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INCREASED ENERGY INTAKE AND A SHIFT TOWARDS HIGH-FAT, NON-STAPLE HIGH-CARBOHYDRATE FOODS AMONGST CHINA'S OLDER ADULTS, 1991-2009

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Abstract: *Objective:* We examined trends from 1991- 2009 in total energy intake and food group intake, and examine whether shifts varied by age or generation. *Design:* Longitudinal time series (1991, 1993, 1997, 2000, 2004, 2006, 2009). *Setting:* Nine provinces in China. *Participants:* Older Chinese aged ≥60 years (n=5,068) from the China Health and Nutrition Survey from 1991-2009. *Methods:* Using three 24-hour recalls and a household food inventory collected over three consecutive days, the top twenty food group contributors to total energy intake from 1991- 2009 were identified, and the mean kilocalorie (kcal) difference between 1991 and 2009 for each food group was ranked. The top twenty food group contributors to total energy intake from 1991- 2009 were identified, and the mean kilocalorie (kcal) difference between 1991 and 2009 for each food group was ranked. Linear regression was used to examine changes in mean calorie intake of food groups between 1991 and 2009, adjusting for age, sex, and region. In addition, we examined changes in the mean kcal per capita intake to examine shifts by age group and generation. *Results:* Mean total energy intake increased significantly among older Chinese adults from 1379 total kilocalories in 1991 to 1463 kilocalories in 2009 ($p< 0.001$). Most food groups showed a significant increase in intake from 1991 to 2009, with plant oil, wheat buns, and wheat noodles showing the greatest increase. At the same age, more recent generations had more energy intake than earlier generations. An aging effect was observed, with energy intake decreasing with age, although more recent generations showed a smaller decrease in energy intake with aging. *Conclusion:* Older Chinese adults in recent generations show an increase in total calorie intake compared to older Chinese of earlier generations, paired with a less significant decrease in calorie intake as they age. Increased consumption of high-fat, non-staple high-carbohydrate foods such as plant oil and wheat buns suggests that diet quality of older Chinese adults is becoming less healthful in recent years.

Key words: Older adults, China, food groups, diet, trends, generation, aging, Asia.

Introduction

Over the past fifty years, the age structure of China's population has grown significantly older, in part due to a dramatic decline in the birth rate stemming from the One Child Policy implemented in 1979 (1). There are currently 178 million people in China over 60 years of age, making up 13% of China's population, with this population expected to comprise nearly 30% by the year 2050 (1). This demographic shift has occurred concurrently with the nutrition transition, which has been characterized by a rapid shift to increased edible oils and animal source foods, decreased physical activity, and increased overweight and obesity (2, 3). However, although the nutrition transition and its effects on chronic disease rates have been well documented in China (2, 4-6), few studies have explored how diets amongst the elderly have changed over recent decades. In addition, most previous work has focused on Hong Kong or Shanghai (7-11), while the dietary pattern of the Chinese elderly in across mainland China has been scarcely studied.

Previous research shows that for some elderly Chinese populations, increasing energy intake may pose a rising problem, while for other groups, malnutrition remains a significant threat. For example, while one study found an overall increase in energy intake over time among the Chinese elderly, especially from fats and proteins (12), another study conducted in 2000 showed that protein calorie malnutrition was observed in Hong Kong's long term care institutions (13). Similarly, consumption of food groups by Chinese elders has also changed over time, shown by the increase of fruit consumers from 11%

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in 1991 to 32.5% in 2009 (14).

Despite this increase in macronutrients, the Chinese elderly still experiences deficiencies in various vitamins and micronutrients such as calcium and potassium, and most still do not meet recommendations for fruits and vegetables (14). In addition, studies of older adults in other populations have shown that energy intake declines with age; however, to our knowledge, no studies have examined whether older Chinese adults also experience decreased energy intake as they age (25, 26, 31). Understanding these diet changes and energy declines amongst older adults in China is important for preventing nutrition-related diseases, such as metabolic syndrome, hypertension, and sarcopenia (13, 15, 16), which are common amongst elderly, as well as understanding dietary determinants of more recent chronic conditions, such as obesity and diabetes.

Previous studies leave a need for a better understanding of broad dietary shifts among older Chinese during this period of rapid economic and demographic transition. No studies to our knowledge have compared the changes over time in earlier versus more recent generations, nor covered populations across urban and rural areas or longer time periods. One key question that remains is whether more recent generations show these similar age-related declines or show higher energy intake with increasing age when compared to earlier generations.

We used the China Health and Nutrition Survey (CHNS), a study from 1991 to 2009 in order to 1) examine trends in total daily energy intake and top food groups of Chinese elderly adults at each time point and 2) identify the changes in energy intake associated with aging, and compare these changes between more recent and earlier generations.

