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Original Article

Age plays an important role in the relationship between smoking status and obesity risk: a large scale cross-sectional study of Chinese adults

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Abstract: Objective: To study the role of age plays in the relationship between smoking status and obesity in both Chinese men and women. Methods: From Chinese Physical and Psychological Database, participants were divided into non-smokers, current smokers, and former smokers. Body mass index (BMI), waist circumference (WC), fat percentage, fat mass, and fat free mass were measured. The mean, standard deviation and frequency of these indicators were calculated for each age bracket. One-way ANOVA and post-hoc test analyses were used to detect the difference among these three groups. Results: In men, from 19 to 24 years old, BMI, WC and fat free mass of current smokers were higher than that of non-smokers ($P<0.01$). However, fat mass and fat percentage of current smokers were lower than that of non-smokers but higher than that of former smokers ($P<0.01$). From 25 to 34 years old, BMI and fat mass of former smokers were higher than non-smokers and current smokers ($P<0.01$). In addition, WC and fat free mass of non-smokers were lower than that of current smokers and former smokers ($P<0.01$). From 45 to older, BMI, WC, fat mass, fat free mass and fat percentage of former smokers were higher than that of current smokers ($P<0.01$). From 55 to older, BMI, WC, fat mass, fat free mass and fat percentage of current smokers were lower than that of non-smokers ($P<0.01$). In women, smoking status might not be significantly related to obesity ($P>0.05$). Conclusion: For young men, smoking might have an effect on increasing fat free mass, BMI and WC, and decreasing fat mass and fat percentage. For middle and older men, smoking might have an effect on decreasing fat free mass, fat mass, BMI, WC, and fat percentage. Obesity risk should be paid more attention in smoking cessation programs for those former smokers.

Keywords: Smoking, obesity, fat percentage

Introduction

According to World Health Organization (WHO), the definitions of overweight and obesity are abnormal or excessive fat accumulation that may impair health. In 2014, 39% of adults aged 18 years and over were overweight, and 13% were obese [1]. Classically, the main risk factors for overweight and obesity were intake of high-fat food and lack of physical activities. Nowadays, it was found that some other factors also affected obesity, such as genes [2], modern habits [3], lifestyle [4], neighborhood, environment [5, 6] and smoking [7].

The use of tobacco had a long history in human's culture. Since the development of industrial revolution, cigarettes have been popularized with an increasing growth rate. However, smoking had a complicated effect on general health, and it played as a risk factor in many diseases, including lung cancer, chronic obstructive pulmonary disease, cardiovascular disease, inflammatory disease, chronic kidney disease, obesity, and so on [7-18]. The relationship between smoking and obesity was complicated and controversial. A lot of studies suggested that smoking had positive effects with regard to weight loss [19-25]. However, there were other

Table 1. The baseline characteristics of participants in this study

	Male		Female		All	
	Number	Percentage	Number	Percentage	Number	Percentage
Number	18589		27478		46067	
Marriage status						
Married	14342	77.15%	20665	75.21%	35007	75.99%
Divorced	212	1.14%	495	1.80%	707	1.53%
Widowed	369	1.99%	1708	6.22%	2077	4.51%
Unmarried	3540	19.04%	4452	16.20%	7992	17.35%
Unknown	126	0.68%	158	0.58%	284	0.62%
Smoking status						
Current smoker	7585	40.80%	722	2.63%	8307	18.03%
Non-smoker	8761	47.13%	25738	93.67%	34499	74.89%
Former smoker	1722	9.26%	117	0.43%	1839	3.99%
Unknown	521	2.80%	901	3.28%	1422	3.09%
Alcohol consumption						
Drinking	7714	41.50%	1498	5.45%	9212	20.00%
No Drink	9310	50.08%	25098	91.34%	34408	74.69%
Drink Cessation	904	4.86%	123	0.45%	1027	2.23%
Unknown	661	3.56%	759	2.76%	1420	3.08%
Physical work						
Very Light Work	7984	42.95%	13396	48.75%	21380	46.41%
Light Work	3476	18.70%	6535	23.78%	10011	21.73%
Medium Work	2992	16.10%	2401	8.74%	5393	11.71%
Heavy Work	1365	7.34%	1055	3.84%	2420	5.25%
Very Heavy Work	137	0.74%	55	0.20%	192	0.42%
Unknown	2635	14.18%	4036	14.69%	6671	14.48%
High-fat diet						
Yes	3415	18.37%	1352	4.92%	4767	10.35%
No	14796	79.60%	23652	86.08%	38448	83.46%
Unknown	378	2.03%	2474	9.00%	2852	6.19%

