

The longitudinal association of smoking behaviors with obesity risk among Chinese adults from the China Health and Nutrition Survey 1991–2015

Jian Zhao

Chinese Academy of Medical Sciences and Peking Union Medical College Institute of Basic Medical Sciences

Dandan Fan

Chaoyang district health commission of Beijing municipality

Chang Su (✉ suchang@nih.chinacdc.cn)

Huijun Wang

Chinese Center for Disease Control and Prevention National Institute for Nutrition and Health

Bing Zhang

Chinese Center for Disease Control and Prevention National Institute for Nutrition and Health

Research

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Abstract

Background

Present study aims to longitudinal explore independent association of smoking status and cigarette consumption with general obesity and abdominal among Chinese adults by gender.

Methods

This study include 75,348 adults (35,907 males and 39,441 females) aged 18-65 years from the longitudinal data of China Health and Nutrition Survey (CHNS, 1991-2015). Multilevel mixed-effects linear and logistic regression models were performed for association analysis.

Results

Among males and females, heavy smokers (> 25 cigarette/d) increased from 5.5% and 0.05% in 1991 to 6.8% and 0.1% in 2015, respectively ($p < 0.001$). After controlling for confounding factors, the net effect on male light (1–14 cigarette/d), moderate (15–24 cigarette/d), and heavy smokers was a significant decrease of 0.40 kg/m² (β : -0.40, 95% CI: -0.48, -0.31), 0.51 kg/m² (β : -0.51, 95% CI: -0.60, -0.43), and 0.29 kg/m² (β : -0.29, 95% CI: -0.43, -0.14) in BMI, respectively. From moderate and light smokers to nonsmokers were linked with significant WC decreases of 0.87 cm (β : -0.87, 95% CI: -1.14, -0.58) and 0.86 cm (β : -0.87, 95% CI: -1.12, -0.59) in males and 1.58 cm (β : -1.58, 95% CI: -2.94, -0.22) and 1.37 cm (β : -1.37, 95% CI: -2.13, -0.59) in females, respectively. The odds ratio (95% CIs) for general obesity in males were 0.72 (0.65–0.81) for light smokers and 0.68 (0.61–0.76) for moderate smokers compared with nonsmokers. Similarly, the odds ratio (95% CIs) for abdominal obesity in males were 0.80 (0.76–0.86) for light smokers and 0.81 (0.76–0.87) for moderate smokers compared with nonsmokers. Moreover, the odds ratio (95% CIs) for abdominal obesity in females were 0.83 (0.71–0.98) for light smokers and 0.73 (0.58–0.91) for moderate smokers compared with nonsmokers.

Conclusions

Compared with nonsmokers, current smokers had lower BMI and WC among Chinese adults regardless of gender. Heavy smokers are more likely to be general obesity and abdominal obesity in male and abdominal obesity in female than other smokers. These findings may improve the understanding on how smoking behaviors affect fat distribution and provide scientific evidence regarding intervention in smoking and obesity by gender.

1. Background

Smoking and obesity are among the leading preventable causes of mortality and morbidity in western societies as well as many developing countries [1]. According to the Chinese Residents Nutrition and Chronic Disease Status Report, the obesity rates of Chinese adults aged 18 and above increased from 4.8% in 2002 to 11.9% in 2015 [2]. In addition to genetic predisposition, this obesity epidemic problem is mostly attributed to behavioral risks, including higher calorie intake, shift toward a sedentary lifestyle, and sex may play a role in such an association[3]. However, other determinants, like smoking, may seriously influence individual results in terms of obesity [4]. Smoking alone or in combination with obesity constitutes a major public health burden[5]. Understanding the pathways that contribute to these risk factors and the nature of the relationship between them is therefore of paramount importance for disease prevention [6].

Evidence suggests that cigarette smoking is associated with both general and abdominal obesity [7], but the existing evidence is complex and not yet completely understood [8, 9]. Meanwhile, although there are extensive studies of the relationship between smoking and obesity, most have been conducted in developed countries [10–12]. A few studies in China have simply used cross-sectional data to explore the association between smoking and general obesity, but to some extent have lacked a comprehensive control of confounding factors such as diet, alcohol consumption, and physical activity [13–16]. Given the metabolic effect of smoking, it is expected that the greater the number of cigarettes smoked, the lower the smoker's body weight, while different studies have reported conflicting results. Some studies have reported that current smokers have more abdominal obesity than nonsmokers [10, 17], but other studies have found no evidence for this association [18, 19], or have even found the opposite [20, 21]. Moreover, longitudinal studies on the impact of smoking intensity on both general obesity and abdominal obesity among Chinese adults are rare.

China, the largest tobacco producer, consumer and manufacturer in the world, is also experiencing a steady rise in obesity rates. Our objectives therefore were to evaluate in a representative longitudinal study of Chinese adults how smoking influenced the BMI and WC, how this was related to general obesity and abdominal obesity, and whether these relationships varied by smoking intensity.

2. Methods

2.1. Study population and data collection

We used data of the China Health and Nutrition Survey (CHNS) for the present investigation, which was an ongoing open-cohort, international collaborative project designed to examine the effects of the social and economic transformation of Chinese society on the health and nutritional status of its population [22]. Using a multistage, random-cluster process to draw a sample of over 30,000 individuals in 15 provinces and municipal cities (Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hubei, Yunnan, Zhejiang, Hunan, Chongqing, Hunan, Guangxi, Guizhou, Beijing, and Shanghai) that vary substantially in geography, economic development, public resources, and health indicators in the survey [23]. Further information on survey procedures is reported in detail elsewhere [24].