Methods

The China Health and Nutrition Survey (CHNS) was conducted in 1991, 1993, 1997, 2000, 2004, 2006, and 2009 in nine provinces of China (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) among non-institutionalized free living residents. Liaoning province was unable to participate in CHNS in 1997, but participated in all other waves. Heilongjian province was added in 1997. The CHNS includes a diverse range of rural, urban, and suburban areas that varied greatly in geography, economic development, public resources, and health indicators such as diet, physical activity, urbanization, and economic change (6, 17). Using the stratified probability sampling strategy, two cities per province (usually a large provincial capital and a small low-income city) and four counties (one high, one low, and two middle income counties) were selected for the study. More specifically, two urban and two suburban communities were randomly selected within cities, while one large-city community and three rural villages were randomly selected within counties. Twenty households within each community were randomly chosen for participation in the CHNS. The study population of the CHNS consists of free-living community members. The study includes a total of 4,400 households with a total of 26,000 individuals of all ages in nine provinces. The study sample was drawn using a multistage, random cluster process. From the total sample, survey data from participants over the age of 60 were included in this study.

The food group analyses include 5,068 unique individuals age 60 and older with repeated observations over 7 surveys. Out of the 5,068 unique individuals, 1,652 participated in 1 survey, 1,179 participated in 2 surveys, 946 participated in 3 surveys, 611 participated in 4 surveys, 398 participated in 5 surveys, 178 participated in 6 surveys, and 104 participated in 7 surveys, for a total of 13,078 observations pooled across 7 surveys. For the age and generation analyses, we included adults age 55 and older in order to be able to examine the most age groups across generations and survey years. Of the 6,811 unique individuals age 55 and older, 2,103 participated in 1 survey, 1,514 participated in 2 surveys, 1,272 participated in 3 surveys, 800 participated in 4 surveys, 571 participated in 5 surveys, 321 participated in 6 surveys, and 230 participated in 7 surveys, for a total of 18,538 observations pooled across 7 surveys

Dietary assessment and food grouping

In each wave, to acquire individual dietary intake data, three 24-hour recalls and a household food inventory were collected over the same period, during three consecutive days. The three consecutive days were randomly allocated to start from Monday to Sunday. For the household food inventory, all available foods at the household (purchased, stored or home produced) were measured on daily basis with Chinese balance (1991-1997) or digital scales (2000-2009). The changes in the household food inventory, as well as the wastage, were used to estimate total household food consumption. For the 24-hour recall, trained interviewers recorded the amounts, type of meal and place of consumption of all food items consumed away from home and consumed at home. For dishes prepared at home, the amount of each dish was estimated from the household food inventory, based on the proportion of each dished the person reported to have consumed (12, 18).

The food groups included in our analysis were based on a food grouping system developed specifically for the CHNS by researchers from UNC-CH and the National Institute of Nutrition and Food Safety, Chinese CDC (18). This system separates foods into nutritional and behavioral meaningful food groups. The food grouping system is described in greater detail in Appendix 1.

Demographic and anthropometric variables

Participants completed demographic questionnaires about socio-demographic background and health related behaviors (i.e. smoking, alcohol consumption). Weight and height measurements were taken by trained interviewers who followed standardized procedures using calibrated equipment (SECA 880 scales and SECA 206 wall-mounted metal tapes). Body mass index (BMI) was calculated as kg/m2. Level of urbanization was determined by an urbanicity scale that was developed for the CHNS, it includes components such as population density, economic activity, transportation infrastructure, sanitation, housing types, etc. (19).

Income and urbanicity were stratified by tertiles into low, medium, and high groups based on value distributions of 2009, in order to compare them over time. Smoking was defined as having smoked in the past year, and alcohol was defined as consuming an alcoholic beverage over the past year.

Statistical Analysis

All analyses were conducted using Stata (version 12, 2011, StataCorp, College Station, TX). The top twenty food group contributors to total energy intake were identified, and ranked by magnitude of change in intake between 1991 and 2009. The top twenty food group contributors were ranked by mean calorie intake from individual food groups. For example, in 1991, the top most-consumed food groups among our study population consisted of rice (with a mean of 380 kcal per capita) and wheat flour (211 kcal per capita), making rice the top food group contributor and wheat flour second (Table 2). Linear regression was used to examine changes in mean calorie intake of food groups between 1991 and 2009, adjusting for age, sex, and region. Due to the non-independence of some individuals who were included in multiple waves, for all analyses, we clustered at the individual level using the robust variance estimator. A sensitivity analysis was conducted to exclude non-plausible reports of either under-reporting or over-reporting. Specifically, we excluded data from subjects who reported total caloric values outside the range of estimated energy requirements of 500 calories to 3500 calories (20). A total of 224 subjects were excluded from this study due to non-plausible reports. We considered p-values under < 0.01 to be statistically significant.

To examine the effect of age and generation on total energy intake, participants were separated into 8 generation groups based on their age group during each wave. For example, generation five (born between 1932-1939) was in the age groups of 55-59 in 1991, 60-64 in 1997, 65-69 in 2004, and 70-74 in 2009. The years born and the age ranges do not match up exactly due to the administration of the survey in uneven intervals. We only used the 1991, 1997, 2004, and 2009 survey years when designing the generation analysis. As a result, while the age ranges are 5 years apart, the gaps between survey years vary between 5 to 7 years apart. For example, we assume that the 60-64 years in 1991 and the 65-69 years in 1997 belong to the same generation, while in actuality, the first were born between 1927-1931 and the second between 1928-1932. As a result, this discrepancy exists for each generation, and this generation classification serves only as a rough estimate.

