extracted from the China National Nutrition and Healthy Survey (CNNHS), a national representative cross-sectional study conducted between 2010 and 2013 by the CCDC. The CNNHS aimed to assess the dietary, nutrition, and health status of Chinese, covering all 31 provinces, autonomous regions, and municipalities (excluding Taiwan, Hong Kong, and Macao). A stratified multistage cluster sampling method was conducted at 150 survey sites. According to the economic and social development status, the four types of survey sites were defined as large cities (n = 34), medium and small cities (n = 41), general rural areas (n = 45), and poor rural areas (n = 30). At each survey site, a multistage and probability sampling design was used in selecting participants. In the first stage, six neighborhood communities in urban or rural areas in administrative villages were selected from each surveillance point. In the second stage, 75 households were randomly selected from each neighborhood community or administrative village. A survey questionnaire and physical examination were conducted, and fasting blood was collected for all ≥ 18-year-old residents in the selected households, among which 30 families were randomly sampled for the dietary surveys, which involved 3-day 24-h diet recalls combined with food weighing.

The CCDC was responsible for the implementation of the national-level training for staff involved in the survey (Grade 1). Provincial-level training for staff at the surveillance points was performed by following a training plan developed by the project team (Grade 2). A face-to-face interview using a standard questionnaire was conducted at the participants' homes, and anthropometric measurements were taken at community health service centers, by trained staff, in both cases[7].

This study's inclusion criteria were as follows: ≥ 60-year-old participants with complete information on demographic and blood sample data. Dietary survey data were collected as a subsample of the study. Based on the dietary survey information, exclusion criteria were as follows: subjects with extreme energy intakes (< 800 kcal/day or > 4,800 kcal/day for male and < 500 kcal/day or > 4,000 kcal/day for female). The study protocol was approved by the ethical review committee of the CCDC (No. 2013[018]). Written informed consent was obtained from all participants.

Data Collection

Dietary assessment applies a combination of three consecutive 24-h diet recalls and a food inventory at the individual and household levels, respectively, over the same 3-day period. All foods remained after the last meal before the beginning of one 24-h dietary assessment, and all purchases and household production, as well as food inventory, at the end of one 24-h dietary assessment were weighted and recorded each day. Preparation waste was estimated when weighing was not possible, and actual household food consumption each day was calculated accordingly. All dietary information was collected by trained interviewers, who asked each household member to report all foods consumed at or away from home over the 24-hour period. Details of all food items consumed, including type and amount of foods and places of food preparation, were collected with the aid of food models and pictures. Based on the percentage of individual consumption of any food as a proportion of what the household food consumed, the amount of individual food consumption was estimated. The average of the three 24-h recall data was the dietary intake for each individual. Food intakes were aggregated into 27 food groups found in the Chinese Food Composition Tables, and then nutrient intakes were calculated accordingly[8] and benchmarked against the Chinese Dietary Reference Intakes (DRIs) of 2013[9].

According to national income statement released by the National Statistics Bureau in 2010, income was reported as three levels (low, middle, and high) (annual household income per capita): low (< 15,000 Chinese yuan (CNY) for urban residents, < 5,000 CNY for rural residents), middle (15,000–19,999 CNY for urban residents, 5,000–9,999 CNY for rural residents), and high (> 20,000 CNY for urban residents, > 10,000 CNY for rural residents)[10]. We also reported the effect of living condition based on the report of household composition. The three living conditions include 'living alone', 'living only with spouse', and 'living with others'. Geographical area were defined according to National Bureau of Statistics as East (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan), Central (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan), and West (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang).

Weight was measured without shoes and in light clothing, which was then reported to the nearest 0.1 kg. Height was determined to the nearest 0.1 cm without shoes. Body mass index (BMI) was calculated as weight measured in kilograms divided by the square of body height measured in meters. The cyanmethemoglobin method was used to measure for hemoglobin in peripheral venous blood samples[6]. According to the criteria of World Health Organization (WHO), anemia is defined as subjects with < 120 g/L hemoglobin level for female and < 130 g/L for male, adjusted by altitude[11].