Our analysis used nine rounds of survey data between 1991 and 2015. Of all the adults (aged 18–65 years), we excluded participants who were pregnant, lactating or missing key variables. Hence, our final sample consisted of 75,348 person-year observations (35,907 male and 39,441 female) with complete demographic data and information on smoking status, obesity indicators, and 3-day, 24 h dietary recalls in a survey year.

2.2 Dietary data collection

Three consecutive 24-h dietary recalls were used to assess individual dietary intake in each wave of the CHNS [24]. The participants were asked to report the kinds and amount of all the food and beverage items (measured in g) consumed at home and away from home [25]. Based on the Chinese Food Composition Table, we measured nutrition intake data by (1) the respondent's dietary energy intake during a 3-day measurement period and (2) the dietary structure as indicated by the percentage of fat in the respondent's dietary energy intake [26].

2.3. Cigarette smoking

The interviewees were asked if they were active smokers at the time of the survey with the question "Do you smoke?," and if they answered "Yes," they were further asked, "How many cigarettes do you smoke per day?". Two variables were constructed to measure smoking behavior. The first was smoking status, which was classified into "current smoker" or "nonsmoker." The second was smoking intensity, based on the "number of cigarettes consumed daily," where current smokers were further divided into heavy (> 25 cigarette/d), moderate (15–24 cigarette/d), and light (1–14 cigarette/d) smokers [15, 25].

2.4. Obesity indicators

Well-trained health workers measured the height (model 206, SECA) and weight (model 880, SECA) of participants following standardized procedures. We calculated body mass index (BMI) by dividing the weight (in kg) by the square of the height (in m²) and grouped it into thin (< 18.5 kg/m²), normal (18.5–23.9 kg/m²), overweight (24–27.9 kg/m²), and obese (> 28 kg/m²), based on the recommended cut-off points of BMI for overweight and obesity in Chinese adults by the Working Group on Obesity in China [26]. We measured waist circumference (WC) from the midpoint between the lower border of the rib cage and the iliac crest to the nearest 0.1 cm, to reflect the distribution of body fat. We defined participants as having abdominal obesity if WC ≥ 85 cm in females and ≥ 90 cm in males in accordance with the guidelines of the National Health Commission of the People's republic of China [27].

2.5. Other variables

We grouped participants into two marital statuses (single and married), three education levels (primary/illiterate, middle, and high school/above) and two drinking status (yes and no) representing whether the respondent had a habit of drinking spirits during the past year. The per-capita annual income in each survey was inflated to 2015 values by adjusting for the consumer price index. Participants reported all physical activities (PA) (occupational, household chore, leisure time, and transportation in average hours per week, and we converted the time spent in each activity into a metabolic equivalent of task (MET) hours per week based on the Compendium of Physical Activities [28].

2.6. Statistical analysis

Statistical analyses were performed with SAS (version 9.4, SAS Institute, Cary, NC, USA) and Stata/SE (Intercooled STATA, version 13.0, StataCorp, TX, USA). The values were reported as means and standard errors for continuous variables or as proportions of the total for categorical variables. One-way analysis of variance or analysis of covariance was used for continuous variables, whereas Chi-square tests were used for categorical variables. A multilevel mixed-effects linear regression model stratified by gender was constructed to estimate smoking behaviors in relation to BMI and WC, and multilevel mixed-effects logistic regression was performed to assess the risk of general obesity and abdominal obesity by smoking intensity. All of the adjusting covariates including age, education level, individual income, physical activity, drinking status, dietary energy intake, percentage of dietary energy intake from fat, survey year, and we calculated regression coefficients and odds ratios.

3. Results

3.1. Descriptive statistics

Table 1
 Characteristics of male and female stratified by smoking intensity, CHNS 1991-2015¹⁻²