We used a multiple linear regression model with total energy intake as the dependent variable and age group and generations as the independent variables, adjusting for age group, region, and gender. Age groups were defined as 55-59, 60-64, 65-69, 70-74, and 75 and older. The region variable classified the nine provinces of the study under "north", "central", and "south" based on its geographic location. Based on the multiple linear regression, we estimated the predicted mean total energy intake for each age and generation group using the margins command in Stata. Interactions between age groups and generation were tested using a Wald "chunk" test. The Wald "chunk" test was used to investigate the joint significance of interaction between variables in the model (21). Interactions between age groups and generation were tested using the Wald "chunk" test to determine if changes in mean calorie intake over time differed by age-generation, with $p< 0.05$ indicating significance. Interactions by gender and region were also investigated using the same method.

Results

Socio-demographics of the sample are presented in Table 1. Of the sample, 52.7% were female. The proportion of individuals with a BMI ≥ 25 increased over time, from 17.2% in 1991 to 29.8% in 2009 (32). Income and urbanicity increased from 1991 to 2009.

Older Chinese adults showed substantial changes in total energy intake, as well as in total energy coming from certain individual food groups, from 1991 to 2009. Mean total energy intake increased from 1379 kilocalories in 1991 to 1463 kilocalories in 2009 ($p< 0.001$). Consumption of fresh fruits and vegetables increased, with a change in intake from 4.1 ± 0.2 to 17 ± 0.6 kcal of fruits ($p< 0.001$) and from 30 ± 0.6 to 36 ± 0.5 kcal of fresh vegetables ($p< 0.001$) from 1991 to 2009 (Table 3). Rice remained as the top food group consumed in each wave, though the total kilocalories per capita of rice consumed decreased significantly from 1991 (380 ± 7.2 kcal/day) to 2009 (323 ± 3.9 kcal/day), $p< 0.001$ (Table 2). The largest change in energy consumption was observed in plant oil, which increased from 206 ± 4.9 kcal/day consumed in 1991 to 293 ± 4.2 kcal/day consumed in 2009 ($p< 0.001$) (Table 3). Wheat buns and breads also increased

Table 1
Distribution of characteristics among older Chinese subjects age ≥60 years from 1991 to 2009 in the China Health and Nutrition Survey

	Year							
	1991[a] n=1251	1993 n=1295	1997 n=1655	2000 n=1790	2004 n=2128	2006 n=2317	2009 n=2642	P[b]
Age (%)								
60-64	39.5	38.2	35.5	33.7	30.6	32.0	33.1	<0.001
65-69	26.3	28.3	27.1	27.9	27.6	25.5	24.0	
70-74	16.5	15.6	19.0	20.8	20.5	20.2	19.5	
≥75	17.8	17.9	18.4	17.5	21.2	22.3	23.4	
Gender (%)								
Male	47.4	48.1	46.1	46.4	47.2	46.9	47.2	0.995
BMI (%)								
≥ 25	17.2	17.3	23.2	25.6	27.9	28.0	29.8	<0.001
Income (%)								
Low	89.4	82.2	79.4	62.2	51.3	51.9	33.3	
Medium	10.2	17.0	18.6	31.7	33.1	30.2	33.3	<0.001
High	0.4	0.9	2.0	6.1	15.7	17.9	33.3	
Education Level (%)								
Illiterate/ Informal	78.5	74.5	70.8	61.5	51.2	54.5	48.8	
Primary	11.9	13.2	14.8	18.3	24.3	18.8	23.3	<0.001
Secondary or higher	9.7	12.3	14.5	20.2	24.5	26.7	28.0	
Urbanicity (%)								
Low	53.3	49.9	44.8	37.6	39.0	37.6	33.6	
Medium	46.7	50.1	54.9	53.6	32.5	32.2	33.2	<0.001
High	0.0	0.0	0.3	8.8	28.5	30.2	33.3	
Alcohol Consumers (%)								
Male	58.3	53.0	49.6	50.8	47.9	46.1	45.9	<0.001
Female	16.3	12.4	10.2	11.9	8.1	9.1	7.1	
Smokers (%)								
Male	60.9	60.1	51.4	52.7	60.2	59.9	58.9	<0.001
Female	12.9	11.1	8.7	9.5	9.2	8.4	7.6	
Region (%)								
South	52.3	55.1	53.8	48.5	46.9	47.2	46.5	<0.001
Central	40.1	36.5	40.2	36.4	36.6	35.7	36.0	
North	7.7	8.4	6.0	15.1	16.6	17.1	17.5	

a. Column percents; b. From Chi-squared tests; c. This study includes 5,068 individuals for a total of 13,078 observations collected across 7 surveys (1991, 1993, 1997, 2000, 2004, 2006, 2009).

