ORIGINAL ARTICLE

Secular trends in meat and seafood consumption patterns among Chinese adults, 1991–2011

ZH Wang, FY Zhai, HJ Wang, JG Zhang, WW Du, C Su, J Zhang, HR Jiang and B Zhang

BACKGROUND/OBJECTIVES: Several studies have suggested differential health effects in relation to different meat composition in Western population. The purpose of the study was to examine secular trends in meat and seafood consumption patterns among Chinese adults between 1991 and 2011.
SUBJECTS/METHODS: Our longitudinal data are from 21 144 adults aged 18–75 in the China Health and Nutrition Survey, prospective cohort study. We assessed the intakes of meat and subtypes with three 24-h dietary recalls. We conducted multilevel mixed-effect logistic and linear regression models to examine meat consumption dynamics.
RESULTS: The proportions of Chinese adults who consumed red meat, poultry and seafood increased from 65.7% in 1991 to 86.1% in 2011, from 7.5 to 20.9% and from 27.4 to 37.8%, respectively. With rapid decrease in meat intakes since 2009, the intakes of total meat, red meat, poultry and seafood among their consumers were 86.7 g/day, 86.4 g/day, 71.0 g/day and 70.3 g/day in 2011, respectively, which were just slightly higher compared with those in 1991. Fatty fresh pork has been predominantly component of total meat overtime, which consituted 54.0% of total meat intake, 80.0% of fresh red meat intake and 98.7% of fatty fresh red meat intake in 2011.
CONCLUSION: Over the past two decades, meat consumption patterns of Chinese adults have been characterized by having a predominant intake of fatty fresh pork, suboptimal intakes of seafood and increased proportion of adults having excessive intakes of red meat and poultry overtime.

INTRODUCTION

Over the past two decades, there has been increasing concern over the role of total meat in chronic disease risks worldwide.[1–3] Recently, many studies in developed countries focused on the dynamics of meat consumption patterns, rather than only total meat intake, because individual meat sources are thought to have differential health benefits and risks.[4–6] Excessive red meat intake has been associated with certain chronic diseases such as obesity,[7–9] cardiovascular disease,[10,11] diabetes,[10,12] stroke[10,13] and certain cancers.[11,14–17] However, more compelling evidence demonstrated that processed meat, rather than fresh red meat, appeared to be responsible for the elevated risks of chronic diseases.[13,18–20] In contrast, fish and certain types of seafood are generally thought to protect from chronic diseases because of their nutrient contents rich in monounsaturated and essential polyunsaturated fatty acids.[21]

Since the early 1990s, China has experienced a rapid socio-economic, environmental and nutrition transition; the emerging rise in obesity and related chronic diseases has been a major public health concern in China, especially in the most recent decades.[22–26] Changes in Chinese diets have been characterized by large shifts toward decreased intakes of coarse grains, vegetables and legumes and increased intakes of total meat and other animal source foods, edible oils, sugars and caloric sweeteners.[22,23,27] However, no study to date has assessed the long-term dynamics of meat and seafood consumption patterns characterized by quantity and type of meat sources in Chinese adults, whereas meat patterns may have a more complex role in

the double burden of nutrient deficiency and obesity-related chronic diseases that China has experienced.

Using longitudinal data from the China Health and Nutrition Survey (CHNS), the objectives of this study were to examine the trends in meat and seafood consumption patterns with an emphasis on red meat (fatty versus lean red meat) consumption among Chinese adults aged 18–75 between 1991 and 2011 and to investigate the differences in consumption patterns across socio-demographic factors.

SUBJECTS AND METHODS

Study population

All data used in this study were derived from the CHNS, an ongoing longitudinal study. The CHNS was initiated in 1989, with a focus on assessing the relationships between the social and economic transformation in China and the resulting effects on the health and nutritional status of the Chinese population.[28] The CHNS used a multistage, random cluster process to draw the sample from the original eight provinces, and communities were selected randomly as the primary sampling units. The sampling procedure has been described in detail elsewhere.[29,30] Such sampling reflects the hierarchical data structure of the CHNS: measurement occasions (level 1) for individuals (level 2) nested in communities (level 3).

The analysis at hand was based on eight waves of survey data between 1991 and 2011, given that population composition in the 1989 survey consisted only of young adults. Of all the participants aged 18–75 who had complete socio-demographic and dietary data, we excluded pregnant or lactating women($n = 1126$), those having implausible energy intake ($n = 1231$, < 800 kcal or > 6000 kcal for men and < 600 kcal or > 4000

kcal for women) and those having total meat intake greater than 500 g/day ($n = 507$). The current analysis therefore consists of 21 144 participants (10 247 males; 10 897 females) clustered in 239 communities, resulting in 69 122 total responses in the eight survey years.

The protocol of the survey was approved by the institutional review committees of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. All subjects gave written informed consent for their participation in the survey.

Dietary measures

Dietary intake at the individual level was assessed by using 24-h dietary recalls from three consecutive days (2 weekdays and 1 weekend day) in each wave of CHNS. Interviewers were trained in standard forms for 24-h dietary recall administration conducted in the household interview. The participants were asked to report the types and amounts of all food and beverage items (measured in grams) that had been eaten both at home and away from home on a 24-h recall basis.[31] For mixed dishes, the participants reported the amount of each ingredient involved in them, except seasonings and edible oil. The average intakes of meat and subtypes from the three 24-hour recalls were calculated for each individual.