Table 1 Characteristics of male and female stratified by smoking intensity, CHNS 1991–2015 ¹⁻²											
Characteristic	Male (N = 35,907)					P	Female (N = 39,441)				
	Nonsmoker (n = 14,572)	Light (n = 8,706)	Moderate (n = 10,452)	Heavy (n = 2,177)			Nonsmoker (n = 38,235)	Light (n = 799)	Moderate (n = 369)	Heavy (n = 38)	P
Age(year)	42.7(0.1)	42.1 (0.1)	43.5(0.1)	46.3 (0.2)	< 0.001	42.7 (0.1)	50.3(0.4)	50.3(0.6)	49.9 (0.2)	< 0.00	
Married (%)	79.6(0.0)	83.0(0.1)	88.3(0.0)	92.6(0.0)	< 0.001	86.1(0.2)	84.1(1.3)	84.8(1.9)	89.5(0.5)	0.31	
Education level (%)											
Primary/illiterate	25.7(0.4)	31.6(0.5)	34.8(0.5)	39.2(1.0)	< 0.001	43.3(0.3)	67.7(1.7)	75.0(2.3)	50.0(2.2)	< 0.00	
Junior	36.6(0.4)	36.3(0.4)	39.9(0.4)	36.8(0.4)	< 0.001	30.1(0.2)	20.0(0.4)	16.5(1.9)	10.5(1.0)	< 0.00	
High /above	36.4(0.4)	30.9(0.5)	24.1(0.4)	22.2(0.9)	< 0.001	24.1(0.2)	9.0(0.1)	5.4(0.1)	31.6(0.8)	< 0.00	
Income(1 k yuan)	19.1(0.5)	15.5 (0.3)	15.5 (0.3)	16.7(0.3)	< 0.001	12.5(0.14)	7.8(0.14)	6.9(0.62)	14.1(3.6)	< 0.00	
Employed (%)	74.4(0.4)	80.7(0.4)	83.4(0.4)	83.9(0.4)	< 0.001	65.2(0.2)	52.4(0.2)	52.3(0.3)	52.6(0.3)	< 0.00	
PA(METs/w)	236.9(1.8)	274.0 (2.5)	293.6(2.3)	302.8(5.0)	< 0.001	277.4(1.2)	315.0(9.5)	314.8(14.4)	257.0(14.8)	< 0.00	
Drinking (%)	48.4(0.01)	72.2(0.01)	72.2(0.01)	74.0(0.01)	< 0.001	9.7(0.2)	26.8(0.2)	30.9(0.2)	34.2(0.7)	< 0.00	
Dietary indicators											
Energy (1 k kcal)	2.4(0.0)	2.4(0.0)	2.5(0.0)	2.6(0.0)	< 0.001	2.1(0.0)	2.1(0.0)	2.0(0.1)	1.9(0.0)	0.07	
Fat (E %) ³	30.4(0.1)	29.4(0.1)	29.9(0.1)	30.4(0.3)	< 0.001	30.3(0.1)	28.0(0.4)	30.1(0.7)	29.6(2.00)	< 0.00	
Obesity indicators											
WC (cm)	83.2(0.1)	81.8(0.1)	81.6(0.1)	82.7(0.2)	< 0.001	79.0(0.1)	80.0(0.4)	80.2(0.7)	82.0(1.7)	< 0.00	
BMI (kg/m ²)	23.3(0.0)	22.8(0.0)	22.7(0.0)	23.0(0.0)	< 0.001	23.0(0.0)	23.1(0.1)	23.3(0.2)	23.4(0.6)	0.61	
General Obesity (%)	8.7(0.2)	6.1(0.1)	5.5(0.0)	7.1(0.0)	< 0.001	8.1(0.1)	10.5(0.1)	13.8(0.2)	13.2(0.6)	< 0.00	
Abdominal Obesity (%)	34.6(0.41)	28.1(0.5)	28.7(0.4)	32.2(0.4)	< 0.001	36.3(0.0)	41.2(0.0)	43.1(0.0)	55.3(0.1)	< 0.00	

Notes: (1) Date comes from CHNS longitudinal data, from 1991 to 2015. (2) The statistics reported are the sample mean with the standard deviation in parentheses. (3) Fat (E %): percentage of energy intake from fat.

Table 1 shows the characteristics of male and female participants stratified by daily cigarette consumption from CHNS 1991–2015. Of the 75,348 adult participants, 35,907 (47.7%) were male and 39,441 (52.3%) were female. The average age of nonsmokers was about 42.7 years, with the oldest being male heavy smokers (46.3 years) and female light smokers (50.3 years). There were significant differences in the distribution of education level, working status, and individual income by cigarette consumption regardless of gender ($p < 0.001$). Average physical activity (PA) increased from 236.9 METs/w in male nonsmokers to 302.8 METs/w in male heavy smokers. Among females, the highest PA was 315.0 METs/w in light smokers and the least was 257.0 METs/w in heavy smokers. The average drinking rate of current smokers was significantly higher than that of nonsmokers regardless of gender ($p < 0.001$). Moreover, as smoking intensity increased, rate of drinking rose significantly ($p < 0.001$). Male heavy smokers had the highest dietary energy intake (2600 kcal) and percentage of dietary energy intake from fat (30.4%), while female nonsmokers had the highest percentage of dietary energy intake from fat (30.3%). The BMI, WC, general obesity, and abdominal obesity rates of male nonsmokers were significantly larger than those of male current smokers, whereas the opposite held true for females. In addition, it is important to note that, among current smokers, male heavy smokers had larger BMI (23.0 kg/m²), WC (82.7 cm), general obesity (7.1%), and abdominal obesity (32.2%) than other smokers ($p < 0.001$).

Figure 1 shows the shift in distribution of smoking status in Chinese adults by gender. Among males, nonsmokers and heavy smokers increased from 31.0% and 5.5% in 1991 to 47.4% and 6.8% in 2015, respectively ($p < 0.001$). However, male moderate smokers and light smokers decreased from 32.7% and 30.8% in 1991 to 23.8% and 22.0% in 2015, respectively ($p < 0.001$). In general, the trend of the smoking intensity distribution in women was consistent with that in men. Specifically, female nonsmokers and heavy smokers increased from 96.0% and 0.05% in 1991 to 98.3% and 0.1% in 2015, respectively ($p < 0.001$). Female moderate smokers and light smokers decreased from 3.30% and 0.65% in 1991 to 1.10% and 0.50% in 2015, respectively ($p < 0.001$).

Figure 2 shows the shift in the distribution of BMI and WC by smoking status among different genders. It is noteworthy that BMI and WC are increasing significantly both in current smokers and in nonsmokers regardless of gender ($p < 0.001$). However, among males, both the BMI and WC of current smokers are higher than those of nonsmokers, which is opposite to the distributions among females ($p < 0.001$).

3.2. Longitudinal relationship of smoking behaviors and body weight outcomes (BMI and WC) in Chinese males and females from 1991 to 2015

Figure 3 shows that the prevalence of general obesity and abdominal obesity increased significantly in both current smokers and nonsmokers in the provinces of mainland China surveyed by CHNS from 1991 to 2015 ($p < 0.001$). In addition, among current smokers with different smoking intensities, the prevalence of general obesity and abdominal obesity in males is significantly higher than in females ($p < 0.001$).