Data Analysis

Mean and standard deviation were used to assess the food and nutrient intake distribution. The prevalence of malnutrition, including underweight (BMI < 18.5 kg/m^2), overweight (BMI ≥ 24.0 kg/m^2 and < 28.0 kg/m^2), and obesity (BMI ≥ 28.0 kg/m^2), was analyzed for province-level administration units based on the reported health standard of China[12] and adjusted by age- and gender-standardized values based on the China National Census 2010 to reflect the population status[13]. Nutrient intake inadequacy was expressed as the percentage of surveyed adults with an average dietary nutrient intake less than the DRI. Specifically, the estimated average requirement (EAR) was used to evaluate carbohydrate, protein, niacin and folate, calcium, iron, magnesium, phosphorus, zinc, selenium, and vitamins A, C, B_1, and B_2. Adequate intake was applied to evaluate intakes of nutrients whose EAR is not established, including vitamin E, biotin, choline, potassium, and sodium. Acceptable Macronutrient Distribution Range was used for fat intake, specific proposed levels for fiber, and Estimated Energy Requirement for total energy intake.

Nutrient intake status was evaluated for two age groups (60–74 y and ≥ 75 y), gender, and malnutrition status based on BMI (underweight, normal weight, overweight, and obesity). Food group intakes were analyzed by the malnutrition status groups. Adjusted mean and 95% confidence interval were obtained with the adjustment for age, gender, urban/rural residence, income level, education level, living condition, area of residence, physical activity, and total energy intake in the general linear model. *P* for trend was calculated by fitting the median intake value of each kind of food as the continuous variable in the adjusted model.

All data analyses were performed using Statistical Analysis System (SAS) for Windows V9.3 (SAS Institute, Cary, North Carolina, USA). $P < 0.05$ was considered statistically significant.

RESULTS

Table 1 shows the subject characteristics, stratified by malnutrition status. A total of 6,752 men (48.3%) and 7,235 women (51.7%) were included in the analysis, among which 82.9% were aged 60–74 y and 17.1% ≥ 75 y. Overall, based on BMI, 5.7% of the subjects were considered

Table 1. Prevalence of underweight, normal weight, overweight and obesity in demographic subgroups of Chinese elderly[1]

Item	Underweight *n* (%)	Normal weight *n* (%)	Overweight *n* (%)	Obesity *n* (%)	Total[2] *n* (%)	*P*-value[3]
National	797 (5.7)	6,596 (47.2)	4,866 (34.8)	1,728 (12.4)	13,987 (100.0)	
Age (years)						
60–74	564 (4.9)	5,394 (46.5)	4,134 (35.7)	1,497 (12.9)	11,589 (82.9)	< 0.0001
75–	233 (9.7)	1,202 (50.1)	732 (30.5)	231 (9.6)	2,398 (17.1)	
Gender						
Male	404 (6.0)	3,418 (50.6)	2,269 (33.6)	661 (9.8)	6,752 (48.3)	< 0.0001
Female	393 (5.4)	3,178 (43.9)	2,597 (35.9)	1,067 (14.8)	7,235 (51.7)	
Residence						
Urban	265 (3.4)	3,261 (41.8)	3,123 (40.0)	1,154 (14.8)	7,803 (55.8)	< 0.0001
Rural	532 (8.6)	3,335 (53.9)	1,743 (28.2)	574 (9.3)	6,184 (44.2)	
Income						
Low	454 (6.4)	3,398 (47.9)	2,380 (33.6)	857 (12.1)	7,089 (50.7)	
Middle	161 (6.1)	1,260 (48.1)	879 (33.5)	321 (12.3)	2,621 (18.7)	< 0.0001
High	156 (4.3)	1,642 (45.2)	1,365 (37.6)	472 (13.0)	3,635 (26.0)	
No response	26 (4.1)	296 (46.1)	242 (37.7)	78 (12.2)	642 (4.6)	
Education						
Primary or below	617 (7.2)	4,253 (49.7)	2,730 (31.9)	963 (11.3)	8,563 (61.2)	
Junior high school	124 (3.8)	1,437 (44.4)	1,196 (37.0)	478 (14.8)	3,235 (23.1)	< 0.0001
Senior high or above	56 (2.6)	906 (41.4)	940 (42.9)	287 (13.1)	2,189 (15.7)	
Living condition						
Living alone	30 (3.8)	378 (47.4)	295 (37.0)	94 (11.8)	797 (5.7)	
Living with spouse	335 (4.7)	3,213 (45.2)	2,608 (36.7)	946 (13.3)	7,102 (50.8)	< 0.0001
Living with others[4]	432 (7.1)	3,005 (49.4)	1,963 (32.2)	688 (11.3)	6,088 (43.5)	
Area						
East	275 (4.8)	2,459 (42.9)	2,184 (38.1)	809 (14.1)	5,727 (41.0)	
Central	255 (5.9)	2,116 (49.3)	1,421 (33.1)	503 (11.7)	4,295 (30.7)	< 0.0001
West	267 (6.7)	2,021 (51.0)	1,261 (31.8)	416 (10.5)	3,965 (28.4)	
Anemia status						
Anemic	191 (11.0)	931 (53.4)	483 (27.7)	140 (8.0)	1,745 (12.5)	< 0.0001
Non-anemic	606 (5.0)	5,665 (46.3)	4,383 (35.8)	1,588 (13.0)	12,242 (87.5)	