substantially from 5 ± 0.9 kcal/ in 1991 to 75 ± 2.3 kcal in , ranking fifth on the list of top food groups consumed in 2009 (p< 0.001). In contrast, intake of wheat flour showed the largest decline in intake, dropping from the second-most consumed food in 1991 (211 ± 6.4 kcal/day) to sixth (51 ± 2.5 kcal/day) (p< 0.001) (Table 2). Older Chinese adults also showed an increase in processed foods, increasing consumption of cake, cookies, and pastries from 11 ± 1.7 kcal/capital in 1991 to 17 ± 1.3 kcal/capita in 2009 (p< 0.001). Similarly, instant noodles and frozen dumplings were not consumed at all in 1991, but increased to 30 ± 1.7 kcal/day consumed in 2009 (p< 0.001) and became the eleventh most-consumed food group, indicating a shift towards high-fat and less micronutrient-dense foods (Table 3).

Within each generation, an aging effect was observed, with total energy intake decreasing with age. For example, within the generation of adults born 1932-1939, participants showed a decline in energy intake from 1488 ± 19 kcal/day at age 55-59 to 1398 ± 20 kcal/day at age 70-74 years (p< 0.001). At the same age, more recent generations (born in later years) consumed significantly more calories on average than earlier generations. For example, adults aged 55-59 in 1991 (generation five, born 1932-1939) consumed an average of 1488 ± 19 kilocalories, while the older adults of the same age group of 55-59 in 2009 (generation eight, born 1950- 1954) consumed 1624 ± 14 kilocalories (Figure 1). The age-related decline in energy intake was notably smaller in more recent generations, with a smaller decrease in calorie consumption as age increases than in earlier generations (p<0.01).

Table 2
Top food groups consumed per capita amongst older Chinese adults age ≥60 years, 1991- 2009

1991 Food Group	Mean ± SE (kcal)	1997 Food Group	Mean ± SE (kcal)	2004 Food Group	Mean ± SE (kcal)	2009 Food Group	Mean ± SE (kcal)
1 Rice	380 ± 7.2	Rice	326 ± 5.2	Rice	343 ± 4.6	Rice	323 ± 3.9
2 Wheat flour	211 ± 6.4	Plant oil	264 ± 5.1	Plant oil	286 ± 4.4	Plant oil	293 ± 4.2
3 Plant oil	206 ± 4.9	Wheat flour	130 ± 4.2	Wheat noodles	112 ± 3.2	High-fat pork	134 ± 2.8
4 High-fat pork	110 ± 3.9	High-fat pork	106 ± 3.0	High-fat pork	108 ± 2.8	Wheat noodles	131 ± 3.1
5 Wheat noodles	69 ± 4.0	Wheat noodles	92 ± 3.4	Wheat flour	85 ± 3.5	Wheat buns	75 ± 2.3
6 Corn/ coarse grain	56 ± 3.9	Corn/ coarse grain	55 ± 2.8	Wheat buns	59 ± 2.6	Wheat flour	51 ± 2.5
7 Fresh vegetables	30 ± 0.6	Legume products	36 ± 1.4	Corn/ coarse grain	44 ± 2.4	Corn/ coarse grain	39 ± 1.9
8 Legume products	29 ± 1.5	Wheat buns	29 ± 1.9	Fresh vegetables	34 ± 0.6	Fresh vs vegetables	36 ± 0.5
9 Dried legumes	25 ± 2.2	Fresh vegetables	29 ± 0.5	Legume products	33 ± 1.2	Legume products	35 ± 1.2
10 Eggs/egg products	20 ± 0.9	Eggs/ egg products	28 ± 0.9	Eggs/ egg products	29 ± 0.8	Eggs/ egg products	31 ± 0.7
11 Starchy roots	19 ± 1.2	Dried legumes	19 ± 1.5	Dried legumes	23 ± 1.6	Instant noodles	30 ± 1.7
12 Fish and seafood	13 ± 0.8	Starchy roots	18 ± 0.9	Deep-fried wheat	21 ± 1.7	Deep-fried wheat	25 ± 1.6
13 Poultry and game	11 ± 1.3	Deep-fried wheat	16 ± 1.3	Starchy roots	19 ± 0.7	Starchy roots	21 ± 0.7
14 Cakes and pastries	11 ± 1.7	Fish and seafood	14 ± 0.6	Cakes and pastries	15 ± 1.4	Cakes and pastries	17 ± 1.3
15 Nuts and seeds	10 ± 1.3	Poultry and game	10 ± 0.9	Fish and seafood	14 ± 0.6	Fruits	17 ± 0.6
16 Deep-fried wheat	10 ± 1.3	Dried vegetables	10 ± 1.5	Poultry and game	11 ± 0.7	Fish and seafood	17 ± 0.6
17 Fresh legumes	7 ± 0.4	Starchy roots	8 ± 0.7	Fresh legumes	9 ± 0.4	Dried legumes	15 ± 1.3
18 Low-fat pork	7 ± 0.8	Cakes and pastries	7 ± 0.8	Nuts and seeds	9 ± 1.0	Nuts and seeds	13 ± 1.0
19 Starchy roots products	6 ± 0.8	Fresh legumes	7 ± 0.3	Animal-based milk	9 ± 0.6	Poultry and game	13 ± 0.7
20 Wheat buns	5 ± 0.9	Nuts and seeds	6 ± 0.9	Fruits	9 ± 0.5	Fresh legumes	11 ± 0.4

a. Data from the China Health and Nutrition Survey. Total observations by year: 1991 (n=1251), 1997 (n=1655), 2004 (n=2128), and 2009 (n=2642). Results from linear regression are adjusted for age, sex, and region; b. The top twenty food group contributors of each survey year are ranked by the total consumed calories contributed by each individual food groups to the individuals' total energy intake.

