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The food retail revolution in China and its association with diet and health

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Abstract

The processed food sector in low- and middle-income countries has grown rapidly. Little is understood about its effect on obesity. Using data from 14,976 participants aged two and older in the 2011 China Health and Nutrition Survey, this paper examines patterns of processed food consumption and their impacts on obesity while considering the endogeneity of those who purchase processed foods. A major assumption of our analysis of the impact of processed foods on overweight and obesity was that the consumption of processed foods is endogenous due to their accessibility and urbanicity levels. The results show that 74.5% of participants consumed processed foods, excluding edible oils and other condiments; 28.5% of participants' total daily energy intake (EI) was from processed foods. Children and teenagers in megacities had the highest proportion of EI (40.2%) from processed foods. People who lived in megacities or highly urbanized neighborhoods with higher incomes and educational achievement consumed more processed foods. When controlling for endogeneity, only the body mass index (BMI) and risk of being overweight of children ages two to eighteen are adversely associated with processed foods (+4.97 BMI units, 95% confidence interval (CI): 1.66–8.28; odds ratio (OR) = 3.63, 95% CI: 1.45–9.13). Processed food purchases represent less than a third of current Chinese food purchases. However, processed food purchases are growing at the rate of 50% per year, and we must begin to understand the implications for the future.

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Keywords

food retail; China; processed food; overweight and obesity; urbanicity; diet

Introduction

Across low- and middle-income countries (LMICs), diets have transformed greatly. An important factor in recent changes appears to be the modern retail food sector (Monteiro and Claro, 2013; Monteiro and Cannon, 2012; Popkin, 2014; Popkin et al., 2012). Asia is in the midst of a major shift in food sources and in the way foods are processed, packaged, and purchased (Minten et al., 2010; Reardon et al., 2014; Reardon et al., 2012). In Latin America the shift from fresh markets as primary food sources began earlier (Reardon and Berdegué, 2002; Reardon et al., 2003), and now over half of the caloric intake of Mexicans and others in Latin America may be from packaged and processed foods (Popkin, 2014). These changes have occurred much more recently in Asia (Garnett, 2014; Popkin, 2014; Reardon et al., 2009; Reardon et al., 2014; Reardon et al., 2012; Wang et al., 2009; Zhang and Pan, 2013). T. Reardon and others have defined three waves in Asia, the first affecting Korea and Taiwan; the second reaching Indonesia, Malaysia, the Philippines, and Thailand; and the third and most recent affecting China and India (Reardon et al., 2014; Reardon et al., 2012). To date, a number of studies have noted the potentially adverse effects of highly processed foods on diet and health, but little research has focused on the potential relationship of actual dietary intake and the changing sources of foods and beverages with health in LMICs.

The most widely cited arguments are that the retail revolution makes ultraprocessed foods high in sugar, fat, and sodium readily available and that the major global food and beverage companies have led this change (Ludwig, 2011; Monteiro and Claro, 2013; Monteiro and Cannon, 2012; Monteiro et al., 2011; Moss, 2013). Much of the work examining this development has been general or has used food expenditure surveys or food balance data from the Food and Agriculture Organization of the United Nations. Others have used sales information in the Euromonitor Passport Global Market Information Databasewhich is highly aggregated (Baker and Friel, 2014; Monteiro and Claro, 2013; Monteiro et al., 2013; Moodie et al., 2013). One cross-sectional study in Guatemala that linked the intake of processed foods with body mass index (BMI) found that higher levels of consumption of processed foods was linked with increased BMI and risk of overweight and obesity (Asfaw, 2011). However, the Living Standard Measurement Survey data did not provide the detailed data needed to precisely categorize food purchases into processed and unprocessed foods and to link them with individual BMI values. He did use similar instrumental variables to model this relationship.

To date, packaged food purchase patterns, sources, and health impacts on consumers are little understood. Some studies in developed countries have linked processed foods with higher energy density intake, higher salt and sugar consumption, and lower dietary fiber intake (Baillie, 2008). As a result, eating processed foods is associated with higher energy intake (EI) or an increased prevalence of obesity and overweight (Cutler et al., 2003; de Graaf, 2006; Pereira et al., 2005). While these authors have not addressed causal factors, the nutrition literature posits that three primary dimensions of processed foods are potentially linked to increased EI and subsequent weight gain. First, the highly refined nature of most processed foods gives them a low glycemic index with all the related biological effects associated with such foods (Lennerz et al., 2013; Ludwig, 2002; Pereira et al., 2004). Second, these foods generally are higher in added sugars and are linked with excessive weight gain, particularly related to beverages (Malik et al., 2013; Morenga, 2013; Morenga et al., 2014). Third, higher fat content in processed foods and the link between fat and weight gain are increasingly controversial today (Bray and Popkin, 1998; Willett, 1998).