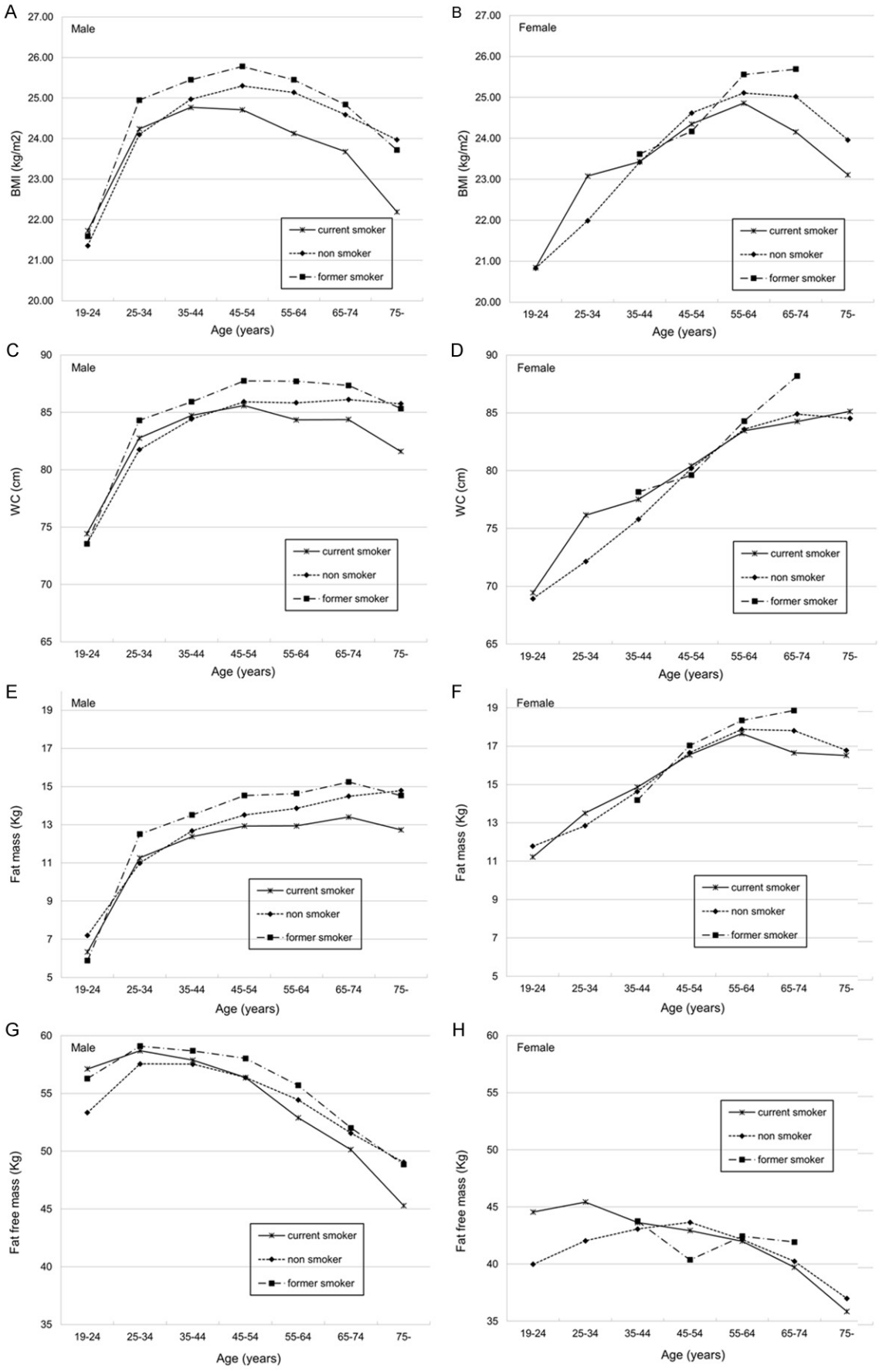
opinions suggesting that smoking was not correlated with obesity risk [26], or suggesting that smoking may increase the obesity risk [27-31].