Discussion

Overall, older Chinese adults have increased total energy intake from 1991 to 2009. This trend is related to changes in diet composition over time and changes within generations, with more recent generations consuming more total energy and showing smaller declines in energy intake as they age. Not only is the diet of the older Chinese population becoming more energy-dense, but it is also increasingly comprised of prepared or precooked foods, reflective of a nutrition transition that occurs from older to younger generations.

This study shows that these increases in total daily energy have occurred simultaneously with major shifts in diet composition. Perhaps most importantly, rice, the most commonly consumed food group, decreased by 81 kilocalories (from 394 to 313 kcal) per capita from 1991 to 2009, while plant oil consumption increased from 205 to 295 kcal per capita. These trends demonstrate the gradual shift towards high-fat foods, such as plant oil. This work is consistent with previous work showing that more than 29% of the total energy intake of the urban Chinese elderly was composed of fats (13). Drewnowski et al. demonstrated that the proportion of the Chinese population consuming a high-fat diet (>30% of energy from fat) increased from 22.8% to 66.6% among high-income households, and from 19.1% to 36.4% even among low-income households from 1989 to 1993 (22). This increase may be partially explained by the increased availability of vegetable oil and soybean oil, which more than tripled in China during the 1990's (22).

In addition, the decrease in rice and wheat flour intake

Table 3
Food groups ranked by change in mean kilocalories per day per capita amongsamong older adults in China age ≥60 years , 1991- 2009[a]

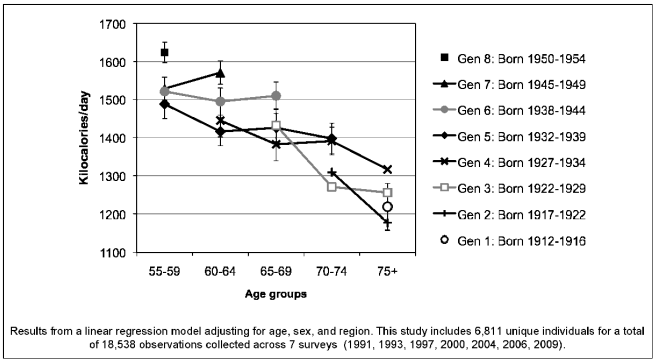
	1991 kcal	2009 kcal	kcal change	kcal % change
Plant oil	206	293*	87	42
Wheat buns, breads	5	75*	70	1400
Wheat noodles	70	131*	61	87
Instant noodles	0	30*	30	6786
High-fat pork	110	134*	24	23
Deep-fried wheat	10	25*	15	150
Fruits	4	17*	13	317
Eggs and eggs products	20	31*	11	51
Fresh vegetable, non-leafy	30	36*	6	22
Cakes, cookies, pastries	11	17*	6	55
Legume products	29	35*	6	21
Dried vegetables	1	7*	6	467
Animal-based milk	4	9*	5	143
Processed meats	2	6*	4	260
Nuts and seeds	7	11*	4	47
Fresh legumes	1	5*	4	216
Fish and seafood	14	17*	3	25
Starchy roots and tubers	19	21	2	12
High-fat red meat	2	4	2	138
Ready-to-eat cereals/ porridge	0	2*	2	860
Poultry and game	11	13*	2	18
Soy milk	1	2*	2	262
Deep-fried rice and legumes	1	2*	1	150
Dairy products	0	1	1	1822
Starchy roots products	6	5	-1	-17
Low-fat red meat	2	1	-1	-60
Candy and high-sugar foods	2	0*	-1	-81
Dried legumes	25	15*	-10	-41
Corn and coarse grain	57	40	-17	-30
Rice	380	323*	-57	-15
Wheat flour	212	51*	-161	-76

a. Data for adults age 60+ from the China Health and Nutrition Survey in 1991 and 2009. Total observations by year: 1991 (n=1251), 1997 (n=1655), 2004 (n=2128), and 2009 (n=2642). Results from linear regression adjusted for age, sex, and region; * Mean daily intake in 2009 was different than 1991 for food group, $p < 0.01$