Studies of processed food consumption in China are limited. Supermarkets and convenience stores, which are the main sources of processed foods, have been expanding rapidly and are changing the profile of China's food supply (Hu et al., 2004). Previous data have indicated that the processed food industry's retail sales are increasing quickly in China (Wang et al., 2011). However, no individual-level consumption data have been available. Our research began with a premise that households that purchase and consume processed foods may differ systematically from those that do not. We used instrumental variable techniques to correct the potential correlation between the error term of the body weight equations and the consumption of processed food through unobservable individual, household, or community factors. We have two sets of valid endogenous instruments, namely, each household's distance to grocery stores and to free markets selling processed foods and urbanicity levels. Free markets are a term used in China to differentiate all the private sector stores from the state stores that existed for many decades and disappeared during the 1990's. These are the term still used in the community questionnaire as that is the way most respondents think of these stores. The most likely unobservables are genetic, mainly tastes for processed foods which may be higher sweet or fatty or salty food presence, but they may also be unmeasurable perceptions that these are higher status foods to purchase and eat.

The Euromonitor reports that retail sales and per capita purchases of processed food increased between 1999 and 2013 in China. They were four times higher in 2013 than in 1999 for 22.4% annual growth over the fifteen-year period (figure 1). Euromonitor data show that over half of the packaged foods sold in China's markets was processed foods. We defined packaged, processed foods according to the data collected by the Euromonitor Passport Global Market Information Database (Euromonitor 2013), including foods available at all retail sales and food services in stores, restaurants, or other food stands, such as processed food, chilled processed food, frozen food, dried food, snacks, baby food, bakery items, canned and preserved food, dairy items, ice cream, meal replacements, ready-made meals, and others.

This study used one wave of the longitudinal China Health and Nutrition Survey (CHNS) from 2011 to examine both the sources of and the intake patterns of packaged and processed foods. Furthermore, controlling for the endogeneity of processed foods and beverage purchases, we examined the relationship of the consumption levels of these foods and beverages with BMI levels and the risk of being overweight.

Methods

Sample and study design

We used data from 14,976 respondents aged two and older in the 2011 CHNS, a nationwide, ongoing, open cohort study that we initiated in 1989 and have subsequently implemented. The CHNS is conducted in nine diverse provinces from the Northeast to the Southwest (Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guizhou, and Guangxi) and three politically autonomous megacities (Beijing, Shanghai, and Chongqing). We used a multistage, random cluster process to randomly draw the sample surveyed in each of the provinces and megacities. We selected two cities and four counties in each province, four communities in each city or county, and twenty households in each community, all randomly selected. All communities were stratified by income and selected on a probability proportional to size basis. At the local level we developed detailed rosters of all residents. We interviewed all household members present over a three-day period and returned on weekends to collect data from students who went to towns or cities for school during the week. The design, sampling, and response rates have been reported previously (Popkin et al., 2010). The institutional review boards of the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, approved the research protocols and instruments and the process for obtaining informed consent for this study. Study participants provided their written, informed consent.

Diet measurement

We collected detailed diet data at the household level and at the individual level using weighing methods in combination with three consecutive twenty-four-hour recalls. The three consecutive days during which we collected detailed household food consumption data were randomly allocated from Monday to Sunday. We used precise (to 1 gram) electronic diet scales to measure household consumption by inventory change from the beginning to the end of each day and recorded all foods purchased from a market or picked from a home garden and all foods stored in the storage room and the refrigerator at the beginning and end of each survey. Trained interviewers visited participants at their homes and recorded all food items consumed, the methods and locations of food preparation, and the times and locations of food consumption during each of the three days. For children younger than twelve, the mother or a mother substitute who prepared food for the household or fed the children helped recall the children's dietary consumption.

Definition of processed food

In each household, each member's twenty-four-hour recall questionnaire included a question regarding whether the food was processed and labeled in any manner. If packaged, frozen, boxed, or bagged, we designated it as processed. We did the same for the inventory items, including oils and condiments that are added during cooking. While most of these foods are highly processed, without a list of all the ingredients in processed foods we cannot accurately know what is ultraprocessed (e.g., sugar-sweetened beverages [SSBs]) or minimally processed (e.g., flour or yogurt).

Anthropometric measurement

Well-trained health workers measured height and weight according to standardized procedures recommended by the World Health Organization (WHO). We used floor digital scales to measure weight with light clothing and portable stadiometers to measure height on bare feet. We calculated BMI as weight (kilograms [kg]) divided by height (square meters [m^2]). We classified overweight or obese as BMI ≥ 25 kg/m^2 for adults according to the WHO references (WHO/FAO, 2003) and the age- and sex-specific BMI cutoff points for children according to the International Obesity Task Force (IOTF) references.

Sociodemographic, community, and spatial data

We used a detailed household questionnaire for household assets and demographic composition and interviewed each individual for individual sociodemographic measures. We collected spatial coordinates for each household except those in the three megacities with standard global positioning system (GPS) receivers. We collected the distance to grocery stores and to free markets in a detailed community questionnaire.

