

New evidence on the effect of smoking on the obesity risk among adults, Findings from the China Health and Nutrition Survey (CHNS, 1991-2015)

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Keywords: Smoking, Obesity, physical activity, dietary intake, drinking

Posted Date: February 17th, 2020

DOI: <https://doi.org/10.21203/rs.2.23668/v1>

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Abstract

Background: To estimate the approximately causal effects of smoking on the obesity risk among Chinese adults.

Methods: Using China Health and Nutrition Survey (CHNS) datasets from 1991 to 2015, this study consisted of 35,907 males and 39,441 females aged 18-65 years. Using ordinary-least squares and probit models to investigate the effects of smoking on risk of obesity among Chinese adults.

Results: Male current smokers had a higher dietary energy intake (23.28 unit), percentage of dietary energy intake from fat (0.47 unit), physical activity (9.96 unit), drinking (0.61 unit) but less likely to be general obesity (0.17 unit) and abdominal obesity (0.12 unit) than nonsmokers. Female current smokers less likely to be general obesity (0.03 unit) and abdominal obesity (0.12 unit) than nonsmokers. Male heavy smokers (>25 cigarettes/d) had higher dietary energy intake (89.65 unit), physical activity (15.31 unit), drinking (0.08 unit) and more likely to be general obesity (0.18 unit) and abdominal obesity (0.10 unit) than other smokers.

Conclusions: Compared with nonsmokers, current smokers had lower probability of being general obesity and abdominal obesity among Chinese adults regardless of gender. Male heavy smokers increased the risk of obesity than other smokers. These findings may improve the understanding on how cigarette smoking affects fat distribution and provide scientific evidence regarding intervention in smoking and obesity, especially for male heavy smokers

Introduction

Smoking alone or in combination with obesity poses the major public health burden in western societies as well as many developing countries[1]. Generally, obesity epidemic is mostly attributed to behavioral risks, however, smoking may seriously influence individual risk of obesity as well. [2–4]. Understanding pathways that contribute to these risk factors, and the nature of the relationship between them, is therefore of paramount importance for disease prevention[5].

Existing evidences about the effects of smoking on obesity risks are complex and not yet completely understood [6, 7]. Numerous cross-sectional studies have reported that BMI are lower in current smokers than in nonsmokers while other studies have found a U-shaped relationship between smoking and BMI[8, 9]. However, heavy smoking has been found to be associated with higher BMI[10]. Moreover, some studies have reported that current smokers have more abdominal obesity than never smokers[11–13], but other studies indicated no evidence for this association[14, 15] or have even found the opposite[16, 17]. There is a general perception that smoking decreases body weight due to reasons like decrease in appetite and calorie intake, enhanced metabolism, and reduced fat accumulation[18]. However, despite their lower body weights, current smokers do not eat less than nonsmokers and tend to eat slightly more[19]. Evidences shows that smoking is associated with more physical activity due to specific occupational groups and activity types[20, 21], while smoking reduced activity is more commonly found[22]. These conflicting results may be because of data differences and model specifications[23]. More empirical evidences are needed to figure out the effects of smoking on obesity risk.

China is the world's largest consumer and manufacturer of tobacco, which 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 risk of obesity, how this was related to be general obesity and abdominal obesity, and whether these relationships varied by smoking intensity.

Methods

Study Population and Data Collection

Data from the China Health and Nutrition Survey (CHNS, 1991-2015), which is a large-scale, longitudinal household-based survey initiated in 1989 that consists of representative participants of varying economic status, health indicators, and geographic areas throughout China[24]. Further information on survey procedures and the sampling scheme was reported in detail elsewhere [25]. We excluded participants who were pregnant, lactating, missing key variables from the analysis. Hence, our final sample consisted of 75,348 person-year observations aged 18-65 years with complete data on demographic, smoking status, obesity indicators.

2.1 Obesity indicators

Well-trained health workers measured the height, weight, and waist circumference (WC) following standardized procedures. Dividing weight (in kg) by the square of height (in m²) we got BMI and grouped it into thin (<18.5 kg/m²), normal (18.5-23.9 kg/m²), overweight

(24-27.9 kg/m²) and obesity (>28 kg/m²) [26]. We defined participants as having abdominal obesity if the WC ≥85 cm in females and ≥90 cm in males in accordance with the national health and family commission for Chinese adults (2013)[27].