Meat and subtypes grouping

The meat grouping system was based on the China food composition table.[32] Figure 1 provides an overview of summarized subgroups within the total meat category. The total meat category consisted of red meat, poultry and seafood. Red meat is defined as pork, beef, mutton and their products. Fresh red meat included all fresh muscle and organ meat that had not been treated, whereas processed red meat included the products of red meat that had undergone treatment (such as various sausages, salami, ham, luncheon meats, etc). We further divided fresh red meat into fatty fresh red meat ($\geqslant 10$ g fat/100 g of edible fresh red meat) and lean fresh red meat (< 10 g fat/100 g of edible fresh red meat) on the basis of the food grouping system developed by Barry M. Popkin et al.[33]

The definition of meat consumption patterns, meat consumers and consumption rate

Meat consumption patterns are characterized by the quantity and quality of total meat and meat subtypes––that is, the proportion of meat subgroups. Over a 3-day period in each wave of the CHNS, an individual is defined as a meat consumer if any type of meat was consumed during that time period and was further defined as a meat subtype-specific consumer if corresponding meat subtypes were eaten. Consumption rate is defined as proportion of participants consuming meat and subtypes.

On the basis of the Chinese Dietary Guidelines (CDG)' recommendation 'consume moderate amounts of fish, poultry, eggs and lean meat',[34] the Chinese Food Guide Pagoda recommends 50–75 g/day of red meat and poultry, and 75–100 g/day of seafood, which varies depending on six established energy requirement levels for Chinese adults.[34] Higher intakes

of red meat and poultry were determined and assessed in comparison with the energy level-specific recommended values.[34,35]

Assessment of socio-demographic factors

Socio-demographic variables include age, gender and income level. We calculated per capita annual family income by dividing annual family income by household size. We inflated the per capita annual family incomes in each survey to 2011 values by adjusting for the consumer price index and then divided them into tertiles (low, medium and high).

The community urbanicity index, a complex measure of urbanization, is based on 12 multidimensional components reflecting economic, social, demographic and infrastructural diversity at the community level.[36] This variable is a continuous time-varying index and presented as tertiles in our analyses.

Statistical analysis

We constructed three-level logistic random intercept regression with survey years (level 1) nested within individuals (level 2) nested in communities (level 3) to assess secular trend in the likelihood of consuming each type of meat. Using the fitted logistic models, we also estimate the adjusted consumption rate overtime by meat subtypes. Next, we performed three-level linear regression models to evaluate longitudinal change in amount of each type of meat among the meat subtype consumers overtime.

Finally, we analyzed the changes in the components of total meat among meat consumers in 1991, 2000 and 2011 and also assessed the proportion of adults whose intakes of red meat and poultry or seafood met the corresponding recommendations in all participants, respectively.

All statistical tests were two-tailed, and we regarded differences as significant at $P < 0.05$. We fitted longitudinal models using the XTMIXED and GLLAMM programs in Stata/SE (Intercooled STATA, version 12.0, StataCorp, TX, USA).

RESULTS

Secular trends in consumption rates of total meat and subgroups between 1991 and 2011

There were significant differences in age group distribution across the survey years (Table 1).

The likelihood of consuming each type of meat in Chinese adults showed significantly increased trend over time after controlling for the socio-demographic factors (Table 2). The proportions of adults who consumed red meat, poultry and seafood increased from 65.7% in 1991 to 86.1% in 2011, from 7.5 to 20.9% and from 27.4 to 37.8%, respectively. The proportion of adults consuming fatty fresh red meat was twice the proportion of adults consuming lean fresh red meat in 2011(75.1% versus 30.8%) (Figure 2). The adjusted consumption rate of processed red
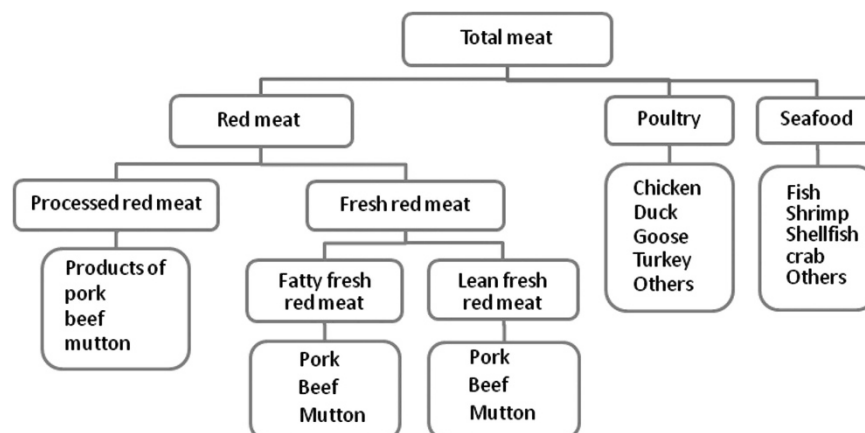

Figure 1. Definition of meat subgroups within the total meat category.