Statistical methods

We stratified all analyses into three age groups: 2–18, 19–59, and 60 and above. Instead of traditional administrative urban and rural areas, we used tertiles of an urbanicity index developed by our team (Jones-Smith and Popkin, 2010) to assess the degree of modernization and possession of infrastructure and services linked with urbanization for each community. This urbanicity index has been reviewed and compared with other, similar indexes and is the only one that adequately incorporates in detail the key dimensions (social and economic traits, infrastructures, services, etc.) to capture community characteristics (Cyril et al., 2013). The index is based on in-depth measures of twelve community components, including population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure, and social services. We have found that the urbanicity index does not fully capture all degrees of urbanization and for the mega and very large cities of China, we needed an additional dummy variable to capture these unmeasured characteristics. We define megacities as population ≥ 20 million and big cities as population higher than 5 million and lower than 20 million. We divided educational achievement into three categories: primary school and below, middle and high school, and above high school. We categorized deflated per capita household income into three tertiles (low, medium, and high income). We divided marriage status into two categories, currently married and not married. We used continuous distance variables in kilometers (km) for distance to the nearest grocery store and to the nearest free market derived from geographic information systems (GIS) for the nine provinces or reported distance collected in the detailed community questionnaire for the three megacities where GIS data were unavailable.

To estimate the association between EI from processed foods and BMI and overweight, we used ordinary least squares (OLS) regressions and logistic regressions, controlled for EI from all other foods, education (mother's or mother substitute's education used for children), gender, per capita household income, physical activity, and sedentary hours. As the OLS results may not reveal the true effects of processed foods on BMI or risk of overweight and obesity, we also used two-stage instrumental variable regressions to correct potential correlation between the error term of the equations and the EI from processed foods due to unobserved explanatory variables at individual, household, and community levels. We treated EI from processed foods as endogenous, because some household and community measures that affect BMI and overweight status probably affect EI from processed foods. We assume that distance to the nearest grocery store and to the nearest free market and urbanicity level are endogenous; that people are more likely to purchase processed foods if there are grocery stores and free markets nearby; and that EI from other foods, gender, education, income, physical activity, and inactivity are exogenous. We performed endogeneity tests to determine if the endogenous regressors are in fact endogenous (Durbin score and Wu-Hausman) and overidentifying restriction tests to determine if the instruments are valid (Sargan score and Basmann). We used SAS software (version 9.3, Cary, NC) and STATA/SE (version 13) to clean, manage, and analyze all the data. We defined the statistically significant level as two-tailed $p < 0.05$.

Results

The mean age of this study population was 44.9 years. Of the participants, 52.2% were women; 88.2% reported education levels below college; and 22.9% lived in megacities and 7.6% in other big cities. The mean BMI was 23.0 kg/m^2, and 31.5% were overweight or obese. Detailed characteristics are in table 1.

The CHNS data provided more details on processed food consumption at the individual level in China. Processed rice and wheat products, mainly breads, noodles, and instant noodles, accounted for 44.9% of processed food consumption (table 2). In our study population, 74.5% consumed at least one kind of processed food. On average 28.5% of total EI was from processed foods (table 2). All of the age groups consumed processed rice and wheat products at similar levels. Processed animal-source products accounted for 19.3% of the processed food consumption on average. The most highly consumed animal-source products were milk and dairy, sausage, other pork products, and chicken. Children and teenagers consumed more processed meat products (34.0%) than adults and older people.

Figure 2 shows the average EI from processed foods and restaurant foods. Differences in the proportion of daily EI from processed foods among the age groups are small (30.6% in children and 27.6% in adults). However, excluding edible oils consumed at the household level, children had significantly higher daily EI from processed foods (20.4%) than adults (14.9%) and older people (14.1%).

In supplemental table S1 we present the details of sources of processed foods in the megacities, the big cities, and all other communities in three levels of urbanicity. Children and teenagers in megacities and big cities show much higher proportions of EI from processed foods (40.2% and 40.5%, respectively) compared to their peers in other communities with low (24.7%), middle (28.8%), and high urbanicity (26.8%) (supplemental table S1).

The predicted EI from processed foods and beverages is in table 3 (results from the first stage of instrumental variable models for each dependent variable—BMI and overweight [0–1]). Distance to the nearest grocery store and to the nearest free market where one can purchase processed foods and tertiles of urbanicity were endogenous, and other controlled variables were exogenous. These results show positive associations between EI from processed foods in terms of kilocalories per day (kcal/day) and higher income and higher levels of urbanicity. Reduced access to free markets was also linked with greater EI from processed foods. Males were much more likely in all age groups to have higher EI from processed foods.

We present the effects of EI from processed foods on BMI and the risk of being overweight for each age group in two sets of results in table 4, controlling for key direct determinants of EI from all other foods, education (mother's or mother substitute's education used for children), gender, per capita household income, physical activity, and sedentary hours. The first two columns are not adjusted for selectivity or endogeneity. For these results, increased EI from processed foods is associated with an increased risk of a higher BMI and increased risk of being overweight in all age groups (table 4). These findings indicate that males are significantly more likely to purchase processed food (+ 97 kcal/day of processed food for every 1000 kcal/day of processed food intake) and those in the middle and upper tertile of urbanization were significantly more likely also to purchase processed food (+127 kcal/day and 154 kcal/day, respectively).