Obesity was affected by a lot of factors including age, geography, race/ethnicity, gender and so on [32-35]. However, most studies focus on the relationship between smoking status and obesity by a simple age adjustment without a detailed age breakdown. In addition, as for the Chinese population, the investigation was limited. There were few researches reported it only in smoking men with two indicators: body mass index (BMI) and waist circumference (WC) [20, 36]. To further study the relationship between smoking status and obesity in both Chinese men and women, and explore whether age plays an essential role in this relationship or not, we performed a cross-sectional population-based study of Chinese adults, with multiple indicators such as BMI, WC, fat mass, fat free mass, and fat percentage.

Methods

Participants

The data used in this study were based on Chinese Physical and Psychological Database, provided by Chinese National Scientific Data Sharing Platform for Population and Health. This survey was conducted in several provinces in China from 2006 to 2011. Those provinces included Inner Mongolia Autonomous Region, Heilongjiang Province, Ningxia Hui Autonomous Region, Sichuan Province, Yunnan Province, and Hunan Province. Following the statistical


A
Male
BMI (kg/m2)
27.00
26.00
25.00
24.00
23.00
22.00
21.00
20.00
current smoker
non smoker
former smoker
19-24
25-34
35-44
45-54
55-64
65-74
75-
Age (years)
B
Female
BMI (kg/m2)
Age (years)
C
Male
WC (cm)
90
85
80
75
70
65
Age (years)
D
Female
WC (cm)
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Fat mass (Kg)
19
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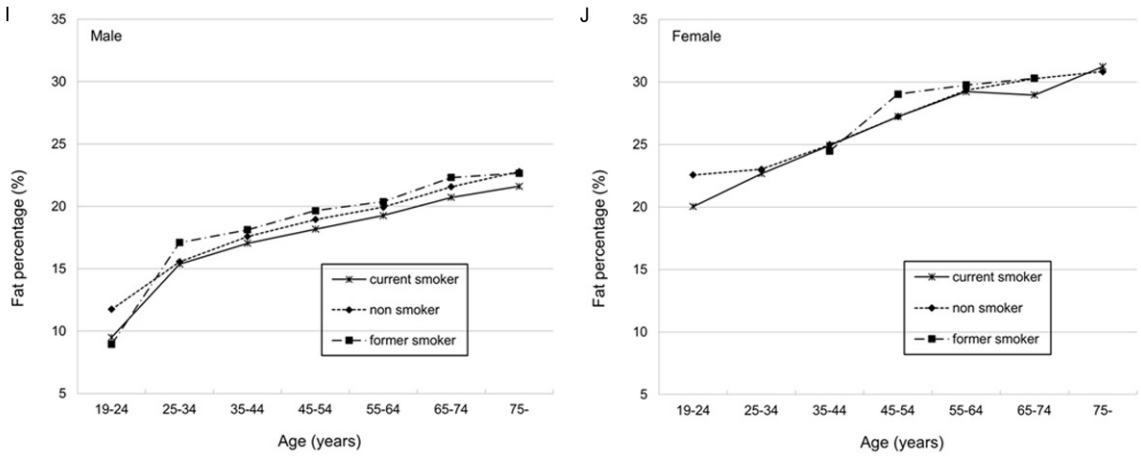

Figure 1. A. The association between BMI and smoking status in men for each age bracket. B. The association between BMI and smoking status in women for each age bracket. C. The association between WC and smoking status in men for each age bracket. D. The association between WC and smoking status in women for each age bracket. E. The association between fat mass and smoking status in men for each age bracket. F. The association between fat mass and smoking status in women for each age bracket. G. The association between fat free mass and smoking status in men for each age bracket. H. The association between fat free mass and smoking status in women for each age bracket. I. The association between fat percentage and smoking status in men for each age bracket. J. The association between fat percentage and smoking status in women for each age bracket.

sampling principles, a multi-stage, stratified, and random cluster sampling method was adopted to ensure that the precision of results was over 95%, that samples nationwide were representative, and that sampling was feasible and reasonable. All participants were from 19 to over 75 years old, and signed written informed consent forms.