Table 1. Cross-sectional characteristics of the study population across survey years, China Health and Nutrition Survey

	1991	1993	1997	2000	2004	2006	2009	2011
All participants	8200	8146	8742	9580	8719	8597	8808	8330
Age groups (%)								
18–44 years	63.9	63.2	58.2	53.6	44.9	43.6	39.7	34.7
45–59 years	22.7	23.0	26.4	30.4	36.0	35.6	37.9	38.5
60–75 years	13.4	13.8	15.5	16.0	19.1	20.7	22.4	26.8
Male (%)	48.5	48.9	50.0	49.7	49.1	48.6	49.0	48.2
Income level[a]								
Low	1208.7	1178.9	1515.3	1569.4	1844.8	2052.3	3411.6	4004.5
Medium	2710.6	2755.1	3465.4	4355.3	5223.8	5922.3	8812.2	10941.1
High	4795.7	5715.2	6804.5	8753.4	12252.5	14064.5	19834.7	23334.5
Urbanicity index[b]								
Low	29.0	29.2	31.8	40.3	39.9	40.4	46.6	48.3
Medium	46.0	46.9	52.0	56.0	59.9	62.6	64.2	68.6
High	64.5	66.5	73.7	79.7	86.0	86.3	89.6	91.1

[a]Per capita annual household income, inflated to 2011. Values presented as median of each tertile. [b]Measured at the community level on a 12-component continuous scale ranging from 0 to 120. Values presented as median of each tertile.

Table 2. Odds Ratios (95% confidence intervals) of meat subtype consumption, China Health and Nutrition Survey[a]

	Red meat	Poultry	Seafood	Fatty fresh red meat	Lean fresh red meat
Survey year					
1991	1.00	1.00	1.00	1.00	1.00
1993	1.22 (1.12,1.33)***	1.18 (1.07,1.31)**	0.96 (0.89,1.04)	1.13 (1.05,1.22)***	1.19 (1.10,1.29)***
1997	1.22 (1.12,1.33)***	1.66 (1.50,1.83)***	1.17 (1.08,1.27)***	1.11 (1.03,1.19)**	1.17 (1.07,1.27)***
2000	1.73 (1.59,1.88)***	2.02 (1.83,2.22)***	1.12 (1.03,1.21)**	1.50 (1.39,1.61)***	1.20 (1.11,1.31)***
2004	1.95 (1.79,2.13)***	2.11 (1.91,2.33)***	1.27 (1.17,1.38)***	1.56 (1.45,1.68)***	1.35 (1.24,1.48)***
2006	2.69 (2.46,2.95)***	2.12 (1.92,2.33)***	1.39 (1.28,1.51)***	1.91 (1.77,2.06)***	1.33 (1.22,1.45)***
2009	3.82 (3.48,4.20)***	3.56 (3.23,3.92)***	1.86 (1.71,2.01)***	2.63 (2.43,2.84)***	1.44 (1.32,1.57)***
2011	4.72 (4.28,5.20)***	4.02 (3.65,4.43)***	1.86 (1.71,2.02)***	2.96 (2.73,3.21)***	1.81 (1.66,1.98)***
Age groups					
18–44 years	1.00	1.00	1.00	1.00	1.00
45–59 years	0.80 (0.76,0.84)***	0.82 (0.78,0.86)***	0.92 (0.88,0.96)***	0.85 (0.81,0.89)***	0.85 (0.81,0.89)***
60–75 years	0.61 (0.57,0.65)***	0.60 (0.56,0.64)***	0.79 (0.74,0.83)***	0.71 (0.67,0.75)***	0.64 (0.60,0.68)***
Gender					
Male	1.00	1.00	1.00	1.00	1.00
Female	0.83 (0.79,0.87)***	0.89 (0.85,0.93)***	0.94 (0.91,0.98)**	0.86 (0.82,0.89)***	0.88 (0.84,0.91)***
Individual income					
Low	1.00	1.00	1.00	1.00	1.00
Medium	1.61 (1.52,1.70)***	1.37 (1.29,1.46)***	1.23 (1.17,1.30)***	1.47 (1.41,1.54)***	1.41 (1.33,1.48)***
High	2.01 (1.88,2.14)***	1.76 (1.65,1.87)***	1.55 (1.47,1.63)***	1.65 (1.57,1.74)***	1.70 (1.61,1.80)***
Urbanicity index					
Low	1.00	1.00	1.00	1.00	1.00
Medium	1.47 (1.38,1.56)***	1.27 (1.18,1.38)***	1.70 (1.61,1.80)***	1.21 (1.14,1.29)***	1.52 (1.41,1.64)***
High	3.04 (2.72,3.41)***	1.64 (1.51,1.78)***	2.54 (2.38,2.71)***	1.55 (1.43,1.68)***	1.81 (1.67,1.96)***

[a]All of the models were constructed using three-level mixed-effects logistic random intercept regression. Random effect part is omitted. *$P < 0.050$, **$P < 0.010$, ***$P < 0.001$.

meat increased slowly from 3.0% in 1991 to 7.0% in 2011 (data not shown).

Secular trends in daily intakes of total meat and subgroups between 1991 and 2011

The intakes of total meat and subtypes among their consumers showed generally increased trend with fluctuation between 1991 and 2009 and then reduced rapidly. Slightly higher compared with those in 1991, the intakes of total meat, red meat, poultry and seafood among the consumers were 86.7 g/day, 86.4 g/day, 71.0 g/day and 70.3 g/day in 2011, respectively (Table 3).

Changes in components of total meat consumption among meat consumers

Figure 3 illustrats the contribution of individual meat subgroups to total meat intake among meat consumers in 1991, 2000 and 2011.