The results of the multilevel mixed-effects linear regression modeling used to examine the effects of smoking behaviors on BMI and WC are presented in Table 2. In general, compared with nonsmokers, male current smokers showed significant negative effects on BMI and WC. After controlling for confounding factors, the net effect on male light smokers, moderate smokers, and heavy smokers was a significant decrease of 0.40 kg/m² (β : -0.40, 95% CI: -0.48, -0.31), 0.51 kg/m² (β : -0.51, 95% CI: -0.60, -0.43), and 0.29 kg/m² (β : -0.29, 95% CI: -0.43, -0.14) in BMI, respectively. Female light smokers and moderate smokers had net effects of significant decrements of 0.61 kg/m² (β : -0.61, 95% CI: -0.86, -0.35) and 0.66 kg/m² (β : -0.66, 95% CI: -1.06, -0.26) in BMI, respectively. The reductions in cigarette consumption from moderate smokers and light smokers to nonsmokers were linked with significant WC decreases of 0.87 cm (β : -0.87, 95% CI: -1.14, -0.58) and 0.86 cm (β : -0.87, 95% CI: -1.12, -0.59) in males and 1.58 cm (β : -1.58, 95% CI: -2.94, -0.22) and 1.37 cm (β : -1.37, 95% CI: -2.13, -0.59) in females, respectively.

3.3. The effects of smoking behaviors on general obesity and abdominal obesity in Chinese males and females from 1991 to 2015

The odds ratios of the multilevel mixed-effects logistic regression model used to examine the effects of smoking behaviors on general obesity and abdominal obesity risks are summarized in Table 3. After controlling for confounding factors, the odds ratio (95% CIs) for general obesity in males were 0.72 (0.65–0.81) for light smokers and 0.68 (0.61–0.76) for moderate smokers compared with nonsmokers. Similarly, the odds ratio (95% CIs) for abdominal obesity in males were 0.80 (0.76–0.86) for light smokers and 0.81 (0.76–0.87) for moderate smokers compared with nonsmokers. Moreover, the odds ratio (95% CIs) for abdominal obesity in females were 0.83 (0.71–0.98) for light smokers and 0.73 (0.58–0.91) for moderate smokers compared with nonsmokers. However, there was no significant effect of smoking intensity on general obesity among females.

Table 2 Regression coefficients of BMI and WC according to smoking intensities among Chinese male and female, CHNS 1991–2015¹⁻⁴

Variables	Male				P _{trend}	Female				F
	Nonsmoker (n = 14,572)	Light (n = 8,706)	Moderate (n = 10,452)	Heavy (n = 2,177)		Nonsmoker (n = 38,235)	Light (n = 799)	Moderate (n = 369)	Heavy (n = 38)	
BMI(kg/m²)										
Model 1	Ref	-0.29*** (-0.38,-0.21)	-0.38*** (-0.46,-0.30)	-0.08** (-0.22,-0.07)	0.001	Ref	-0.01 (-0.26, 0.24)	-0.03 (-0.43, 0.37)	-0.11 (-0.16,0.94)	0
Model 2	Ref	-0.32*** (-0.40,-0.28)	-0.45*** (-0.53,-0.37)	-0.23*** (-0.38,-0.09)	0.001	Ref	-0.59*** (-0.83,-0.33)	-0.63*** (-1.04,-0.23)	-0.52 (-1.59,0.54)	0
Model 3	Ref	-0.39*** (-0.48,-0.32)	-0.50*** (-0.59,-0.42)	-0.28*** (-0.42,-0.13)	0.001	Ref	-0.60*** (-0.85,-0.34)	-0.64*** (-1.04,-0.24)	-0.54 (-1.60,-0.51)	0
Model 4	Ref	-0.40*** (-0.48,-0.31)	-0.51*** (-0.60,-0.43)	-0.29*** (-0.43,-0.14)	0.001	Ref	-0.61*** (-0.86,-0.35)	-0.66*** (-1.06,-0.26)	-0.53 (-1.58,-0.53)	0
WC(cm)										
Model 1	Ref	-0.58*** (-0.86,-0.30)	-0.53*** (-0.79,-0.27)	-0.36 (-0.46,-0.30)	0.054	Ref	1.03*** (0.26,1.81)	0.82 (-0.54,2.19)	2.02 (-1.03,5.08)	0
Model 2	Ref	-0.62*** (-0.89,-0.34)	-0.69*** (-0.95,-0.42)	-0.07 (-0.53,0.39)	0.001	Ref	-1.38*** (-2.15,-0.61)	-1.63*** (-2.99,-0.28)	0.23 (-2.85,3.30)	0
Model 3	Ref	-0.86*** (-1.14,-0.59)	-0.84*** (-1.10,-0.57)	-0.19 (-0.65,0.28)	0.001	Ref	-1.33*** (-2.10,-0.55)	-1.54*** (-2.90,-0.18)	0.33 (-2.73,3.40)	0
Model 4	Ref	-0.87*** (-1.14,-0.58)	-0.86*** (-1.12,-0.59)	-0.19 (-0.66,0.27)	0.001	Ref	-1.37*** (-2.13,-0.59)	-1.58*** (-2.94,-0.22)	0.36 (-2.70,3.41)	0
<p>Note: (1) The statistics reported are the marginal effects of independent variables with 95% confidence interval in parenthesis. (2) Model 1 was the crude unadjusted model; Model 2 adjusted for age, working status, marriage status, individual income, education level; Model 3 additionally adjusted for physical activity, drinking status; model 4 further adjusted for dietary energy intake and percentage of energy intake from fat. (3) BMI: Body mass index, WC: waist circumference. (4) ***, ** and * indicates statistical significance at the 1% 5% and 10% level, respectively.</p>										