Measurements

Indicators of height, weight, BMI, and WC were measured by weighing scale, height meter, and measuring scale for the waistline. Indicators of fat percentage, fat mass, and fat free mass were measured by Biodynamics BI-310 Body Composition Analyzer (US Biodynamics Corporation). Testing Procedures and Considerations included: 1) The participant lies on the back with his/her body relaxed. 2) The participant should expose the right wrist and the tester should place an electrode near the wrist. The edge of the electrode should be placed at the crease between the hand and wrist. The tester should place another electrode on the back center of the same hand, close to metacarpophalangeal joints. 3) Place an electrode close to the ankle of the participants. The edge of the electrode should be placed at the crease between the foot and leg; the tester should place another electrode on the back center of the same foot, close to the base of the toes. 4) Connect the instrument to the induction line and the electrodes. 5) Respectively input the participant's ID number, gender, age, height, weight, etc., according to the display menu. 6) Begin the test after confirmation.

Statistical analyses

Statistical analyses were conducted using SPSS 19.0. Participants were divided into three groups: current smokers, non-smokers and former smokers. The mean, standard deviation and frequency were calculated in BMI, WC, fat percentage, fat mass, and fat free mass for each age bracket. One-way ANOVA was used to detect the difference among these three groups. If $P<0.05$ in the ANOVA test, then post-hoc test analysis was used to determine the difference between each two groups. $P<0.05$ was considered as statistical significance.

Results

Baseline characteristics

There were 46,067 residents participated in this study, including 18,589 men and 27,478 women. The baseline characteristics of participants were shown in **Table 1**. For men, there

Table 2. The comparison of BMI among current smokers, non-smokers and former smokers in both men and women for each age bracket

	Age (years)	Current smoker		Non-smoker		Former smoker		*P value*
		Mean (kg/m^2)	SD	Mean (kg/m^2)	SD	Mean (kg/m^2)	SD	
Men								
	19-24	21.73	2.97	21.36	2.79	21.59	2.59	-a**
	25-34	24.24	3.76	24.1	3.33	24.95	3.3	b**; c**
	35-44	24.77	3.6	24.97	3.42	25.45	3.5	b**; c**
	45-54	24.71	3.44	25.3	3.35	25.78	3.28	a**; b**; c**
	55-64	24.13	3.33	25.14	3.29	25.45	3.23	a**; b**; c**
	65-74	23.68	3.35	24.59	3.34	24.84	3.15	a**; b**
	75-	22.19	3.58	23.97	3.34	23.72	3.29	a**; b**
	All	24.03	3.46	24.03	3.23	25.03	3.24	b**; c**
Women								
	19-24	20.84	2.97	20.83	2.43	-	-	*P=0.984*
	25-34	23.08	3.83	21.99	3.02	-	-	*P=0.051*
	35-44	23.43	3.55	23.42	3.1	23.62	2.98	*P=0.949*
	45-54	24.35	3.88	24.62	3.25	24.17	4.15	*P=0.458*
	55-64	24.86	3.88	25.11	3.54	25.56	3.65	*P=0.469*
	65-74	24.16	4.36	25.02	3.62	25.69	4.11	a**; b**
	75-	23.11	4.65	23.96	3.75	-	-	*P=0.317*
	All	23.4	3.92	23.56	3.19	24.76	3.79	b**; c**

Note: -a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was lower than that of current smokers; a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was higher than that of current smokers; b= the comparison between current smokers and former smokers, and the indicator of former smokers was higher than that of current smokers; c= the comparison between non-smokers and former smokers, and the indicator of former smokers was higher than that of non-smokers; **=$P<0.01$; SD= standard deviation.

were 40.80% current smokers, 47.13% non-smokers and 9.26% former smokers; while for women, there were 2.63% current smokers, 93.67% non-smokers and 0.43% former smokers. According to these results, in China, men smoked more frequently than women.

The association of BMI and smoking status

BMI was calculated for current smokers, non-smokers and former smokers in both men and women for each age bracket, seeing in **Figure 1A**, **1B**. And the comparison of BMI among these three groups was analyzed by ANOVA and post hoc test in **Table 2**. In men, from 19 to 24 years old, BMI of current smokers was higher than that of non-smokers. From 25 to 44 years old, BMI of former smokers was higher than that of non-smokers and current smokers. From 45 to 64 years old, BMI of former smokers was the highest, and BMI of non-smokers was in the middle, and BMI of current smokers was the lowest. From 65 to over 75 years old, BMI of current smokers was lower than that of former smokers and non-smokers. From 19 to over 75 years old, BMI of former smokers was higher than that of non-smokers and current smokers. In women, from 65 to 74 years old, BMI of non-smokers was higher than that of current smokers, but lower than that of former smokers. From 19 to over 75 years old, BMI of former smokers was higher than that of non-smokers and current smokers.