Note. [1]The percentages in columns 'underweight', 'normal weight', 'overweight', 'obesity' are row percentages. The percentages in column 'Total' are column percentages within each subgrouping factor. [2]Only subjects with both dietary intake data and hemoglobin/anemia records are included in this analysis. [3]*P*-values are two-sided from non-parametric chi-squared tests. [4]Living with others: others including sons/daughters/grandchildren/other relatives/caregivers.

underweight, 34.8% overweight, and 12.4% obese. The prevalence of underweight elderly was higher among older old (≥ 75 y), rural residents, and those with low income, low education status, living with others rather than with spouse, and residing in provinces in the West area. Correspondingly, the prevalence of the overweight and obese was higher among younger old (60–74 y), females, urban residents, and those with high income, higher education status, living with spouse, and residing in the East. Anemia had an overall prevalence of 12.5% in the elderly subjects, which almost doubled (191/797, 24.0%) among those who were underweight.

Table 2 presents the intakes of energy, macronutrients, and micronutrients, subgrouped by age and gender. Besides the energy imbalance-related underweight and overweight/obesity, micronutrient deficiency is another important component of malnutrition. Table 3 examines the prevalence of inadequate micronutrient intakes in the studied Chinese elderly sample, with subgroup comparisons by age and gender. The intake of numerous micronutrients was inadequate: > 75.0%

Table 2. Mean nutrient intakes per capita in Chinese elderly with different age, gender[1]