In OLS regression and logistic models, increased EI from processed foods significantly increased BMI in all age groups and increased the risk of being overweight in children and adults. However, when we adjusted for endogeneity in columns 3 and 4, the effects were significant and stronger only among children and adolescents, age group 2–18. Both Durbin and Wu-Hausman tests of endogeneity are significant ($p < 0.05$); tests of overidentifying restrictions indicate that the instruments are valid [both Sargan and Basmann tests are not significant ($p > 0.29$)]; and the first-stage regressions are significant ($F=14.1$, $p < 0.001$). The significant effects for adults and the elderly disappeared, possibly due to heteroskedasticity in our instrumental models. For the 2–18 age group, an added 1000 kcal/day of processed food was associated with a 1.32 units of BMI and a 39% higher risk of being overweight. For adults and the elderly all tests failed.

A second issue is whether EI from processed packaged foods has a different impact on BMI and the risk of being overweight than EI from unprocessed foods. We tested this difference and found that the effects of EI from processed foods on BMI and the risk of being overweight and obese were also stronger than the effects of EI from unprocessed foods among children and adolescents. The differences were statistically significant in all models except the OLS models on BMI for children and adolescents.

Discussion

Processed food consumption has increased remarkably in the past fifteen years in China. The retail sales and per capita purchases quadrupled from 1999 to 2013. In 2011 on average processed foods contributed to 28.5% of EI. Children and teenagers and people living in megacities and big cities consumed more processed foods than other groups. Consuming processed foods significantly increased the risk of a higher BMI and being overweight and obese among children and adolescents aged two to eighteen years but not among adults or the elderly. However, we need to extrapolate results from BMI models with caution, as BMI increases in underweight people may be beneficial. Nevertheless we have shown elsewhere that the BMI distribution for Chinese of all ages has shifted markedly higher and few children or adults have a low BMI. There are some instances of underweight among adults over seventy-five years old (Dearth-Wesley et al., 2008; Gordon-Larsen et al., 2014; Ji and Cheng, 2008; Popkin, 2006).

The market for processed foods is rising rapidly throughout LMICs. The substantial growth of ultraprocessed products has paralleled this transformation, and many have attributed the large shift in noncommunicable diseases and obesity in LMICs to this shift (Asfaw, 2011; MacInnis and Rausser, 2005; Monteiro et al., 2010; Monteiro and Cannon, 2012; Monteiro et al., 2011). The nutritional side of this relationship has mainly been examined in Latin America (Asfaw, 2011; Popkin, 2014), but one recent ecological analysis examined Asia's nutrition transition (Baker and Friel, 2014). Our study adds to the limited literature on the dietary dimension of this issue for Asia and highlights the importance of grain-based food items. It also shows that, unlike in Mexico, where SSBs and other processed beverages and grain-based sweet foods and desserts are very significant, in China snacks, sweets, and SSBs are currently a very tiny portion of the processed food intake pattern (Popkin, 2014; Stern et al., 2014).

China is in the very early stages of this transformation. However, scholars such as Reardon and B. Minten have shown in repeated studies that the growth of the Chinese retail sector is unprecedented and increasing rapidly today (Reardon et al., 2014; Reardon et al., 2012; Zhang and Pan, 2013; Zhang et al., 2012). In other research we have shown that while SSBs have a very small caloric impact on the current Chinese diet, the annual rate of increase is very rapid (Kleiman et al., 2011).

In China food preparation and cooking are still important, although all the modern eating behaviors, such as snacking and eating away from home, are rapidly accelerating (Wang et al., 2012). This differs from the United States and many other countries, where food preparation time is diminishing and processed foods are a very large component of the diet (Ng et al., 2014; Slining et al., 2013; Smith et al., 2014). Many feel that people in LMICs consume much lower proportions of their calories from processed foods (Monteiro et al., 2011; Moubarac et al., 2013; Slimani et al., 2009), however, our study in Mexico questions this assertion. We found that in the United States about 66–70% of all food consumed is processed and that in Mexico 58% of EI is from processed foods (Popkin, 2014).

Economic growth seems to be strongly correlated with rising consumption of processed foods (Monteiro and Cannon, 2012; Stuckler and Nestle, 2012). Higher urbanicity and education levels significantly correlate with consumption of processed foods in our study, which is similar to other reports (Asfaw, 2011; Levy et al., 2012; Monteiro et al., 2011). China has experienced a rapid transformation in recent years. Only twenty years ago most people lived in rural areas, and a large variety of food items were grown for household consumption and sold in local markets. Now the transnational corporations and modern retailers have spread, especially in some megacities and big cities, and this emergence of retailers has substantially increased access to processed and packaged foods (Stuckler et al., 2012). In China 80% of packaged and processed foods are purchased in supermarkets (Gómez and Ricketts, 2013). In addition, the market for processed food items is expanding, including breakfast cereals, ready-to-eat or ready-to-heat food, and soft drinks, among others, as these products have become more convenient and attractive to people.