2.2 Smoking indicators

In the CHNS questionnaire, 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 question about “number of cigarettes consumed daily”, current smokers were further divided into heavy (≥25cigarette/d), moderate (15-24cigarette/d) and light smokers (1-14cigarette/d)[18].

2.3 Other variables

We grouped participants into three education level (primary/illiterate, middle, and high school/above), two marital statuses (single / married), two geographical regions (rural / urban), three income levels (low / medium / high) and two drinking status (yes/no). The per-capital annual income in each survey was inflated to values in 2015. Participants reported all physical activities (PA) 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]. Dietary intake at the individual level was assessed by using three consecutive 24-h dietary recalls in each wave of the CHNS [24]. Based on the Chinese Food Composition Table, we measured nutrition intake data by (1) the respondent’s daily calorie intake per day during a 3-day measurement period and (2) the dietary structure as indicated by the percentage of fat in the respondent’s daily calorie intake [26].

3. Statistical Analysis

Statistical analyses were performed using the STATA 13.0 (STATA, Stata Corp). We first employed a pooled ordinary least square (OLS) model covering from 1991 to 2015. Outcome variables including dietary energy intake, the percentage of dietary intake from fat and physical activity.

The equation we used for this model is

$$K_{abc} = \alpha_0 + \alpha_1 \text{SMOKE}_{abc} + \alpha_2 X_{abc} + \delta_c + \alpha_b + \varepsilon_{abc} \quad (1)$$

K_{abc} denote the lifestyle behavior of individual a in province b and year c.

SMOKE_{abc} indicating whether the individual is current smoker or nonsmoker in year c;

X_{abc} contains control variables;

δ_c and α_b indicate time and province fixed-effects, respectively;

ε_{abc} is the random error that varies with individual, province and year.

α_1 indicates the impact of smoking on the lifestyle behavior.

Then we employed Probit model for binary dependent variables. Outcome variables including drinking status, general obesity and abdominal obesity. The equation we used for this model:

$$K'_{abc} = \alpha_0 + \alpha_1 \text{SMOKE}_{abc} + \alpha_2 X_{abc} + \delta_c + \alpha_b + \varepsilon_{abc} \quad (2)$$

$$P = (K_{abc} = 1 | \text{SMOKE}, X, \delta, \alpha) = P(K'_{abc} = 1 | \text{SMOKE}, X, \delta, \alpha)$$

$$= G(\alpha_1 \text{SMOKE}_{abc} + \alpha_2 X_{abc} + \delta_c + \alpha_b + \varepsilon_{abc}) \quad (3)$$

K'_{abc} is the latent variable specifying the tendency of drinking, being general obesity and abdominal obesity. If $K'_{abc} > 0$, then $K_{abc} = 1$; otherwise $K_{abc} = 0$.

$G(\cdot)$ is the cumulative distribution function of random error ε_{abc} .

When we investigate the effects of smoking intensity on lifestyle behaviors. We change the $SMOKE_{abc}$ in model 1–3 to $SMOKEI_{abc}$. $SMOKEI_{abc}$ is dummy variable indicating whether the current smoker is heavy smoker (1 = yes, 0 = no), moderate smoker (1 = yes, 0 = no) or light smoker (1 = yes, 0 = no).

Results

Descriptive statistics

Table 1 shows descriptive statistics for the variables by smoking status. Among the 75,348 participants, 22,541(29.90%) were current smokers and 52,807(70.10%) were nonsmokers. Current smokers were about a year older on average than nonsmokers in our sample (43.58 vs. 42.72). The mean value of dietary energy intake was 2,280 kcal/d, current smokers had higher dietary energy intake than nonsmokers (2,480 kcal/d vs. 2,180 kcal/d) ($p < 0.001$). Nonsmokers consumed more percentage of energy intake from fat than current smokers (30.30% vs. 29.70%) ($p < 0.001$). The average rates of general obesity and abdominal obesity were significantly higher in nonsmokers than in smokers (8% vs. 6% and 41% vs. 35%, respectively) ($p < 0.001$).