Nutrients	Total		Age (years)					Gender				
			60–74		75–		*P*-value[2]	Male		Female		*P*-value[2]
	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Energy (kcal)	1848.8	634.9	1889.1	637.7	1653.8	583.3	< 0.0001	2005.9	658.6	1702.1	574.3	< 0.0001
Fat (g)	66.9	34.8	68.3	35.2	60.4	32.2	< 0.0001	72.3	36.7	61.9	32.1	< 0.0001
Fat (% En)	32.5	11.6	32.4	11.5	32.7	12.0	0.58	32.4	11.6	32.6	11.7	0.27
Protein (g)	55.9	22.8	57.0	22.8	50.9	22.0	< 0.0001	60.1	23.4	52.0	21.5	< 0.0001
Protein (% En)	12.3	3.3	12.2	3.3	12.4	3.4	0.006	12.2	3.2	12.4	3.4	0.0064
Carbohydrate (g)	257.2	106.5	263.0	107.4	228.8	97.0	< 0.0001	277.0	111.3	238.6	98.3	< 0.0001
Carbohydrate (% En)	55.8	12.1	55.8	12.0	55.5	12.3	0.3368	55.4	12.2	56.1	11.9	0.0025
Fiber	10.0	6.4	10.3	6.5	8.8	5.6	< 0.0001	10.6	6.6	9.5	6.1	< 0.0001
Vit A (μg RAE)	402.0	452.4	403.0	440.0	396.8	508.3	0.02	420.3	469.5	384.8	435.1	< 0.0001
Vit C (mg)	73.1	51.7	74.6	51.9	65.9	50.3	< 0.0001	76.2	53.8	70.3	49.4	< 0.0001
Vit B_1 (mg)	0.8	0.4	0.8	0.4	0.7	0.3	< 0.0001	0.8	0.4	0.7	0.3	< 0.0001
Vit B_2 (mg)	0.7	0.3	0.7	0.3	0.6	0.3	< 0.0001	0.7	0.3	0.6	0.3	< 0.0001
Niacin (mg NE)	12.1	6.1	12.4	6.2	10.9	5.5	< 0.0001	13.1	6.4	11.2	5.6	< 0.0001
Folate (μg DFE)	134.7	82.4	136.7	82.3	125.4	82.0	< 0.0001	143.3	86.5	126.8	77.5	< 0.0001
Biotin (mg)	27.0	16.4	27.6	16.6	24.0	14.8	< 0.0001	29.2	18.0	25.0	14.3	< 0.0001
Vit E (mg α-TE)	7.7	6.9	7.8	7.1	7.0	6.3	< 0.0001	8.3	7.5	7.1	6.3	< 0.0001
Choline (mg)	182.0	81.6	184.8	81.9	168.9	79.2	< 0.0001	196.2	85.0	168.8	76.0	< 0.0001
Ca (mg)	348.3	203.9	351.2	204.6	333.8	199.9	< 0.0001	367.8	214.0	330.0	192.3	< 0.0001
Fe (mg)	18.9	8.9	19.3	8.9	17.0	8.9	< 0.0001	20.3	9.5	17.7	8.2	< 0.0001
Mg (mg)	256.4	106.0	261.9	106.3	230.0	100.2	< 0.0001	274.2	109.9	239.8	99.4	< 0.0001
P (mg)	840.8	316.6	857.2	316.5	761.5	305.3	< 0.0001	902.6	327.6	783.2	294.7	< 0.0001
Zn (mg)	9.1	3.7	9.3	3.7	8.3	3.6	< 0.0001	9.9	3.9	8.5	3.4	< 0.0001
Se (μg)	38.4	22.9	39.2	23.3	34.7	20.3	< 0.0001	41.3	23.2	35.7	22.2	< 0.0001
K (mg)	1454.1	646.4	1482.6	648.1	1316.1	620.1	< 0.0001	1548.4	681.6	1366.0	598.5	< 0.0001
Na (mg)	5030.1	5081.2	5126.6	5342.4	4563.7	3521.9	< 0.0001	5368.2	4022.9	4714.5	5882.7	< 0.0001

Note. [1]Abbreviations: RAE: retinol-activity equivalent; NE: niacin equivalent; DFE: dietary folate equivalent; α-TE: α-tocopherol equivalent. [2]*P*-values are two-sided from non-parametric chi-squared tests.

of the elderly did not meet the Chinese DRIs for 10 out of the 17 micronutrients examined (vitamin A, vitamin B_1, vitamin B_2, folate, vitamin E, calcium, selenium, potassium, biotin, and choline). In general, the prevalence of dietary intake inadequacy for most nutrients increased with age. Female intakes were more inadequate in particular for magnesium, phosphorus, and selenium, while male intakes were more likely inadequate for zinc.

Then, we studied the food consumption patterns among subjects with different nutritional statuses. Table 4 shows the adjusted means of intakes for 27 major food groups across the 4 BMI categories, with adjustment for age, gender, urban/rural residence, income level, education level, living condition, area of residence, physical activity level, and total energy intake. Compared with underweight subjects, overweight and obese subjects consumed a significantly lower amount of rice, dark-colored vegetables, pork, animal viscera, poultry, and animal oils and a higher amount of wheat products, coarse cereals, and vegetable oils. It is worth noting that the population mean intakes of many food groups did not meet the Chinese Dietary Guideline recommendations regardless of their nutritional status. The biggest gaps exist in the food groups of dairy and fruits, with the recommendation of 300 g/d for dairy and 200–350 g/d for fruits in the Chinese Dietary Guideline. Such population-wide dietary patterns partly explained the numerous key nutrient inadequacies.

DISCUSSION

Using data from the 2010–2013 CNNHS, we provided herein a comprehensive analysis of the nutritional status of the older adults, the findings of which provide an important resource for nutrition researchers and policymakers that could be used in complementing or implementing national policies for healthy aging. Furthermore, it also provides more information for other countries that experience a similar social economic and demographic transition.