Table 3 Odds ratio of general obesity and abdominal obesity across smoking intensities among Chinese male and female, CHNS 1991–2015 ¹⁻⁴										
Variables	Male					Female				
	Nonsmoker (n = 14,572)	Light (n = 8,706)	Moderate (n = 10,452)	Heavy (n = 2,177)	P _{trend}	Nonsmoker (n = 38,235)	Light (n = 799)	Moderate (n = 369)	Heavy (n = 38)	P _{trend}
General obesity										
Model 1	1.00 Ref	0.76 ^{***} (0.69, 0.85)	0.72 ^{***} (0.65,0.80)	0.96 (0.81,1.15)	⊠0.001	1.00 Ref	1.31 (1.03, 1.66)	1.61 (1.19, 2.19)	1.26 (0.48,3.28)	0.755
Model 2	1.00 Ref	0.76 ^{***} (0.69, 0.85)	0.70 ^{***} (0.63,0.78)	0.93 (0.78,1.11)	⊠0.001	1.00 Ref	0.87 (0.69, 1.11)	1.03 (0.75,1.40)	0.92 (0.35,2.44)	0.710
Model 3	1.00 Ref	0.73 ^{***} (0.65, 0.82)	0.69 ^{***} (0.61,0.76)	0.91 (0.75,1.09)	⊠0.001	1.00 Ref	0.87 (0.68, 1.11)	1.02 (0.75,1.40)	0.91 (0.34,2.43)	0.655
Model 4	1.00 Ref	0.72 ^{***} (0.65, 0.81)	0.68 ^{***} (0.61,0.76)	0.90 (0.75,1.09)	⊠0.001	1.00 Ref	0.87 (0.68,1.12)	1.01 (0.74,1.39)	0.93 (0.35,2.46)	0.663
Abdominal obesity										
Model 1	1.00 Ref	0.84 ^{***} (0.79,0.89)	0.85 ^{***} (0.80,0.90)	1.03 (0.93,1.14)	⊠0.001	1.00 Ref	1.39 ^{**} (1.19,1.62)	1.22 (0.98,1.52)	1.71 (0.87,3.36)	⊠0.001
Model 2	1.00 Ref	0.84 ^{***} (0.79,0.90)	0.84 ^{***} (0.79,0.89)	0.98 (0.88,1.09)	⊠0.001	1.00 Ref	0.83 ^{**} (0.71,0.98)	0.73 ^{***} (0.58, 0.91)	1.21 (0.60,2.44)	⊠0.001
Model 3	1.00 Ref	0.81 ^{***} (0.76, 0.86)	0.82 ^{***} (0.77,0.87)	0.96 (0.86,1.07)	⊠0.001	1.00 Ref	0.84 ^{**} (0.72, 0.99)	0.74 ^{***} (0.59, 0.92)	1.23 (0.61,2.48)	⊠0.001
Model 4	1.00 Ref	0.80 ^{***} (0.76,0.86)	0.81 ^{***} (0.76,0.87)	0.95 (0.86,1.07)	⊠0.001	1.00 Ref	0.83 ^{**} (0.71,0.98)	0.73 ^{***} (0.58, 0.91)	1.24 (0.62,2.48)	⊠0.001
Note: (1) Data comes from CHNS longitudinal data, from 1991 to 2015. (2) The statistics reported are the odds ratio with 95% confidence interval in parenthesis. (3) Model 1 was the crude unadjusted model; Model 2 adjusted for age, working status, marriage status, individual income, education level; Model 3 additionally adjusted for physical activity, drinking status; model 4 further adjusted for dietary energy intake and percentage of energy intake from fat. (4) ^{***} , ^{**} and [*] indicates statistical significance at the 1% 5% and 10% level, respectively.										

4. Discussion

4.1. Smoking and lifestyle choices

Using a representative cohort with a more than 20-year follow-up, in summary, it appears that male current smokers reported more physical activity and higher dietary energy intake than nonsmokers, contradictory to their significantly lower body weight outcomes in this research. Although smoking is more commonly associated with reduced activity and other studies found negative associations [29, 30], there is evidence that smoking is associated with increased physical activity due to its prevalence in specific occupational groups and activity types [31]. Participants in this survey, aged between 18 and 65, were more likely to be involved in professional work activities. It may be that people with manual occupations are more likely to smoke and drink heavily, in addition to being more physically active due to the nature of their work, than people with non-manual occupations [32]. Moreover, previous studies performed mostly among working-age people have shown smokers to be leaner than nonsmokers [33, 34].

Biologically, there is a general perception that smoking decreases body weight outcomes due to decreases in appetite and calorie intake, enhanced metabolism, and reduced fat accumulation [35]. However, a previous study showed that, despite their lower body weights, smokers not only do not eat less than non-smokers but in fact tend to eat slightly more [36]. Results of a meta-analysis from 15 developed countries [37] reported that current smokers reported significantly higher intakes of energy and alcohol than nonsmokers, consistent with our findings for Chinese male smokers. The connection between smoking and dietary intake is extremely complex. On the one hand, previous studies have demonstrated that smoking is associated with a significant reduction in

monoamine oxidase, an enzyme that is associated with mood function, affecting dietary intake by inhibiting appetite. On the other hand, particular food choices might also correspond to an unhealthy lifestyle associated with smoking or a lack of nutrition knowledge.