The association of WC and smoking status

WC was calculated for current smokers, non-smokers and former smokers in both men and women for each age bracket, seeing in **Figure 1C**, **1D**. And the comparison of WC among these three groups was analyzed in **Table 3**. In men, from 19 to 24 years old, WC of current smokers was higher than that of non-smokers. From 25 to 34 years old, WC of current smokers was higher than that of non-smokers, but lower than that of current smokers. From 45 to 54 years old, WC of former smokers was higher than that of non-smokers and current smokers. From 55 to 74 years old, WC of former smokers was the highest, and WC of non-smokers was in the middle, and WC of current smokers was the lowest. From 65 to over 75 years old, WC of current smokers was lower than that of former smokers and non-smokers. From 19 to over 75 years old, WC of former smokers was the highest, and WC of non-smokers was in the middle,

Table 3. The comparison of WC among current smokers, non-smokers and former smokers in both men and women for each age bracket

	Age	Current smoker		Non-smoker		Former smoker		*P value*
		Mean	SD	Mean	SD	Mean	SD	
Men								
	19-24	74.42	8.44	73.54	7.72	73.55	7.16	-a**
	25-34	82.76	10.32	81.74	9.27	84.3	9.37	-a**; c**
	35-44	84.73	9.99	84.42	9.74	85.92	10.14	*P=0.075*
	45-54	85.59	9.94	85.92	9.54	87.74	9.69	b**; c**
	55-64	84.35	9.53	85.84	9.54	87.71	8.97	a**; b**; c**
	65-74	84.38	9.67	86.11	9.49	87.35	8.86	a**; b**; c**
	75-	81.59	9.67	85.75	9.21	85.33	10.27	a**; b**
	All	82.55	9.77	83.33	9.13	84.56	9.27	a**; b**; c**
Women								
	19-24	69.43	8.86	68.93	6.54	-	-	*P=0.785*
	25-34	76.16	11.57	72.15	7.83	-	-	-a*
	35-44	77.52	9.58	75.8	8.06	78.16	6.74	-a**
	45-54	80.42	10.46	80.21	8.71	79.62	9.26	*P=0.905*
	55-64	83.46	9.97	83.58	9.49	84.29	9.78	*P=0.893*
	65-74	84.25	10.99	84.9	9.62	88.19	8.85	*P=0.077*
	75-	85.12	9.87	84.51	9.76	-	-	*P=0.739*
	All	79.48	10.27	78.58	8.44	82.57	8.82	-a**; b**; c**

Note: -a= the comparison between current smokers and non-smokers (the indicator of current smoker was higher than that of non-smokers); a= the comparison between current smokers and non-smokers (the indicator of current smoker was lower than that of non-smokers); b= the comparison between current smokers and former smokers; c= the comparison between non-smokers and former smokers; *= $P<0.05$; **= $P<0.01$; SD= standard deviation.

and WC of current smokers was the lowest. In women, from 25 to 44 years old, WC of current smokers was higher than that of non-smokers. From 19 to over 75 years old, WC of former smokers was the highest, and WC of current smokers was in the middle, and WC of non-smokers was the lowest.

The association of fat mass and smoking status

Fat mass was calculated for current smokers, non-smokers and former smokers in both men and women across age, seeing in **Figure 1E**, **1F**. And the comparison of fat mass among these three groups was analyzed in **Table 4**. In men, from 19 to 24 years old, fat mass of non-smokers was higher than that of current smokers and former smokers. From 25 to 34 years old, fat mass of former smokers was higher than that of current smokers and non-smokers. From 35 to 44, fat mass of former smokers was higher than that of current smokers. From 45 to 74 years old, fat mass of former smokers was the highest, and fat mass of non-smokers was in the middle, and fat mass of current smokers was the lowest. Over 75 years old, fat mass of current smokers was lower than that of non-smokers and former smokers. From 19 to over 75 years old, fat mass of former smokers was the highest, and fat mass of non-smokers was in the middle, and fat mass of current smokers was the lowest. In women, from 65 to 74 years old, fat mass of non-smokers was higher than that of current smokers. From 19 to over 75 years old, fat mass of former smokers was higher than that of non-smokers and current smokers.