Table 2 shows the trends of characteristic of current smokers. From 1991 to 2015, heavy smokers increased from 8% to 14% ($p < 0.001$), while light smokers decreased from 45% to 39% ($p < 0.001$). Dietary energy intake of current smokers decreased from 2,890 kcal to 2,240 kcal ($p < 0.001$), while the percentage of energy intake from fat increased from 25.93% to 36.72% ($p < 0.001$). It is noteworthy, the prevalence of overweight and obesity in current smokers increased significantly in mainland China from CHNS 1991 to 2015 ($p < 0.001$) (Figure 1).

Effects of smoking behavior on risk of obesity among the whole population

The OLS and Probit results were presented in Table 3 and Table 4, respectively. There was a significant correlation between smoking behavior and obesity risk. Male current smokers had higher dietary energy intake, percentage of energy intake from fat, physical activity and likelihood being drinking by 23.28 unit, 0.47 unit, 9.96 unit and 0.61 unit than nonsmokers, respectively. Female current smokers also had higher percentage of energy intake from fat and likelihood being drinking by 0.60 unit and 0.79 unit than female nonsmokers, respectively (Table 3).

After controlling for confounding factors, current smokers had a lower BMI and WC than nonsmokers regardless of gender. Smoking decreased the likelihood being general obesity by 0.17 unit in males and 0.03 unit in females, and abdominal obesity by 0.12 unit in males and females (Table 4).

Marginal effects of smoking intensities among current smokers

Figure 2 shows that the prevalence of general and abdominal obesity among smokers varies by smoking intensity among males and females. In addition, male had higher prevalence of general obesity and abdominal obesity than female across different smoking intensities. Male heavy smokers had more dietary energy intake by 89.65 unit, percentage of energy intake from fat by 15.31 unit, and more likelihood being drinking by 0.08 unit. While there were no differences among smoking intensities in female (Table 3). After controlling confounding factors, male moderate smokers had lower WC by 0.15 unit, BMI by 0.20 units, and less likely to be general obese by 0.05 unit than other smokers. Male heavy smokers had larger BMI by 0.22 unit, WC by 0.32 unit, increased the likelihood being general obesity by 0.18 units and abdominal obesity by 0.10 units than other smokers (Table 4).

Discussion

Smoking and risk of obesity

Using a representative cohort with more than 20-year follow-up, in summarize, it appears that male current smokers declared higher intakes of dietary energy, fat and alcohol than male nonsmokers, contradicting their significantly lower body weight outcomes in this research. This result is consistent with the results of a meta-analysis from 15 developed countries[29]. While Chiolerio et al. found that smoking can decrease energy intake by inhibiting appetite[30]. Smoking was associated with more participation in activity from this study. Similar to our results, Poortinga et al.[31] found a positive clustering between physical activity and smoking whereas other studies found negative associations[32, 33]. Possible explanations include: (1) smoking is associated with different types of physical activity (2) 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 a manual occupation are more likely to smoke and to drink heavily, in addition to being more physically active due to the nature of their work, as compared to people with a non-manual occupation [34]. Moreover, previous studies performed mostly among working-age people have shown smokers to be leaner than nonsmokers [35, 36].

In this longitudinal survey among Chinese adults, we found that current smokers had lower BMI than nonsmokers is consistent with many previous studies [37-39]. While the association between smoking and abdominal obesity yielded inconsistent findings. Xu et al. found male nonsmokers had non-significantly larger mean WC than current smokers [40]. In contrast, Mizuno et al. reported current smokers had a significant larger WC than nonsmoker just in obese male [41]. Liu et al. found nonsmokers had a larger WC than current smokers [42]. In the present study, after adjusting for potential confounders, we found that current smokers had a lower WC compared with nonsmokers regardless of gender. These contradictory findings show that the association still requires more attention.

Smoking intensity and risk of obesity

Moreover, the notable finding in the present study is that male who smoke equal to or more than 25 cigarettes per day increased the risk of the onset of general obesity and abdominal obesity compare to other smokers both independently and significantly. The heavy frequency of smoking was positively associated with BMI in male was in line with previous studies [43-45]. Moreover, it is suggested that heavy smokers have a higher risk of obesity than light smokers among working-age people [46]. In our study, we find that heavy smoking increased dietary energy intake, physical inactivity and likelihood being drinking. After adjusting for these variables considerably change the estimated mean difference in BMI between heavy and other smokers. One possible explanation from Chioleri et al. is that heavy smokers also have behaviors favoring weight gain such as physical inactivity, unhealthy diet and high alcohol consumption [30].