also point to the increased diversity of diet (i.e. increased fruit, vegetable, pastry consumption) by allocating fewer calories to rice and wheat flour. Despite this representing an increasingly diverse diet, it is not necessarily a nutritionally improved diet. For example, while older Chinese adults increased their intake of fruits and vegetables, this has occurred alongside substantial increases in the consumption of instant noodle, cookies, cakes, and other high-sugar snacks. The increase in fruit and vegetable intake from 325.7 g/d in 1991 to 379.0 g/d in 2009 represents a dietary improvement, considering that low fruit and vegetable intake is associated with risks of non-communicable diseases, such as cancer, stroke, and coronary heart disease (14). However, despite this improvement, fruit and vegetable intake among older Chinese adults is still below the minimum of 400 g/d recommended by the World Health Organization (14). The recommended minimum of 400 g/d is aspirational but difficult to achieve without intervention. The increases in cookies, cakes and sugary snacks are consistent with other work, indicating increases in sugar consumption in China (23). This increase in sugary snacks is alarming, considering that excessive sugar consumption has been linked to metabolic abnormalities and adverse health effects, including elevated fasting cholesterol levels, higher body weight, lower intake of essential nutrients, and type 2 diabetes (24, 25). We also note how the increased intake of wheat buns rather than wheat flour reflects the shift towards increased consumer packaged food purchases along with increased away-from-home eating. As clarification, the separate food groups of wheat buns/ breads and wheat flour are nutritionally the same but culturally different; reports of wheat flour indicate self-cooking, while wheat buns/ breads indicate the purchase of prepared products outside of the home (Appendix 1). Overall, this increase in processed foods that are high in fat and sugar contributes to the overall nutrition transition in China to

an energy-dense (in reference to caloric energy) and high-fat Western diet.

Figure 1
Predicted change in total energy intake from 1991- 2009 among older Chinese adults by generation and age group, for adults age >55



Results from a linear regression model adjusting for age, sex, and region. This study includes 6,811 unique individuals for a total of 18,538 observations collected across 7 surveys (1991, 1993, 1997, 2000, 2004, 2006, 2009).

In older adults, this shift towards higher energy density, more processed foods may be especially problematic if this diet is less micronutrient-dense, making this population increasingly susceptible to nutritional deficiencies as it ages. In this study, we find that older Chinese adults within the same cohort consume fewer calories as they age. For example, the 60-64 year-old Chinese adults consumed 1445 ± 21 kilocalories per capita in 1991, and roughly the same group of subjects (now aged 75+) consumed 1317 ± 19 kilocalories in 2009. These results are consistent with studies showing that elderly adults decrease consumption in nearly all food groups (26). A US-based study similarly demonstrated the dramatic decline in total energy intake as adults age, by up to 1200 kcal in men and 800 kcal in women between the age groups of 20-30 years and 80+ years (27). This aging effect can be explained by physiological changes that occur concurrently with aging and impact diet, such as decreased appetite, diminished sense of taste and smell, loss of teeth, and slower gastrointestinal motility (28). While it is possible that increased energy density could provide some benefit in avoiding undernutrition in the elderly, concerns about concurrent increases in obesity and increases in unhealthy, energy-dense and nutrient-poor foods (such as cookies, cakes, etc.) warrant further research to examine the health effects of these dietary shifts in this population.

In addition to the aging effect, a generation effect is illustrated by the increase in total calorie consumption in more recent generations of older Chinese adults. This increase in energy consumption exemplifies the results of China's rapid nutrition transition and societal changes over time (3). More recent generations are born and grow into an increasingly urbanized, Westernized society, which makes them more likely to eat high-fat, energy-dense diets at younger ages, and then sustain these higher energy diets as they age. These shifts towards increased total energy are particularly problematic given concurrent declines in physical activity (29, 30), making these recent generations increasingly susceptible to obesity and related chronic disease as they age. On the flipside, these trends could also be related to a decreased prevalence of undernutrition. Given the rapidly growing size of this demographic, more research is needed in order to understand the overall effect of our findings on mortality and quality of life.

Key changes in socio-demographic patterns may help explain the shift towards higher energy in younger cohorts. For example, China has undergone a massive urbanization over time, which is often associated with more meals consumed outside of home, increased prevalence of fast food and Westernization, sedentary lifestyles, and increased calorie intake (3, 4). One possibility is that older adults have undergone a similar shift, and may increasingly rely on processed food away from home. Another possibility is the shift in family structure away from children living with their elderly parents, potentially reducing cooking opportunities and increasing intake of higher-energy, pre-prepared processed food among older adults. For example, studies in the US and England have shown that single men who lived alone had the lowest fruits-and-vegetables consumption, the least varied food selections, and the greatest risk for vitamin and mineral deficiencies when compared to men living with a spouse or other family members (13). These socio-demographic changes may be key contributors to increased energy and declining diet quality among older Chinese adults; however, more research is needed to fully explore the reasons behind these changes.

Limitations

Although this study demonstrates changes in several key food groups, reliance upon a Chinese food composition that (as in all nutrition surveys around the world) cannot keep up with the emergence of new products and re-formulations on the food supply, means that these trends may not fully reflect changes in with newly emergent foods such as sugary beverages and processed, packaged snacks. Another limitation is that advanced age is associated with decreased cognition, which could result in dietary underreporting on 24-hour recalls (31). Because this effect likely increases with age, increased underreporting could account for the observed age-related decline in energy intake. However, results from other studies in older adults also showed energy intake declines with age, suggesting that the observed results are not simply a reflection of increased underreporting but a true decline in energy intake (32).