4.2. Smoking intensity and obesity indicators

The association between smoking and body weight has become a central issue in the obesity literature, but the accumulating evidence is conflicting. Some cross-sectional studies indicate that BMIs are lower in current smokers than in nonsmokers [38, 39], while other studies report a U-shaped relationship between smoking and BMI [40, 41]. Our study examined the relationship between smoking behaviors and BMI in Chinese adults, showing that on average current smokers had a lower BMI than nonsmokers. Previous cross-sectional studies indicate that heavy smoking could be associated with a greater risk of obesity, especially among males. One study of German adults found that male heavy smokers were more likely to be obese than male light smokers [42]. Similarly, Shimokata et al. reported heavy smoking to be associated with higher BMI in US males [43]. After adjustment for age, working status, marriage status, individual income, education level, physical activity, drinking status, dietary energy intake, and percentage of dietary energy intake from fat, we found that both light and moderate smoking were associated with significantly lower BMI regardless of gender. Moreover, a notable finding of the present study is that light and moderate smoking decreased the risk of the onset of general obesity only among male current smokers. This suggests that there are gender differences in the impact of smoking on obesity risk. Furthermore, male heavy smokers are more likely to be obese than either other smokers or nonsmokers. One possible explanation is that there are biological differences between smokers and nonsmokers; another is that heavy smokers also have behaviors favoring weight gain such as physical inactivity, unhealthy diet, and high alcohol consumption [44]. Moreover, our study indicates that although there was a significant increase of nonsmokers in China from 1991 to 2015, it is of concern that the number of heavy smokers among Chinese adults increased significantly regardless of gender. In our own study, we found that male heavy smokers were more likely to drink alcohol and have a high-calorie/high-fat diet, while female heavy smokers were more likely to drink alcohol and be physically inactive.

Previous studies using WC to examine the association between smoking and abdominal obesity yielded inconsistent results. Xu et al. found that male nonsmokers had non-significantly larger mean WC than current smokers [45]. In contrast, Mizuno et al. found that smokers had a significantly larger WC than nonsmokers only in obese males [46], while Liu et al. found that nonsmokers had a larger WC than current smokers [47]. In the present study, we found that male nonsmokers had a significantly larger WC than current smokers, contrary to the findings for females. These contradictory findings show that the association still requires attention. One possible explanation is that smoking affects the fat distribution in the abdominal area through a variety of biological mechanisms, as by affecting the regulation of sex hormones [14] [44]. For example, lower levels of androgens in male smokers have been found to increase abdominal obesity [48]. Furthermore, the amount smoked daily by smokers has also been reported to be positively associated with abdominal obesity [12]. We found that light and moderate smoking significantly decreases the likelihood of general obesity and abdominal obesity regardless of gender. Unhealthy behaviors may favor weight gain and partly explain the accumulation of visceral fat.

Moreover, our study indicates that although there was a significant increase of nonsmokers in China from 1991 to 2015, it is of concern that the number of heavy smokers among Chinese adults increased significantly regardless of gender. One possible explanation is that heavy smokers are more strongly addicted to nicotine and therefore experience more withdrawal symptoms, cravings, and other difficulties when attempting to quit. Zhang et al. reported that heavy smoking was also associated with poorer quality of life, such as greater perceived stress, poorer overall subjective quality of life, and lower satisfaction with finances, health, leisure activities, and social relationships [49]. This suggests that more interventions are needed for heavy smokers.

Strengths and limitations

First of strengths in this study was that we simultaneously analyzed the associations of smoking with general obesity (i.e. BMI) and abdominal obesity (i.e. WC), which allowed us to better clarify the relationships of smoking with fat distribution and related metabolic disorders. Second, we examined the association between smoking and risk of obesity by combine use levels of smoking intensity (based on the number of cigarette smoked in a day) with binary indicator of smoking participation (current smoker and nonsmoker). Third, the longitudinal study design could confirmative evidence to causality. Fourth, we controlled several important sociodemographic and behavioral confounders and assess sex differences in estimated associations, which helped to improve the validity of our findings.

However, some limitations need to be mentioned. First, we were not able to control for former smokers' body weight status in smoke quitting period because of data usage restrictions that might lead to selection effect. Second, dietary data were collected using three consecutive 24-h dietary recalls, which might show relatively limited variations for a participant as compared to non-consecutive 24-h recalls. However, the average intake over three days could offer a relatively valid estimate of nutrient intake, as shown in an earlier study using the CHNS data.

Conclusions

Compared with nonsmokers, current smokers had lower BMI and WC among Chinese adults regardless of gender. Heavy smokers are more likely to be general obesity and abdominal obesity in male and abdominal obesity in female. These findings may improve the understanding on how cigarette smoking affects fat distribution and provide scientific evidence regarding intervention in smoking and obesity by gender.

Abbreviations

CHNS: China Health and Nutrition Survey; BMI: Body mass index; WC: Waist circumference; PA: Physical activity; MET: Metabolic equivalent of task

Declarations

Ethics approval and consent to participate

All participants provided informed consent before the start of the study. The study was approved by 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. Each participant provided written informed consent (No. 201524).

Consent for publication

Not applicable.

Availability of data and materials

We used data of the China Health and Nutrition Survey (CHNS), which is publicly available at <https://www.cpc.unc.edu/projects/china/data/datasets>.

Competing of interest

The authors declare that they have no competing interests.