Yet other studies have reported that WC increases with increasing pack years among current daily smokers [47, 48]. The amount smoked daily by smokers have also been reported to be positively associated with abdominal obesity [49]. Moreover, heavy smokers in the present study had a larger WC than other smokers. These findings were in accordance with several previous studies [50]. Several hypotheses might explain the association between heavy smoking and abdominal obesity in male. First, it has been reported that smoking affects fat distribution in the abdominal area by various biological mechanisms such as smoking affects the regulation of the sex hormones [30]. For example, firstly, lower levels of androgens in male current smokers has been found to increase abdominal obesity [51]. Secondly, male heavy smokers are more likely to have unhealthy behaviors such as more calorie intake, increased alcohol use, which was also found in our study. These unhealthy behaviors may favor weight gain and partly explain the accumulation of visceral fat mass in abdominal area.

Strengths and limitations

First of strengths in this study was that we examined the association between smoking and risk of obesity by combine use smoking status and smoking intensity (based on the number of cigarette smoked in a day). Second, the longitudinal study design could confirmative evidence to causality. Third, 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.

Conclusions

Compared with nonsmokers, current smokers had lower probability of being general obesity and abdominal obesity among Chinese adults regardless of gender. Male heavy smokers significantly increased the risk of obesity than other smokers. These findings may improve the understanding on how smoking affects fat distribution and provide scientific evidence regarding intervention in smoking and obesity, especially for male heavy smokers.

Abbreviations

CHNS: China Health and Nutrition Survey; BMI: Body mass index; WC: Waist circumference; CDC: Centers for Disease Control and Prevention; MET: metabolic equivalents of task; WHO: World Health Organization; CDG: Chinese dietary guideline; DRI: Dietary Reference Intake; MET: Metabolic Equivalent of Task; PA: Physical Activity

Declarations

Ethics approval and consent to participate

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 material

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Funding

This work was supported by research grant from the Carolina Population Center (5 R24 HD050924), University of North Carolina at Chapel Hill, the National Institutes of Health (NIH) (R01-HD30880, DK056350, and R01-HD38700) and the Fogarty International Center, NIH (5D43TW007709 and 5D43TW009077).

Acknowledgement

The authors thank the team at the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention and the Carolina Population Center, University of North Carolina at Chapel Hill. The authors are also grateful to the participants for their involvement in the survey.

Author's Contributions

All authors contributed significantly to this article. JZ analyzed the data and wrote the manuscript, JS critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

Competing Interests

The authors have no conflict of interest to declare

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Tables

Table 1 Characteristics of 1991-2015 CHNS adults by smoking Status¹⁻³

Variables	Total	Smoker	Non-smoker
<i>Demographic Characteristics</i>			
Age(year)	42.98(12.70)	43.58(12.17)	42.72(12.92)***
Male	0.48(0.50)	0.95(0.23)	0.28 (0.45) ***
<i>Socioeconomic Status</i>			
Education level			
Primary/illiterate	0.38(0.49)	0.36(0.48)	0.38(0.49) ***
Junior	0.35(0.47)	0.38(0.48)	0.34(0.47) ***
High school/above	0.27(0.44)	0.26(0.44)	0.28(0.45) ***
Income level			
Low	0.33(0.47)	0.30 (0.46)	0.35(0.48) ***
Medium	0.34 (0.47)	0.32(0.47)	0.35(0.48) ***
High	0.33 (0.47)	0.38(0.49)	0.30(0.46) ***
PA(METs/w)	272.73(231.95)	287.96 (233.18)	266.22(231.13)***
Married	0.85 (0.36)	0.86(0.34)	0.84 (0.36) ***
Employed	0.72 (0.45)	0.81 (0.39)	0.68(0.47) ***
Urban	0.35(0.48)	0.33(0.47)	0.36(0.48)***
<i>Dietary nutrition intake</i>			
Energy (1k kcal)	2.28 (0.96)	2.48 (1.09)	2.19 (0.88) ***
Fat (E %) ⁴	30.12(13.00)	29.70 (13.42)	30.30(12.81) ***
<i>Obesity indicators</i>			
WC (cm)	80.66(10.59)	81.73(10.30)	80.21(10.68) **
BMI (kg/m ²)	23.04(3.44)	22.77(3.22)	23.16(3.52) ***
General Obesity	0.08(0.27)	0.06(0.24)	0.08 (0.28) ***
Abdominal Obesity	0.39 (0.49)	0.35 (0.48)	0.41 (0.49) ***
<i>Smoking intensity</i>			
Light (1~14 /d)	/	0.42 (0.24)	/
Moderate (15~25 /d)	/	0.48 (0.25)	/
Heavy (25+ /d)	/	0.10(0.06)	/
N	75,348	22,541	52,807

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) ***, **and *indicates statistical significance at the 1% 5% and 10% level, respectively. (4) Fat (E %)⊖percentage of energy intake from fat.