Conclusion

This study shows that older Chinese adults have increased total daily energy intake from 1991 to 2009, and this increase in energy intake has been accompanied by substantial shifts in diet composition, including increases in edible oils and high-energy processed foods like instant noodles, cookies, and cakes. Increased energy intake amongst more recent generations, coupled with smaller age-related declines in energy within this group, suggests that as more recent generations age, they will sustain higher energy intakes into older age. Taken together, these results suggest that diets among the Chinese elderly appear to be increasingly energy-dense, which is reflective of the nutrition transition. More work is needed to understand how these changes in total energy and diet composition are related to diet-related diseases, including obesity and other non-communicable diseases, amongst China's older, and most rapidly growing, demographic group.

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References

1. Banister, J., D.E. Bloom, and L. Rosenberg, Population aging and economic growth in China. Program on Global Demography and Aging, Harvard University, Working Paper, 2010. 53: p. 2010-11.
2. Fengying, Z., Du, Shufa, Wang, Zhihong, Zhang, J, Du, Wenwen, Popkin, Barry M., Dynamics of the Chinese Diet and the Role of Urbanization, 1991–2011. Obesity Reviews, 2014. 15.
3. Popkin, B.M., L.S. Adair, and S.W. Ng, Global nutrition transition and the pandemic of obesity in developing countries. Nutrition Reviews, 2012. 70(1): p. 3-21.
4. Popkin, B.M., et al., The nutrition transition in China: a cross-sectional analysis. Eur J Clin Nutr, 1993. 47(5): p. 333-46.
5. Adair, L.S., Gordon-Larsen, Penny, Du, Shufa, Zhang, Bing, Popkin,Barry,, The emergence of cardiometabolic disease risk in in Chinese children and adults: consequences of changes patterns of diet, physical activity, and obesity. Obesity Reviews, 2014.
6. Gordon-Larsen, P., Wang, Huijun, Popkin, Barry M., Overweight dynamics in Chinese children and adults Obesity Reviews, 2014. 15.
7. Lee, S.-A., et al., Dietary patterns and blood pressure among middle-aged and elderly Chinese men in Shanghai. British Journal of Nutrition, 2010. 104(02): p. 265-275.
8. Woo, J., et al., Nutritional status of the water-soluble vitamins in an active Chinese elderly population in Hong Kong. Eur J Clin Nutr, 1988. 42(5): p. 415-24.
9. Woo, J., et al., Protein calorie malnutrition in elderly chronic care institutions in Hong Kong. Nutrition reports international, 1989. 40(5): p. 1011-1018.
10. Woo, J., et al., Nutritional status of healthy, active, Chinese elderly. British Journal of Nutrition, 1988. 60(01): p. 21-28.
11. Ko, G.T., et al., Associations between dietary habits and risk factors for cardiovascular diseases in a Hong Kong Chinese working population--the "Better Health for Better Hong Kong" (BHBHK) health promotion campaign. Asia Pac J Clin Nutr, 2007. 16(4): p. 757-65.
12. Zhai, F., Evaluation of the 24-hour individual recall method in China. Food and nutrition bulletin, 1996. 17: p. 154.
13. Wang, D.H., J. Li, and S. Kira, A comparative study of dietary intake among urban Japanese and Chinese aged 50 approximately 79. Environ Health Prev Med, 2000. 5(1): p. 18-24.
14. Li, Y., et al., Consumption of, and factors influencing consumption of, fruit and vegetables among elderly Chinese people. Nutrition, 2012. 28(5): p. 504-508.
15. Gu, D., et al., Prevalence, awareness, treatment, and control of hypertension in China. Hypertension, 2002. 40(6): p. 920-927.
16. Hai, R., et al., An epidemiological investigation of sarcopenia in the Chinese population. Bone, 2010. 47: p. S437.
17. Popkin, B.M., et al., Cohort Profile: The China Health and Nutrition Survey--monitoring and understanding socio-economic and health change in China, 1989-2011. Int J Epidemiol, 2010. 39(6): p. 1435-40.
18. Popkin, B.M., B. Lu, and F. Zhai, Understanding the nutrition transition: measuring rapid dietary changes in transitional countries. Public Health Nutr, 2002. 5(6A): p. 947-53.
19. Jones-Smith, J.C. and B.M. Popkin, Understanding community context and adult health changes in China: development of an urbanicity scale. Social Science & Medicine, 2010. 71(8): p. 1436-1446.
20. Willett, W., Nutritional Epidemiology, 2012, Oxford Scholarship Online.
21. Poti, J.M., K. Duffey, and B. Popkin, The association of fast food consumption with poor dietary outcomes and obesity among children: is it the fast food or the remainder of the diet? American Journal of Clinical Nutrition, 2014. 99(1): p. 162-171.
22. Drewnowski, A. and B.M. Popkin, The nutrition transition: new trends in the global diet. Nutrition reviews, 1997. 55(2): p. 31-43.
23. Ismail, A.I., J.M. Tanzer, and J.L. Dingle, Current trends of sugar consumption in developing societies. Community dentistry and oral epidemiology, 1997. 25(6): p. 438-443.
24. Johnson, R.K., et al., Dietary sugars intake and cardiovascular health a scientific statement from the american heart association. Circulation, 2009. 120(11): p. 1011-1020.
25. Schulze, M.B., et al., Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. JAMA: the journal of the American Medical Association, 2004. 292(8): p. 927-934.
26. Donkin, A.J., et al., Gender and living alone as determinants of fruit and vegetable consumption among the elderly living at home in urban Nottingham. Appetite, 1998. 30(1): p. 39-51.
27. Wakimoto, P. and G. Block, Dietary Intake, Dietary Patterns, and Changes With Age An Epidemiological Perspective. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 2001. 56(suppl 2): p. 65-80.
28. Weimer, J.P., The Nutritional Status of the Elderly. Journal of Nutrition For the Elderly, 1983. 2(4): p. 17-26.
29. Ng, S.W. and B.M. Popkin, Time use and physical activity: a shift away from movement across the globe. Obesity Reviews, 2012: p. no-no.
30. Ng, S., et al., Estimation of a dynamic model of weight. Empirical Economics, 2012. 42(2): p. 413-443.
31. Mather, M. and M. Mather, Aging and cognition. Wiley interdisciplinary reviews. Cognitive science, 2010. 1(3): p. 346-362.
32. Burr, M.L., J.E. Milbank, and D. Gibbs, The nutritional status of the elderly. Age Ageing, 1982. 11(2): p. 89-96.