The proportion of lean and fatty fresh red meat decreased by 2.8 and 6.3 percentages points, whereas the proportion of poultry and seafood increased by 6.4 and 2.2 pencentage points, respectively. Analyzing fatty fresh red meat groups in greater depth, fatty fresh pork has been predominantly component, which consituted 54.0% of total meat intake, 80.0% of fresh red meat intake and 98.7% of fatty fresh red meat intake in 2011, whereas fresh beef and fresh mutton were both extremely low proportion.

Comparison with the recommended intake by CDG

In general, the proportion of adults who met energy-specific red meat and poultry recommendations increased steadily from 40.0% in 1991 to 55.1% in 2009 and then decreased slightly to 50.6% in 2011; there were about 26.7% of adults consuming red meat and poultry above 125 g/day in 2011. The proportion of adults whose fish intake met the recommendation was only 13.5% in 2011, despite a slow increasing trend overtime (data not shown).

Demographic determinants of meat and seafood consumption patterns

As shown in Table 2, male or younger adults tend to have significantly higher consumption rates of all types of meat. Adults
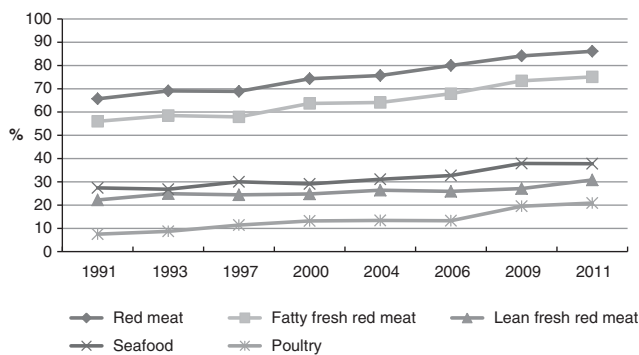
Figure 2. Secular trends in the adjusted consumption rate of each type of meat and seafood among Chinese adults, CHNS.

with high income or living in high urbanicity communities most likely consume any type of meat.

In respect to amounts of meat intake, higher urbanicity was associated with increased fatty fresh red meat intake (2.82 g/day; 95% confidence interval: 0.09–5.55) and decreased poultry intake (−6.63 g/day; 95% confidence interval: −10.45 to −2.81). Positive association of high income was observed with each type of meat (Table 3).

DISCUSSION

This study investigated the 21-year dynamics of meat and seafood consumption patterns and variation across demographic groups in Chinese adults using data from the CHNS. During the period of 1991–2011, the consumption rates of meat and meat subtypes among Chinese adults had been on the rise. However, the proportion of Chinese adults consuming poultry or seafood was still low (20.9% versus 37.8%). Among meat consumers, fatty fresh pork had been the predominant component consituting over half of total meat intake, four-fifth of fresh red meat intake and almost single source of fatty fresh red meat intake in 2011. Because of the big decrease in the intakes of meat and subtypes between 2009 and 2011, the current average intake of total meat among consumers was 86.4 g/day, only slightly higher compared with those in 1991(83.0 g/day). Rapid increase in the price of meat and seafood in 2011 may be one possible explanation for such a big reduction in meat intakes. The Consumer Price Index of red meat and poultry and seafood in 2011 increased significantly, much higher compared with that in 2009 (122.6 versus 91.3 and 112.1 versus 102.5, respectively).[37] Andreyeva et al.[38] found that meat, with the highest price elasticity, is most responsive to price changes. Green et al.[39] suggested greater reductions in food consumption because of increased price in poor countries and a 1% increase in the price of meat results in reductions in consumption of 0.78% and 0.60% in low- and high-income countries, respectively.Moreover, low-income households will be the most affected by increased prices.[39] About two-thirds of participants in our study were sampled from lower income rural communities who might be most responsive to rapid increase in meat price and subsequently reduced or consumed no meat