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Note: (1) Date comes from CHNS longitudinal data, from 1991 to 2015. (2) The statistics reported are the marginal effects of independent variables with standard errors in parenthesis. (3) ***, **and*indicates statistical significance at the 1% 5% and 10% level, respectively. (4) Model 1 and Model 2 are conducted among total sample, which contains smokers and nonsmokers. Model 3 and Model 4 are conducted among current smokers. (5) Model1 and Model3: Ordinary least squares estimation (OLS), is used for regressions on total calorie, percentage of energy intake from fat and physical activity (PA). Model 2 and Model4: Probit model is used for drinking status. (6) Control variables of Model1and Model2 are includes: age, education levels, living area, income levels, work status, marriage status, province dummies and survey year dummies.

Note: (1) Date comes from CHNS longitudinal data, from 1991 to 2015. (2) The statistics reported are the marginal effects of independent variables with standard errors in parenthesis. (3) ***, **and*indicates statistical significance at the 1% 5% and 10% level, respectively. (4) Model 5 and Model 6 are conducted among total sample, which contains smokers and nonsmokers. Model 7 and Model 8 are conducted among current smokers. (5) Model5 and Model7: Ordinary least squares estimation (OLS), is used for regressions on waist circumference (WC) and body mass index (BMI). Model 6 and Model8: Probit model is used for general obesity and abdominal obesity. (6) Control variables of Model5 to Model8 are includes: age, education levels, living area, income levels, work status, marriage status, total calorie intake, percentage of energy intake from fat, physical activity(PA), drinking status, province dummies and survey year dummies.