Appendix 1

Food groups and corresponding examples of food items

Food group	Example of food items
Rice	White and brown rice
Wheat noodles	Wheat noodles
Wheat flour	Wheat flour
Wheat buns, breads	Bun, butter bread, salty bread
Cakes, cookies and pastries	Cookies, mooncake, fruit cake, chocolate cake, fruit pie
Deep-fried wheat	Deep-fried dough stick, deep-fried cake with red bean paste and sugar, deep-fried sweet sesame seed ball
Deep-fried rice and legumes	Deep-fried rice flour doughnut, deep-fried soybean, deep-fried broad bean
Corn and coarse grain	Corn, corn grits, corn flour, barley, oats, foxtail millet, sorghum
Starchy roots and tubers	Potato, yam, taro, lotus root, water chestnut, cassava, sweet potato
Fresh legumes	Soybean sprouts, peas with pod, mung bean sprouts
Dried legumes	Soybean flour, dried beans, beans flour, roasted broad bean
Legume products	Tofu, tofu products, red/mung bean paste
Nuts and seeds	Sesame, sunflower, watermelon seeds, lotus seeds, peanuts, walnuts, almonds, hazelnuts, pine-nuts, pistachios, cashew nuts
Starchy roots products and tubers products	Potato starch, lotus root starch, potato flour, corn starch, starch
Fresh vegetables, non-leafy	Cauliflower, tomatoes, cucumber, zucchini, mushrooms
Fresh vegetables, leafy	Spinach, 'bok choy', cabbage
Pickled, salted or canned vegetables	Canned tomato sauce, preserved vegetables, vegetables in soy sauce
Dried vegetables	Dried radish, dried bamboo shoot, dried lily
Seaweed	Fresh or dried seaweed
Fruits	Fresh and canned (no added sugar) fruits
Dried fruit	Dates, dried longan, raisins
Preserved fruit with added sugar	Dried and canned fruit with added sugar
Low-fat red meat	Low-fat beef, low-fat lamb, donkey, rabbit
High-fat red meat	High-fat beef, high-fat lamb
Low-fat pork	Pork tenderloin pork, pork tendons
High-fat pork	Pork belly, leg, rib chop
Organ meats	Liver, kidney, large intestine, blood
Processed meats	Sausages, ham, luncheon meat, dried meat, smoked meat
Poultry and game	Chicken, duck, goose
Eggs and eggs products	Whole eggs, yolk, white, preserved eggs
Fish and seafood	Fresh- and salt-water fish, dried fish, shellfish
Soy milk	Sweetened and un-sweetened soy milk
Animal-based milk	Cow milk, goat milk, skim milk, flavored milk
Dairy products	Cheese, yogurt
Sweetened dairy products	Ice cream
Western-style fast-food	Fried chicken, sandwich, hamburger, hotdog, pizza
Instant noodles and frozen dumplings	Instant noodles, frozen dumplings
Ready-to-eat cereals/porridge	Instant multigrain porridge, corn flakes, instant oatmeal
Salty snacks	Corn crisps, onion rings, potato chips,
Candy, sugar and other high-sugar foods	Jelly, jam, chocolate, honey, sugar, candies
Calorically-sweetened beverages	Fruit or flavored drinks, fruit juice, soft drinks
Low-caloric beverages	Tea, bottled water

a. Grouping was based on a food grouping system developed specifically for the CHNS by researchers from UNC-CH and the National Institute of Nutrition and Food Safety, Chinese CDC