Fighting Obesity as the First Nutrition Challenge

We initially explored the prevalence of three

Table 3. Percentage of Chinese elderly with inadequate nutrient intakes among age and gender subgroups[1]

Nutrients	Total (%)	Age (years)			Gender		
		60–74 (%)	75– (%)	*P*-value[2]	Male (%)	Female (%)	*P*-value[2]
Vit A (μg RAE)	77.3	76.7	80.3	0.0001	78.5	76.1	0.0007
Vit C (mg)	69.0	67.8	74.7	< 0.0001	66.8	71.0	< 0.0001
Vit B_1 (mg)	83.9	82.6	90.3	< 0.0001	84.9	83.0	0.0023
Vit B_2 (mg)	91.5	91.1	93.3	0.0005	92.7	90.3	< 0.0001
Niacin (mg NE)	43.5	42.6	47.7	< 0.0001	45.1	42.0	0.0002
Folate (μg DFE)	96.5	96.4	96.9	0.29	95.9	97.1	0.0001
Biotin (mg)	86.3	85.5	90.0	< 0.0001	83.4	89.0	< 0.0001
Vit E (mg α-TE)	90.5	89.9	93.5	< 0.0001	88.3	92.6	< 0.0001
Choline (mg)	99.4	99.3	99.7	0.02	99.7	99.1	< 0.0001
Ca (mg)	96.9	96.9	96.9	0.89	96.1	97.6	< 0.0001
Fe (mg)	4.0	3.1	8.3	< 0.0001	2.1	5.7	< 0.0001
Mg (mg)	64.1	62.5	71.6	< 0.0001	57.3	70.4	< 0.0001
P (mg)	21.2	19.3	30.4	< 0.0001	14.8	27.3	< 0.0001
Zn (mg)	43.3	41.0	54.7	< 0.0001	63.3	24.7	< 0.0001
Se (μg)	78.5	77.5	83.2	< 0.0001	73.6	83.1	< 0.0001
K (mg)	83.8	82.8	88.7	< 0.0001	80.3	87.0	< 0.0001
Na (mg)	4.1	3.9	5.1	0.01	3.4	4.8	< 0.0001

Note. [1]Abbreviations: RAE: retinol-activity equivalent; NE: niacin equivalent; DFE: dietary folate equivalent; α-TE: α-tocopherol equivalent. [2]*P*-values are two-sided from non-parametric chi-squared tests.

malnutrition indicators, underweight, overweight, and obesity, and their relation to socioeconomic and geographical factors in China. BMI is rising in most countries, and urbanization is one of the most important drivers as diet and lifestyle in cities lead to higher adiposity. Our study showed that this is also true in China with the older population. According to the BMI classification for Chinese adults, both overweight and obesity culminate at -56% in urban elderly *vs.* -44% in rural elderly. A few additional factors, namely, lower age, higher incomes, higher education, female gender, and living with spouse and in the wealthiest Eastern area, had a noticeable impact on the increase of overweight and obesity, which concurred with other smaller studies conducted in different provinces[14-16].

Recently, the NCD Risk Factor Collaboration analyzed the worldwide evolution of adult BMI trends from 1985 to 2017. While worldwide urbanization increased from 41% to 55%, a faster

Table 4. Adjusted means of food intakes in Chinese elderly with different nutritional status[1]