Interestingly, in high-income countries it has been shown that the cost has a significant effect on the amount of ultraprocessed foods consumed. In a series of studies A. Drewnowski and others have shown that processed foods are less expensive per calorie, which might explain the high intake of processed foods and the poor diets of low-income Americans (Drewnowski and Rehm, 2013a, b; Monsivais et al., 2013).

Our study differs from the one other LMIC study that linked processed food consumption with higher BMIs in its concern for the unique selectivity of the individuals who purchase and eat processed foods in any country. The previous study conducted in Guatemala showed that a 10.0% increase in the proportion of highly processed foods consumed increases the BMI of an individual by 4.25% (Asfaw, 2011). Our results only show a significant (but stronger) impact of processed food intake on children and adolescents. However, both are cross-sectional analyses, and one must take great care in assuming causality. Lack of selectivity control is a common problem, but also the timing of the relationships must be considered. An interesting issue is that the processed food effect is significant only among adolescents and children. This may be because this is the group in the large and megacities most likely to consume the least healthy snacks—the highly processed savory snacks, SSB's and desserts. Also, it is important to note that we interpreted these changes by examining the effect of a 1,000 kcal/day increase in processed food. This is small for the average American household member where half of all kcal/day come from highly processed food (Poti et al., 2015) but still far higher than the amount of processed food consumed by most Chinese. However, this will change rapidly with the growth of this sector (Reardon et al., 2014).

A major limitation of our study is our inability to examine the ingredients of each package and categorize it by the extent of processing. Consequently it is impossible to differentiate processed foods such as brown rice, whole wheat flour, or frozen vegetables, all healthy options, from SSBs or ramen noodles, one of the most common processed high-sodium products in Asia. There are many degrees of processing, some of which, like fermentation, freezing, and squeezing olives to create olive oil, are healthful. We realize that without full descriptors and ingredient lists we cannot accurately categorize packaged and processed foods.

This is the first in-depth analysis of the nutritional impact of packaged and processed foods in Asia. China has rapidly growing problems with obesity and other noncommunicable diseases. Much more research is needed to understand how the transformation of the retail sector into a major source of Chinese calories will affect the nutritional status and health of the Chinese people. This first study suggests that processed foods might affect body composition in Chinese children and adolescents. Further research is needed to assess the patterns, trends, and health impacts of this major component of the Chinese diet.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations used

BMI	body mass index
CHNS	China Health and Nutrition Survey
CI	confidence interval
EI	energy intake
GIS	geographic information system
GPS	global positioning system
IOTF	International Obesity Task Force
kcal/day	kilocalories per day
kg	kilogram
km	kilometer
LMIC	low- and middle-income country
m^2	square meter
NIH	National Institutes of Health
OLS	ordinary least squares
OR	odds ratio
SD	standard deviation
SE	standard error
SSBs	sugar-sweetened beverages
WHO	World Health Organization

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Highlights

- 74.5% of the CHNS participants from 12 provinces consume packaged processed foods.
- 28.5% of individuals 2yrs age consume daily energy intake from processed foods
- Processed food intake increased BMI and overweight risk only among 2–18 yr. olds.

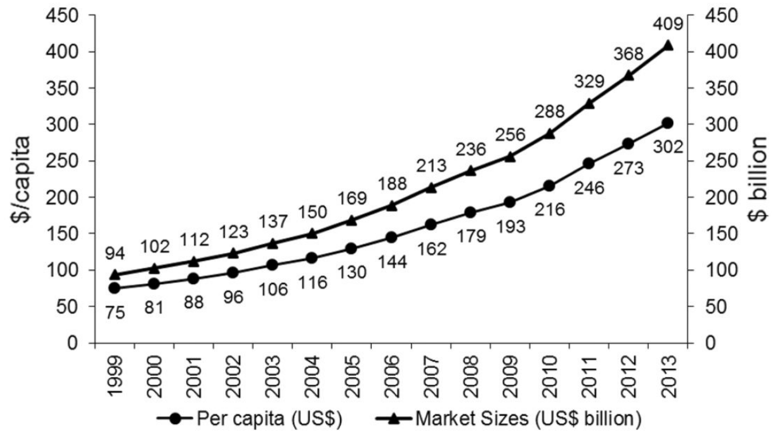

Figure 1.

Processed food retail values in China, 1999–2013 (fixed 2013 exchange rate)