Table 3.	Parameter estimates (95% confidence intervals) of meat subtype intakes,China Health and Nutrition Survey[a]					
	Total meat	*Red meat*	*Poultry*	*Seafood*	*Fatty fresh red meat*	*Lean fresh red meat*
Intercept	82.96 (78.74,87.18)[***]	82.95 (78.75,87.15)[***]	66.93 (62.31,71.56)[***]	65.02 (60.99,69.05)[***]	73.76 (70.37,77.15)[***]	60.65 (56.68,64.61)[***]
Survey year						
1993	9.79 (7.52,12.06)[***]	9.69 (7.43,11.95)[***]	−0.29 (−4.40,3.81)	1.24 (−1.51,4.00)	6.63 (4.50,8.77)[***]	6.29 (3.45,9.13)[***]
1997	5.99 (3.67,8.31)[***]	5.43 (3.12,7.74)[***]	7.67 (3.75,11.58)[***]	12.09 (9.33,14.85)[***]	3.76 (1.57,5.94)[***]	−0.90 (−3.81,2.00)
2000	13.61 (11.38,15.84)[***]	13.23 (11.01,15.45)[***]	6.76 (2.97,10.55)[***]	9.59 (6.88,12.30)[***]	10.84 (8.76,12.93)[***]	0.61 (−2.25,3.47)
2004	10.06 (7.78,12.35)[***]	9.67 (7.40,11.94)[***]	9.32 (5.45,13.19)[***]	14.20 (11.45,16.96)[***]	5.70 (3.56,7.85)[***]	4.02 (1.14,6.91)[**]
2006	13.56 (11.29,15.82)[***]	13.30 (11.04,15.56)[***]	10.25 (6.37,14.13)[***]	18.27 (15.53,21.01)[***]	10.82 (8.70,12.95)[***]	−1.34 (−4.23,1.56)
2009	13.12 (10.86,15.37)[***]	12.83 (10.59,15.07)[***]	6.10 (2.42,9.77)[**]	14.15 (11.46,16.83)[***]	7.93 (5.82,10.03)[***]	−0.56 (−3.44,2.32)
2011	3.79 (1.51,6.07)[**]	3.46 (1.19,5.73)[**]	4.09 (0.39,7.78)[*]	5.26 (2.52,7.99)[***]	−0.56 (−2.69,1.57)	−9.43 (−12.30, −6.56)[***]
Age groups						
45–59 years	−4.92 (−6.19, −3.65)[***]	−4.83 (−6.09, −3.56)[***]	0.27 (−1.56,2.11)	3.37 (1.85,4.89)[***]	−3.06 (−4.23, −1.89)[***]	−0.56 (−2.10,0.99)
60–75 years	−15.23 (−16.79, −13.66)[***]	−14.99 (−16.55, −13.43)[***]	−4.09 (−6.42, −1.76)[***]	−0.32 (−2.20,1.57)	−8.85 (−10.28, −7.41)[***]	−6.87 (−8.81, −4.93)[***]
Female	−17.31 (−18.43, −16.18)[***]	−17.08 (−18.20, −15.96)[***]	−6.68 (−8.28, −5.08)[***]	−7.92 (−9.25, −6.58)[***]	−13.34 (−14.35, −12.32)[***]	−8.55 (−9.88, −7.22)[***]
Individual income						
Medium	7.90 (6.48,9.32)[***]	7.72 (6.31,9.14)[***]	1.79 (−0.50,4.09)	0.11 (−1.70,1.93)	4.45 (3.13,5.78)[***]	2.25 (0.37,4.13)[*]
High	14.80 (13.27,16.33)[***]	14.38 (12.86,15.90)[***]	2.72 (0.36,5.08)[*]	4.05 (2.18,5.93)[***]	9.11 (7.68,10.53)[***]	3.45 (1.52,5.38)[***]
Urbanicity index						
Medium	1.38 (−0.89,3.64)	1.18 (−1.08,3.43)	−7.86 (−11.16, −4.57)[***]	−1.63 (−4.34,1.07)	0.29 (−1.79,2.36)	−1.98 (−5.06,1.11)
High	5.48 (2.47,8.50)[***]	5.50 (2.50,8.50)[***]	−6.63 (−10.45, −2.81)[***]	−1.69 (−5.13,1.75)	2.82 (0.09,5.55)[*]	0.71 (−2.80,4.23)

[a]All of the models were constructed using three-level mixed-effects linear random intercept regression. Random effect part is omitted. 1991 survey year, aged 18–44, male, low income and low urbanicity as the reference groups.*P < 0.050, **P < 0.010, ***P < 0.001.
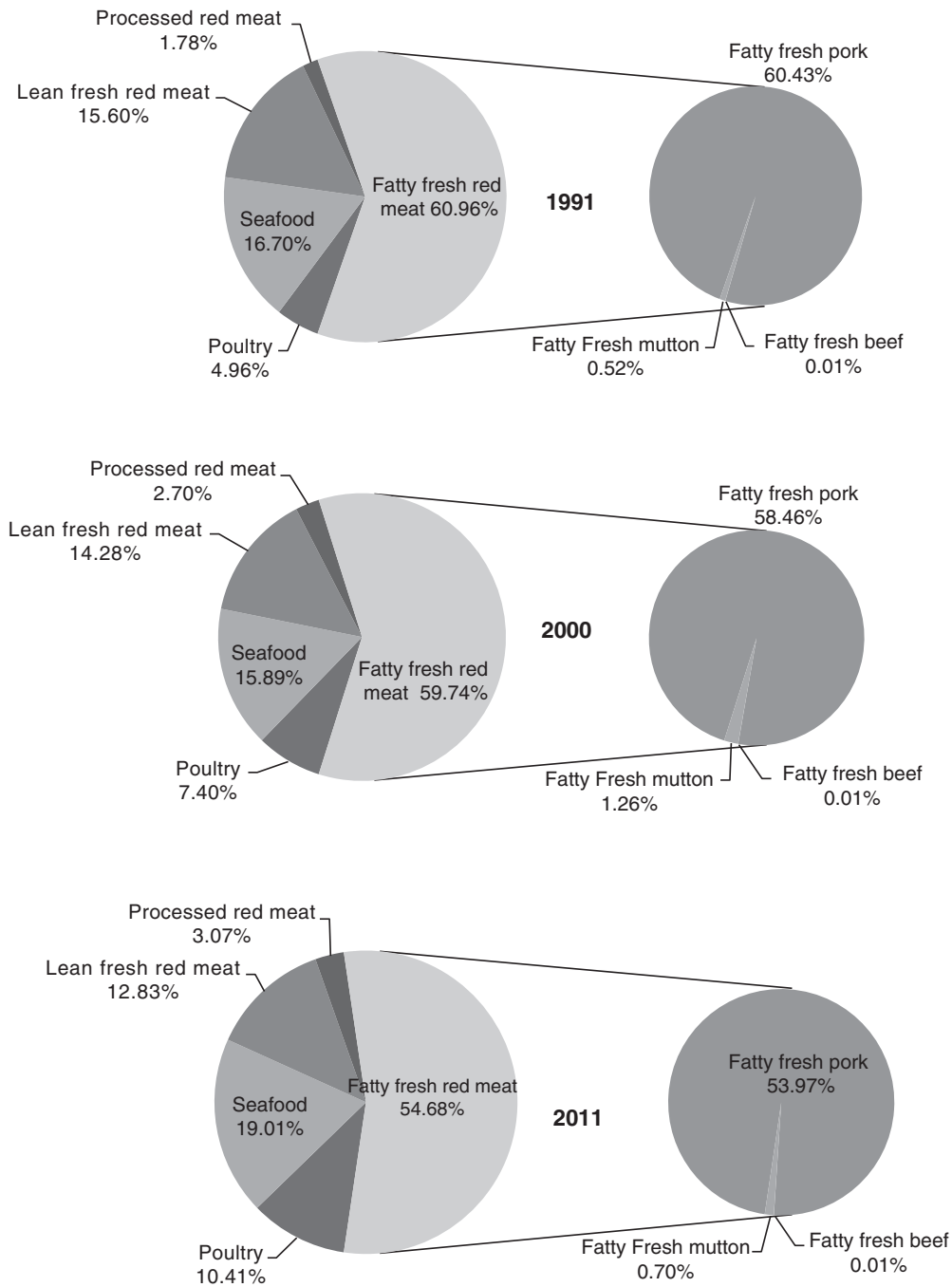
Figure 3. Percentage distribution of intakes of meat subtypes among meat consumers, CHNS, 1991, 2000 and 2011.