Table 2 Trends of characteristics among adult smokers from CHNS 1991 to 2015¹⁻³

Characteristic	1991	1993	1997	2000	2004	2006	2009	2011	2015
Age(year)	39.74(0.25)	40.14(0.25)	40.59(0.27)	42.24 (0.23)	44.22(0.23)	45.43(0.24)	45.79(0.24)	46.78(0.22)	47.98(0.24)***
Male	0.94 (0.01)	0.94 (0.01)	0.94 (0.01)	0.94 (0.01)	0.95 (0.01)	0.95 (0.01)	0.95 (0.01)	0.96 (0.01)	0.96 (0.01)***
1~14cigarettes/d	0.45(0.01)	0.42(0.01)	0.39(0.01)	0.41(0.01)	0.41(0.01)	0.39(0.01)	0.38(0.01)	0.38(0.01)	0.39(0.01)***
15~24 cigarettes/d	0.47(0.01)	0.50(0.01)	0.52(0.01)	0.48(0.01)	0.48(0.01)	0.49(0.01)	0.49(0.01)	0.48(0.01)	0.47(0.01)***
25+ cigarettes/d	0.08(0.01)	0.08(0.01)	0.09(0.01)	0.11(0.01)	0.11(0.01)	0.12(0.01)	0.13(0.01)	0.14(0.01)	0.14(0.01)***
Primary/illiterate	0.55(0.01)	0.49(0.01)	0.47 (0.01)	0.41(0.01)	0.36(0.01)	0.33 (0.01)	0.28 (0.01)	0.20(0.01)	0.11(0.01)***
Junior	0.29(0.01)	0.34(0.01)	0.33(0.01)	0.36(0.01)	0.39(0.01)	0.40(0.01)	0.44(0.01)	0.42(0.01)	0.39(0.01)***
High school/above	0.16(0.01)	0.16(0.01)	0.19 (0.01)	0.22(0.01)	0.24(0.01)	0.27(0.01)	0.28(0.01)	0.37(0.01)	0.43(0.01)***
Income(Low)	0.34(0.01)	0.31(0.01)	0.31(0.01)	0.30(0.01)	0.26(0.01)	0.25(0.01)	0.30(0.01)	0.28(0.01)	0.31(0.01)***
Income (Medium)	0.24(0.01)	0.31(0.01)	0.29(0.01)	0.35(0.01)	0.36(0.01)	0.37(0.01)	0.34(0.01)	0.34(0.01)	0.30(0.01)***
Income (High)	0.42(0.01)	0.38(0.01)	0.40(0.01)	0.35(0.01)	0.38(0.01)	0.38(0.01)	0.36(0.01)	0.38(0.01)	0.39(0.01)***
Married	0.84(0.01)	0.84(0.01)	0.83(0.01)	0.85(0.01)	0.86(0.01)	0.89(0.01)	0.88(0.01)	0.89(0.01)	0.90(0.01)***
Employed	0.89(0.01)	0.89(0.01)	0.89(0.01)	0.84(0.01)	0.76(0.01)	0.75(0.01)	0.77(0.01)	0.78(0.01)	0.67(0.01)***
Drinking	0.73(0.01)	0.69(0.01)	0.72(0.01)	0.70(0.01)	0.68(0.01)	0.69(0.01)	0.69(0.01)	0.71(0.01)	0.68(0.01)***
Urban	0.31(0.01)	0.30(0.01)	0.32(0.01)	0.32(0.01)	0.33(0.01)	0.34(0.01)	0.33(0.01)	0.39(0.01)	0.35(0.01)***
Energy (1k kcal)	2.89(0.01)	2.77(0.01)	2.57(0.01)	2.48(0.01)	2.42 (0.01)	2.41(0.01)	2.40(0.01)	2.18 (0.01)	2.24 (0.02)***
Fat(%E) ⁴	25.93(0.25)	25.48(0.26)	25.89(0.24)	28.44(0.22)	26.88(0.26)	30.95(0.34)	31.33(0.23)	35.91(0.24)	36.72(0.26)***
Carbohydrates(%E)	60.08(0.28)	60.09(0.29)	61.12(0.25)	58.31(0.25)	59.13(0.27)	53.94(0.28)	52.63 (0.25)	49.55(0.24)	48.84(0.26)***
PA(METs/w)	396.72(4.67)	342.93(4.45)	364.04(4.54)	301.35(4.30)	261.93(4.75)	262.38(5.18)	248.12(4.66)	235.34(3.86)	158.93(3.45)***

Table 3 Effects of smoking behavior on risk of Obesity¹⁻⁶

	Female				Male				Figures
	Total calorie (Kcal)	Fat (%E)	PA (METs/w)	Drinking	Total calorie (Kcal)	Fat (%E)	PA (METs/w)	Drinking	
Marginal effects of smoking status(N=75,348)									
Model 1	-29.57 (29.07)	0.60(0.34)*	10.07(6.17)		23.28(11.32)**	0.47(0.13)***	9.96(2.02)***		
Model 2				0.79(0.04)**				0.61(0.01)***	
Marginal effects of number of cigarettes consumed daily (current smoker)n=22,541									
Light smoker(1~14 /d)									
Model 3	3.20(3.91)***	-1.35(0.72)*	7.35(128)		-81.23(13.80)***	-0.59(0.17)***	-7.80(2.72)***		
Model 4				-0.27(0.09)***				-0.02(0.02)	
Moderate smoker(15~25 /d)									
Model 3	6.36(3.87)***	1.62(0.75)**	-2.23(1.31)		43.44(14.24)***	0.51(0.17)***	1.75(2.66)		
Model 4				0.26(0.09)***				-0.01(0.02)	
Heavy smoker(25+ /d)									
Model 3	-6.57(9.05)	-1.25(1.56)	-2.24 (1.31)		89.65(19.76)***	0.13(0.29)	15.31(4.68)***		
Model 4				0.18(0.23)				0.08(0.03)***	

Table 4 Effects of smoking behavior on risk of being General obesity and Abdominal obesity¹⁻⁶