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Authors' Contributions

J.Z. performed the analyses, interpreted the data and drafted the manuscript; DD.F contributed to the revision of the paper; HJ.W and B.Z developed the questionnaire, research protocol and conducted the data collection. C.S. contributed to a critical revision of the manuscript for important intellectual content and takes responsibility for the integrity of the data. All authors read, provided major revisions and approved the final submitted version of the manuscript.

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Figures

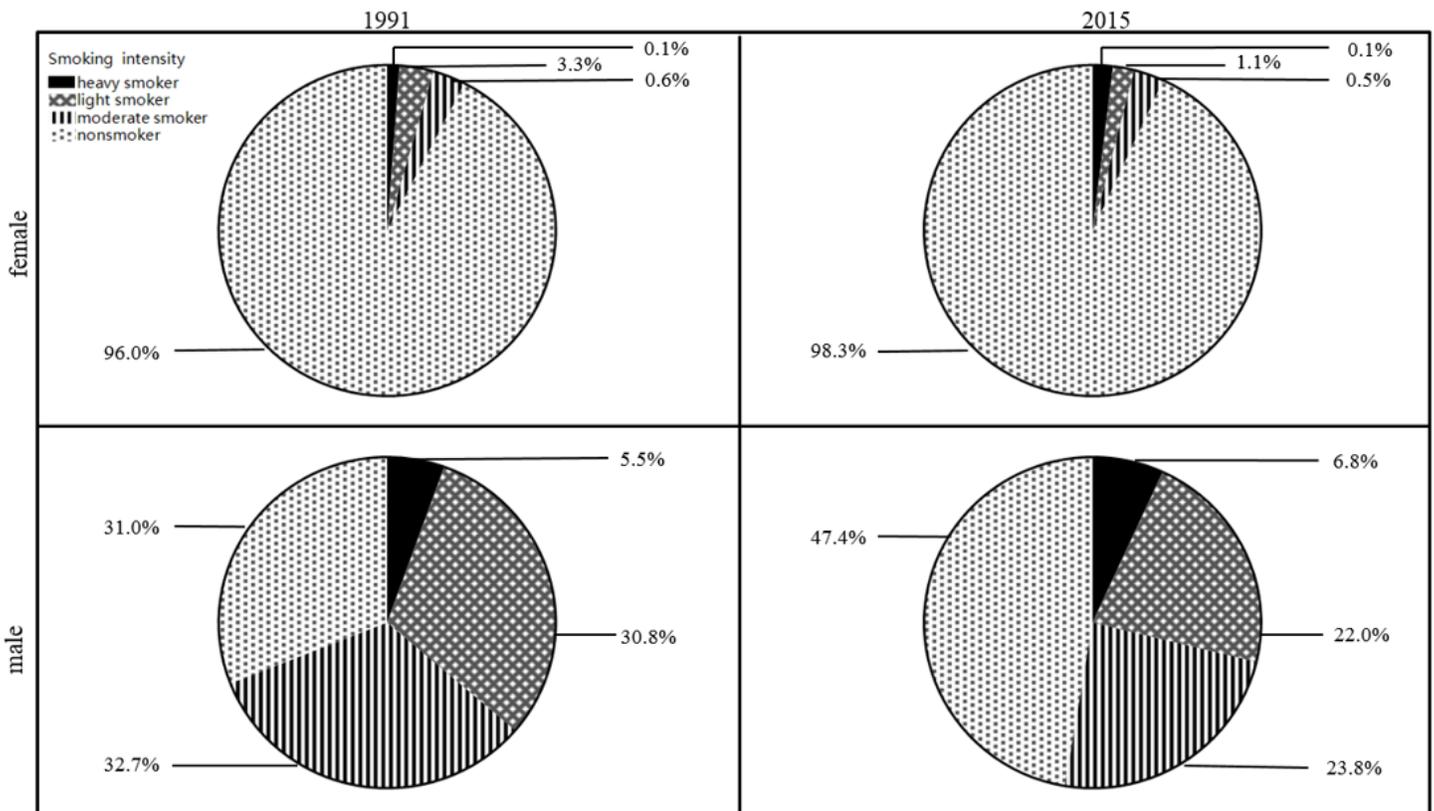


Figure 1

Shift in distribution of smoking status in Chinese adults from 1991 to 2015

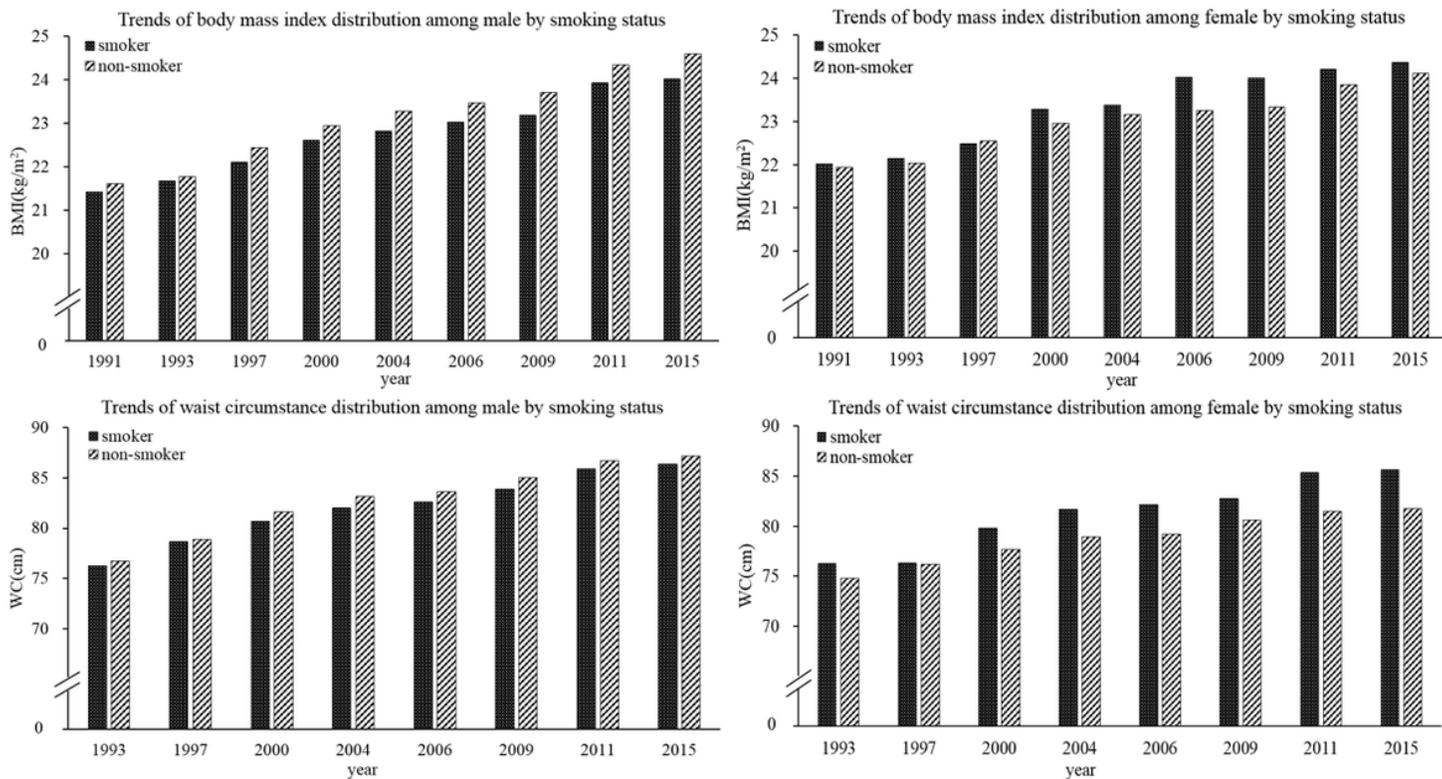
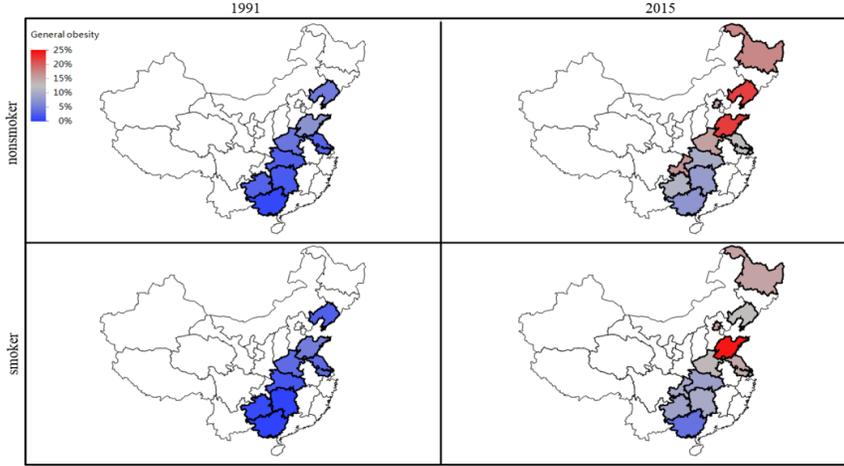