Source: Euromonitor Passport Global Market Information Database

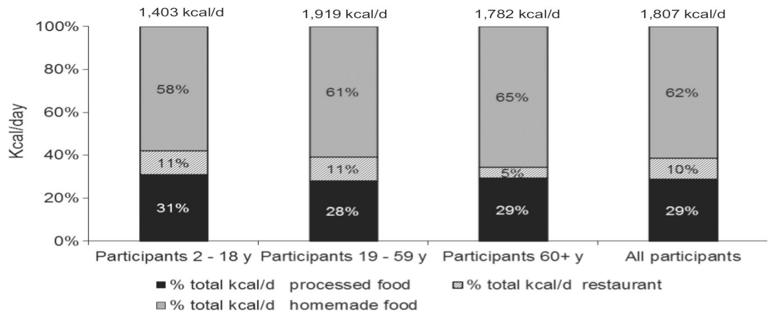

Figure 2.
Distribution of energy intake from different sources

Table 1

Characteristics of the CHNS study population stratified by age

	Total		2–18 years		19–59 years		60+ years	
	Mean	**SD**[1]	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Sample size	14,976	—	2,284	—	9,007	—	3,685	—
Age, years	44.9	20.6	9.5	4.6	43.9	10.7	69.3	7.2
Female, %	52.2	—	47.6	—	53.4	—	52.3	—
Megacities, %	22.9	—	25.5	—	24.0	—	18.6	—
Big cities, %	7.6	—	4.6	—	7.3	—	10.0	—
Urbanicity, low tertile,* %	30.7	—	34.3	—	29.5	—	31.4	—
Urbanicity, middle tertile,* %	24.2	—	23.5	—	24.4	—	24.0	—
Urbanicity, high tertile,* %	14.6	—	12.1	—	14.7	—	16.0	—
BMI, kg/m^2	23.0	4.6	18.0	4.4	24.0	4.0	23.7	4.0
Overweight, %	31.5	—	18.4	—	34.1	—	33.2	—
Household income, yuan	15,340	16,785	11,890	13,383	16,208	17,941	14,760	14,906
Low	3,759	4,347	3,548	3,646	3,857	5,045	3,672	2,928
Medium	11,586	2,337	11,361	2,303	11,605	2,350	11,646	2,310
High	30,025	20,269	28,432	17,330	30,774	21,925	28,645	16,347
Education, %								
Primary school and below	34.4	—	25.0	—	25.0	—	63.0	—
Middle and high school	53.9	—	66.5	—	60.1	—	30.9	—
University and above	11.8	—	8.5	—	14.9	—	6.2	—

1 Standard deviation.

* Communities not in megacities (> 20 million population) or big cities (5–20 million population).

Table 2

Food group sources of kcal/day from processed foods, CHNS 2011

	A. Percentage of kcal in each food group from processed foods				B. Percentage of total daily kcal from food group				C. Percentage of total daily kcal from processed foods			
Age	2–18	19–59	60+	2+	2–18	19–59	60+	2+	2–18	19–59	60+	2+
Milk and dairy	79.6	69.0	75.6	72.7	3.7	1.3	1.6	1.7	3.1	1.0	1.3	1.4
Animal-source foods	10.1	8.1	7.4	8.2	19.3	18.1	15.9	17.8	2.2	1.6	1.3	1.6
Legumes and nuts	15.9	16.0	14.7	15.7	3.0	4.0	4.2	3.9	0.6	0.8	0.7	0.7
Mixed dishes	32.6	26.3	29.4	27.9	3.8	4.2	2.9	3.8	1.2	1.1	0.8	1.0
Grains	16.8	14.8	13.8	14.9	46.3	48.7	49.2	48.4	7.4	7.1	6.7	7.0
Snacks and sweets	90.9	85.4	90.1	88.0	4.1	1.4	1.6	1.8	3.7	1.2	1.4	1.6
Fruits and vegetables	4.8	4.5	4.0	4.4	7.6	7.7	7.9	7.7	0.4	0.4	0.3	0.4
Beverages, nonalcoholic	91.5	87.5	87.0	88.7	0.7	0.4	0.1	0.4	0.6	0.3	0.1	0.3
Beverages, alcoholic	100.0	95.6	97.8	96.2	0.0	0.7	0.8	0.6	0.0	0.7	0.7	0.6
Fats and oils	100.0	100.0	100.0	100.0	10.2	12.7	15.1	12.9	10.2	12.7	15.1	12.9
Other foods/condiments	96.7	96.6	97.9	97.0	1.4	0.9	0.9	1.0	1.3	0.8	0.9	0.9
Total	—	—	—	—	100.0	100.0	100.0	100.0	30.6	27.6	29.2	28.5

Table 3

Factors associated with energy intake from processed foods in instrumental variable models for the two outcomes