	Female				Male			
	WC (cm)	BMI (kg/m ²)	General Obesity	Abdominal Obesity	WC (cm)	BMI (kg/m ²)	General Obesity	Abdominal Obesity
Marginal effects of smoking status (N=75,348)								
Model 5	-1.35(0.35)***	-0.60(0.11)***			-0.87(0.11)***	-0.46(0.03)***		
Model 6			-0.03(0.05)***	-0.12(0.01)***			-0.17(0.02)***	-0.12(0.02)***
Marginal effects of number of cigarettes consumed daily (current smoker)n=22,541								
Light smoker(1~14 /d)								
Model 7	0.13(0.76)	0.02(0.24)			0.07(0.04)*	-0.11(0.14)		
Model 8			0.13(0.11)	0.01(0.09)			-0.02(0.03)	-0.01(0.02)
Moderate smoker(15~25 /d)								
Model 7	-0.34(0.80)	-0.01(0.24)			-0.15(0.14)***	-0.20(0.14)		
Model 8			-0.13(0.11)	-0.04(0.09)			-0.05(0.03)**	-0.03(0.02)
Heavy smoker(25+ /d)								
Model 7	1.33(1.64)	0.10(0.57)			0.81(0.22)***	0.23(0.07)***		
Model 8			0.03(0.32)	0.19(0.24)			0.18(0.05)***	0.10(0.03)***

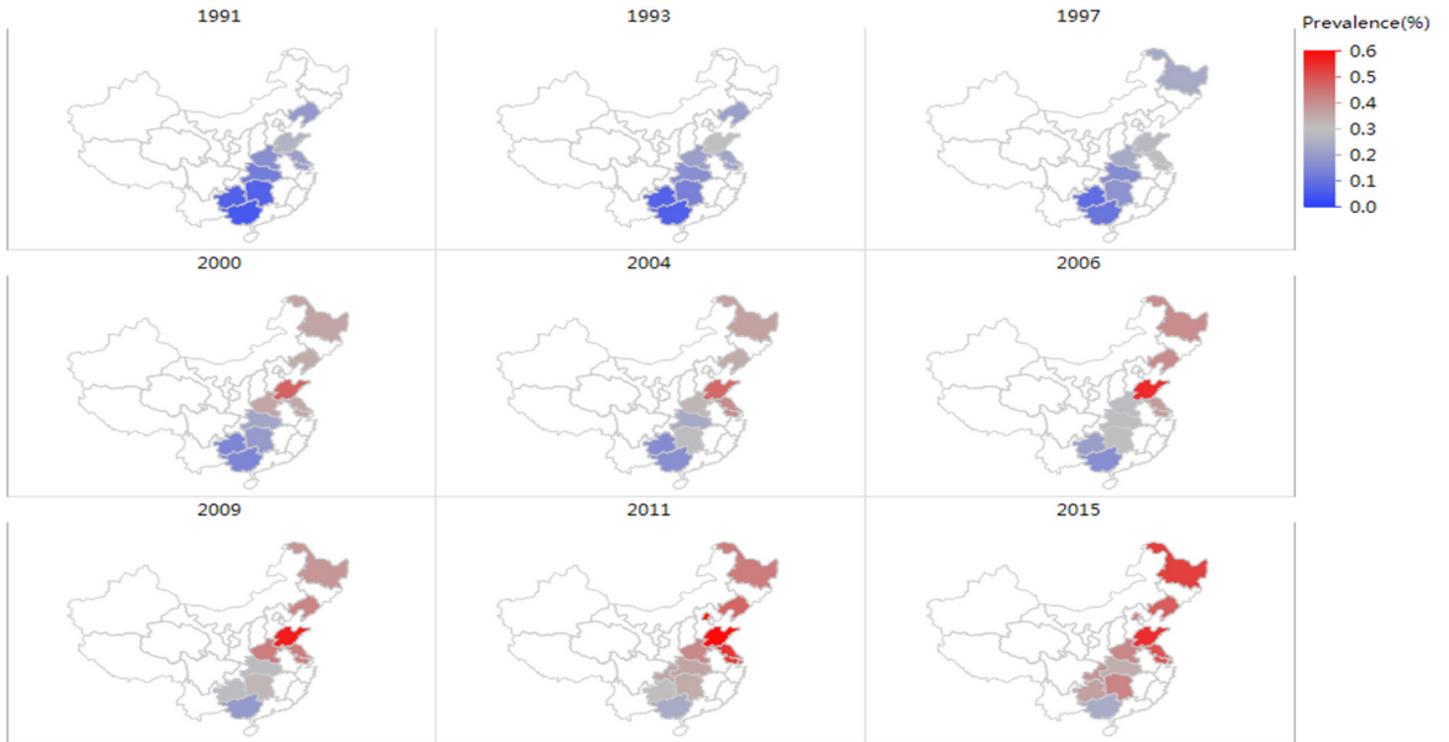


Figure 1

Shift in distribution of prevalence of overweight and obesity in current smokers among Chinese adults from CHNS1991 to 2015. Note: The map includes provinces in mainland China but excludes Taiwan, Hong Kong and Macau. 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.