Item	Underweight			Normal			Overweight			Obesity			*P*-trend
	Mean	95% *CI*		Mean	95% *CI*		Mean	95% *CI*		Mean	95% *CI*		
Rice (g/d)	183.4	173.3	193.6	150.8	144.8	156.8	129.9	123.6	136.2	117.3	109.4	125.1	< 0.0001
Wheat (g/d)	88.7	79.6	97.9	111.3	105.9	116.8	126.8	121.1	132.5	141.4	134.2	148.5	< 0.0001
Coarse cereals (g/d)	15.0	11.5	18.4	17.2	15.2	19.2	20.0	17.9	22.2	20.6	17.9	23.2	< 0.0001
Tubers (g/d)	27.7	23.3	32.0	28.0	25.4	30.6	29.2	26.5	32.0	29.7	26.3	33.1	0.13
Legumes (g/d)	2.8	1.5	4.0	3.4	2.7	4.2	3.9	3.2	4.7	3.8	2.8	4.8	0.04
Soybean products (g/d)	9.9	8.3	11.6	10.4	9.4	11.3	10.1	9.1	11.1	10.6	9.4	11.9	0.71
Dark color vegetables (g/d)	84.6	77.5	91.6	80.6	76.5	84.8	74.3	69.9	78.7	67.1	61.6	72.6	< 0.0001
Light color vegetables (g/d)	145.8	135.8	155.8	152.0	146.1	157.9	152.8	146.6	159.1	154.5	146.8	162.3	0.17
Salted vegetables (g/d)	3.1	2.1	4.2	2.9	2.3	3.5	2.8	2.1	3.4	2.8	2.0	3.6	0.53
Fruits (g/d)	42.9	35.9	50.0	44.2	40.0	48.3	47.3	42.9	51.7	45.1	39.6	50.5	0.19
Nuts (g/d)	3.8	2.8	4.8	3.9	3.3	4.5	4.3	3.7	4.9	4.5	3.7	5.3	0.03
Pork (g/d)	51.8	47.6	56.0	51.1	48.6	53.6	49.3	46.7	51.9	46.8	43.6	50.1	0.001
Other livestock meats (g/d)	5.3	3.6	7.1	5.6	4.6	6.6	6.0	4.9	7.0	6.9	5.6	8.3	0.03
Animal viscera (g/d)	2.9	2.1	3.7	1.6	1.1	2.1	1.1	0.6	1.6	1.2	0.5	1.8	< 0.0001
Poultry (g/d)	10.8	8.7	12.9	10.0	8.7	11.2	9.3	8.0	10.6	7.6	5.9	9.2	0.0004
Milk (g/d)	43.3	36.4	50.1	42.3	38.3	46.3	47.6	43.4	51.8	45.2	39.9	50.5	0.02
Eggs (g/d)	23.3	21.1	25.6	24.0	22.6	25.3	25.6	24.2	27.0	23.8	22.1	25.6	0.12
Fish (g/d)	21.3	17.9	24.6	19.9	17.9	21.8	19.5	17.4	21.6	17.0	14.4	19.6	0.01
Vegetable oils (g/d)	30.2	28.2	32.1	31.9	30.8	33.1	33.9	32.6	35.1	34.2	32.7	35.8	< 0.0001
Animal oils (g/d)	5.8	4.9	6.7	4.1	3.5	4.6	3.0	2.5	3.6	2.7	2.0	3.4	< 0.0001
Cakes (g/d)	7.7	5.7	9.8	9.0	7.8	10.2	8.4	7.1	9.7	9.2	7.6	10.8	0.72
Sugar (g/d)	4.3	3.0	5.7	5.5	4.7	6.3	5.5	4.7	6.4	5.8	4.8	6.8	0.12
Salt (g/d)	8.8	7.9	9.7	8.8	8.3	9.4	9.1	8.5	9.7	8.9	8.2	9.7	0.37
Condiments (g/d)	15.6	13.6	17.7	14.3	13.1	15.5	14.5	13.2	15.8	14.6	13.0	16.2	0.83
Others (g/d)	7.8	5.6	10.1	8.8	7.4	10.1	9.2	7.8	10.6	10.6	8.8	12.3	0.01
Soft drinks (mL/d)	20.0	10.9	29.2	18.7	13.3	24.1	19.1	13.4	24.8	21.9	14.8	29.1	0.49
Alcoholic beverages (mL/d)	1.4	0.4	2.4	2.2	1.6	2.7	1.4	0.8	2.0	1.2	0.5	2.0	0.01

Note [1]Mean and 95% *CI* are calculated from general linear model with adjustment for age, gender, urban/rural residence, income level, education level, living condition, area of residence, physical activity, and total energy intake. Abbreviations: *CI*: confidence interval. [2]*P*-trend is calculated from general linear model using the median BMI values in each category as continuous variables.

rural BMI rise explained most of the current global obesity epidemic[17]. Therefore, the authors observed a gap closure in BMI between urban and rural areas in many regions worldwide, including Central Asia, which was not so obvious in our study and could reflect the age difference of the population and methodology used. However, between 1991 and 2009, the overweight and obesity prevalence observed in the Chinese adult population had grown, which was faster in rural (from 26.7% to 38.3%) than urban (from 36.1% to 40.1%) areas, supporting a closure in the gap in BMI between them[18]. The slower speed observed in the elderly category may reflect age-related behavior differences regarding daily work, domestic activities, and/or eating behavior. Therefore, we also suggest that the so-called urbanization of rural life[19] has impacted the evolution of BMI in China, which embraces the impact of globally better infrastructures, less energy expenditure associated to agricultural workload, and higher incomes, allowing access to calorie-dense processed food. Altogether, the current rural lifestyle could contribute to the higher prevalence of overweight and obesity in China as supported by others in a single province or some provinces and confirmed herein at the national level.