intake over a 3-day period in 2011. However, the observed decreased trends in meat consumption of Chinese adults in 2011 and potential influence of price fluctuation warrant further investigation. The CHNS will conduct a new wave of survey in 2015 that will allow us to keep track on the following trends in meat consumption patterns in Chinese population.

Lack of uniform definition of total meat and subtypes, especially red meat, makes comparion across studies difficult. Our study defines red meat as pork, beef and mutton, which is relatively similar to the definition used by USA and some European coutries.[4–6] In general, Chinese meat consumption patterns are different from the Western populations including lower intake of total meat and red meat with extremely higher proportion of fatty

pork and lower beef intake. It has important health implication given threshold effect of total meat and subtypes on disease risk and different fatty acid composition between pork and beef, and between fatty and lean red meat.

Several studies suggest that processed red meat, not fresh red meat, is related to increased risks of certain chronic diseases.[18,19] Thus, separate analysis of processed and fresh red meat consumption has important public health implications. The present study found that less than 10% of Chinese adults consumed processed red meat, which constituted only 3.1% of total meat intake in 2011. In a comparison of 22% of total meat consumed as processed in the USA,[4] Chinese processed red meat consumption may not be of concern at the moment, but the rising

trend in intake should be monitored given its important role in chronic disease risk.

CDG, revised in 2007, emphasize the importance 'eating moderate amounts of fish, poultry, eggs and lean meat for healthy adults'.[34] In line with the guidelines, the Chinese food guide Pagoda recommends 50–75 g/day of red meat and poultry meat and 75–100 g/day of seafood varying depending on individual energy requirement levels.[25] We found that about one-fourth of Chinese adults consumed red meat and poultry higher than 125 g/day in 2011. It is of concern given that several studies in China have suggested the potential risk of red meat consumption on obesity,[40] diabetes[12] and mortality.[41] In addition, there were only 13.6% of adults meeting the recommended seafood intake. Fish and other type of seafood are generally thought of as being major source of high-quality protein and protective factors against certain chronic diseases,[21] It is therefore essential to take effective strategies to advocate optimal intake of seafood as substitutes for red meat.

With regard to the current Chinese meat-related recommendations, several issues need to be considered. First of all, it is important that the Chinese Food Guide Pagoda provides the recommended intakes of red meat and poultry separately, given their differential impact on health outcomes; second, it appears appropriate for the Chinese Food Guide Pagoda to address emphasis on the intake of lean fresh meat as CDG do. Another issue regarding the absence of processed meat recommendations in the CDG should be taken into consideration, so an intake level could be established and serve as a basis for making food choices. In respect of meat intake, the CDG and Chinese Food Guide Pagoda were originally designed based predominantly on Chinese dietary practices, present nutritional status and some general knowledge related to maintaining a healthy diet, unlike Western guidelines that are developed on the basis of scientific evidence of meat-disease relationship. In this regard, large prospective studies in the Chinese context are needed to investigate the effect of total meat and meat subtype consumption on health outcomes. The recommended value of red meat by CDG is generally lower than that by Western dietary guidelines, such as consuming red meat sparingly by the Harvard Healthy Eating Pyramid,[42] consuming an average of 71.4 g/day of cooked red meat (beef and pork) and processed meats by the World Cancer Research Fund.[43] The recommended red meat intake of Chinese adults should take into account its two aspects of health benefit and risks, on the one hand, its contribution to intakes of essential nutrients and on the other hand, its associated risk of chronic diseases, in order to fight the double burden of under- and overnutrition that China has experienced over recent decades.[22,24]