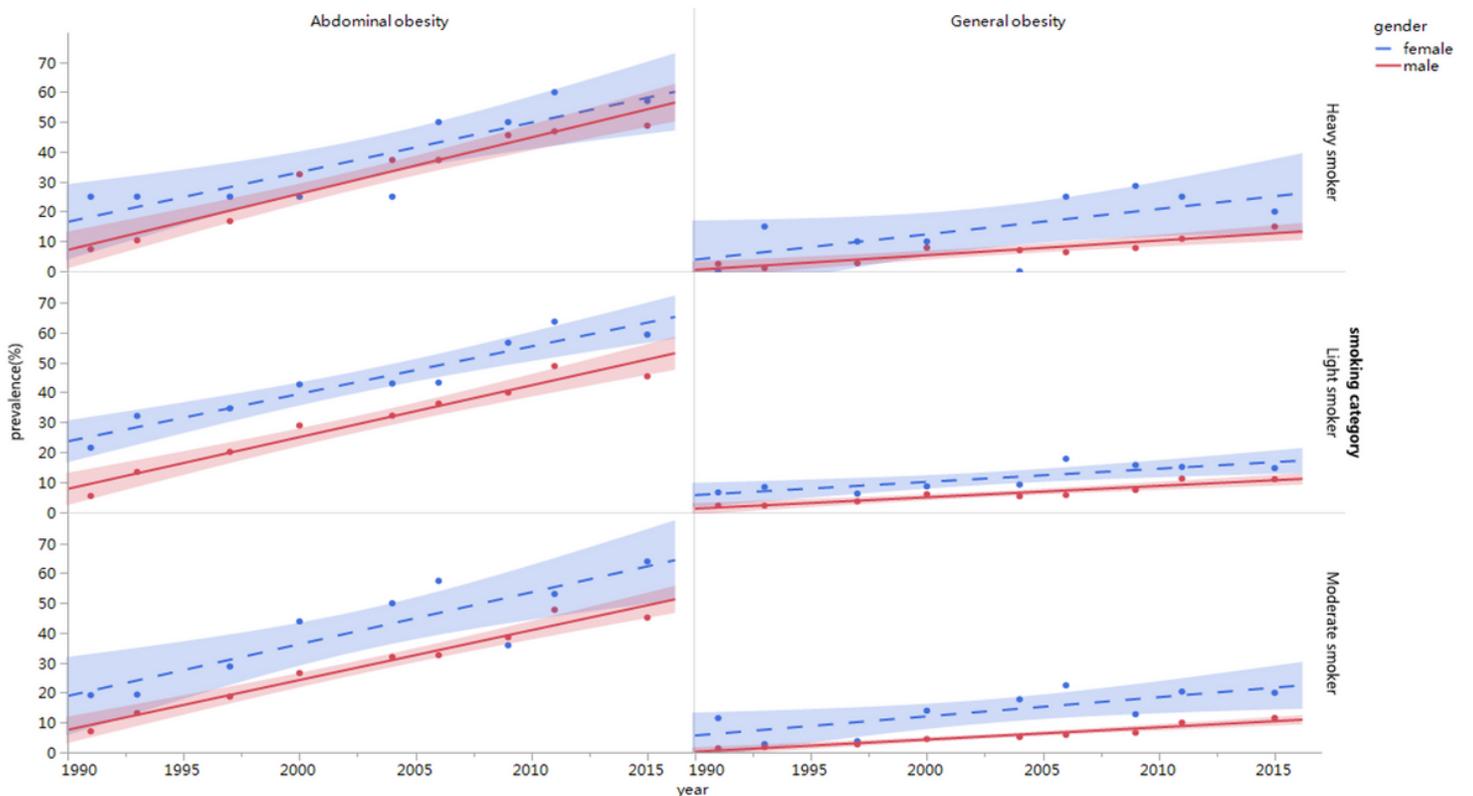


Figure 2

Trends of general obesity and abdominal obesity in Chinese adults by smoking intensity from CHNS1991 to 2015