Promising Reduction in Underweight and Anemia Status

Conversely, we observed a low overall prevalence of underweight elderly (5.7%) but higher values in the anemic population (11.0%), older old (9.7%), rural area (8.6%), and people with low education (7.2%), living with others (7.1%), with low income (6.4%), or living in the Western area (6.7%). Such low numbers are expected in industrialized countries as China with a booming economy and existing history of a program that tackles undernutrition especially in rural areas. Therefore, those underweight individuals may represent (i) some of the poorest with social disadvantages and exposed to food insecurity or a lack of access to sufficient and affordable food and/or (ii) those with age-related chronic diseases and malnutrition features. For instance, numerous studies have identified mental health disorders[20], being frail with poor mobility and/or lacking muscle strength[21], and having visual impairment[22] as a single risk factor or multiple risk factors for malnutrition. Presumably, those older individuals with one or multiple comorbidities in addition to other sociodemographic factors have reduced food preparation and cooking skills, which ultimately contribute to their undernutrition status.

Anemia in the elderly is known to be more prevalent in the oldest old, affecting the overall morbidity and mortality[23]. We found that 12.5% of anemic Chinese were > 60 years old, reflecting a great achievement of the local prevention policies with a steady decrease since the past two to three decades[24]. According to the WHO classifications, anemia has a mild public health significance in China as many other developed countries. By comparison, in the US National Health and Nutrition Examination Survey (2013–2016), anemia prevalence was 14.1% for men and 10.2% for women aged 65 and older[25]. As a global trend, a systematic review analyzed a pooled sample of ≥ 65-year-old 85,409 subjects from 34 cohorts in developed countries and reported a similar value, with a weighted mean prevalence of 12% anemia in community-living elderly[26].

Iron deficiency is the main cause of anemia in developing countries. However, in this study, we find that the average intake of iron is near 19.0 mg per capita and the percentage of elderly people with inadequate intake of iron is low. More analysis showed that Chinese dietary iron is mainly from plant foods, approximately 58% of dietary iron from cereals, while only about 15% from animal foods. The bioavailability of plant source iron is much lower than that of heme iron from animal foods. So, considering the relatively high prevalence of anemia among elderly people, increasing the appropriate heme iron intake from animal foods is still important. Except iron deficiency, other nutritional factors are important but have received less attention. In European elderly individuals, anemia was specifically associated with folate deficiency[27]. In Chinese adults, despite normal iron intake, inadequate riboflavin (vitamin B_2) intake is common, and it increases the risk of anemia presumably because it limits iron utilization[28,29]. We observed > 95% and > 90% prevalence of inadequate intake of folate and riboflavin, respectively, independent of gender or BMI categories in old Chinese. Therefore, further anemia reduction could be achieved by improving folate and riboflavin intake and promoting intake of green vegetables and dairy foods or alternatively fortified and enriched products or supplements.

Existence of Geographical Disparities

We presented a geographical variation in malnutrition conditions. The prevalence of overweight and obesity in the Eastern regions was higher than that in the Western regions, but the

prevalence of underweight was lower. Such inter-regional differences could be due to a combination of economic development status and food culture and cooking habits[30,31,32]. The spatial pattern of overweight and obesity was also similar to the geographic variation of cardiovascular disease incidences, including ischemic heart disease[33], stroke[34], and hypertension[35]. Geographically based strategies may be helpful in managing overweight and obesity as part of the effort for cardiovascular disease prevention and control. These results provide an important reference for the development of targeted nutrition policies, recommendations, education, and interventions, which will be the key for success at addressing nutrition challenges and enabling healthy aging.