To the best of our knowledge, this study is the first to examine the 21-year dynamic shifts in meat consumption patterns with an emphasis on the intakes of fatty and lean fresh red meat among Chinese adults in depth. A major strength of this study is the use of trained interviewers who administered three consecutive 24-h recalls to assess meat intake. Twenty-four hour dietary recalls capture extensive and complete information on all foods consumed as well as ingredients within mixed dishes, allowing accessibility to the intakes of individual meat and processed red meat sources to provide more accurate data and analyses. Further, multilevel mixed-effects modeling contributed to more precise estimates of longitudinal changes in meat and subtype consumption due to its ability of maximum use of unbalanced longitudinal data and handling dependence of individual nested in the same communities.[44,45]

Our study also encountered some limitations. Twenty-four hour dietary recall method cannot generally evaluate usual dietary intake, but the average intake from three 24-h dietary recalls can reduce random variation and provide estimates close to usual meat consumption.[46] As well, each round of the CHNS was conducted between the months of August and November, so dietary data may not reflect seasonal changes in meat consumption. In addition, some studies found that the cooking and trimming of visible fatty tissue considerably decrease the fat content,[47] our definition of fatty versus lean fresh red meat based on fat content of uncooked meat may be susceptible to misclassification. However, there is lack of related information to fully assess this point. Besides, total meat consumption did not account for meat present in fast foods because of limited availability of current China food composition tables. However, this limitation likely did not have substantial influence on the results because Chinese fast food intakes are still relatively low.

In conclusion, this large 21-year longitudinal prospective study confirmed an upward trend in consumption rates of meat subtypes in Chinese adults aged 18–75 years. Slightly lower compared with those in 1991, the average intakes of red meat, poultry and seafood among their consumers were 86.4 g/day, 71.0 g/day and 70.3 g/day in 2011, respectively. Meat patterns of Chinese meat consumers were characterized by predominant intake of fatty fresh pork, suboptimal intake of seafood, and increasing proportion of adults having excessive intakes of red meat and poultry overtime. Findings from this study will enhance our understanding of the potential role of meat consumption patterns in the double burden that China has faced over the past two decades.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1 McAfee AJ, McSorley EM, Cuskelly GJ, Moss BW, Wallace JM, Bonham MP *et al.* Red meat consumption: an overview of the risks and benefits. *Meat Sci* 2010; **84**: 1–13.

2 Azadbakht L, Rouhani MH. Red meat consumption: Emphasis on chronic diseases or sticking to nutrient deficiency? *J Res Med Sci* 2012; **17**: 315–316.

3 McNeill S, Van Elswyk ME. Red meat in global nutrition. *Meat Sci* 2012; **92**: 166–173.

4 Daniel CR, Cross AJ, Koebnick C, Sinha R. Trends in meat consumption in the USA. *Public Health Nutr* 2011; **14**: 575–583.

5 Wang Y, Beydoun MA, Caballero B, Gary TL, Lawrence R. Trends and correlates in meat consumption patterns in the US adult population. *Public Health Nutr* 2010; **13**: 1333–1345.

6 Linseisen J, Kesse E, Slimani N, Bueno-De-Mesquita HB, Ocke MC, Skeie G *et al.* Meat consumption in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts: results from 24-hour dietary recalls. *Public Health Nutr* 2002; **5**: 1243–1258.

7 Montonen J, Boeing H, Fritsche A, Schleicher E, Joost HG, Schulze MB *et al.* Consumption of red meat and whole-grain bread in relation to biomarkers of obesity, inflammation, glucose metabolism and oxidative stress. *Eur J Nutr* 2013; **52**: 337–345.

8 Vergnaud AC, Norat T, Romaguera D, Mouw T, May AM, Travier N *et al.* Meat consumption and prospective weight change in participants of the EPIC-PANACEA study. *Am J Clin Nutr* 2010; **92**: 398–407.

9 Wang Y, Beydoun MA. Meat consumption is associated with obesity and central obesity among US adults. *Int J Obes* 2009; **33**: 621–628.

10 Micha R, Wallace SK, Mozaffarian D. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. *Circulation* 2010; **121**: 2271–2283.

11 Cross AJ. Higher red meat consumption is associated with increased risk of all-cause, cardiovascular, and cancer mortality. *Evid Based Nurs* 2012; **15**: 121–122.

12 Villegas R, Shu XO, Gao YT, Yang G, Cai H, Li H et al. The association of meat intake and the risk of type 2 diabetes may be modified by body weight. Int J Med Sci 2006; 3: 152–159.

13 Chen GC, Lv DB, Pang Z, Liu QF. Red and processed meat consumption and risk of stroke: a meta-analysis of prospective cohort studies. Eur J Clin Nutr 2013; 67: 91–95.

14 Wang J, Joshi AD, Corral R, Siegmund KD, Marchand LL, Martinez ME et al. Carcinogen metabolism genes, red meat and poultry intake, and colorectal cancer risk.Int J Cancer 2012; 130: 1898–1907.

15 Alexander DD, Miller AJ, Cushing CA, Lowe KA. Processed meat and colorectal cancer: a quantitative review of prospective epidemiologic studies. Eur J Cancer Prev 2010; 19: 328–341.

16 Xu X, Yu E, Gao X, Song N, Liu L, Wei X et al. Red and processed meat intake and risk of colorectal adenomas: a meta-analysis of observational studies.Int J Cancer 2013; 132: 437–448.

17 Chan DS, Lau R, Aune D, Vieira R, Greenwood DC, Kampman E et al. Red and processed meat and colorectal cancer incidence: meta-analysis of prospective studies. PLoS One 2011; 6: e20456.