	BMI			Overweight		
	β	SE[1]	p	β	SE	p
A. Age 2–18 years						
Energy from other foods (kcal)	−0.177	0.017	***	−0.178	0.017	***
Female	−0.097	0.016	***	−0.097	0.016	***
Education						
Middle and high school	0.034	0.020	NS	0.036	0.020	NS
Above high school	−0.020	0.035	NS	−0.019	0.035	NS
Income						
Middle tertile	−0.016	0.019	NS	−0.015	0.019	NS
High tertile	0.118	0.026	***	0.119	0.026	***
Physical activity						
Middle tertile	0.035	0.020	NS	0.036	0.020	NS
High tertile	0.056	0.021	**	0.057	0.021	**
Sedentary hours (hours/day)	0.013	0.005	**	0.013	0.005	**
Distance to grocery stores (km)	−0.002	0.001	NS	−0.002	0.001	NS
Distance to free markets (km)	0.005	0.003	NS	0.007	0.003	**
Urbanization index						
Middle tertile	0.127	0.021	***	0.126	0.020	***
High tertile	0.154	0.023	***	0.152	0.022	***
B. Age 19–59 years						
Energy from other foods (kcal)	−0.235	0.008	***	−0.235	0.008	***
Female	−0.149	0.010	***	−0.149	0.010	***
Education						
Middle and high school	0.021	0.012	NS	0.022	0.012	NS
Above high school	0.006	0.019	NS	0.008	0.019	NS
Income						
Middle tertile	0.011	0.012	NS	0.011	0.012	NS
High tertile	0.056	0.013	***	0.056	0.013	***
Physical activity						
Middle tertile	−0.006	0.012	NS	−0.006	0.012	NS
High tertile	−0.010	0.013	NS	−0.011	0.013	NS
Sedentary hours (hours/day)	−0.005	0.003	NS	−0.005	0.003	NS
Distance to grocery stores (km)	0.000	0.001	NS	0.000	0.001	NS
Distance to free markets (km)	0.006	0.002	***	0.005	0.002	**
Urbanization index						
Middle tertile	0.003	0.014	NS	−0.006	0.015	NS
High tertile	−0.033	0.015	*	−0.037	0.015	*
C. Age 60+ years						

	BMI			Overweight		
	β	SE[1]	p	β	SE	p
Energy from other foods (kcal)	−0.192	0.012	***	−0.192	0.012	***
Female	−0.089	0.014	***	−0.089	0.014	***
Education						
Middle and high school	0.062	0.017	***	0.059	0.017	***
Above high school	0.072	0.032	*	0.069	0.032	*
Income						
Middle tertile	0.018	0.017	NS	0.021	0.018	NS
High tertile	0.065	0.018	***	0.066	0.019	***
Physical activity						
Middle tertile	0.040	0.017	*	0.039	0.017	*
High tertile	0.024	0.017	NS	0.023	0.018	NS
Sedentary hours (hours/day)	0.010	0.004	*	0.009	0.004	*
Distance to grocery stores (km)	0.002	0.001	NS	0.000	0.000	NS
Distance to free markets (km)	0.005	0.002	NS	0.000	0.001	NS
Urbanization index						
Middle tertile	0.039	0.019	*	−0.005	0.015	NS
High tertile	0.013	0.022	NS	−0.007	0.022	NS

NS = not significant.

[1] Standard error.

*** $p < 0.001$;

** $p < 0.01$;

* $p < 0.05$;

Table 4

Association of energy intake from processed food consumption with BMI and probability of overweight

Variables	A. OLS and logistic regressions						B. Instrumental variable regressions					
	BMI			Overweight			BMI			Overweight		
	β	SE[1]	p	OR[2]	SE	p	β	SE	p	β	SE	p
A. Age 2–18 years												
Energy from processed foods (kcal)	1.32[§]	0.27	***	1.39[‡]	0.21	*	4.97[†]	1.69	**	1.29[‡]	0.47	**
Energy from other foods (kcal)	0.90[§]	0.21	***	0.90[‡]	0.12	NS	1.54[†]	0.37	***	0.15[‡]	0.11	NS
Female	−0.44	0.19	*	0.76	0.09	*	−0.10	0.26	*	−0.04	0.09	NS
Education												
Middle and high school	0.44	0.24	*	1.06	0.17	NS	0.32	0.27	NS	−0.02	0.09	NS
Above high school	0.41	0.43	NS	1.09	0.28	NS	0.55	0.43	NS	0.05	0.14	NS
Income												
Middle tertile	0.39	0.24	NS	1.44	0.22	*	0.46	0.24	NS	0.20	0.08	*
High tertile	1.20	0.32	***	1.80	0.35	**	0.78	0.41	NS	0.17	0.14	NS
Physical activity												
Middle tertile	0.13	0.25	NS	0.69	0.10	*	0.02	0.27	NS	−0.23	0.08	**
High tertile	0.38	0.26	NS	0.61	0.10	**	0.20	0.30	NS	−0.32	0.09	***
Sedentary hours (hours/day)	0.13	0.06	*	1.02	0.04	NS	0.08	0.07	NS	−0.01	0.02	NS
Distance to grocery stores (km)	−0.03	0.02	NS	0.99	0.01	NS	—	—	—	—	—	—
Distance to free markets (km)	0.06	0.03	*	1.05	0.02	*	—	—	—	—	—	—
Urbanicity index												
Middle tertile	0.32	0.25	NS	1.33	0.22	NS	—	—	—	—	—	—
High tertile	0.65	0.28	*	1.39	0.24	NS	—	—	—	—	—	—

Durbin (score) $\chi^2 = 4.96$ (p = 0.026)

Wu-Hausman F(1,2107) = 4.95 (p = 0.026)

First-stage regression F(4, 2105)=14.1 (p=0.0000)

Sargan (score) χ^2 (3) = 3.76 (p = 0.289)

Basmann χ^2 (3) = 3.74 (p = 0.291)