Figure 2

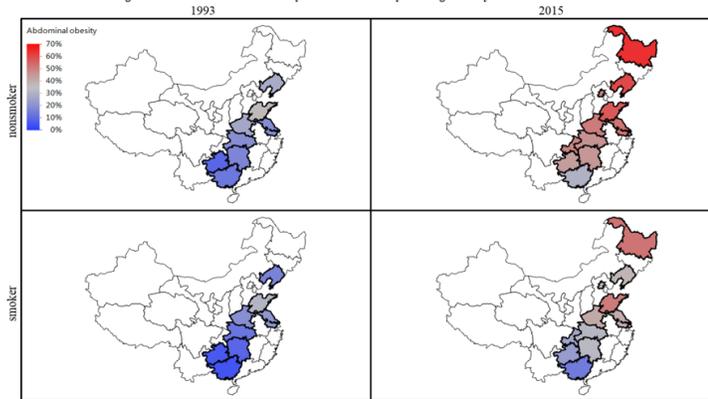
Shift in distribution of Body Mass Index (BMI) and Waist circumference (WC) in Chinese adults by smoking status from 1991 to 2015

Figure 3a Trends of general obesity in Chinese adults by smoking intensity from CHNS1991 to 2015



Note: the map includes provinces in mainland China but excludes Taiwan, Hong Kong and Macau.

Figure 3b Trends of abdominal obesity in Chinese adults by smoking intensity from CHNS1991 to 2015



Note: the map includes provinces in mainland China but excludes Taiwan, Hong Kong and Macau.

Figure 3

3a Trends of general obesity in Chinese adults by smoking intensity from CHNS1991 to 2015. 3b Trends of abdominal obesity in Chinese adults by smoking intensity from CHNS1991 to 2015. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.