18 Fretts AM, Howard BV, McKnight B, Duncan GE, Beresford SA, Mete M et al. Associations of processed meat and unprocessed red meat intake with incident diabetes: the Strong Heart Family Study. Am J Clin Nutr 2012; 95: 752–758.

19 Larsson SC, Virtamo J, Wolk A. Red meat consumption and risk of stroke in Swedish women. Stroke 2011; 42: 324–329.

20 Lajous M, Tondeur L, Fagherazzi G, de Lauzon-Guillain B, Boutron-Ruaualt MC, Clavel-Chapelon F. Processed and unprocessed red meat consumption and incident type 2 diabetes among French women. Diabetes care 2012; 35: 128–130.

21 Rosell M, Appleby P, Spencer E, Key T. Weight gain over 5 years in 21,966 meat-eating, fish-eating, vegetarian, and vegan men and women in EPIC-Oxford. Int J Obes 2006; 30: 1389–1396.

22 Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev 2012; 70: 3–21.

23 Zhai F, Wang H, Du S, He Y, Wang Z, Ge K et al. Prospective study on nutrition transition in China. Nutr Rev 2009; 67: S56–S61.

24 Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes 2004; 28: S2–S9.

25 Yan S, Li J, Li S, Zhang B, Du S, Gordon-Larsen P et al. The expanding burden of cardiometabolic risk in China: the China Health and Nutrition Survey. Obes Rev 2012; 13: 810–821.

26 Adair LS, Gordon-Larsen P, Du SF, Zhang B, Popkin BM. The emergence of cardiometabolic disease risk in Chinese children and adults: consequences of changes in diet, physical activity and obesity. Obes Rev 2014; 15: 49–59.

27 Zhai FY, Du SF, Wang ZH, Zhang JG, Du WW, Popkin BM. Dynamics of the Chinese diet and the role of urbanicity, 1991-2011. Obes Rev 2014; 15: 16–26.

28 CPC-UNC China Health and Nutrition Survey. Available at http://www.cpc.unc. edu/projects/china (Accessed 10 March 2014) 2011.

29 Popkin BM, Du S, Zhai F, Zhang B. 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: 1435–1440.

30 Zhang B, Zhai FY, Du SF, Popkin BM. The China Health and Nutrition Survey, 1989-2011. Obes Rev 2014; 15: 2–7.

31 Popkin BM. Reducing meat consumption has multiple benefits for the world's health. Arch Intern Med 2009; 169: 543–545.

32 Yang Y, Wang G, Pan X. China Food Composition Table 2009. 2nd edn. Peking University Medical Press: Beijing, China, 2009.

33 Popkin BM, Lu B, Zhai F. Understanding the nutrition transition: measuring rapid dietary changes in transitional countries. Public Health Nutr 2002; 5: 947–953.

34 China Nutrition Society. Dietary Guidelines for Chinese Residents. 1st edn. Tibet People's Publishing House: Lhasa, China, 2010.

35 China Nutrition Society. Chinese Residens' Dietary Reference Intakes. 1st edn China Light Industry Press: Beijing, China, 2002).

36 Jones-Smith JC, Popkin BM. Understanding community context and adult health changes in China: development of an urbanicity scale. Soc Sci Med 2010; 71: 1436–1446.

37 National Bureau of Statistics of China China Statistical Yearbook. Available at http://www.yearbookchina.com/naviBook-YINFN-0.html (Accessed 12 July 2014) 2012.

38 Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. Am J Public Health 2010; 100: 216–222.

39 Green R, Cornelsen L, Dangour AD, Turner R, Shankar B, Mazzocchi M et al. The effect of rising food prices on food consumption: systematic review with meta-regression. Brit Med J 2013; 346: f3703.

40 Wang ZH, Zhang B, Wang HJ, Zhang JG, Du WW, Su C et al. Study on the multilevel and longitudinal association between red meat consumption and changes in body mass index, body weight and risk of incident overweight among Chinese adults. Zhonghua Liu Xing Bing Xue Za Zhi 2013; 34: 661–667.

41 Takata Y, Shu XO, Gao YT, Li H, Zhang X, Gao J et al. Red meat and poultry intakes and risk of total and cause-specific mortality: results from cohort studies of Chinese adults in Shanghai. PLoS One 2013; 8: e56963.

42 Harvard School of Public Health The Long Road to the 2010 Dietary Guidelines for Americans. Available at http://www.hsph.harvard.edu/nutritionsource (Accessed 10 March 2014) 2011.

43 World Cancer research Fund/American Institute for Cancer Research Food, Nutrition, Physical activity and the Prevention of Cancer: a Global Perspective. Available at http://www.dietandcancerreport.org/expert_report/report_contents/index.php (Accessed 10 March 2014) 2007.

44 Miglioretti DL, Heagerty PJ. Marginal modeling of multilevel binary data with time-varying covariates. Biostatistics 2004; 5: 381–398.

45 Von Korff M, Koepsell T, Curry S, Diehr P. Multi-level analysis in epidemiologic research on health behaviors and outcomes. Am J Epidemiol 1992; 135: 1077–1082.

46 Willett W. Nutritional Epidemiology. 2nd ed. Oxford University Press: New York, 1998.

47 Gerber N, Scheeder MR, Wenk C. The influence of cooking and fat trimming on the actual nutrient intake from meat. Meat Sci 2009; 81: 148–154.