Suboptimal Diet as an Important Nutritional Challenge

The present study also provided a comprehensive picture of the nutrient and food intake of elderly Chinese. We found a high prevalence of inadequate intake (> 75%) for more than half of the micronutrients examined, that is, vitamins A, B_1, and B_2, folate, biotin, choline, calcium, selenium, and potassium, and such inadequacies were independent of age, gender or BMI categories, showing that micronutrient inadequacy remains an important nutritional problem for Chinese elderly and may reflect poor dietary behavior with less nutrient-dense food. This may represent a major nutrition goal for the aging population to cope with their higher nutritional requirements and deal with issues like poor oral health[36], appetite loss[37], and/or altered digestive functions[38]. Similarly, the elderly in Western countries are facing the same issue but with different micronutrients, which may reflect differences in their diets and/or national recommendations. In a systematic review pooling together 37 studies on the habitual dietary intake of community-living 65 years and above, 6 micronutrients of the 20 studied (vitamins D, B_1, and B_2, calcium, magnesium, and selenium) were at risk of inadequate intake, which was suggested to be a public health concern[39]. As our study did not include vitamin D, four among the other five micronutrients (i.e., vitamins B_1 and B_2, calcium, and selenium) were also of similar concern in China. Sufficient dietary nutrient supply relies on a high-quality diet, and suboptimal diet is a leading risk factor for disabilities and death[4,24,33]. We noticed that overweight and obese elderly had significantly more wheat, coarse cereals, and vegetable oils and less rice, vegetables, animal oils, pork, and poultry than the lower BMI categories. The observed food consumption patterns may reflect the multilevel heterogeneity among Chinese provinces, where many conventional socioeconomic factors interweave with more complex factors like geography, cultural heritage, Western influences, and cooking style to impact eating behaviors. We also evaluated the food intake quality based on adherence to the Chinese Dietary Guideline. The main features of the unbalanced Chinese diets consisted of low intake in nutrient-dense food groups, such as fruits, dairy, soy and nuts, eggs, fish, and seafood, whereas consumption of fat- and sodium-contributing food groups, such as cooking oil and salt, were higher than recommended. Cohort data have shown that suboptimal diet was associated with a significant increase in the risk of diabetes and cardiovascular diseases (CVD) in China[4,16,24,34,35,40]. Considering the global burden of chronic diseases, promoting healthy eating behaviors and reducing population exposure to unbalanced diets should be considered as a priority for Chinese public health policymakers.

Strengths and Limitations of the Study

To our knowledge, this study is the largest, most up-to-date nationwide survey in China with a focus on the elderly. The detailed examination of food and nutrient intakes also allowed a comprehensive understanding of the dietary patterns of this special population. However, this study has several limitations. Firstly, the participants of this study were recruited from the community, while those living in nursing homes with more severe malnutrition problems were not included. Secondly, our approach to assess energy and nutrient intake through three consecutive 24-h recalls may not reflect the long-term food intake status, especially for seasonal foods. Finally, except participants with extreme energy intakes, we did not exclude community-living participants with presumably major age-associated chronic diseases. Some of those diseases related to nutrition are particularly relevant to aging populations with a high prevalence of common chronic diseases, such as diabetes and CVD, or geriatric syndromes, such as frailty, sarcopenia, and cognitive impairment. This work is currently ongoing and will be reported soon elsewhere.

CONCLUSIONS

Fighting malnutrition is the major challenge for

the rapidly aging population in China. While an important decline has been observed, the prevalence of anemia and underweight is still high among the more susceptible subgroups, such as rural elderly and older old residents. Low intake of nutrient-dense food groups, such as fruits, dairy, soy and nuts, eggs, and fish and seafood, and high intake of high-fat and sodium-contributing food groups, such as cooking oil and salt, lead to micronutrient inadequacy and high risk of chronic diseases, which remain to be the important nutritional problems for Chinese elderly. This study provides important reference for policymakers to support the China National Nutrition Plan 2017–2030, promoting that public health authorities should provide further improvement with targeted approaches.

AUTHOR CONTRIBUTIONS

The authors' contributions were as follows: ZHANG Jian, project design, quality control, and manuscript drafting; SONG Peng Kun, working-site questionnaire, data clearance, and analysis; ZHAO Li Yun, project design and organization in working-site; SUN Ye, YU Kai, and YIN Jing, data analysis and manuscript drafting; PANG Shao Jie, LIU Zhen, and LI Cheng, data clearance and analysis; MAN Qing Qing, biochemical measurements; HE Li, quality control and manuscript drafting; ARIGONI Fabrizio and BOSCO Nabil, manuscript drafting; DING Gang Qiang, project design and manuscript drafting; and ZHAO Wen Hua project design, quality control, and approval of the final version.

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CONFLICTS OF INTEREST

The authors declare no competing interests.

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