B. Age 19–59 years

Variables	A. OLS and logistic regressions						B. Instrumental variable regressions					
	BMI			Overweight			BMI			Overweight		
	β	SE[1]	p	OR[2]	SE	p	β	SE	p	β	SE	p
Energy from processed foods (kcal)	0.34‡	0.10	***	1.17‡	0.06	**	−1.80§	1.63	NS	−0.56§	0.58	NS
Energy from other foods (kcal)	−0.10‡	0.08	NS	1.01	0.04	NS	−0.63§	0.39	NS	−0.15§	0.14	NS
Female	−0.44	0.09	***	0.82	0.04	**	−0.76	0.26	**	−0.21	0.08	**
Education												
Middle and high school	−0.28	0.11	**	0.85	0.05	**	−0.19	0.11	NS	−0.07	0.04	*
Above high school	−0.89	0.17	***	0.62	0.06	***	−0.84	0.17	***	−0.26	0.05	***
Income												
Middle tertile	0.17	0.11	NS	1.03	0.06	NS	0.20	0.11	NS	0.03	0.04	NS
High tertile	0.42	0.12	***	1.17	0.07	*	0.53	0.14	***	0.13	0.04	**
Physical activity												
Middle tertile	−0.14	0.11	NS	0.85	0.05	**	−0.17	0.11	NS	−0.11	0.03	**
High tertile	−0.17	0.12	NS	0.92	0.06	NS	−0.26	0.11	*	−0.08	0.04	*
Sedentary hours (hours/day)	−0.04	0.03	NS	0.98	0.01	NS	−0.05	0.03	NS	−0.02	0.01	NS
Distance to grocery stores (km)	−0.01	0.01	NS	1.00	0.00	NS	—	—	—	—	—	—
Distance to free markets (km)	0.00	0.01	NS	1.00	0.01	NS	—	—	—	—	—	—
Urbanicity index												
Middle tertile	0.33	0.12	**	1.22	0.08	**	—	—	—	—	—	—
High tertile	0.16	0.14	NS	1.15	0.09	NS	—	—	—	—	—	—
C. Age 60+ years												
Energy from processed foods (kcal)	0.46§	0.17	**	1.13§	0.10	NS	0.99§	2.81	NS	−0.27§	0.97	NS
Energy from other foods (kcal)	0.34§	0.12	**	1.10§	0.08	NS	0.38§	0.55	NS	−0.02§	0.19	NS
Female	0.44	0.14	**	1.28	0.10	**	0.56	0.29	NS	0.14	0.10	NS

Durbin (score) χ^2 = 1.81 (p = 0.178)

Wu-Hausman F(1,8427) = 1.81 (p = 0.178)

First-stage regression F(4, 8425)=7.86 (p=0.0000)

Sargan (score) χ^2 (3) = 12.6 (p = 0.006)

Basmann χ^2 (3) = 12.6 (p = 0.006)

Variables	A. OLS and logistic regressions						B. Instrumental variable regressions					
	BMI			Overweight			BMI			Overweight		
	β	SE[1]	p	OR[2]	SE	p	β	SE	p	β	SE	p
Education												
Middle and high school	0.17	0.17	NS	1.14	0.10	NS	0.34	0.23	NS	0.15	0.08	*
Above high school	−0.45	0.31	NS	0.80	0.14	NS	−0.20	0.36	NS	−0.04	0.12	NS
Income												
Middle tertile	0.25	0.17	NS	1.15	0.11	NS	0.50	0.18	**	0.16	0.06	**
High tertile	0.53	0.18	**	1.24	0.12	*	0.90	0.25	***	0.26	0.09	**
Physical activity												
Middle tertile	0.42	0.17	*	1.17	0.11	NS	0.37	0.20	NS	0.10	0.07	NS
High tertile	0.20	0.17	NS	1.03	0.10	NS	−0.17	0.18	NS	−0.06	0.06	NS
Sedentary hours (hours/day)	0.09	0.04	*	1.03	0.02	NS	0.13	0.05	**	0.03	0.02	*
Distance to grocery stores (km)	0.01	0.01	NS	1.00	0.01	NS	—	—	—	—	—	—
Distance to free markets (km)	−0.03	0.02	NS	0.98	0.01	NS	—	—	—	—	—	—
Urbanicity index												
Middle tertile	1.07	0.19	***	1.51	0.16	***	—	—	—	—	—	—
High tertile	1.33	0.21	***	1.73	0.21	***	—	—	—	—	—	—
							Durbin (score) χ^2 = 0.04 (p = 0.849)					
							Wu-Hausman F(1,3528) = 0.04 (p = 0.849)					
							First-stage regression F(4, 3526)=3.13 (p=0.014)					
							Sargan (score) χ^2 (1) = 56.6 (p = 0.000)					
							Basmann χ^2 (1) = 57.3 (p = 0.000)					

NS = not significant.

Differences between effects of energy from processed foods and effects from unprocessed foods:

NS = not significant.

[1] Standard error.

[2] Odds ratio.

*** $p < 0.001$;

** $p < 0.01$;

* $p < 0.05$;

‡ $p < 0.01$;

† $p < 0.05$;

§ $p > 0.05$;

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