The association of fat free mass and smoking status

Fat free mass was calculated for current smokers, non-smokers and former smokers in both men and women across age, seeing in **Figure 1G**, **1H**. And the comparison of fat free mass among these three groups was analyzed in **Table 5**. In men, from 19 to 34 years old, fat free mass of non-smokers was lower than that of current smokers and former smokers. From 45 to 54, fat free mass of former smokers was higher than that of current smokers and non-smokers. From 55 to 64 years old, fat free mass of former smokers was the highest, and fat free mass of non-smokers was in the middle, and fat free mass of current smokers was the lowest. From 65 to over 75 years old, fat free mass of current smokers was lower than that of non-smokers and former smokers. From 19 to over 75 years old, fat free mass of former smokers was higher than that of non-smokers

Table 4. The comparison of fat mass among current smokers, non-smokers and former smokers in both men and women for each age bracket

	Age (years)	Current smoker		Non-smoker		Former smoker		*P value*
		Mean (kg)	SD	Mean (kg)	SD	Mean (kg)	SD	
Men								
	19-24	6.33	5.71	7.2	5.33	5.88	5.07	a**; -c**
	25-34	11.26	6.72	10.99	5.88	12.51	6.15	b**; c**
	35-44	12.38	6.3	12.68	6.1	13.51	6.7	b**
	45-54	12.93	6.1	13.51	5.98	14.53	5.73	a**; b**; c**
	55-64	12.94	5.89	13.86	5.67	14.63	6.03	a**; b**; c**
	65-74	13.4	5.75	14.49	5.75	15.24	5.83	a**; b**; c**
	75-	12.73	5.21	14.79	5.9	14.53	5	a**; b**
	All	11.71	6.12	12.5	5.76	12.98	5.92	a**; b**; c**
Women								
	19-24	11.22	3.97	11.78	3.86	-	-	*P=0.498*
	25-34	13.51	4.8	12.85	4.79	-	-	*P=0.338*
	35-44	14.86	5.81	14.64	5.02	14.18	3.58	*P=0.792*
	45-54	16.55	6.44	16.66	5.44	17.03	6.67	*P=0.919*
	55-64	17.65	6	17.87	5.73	18.34	6.09	*P=0.780*
	65-74	16.65	5.65	17.81	5.61	18.86	6.88	a**
	75-	16.52	5.98	16.78	5.47	-	-	*P=0.912*
	All	15.28	5.88	15.48	5.15	17.1	6.09	b**; c**

Note: a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was higher than that of current smokers; b= the comparison between current smokers and former smokers, and the indicator of former smokers was higher than that of current smokers; c= the comparison between non-smokers and former smokers, and the indicator of former smokers was higher than that of non-smokers; -c= the comparison between non-smokers and former smokers, and the indicator of former smokers was lower than that of non-smokers; **= $P<0.01$; SD= standard deviation.

and current smokers. In women, from 19 to 34, fat free mass of non-smokers was lower than that of current smokers. From 45 to 54, fat free mass of former smokers was lower than that of current smokers. From 19 to over 75 years old, fat free mass of non-smokers was lower than that of current smokers.

The association of fat percentage and smoking status

Fat percentage was calculated for current smokers, non-smokers and former smokers in both men and women across age, seeing in **Figure 1I**, **1J**. And the comparison of fat percentage among these three groups was analyzed in **Table 6**. In men, from 19 to 24 years old, fat percentage of non-smokers was higher than that of current smokers and former smokers. From 35 to 44 years old, fat percentage of non-smokers was higher than that of current smokers. From 45 to 74, fat percentage of current smokers was lower than that of non-smokers and former smokers. From 19 to over 75 years old, fat percentage of current smokers was lower than that of non-smokers and former smokers. In women, from 19 to 24 years old, fat percentage of non-smokers was higher than that of current smokers. From 19 to over 75 years old, fat percentage of former smokers was the highest, and fat percentage of non-smokers was in the middle, and fat percentage of current smokers was the lowest.

Discussion

The association between smoking status and obesity was studied a lot. However, the results were different and contradictory. In 2001, Oh et al. [27] reported that, among Korean men from 20 to 76 years old, The relationship between smoking intensity and BMI was parabolic, and the relationship between smoking intensity and the percentage of body fat was able to be explained both by a linear and a quadratic model. According to its results, heavy smoking had a positive relationship with obesity. In 2005, John et al. [21] reported that, among German men and women from 18 to 79 years old, the number of cigarettes per day was positively related to being overweight and more so to obesity among former smoking men, but not women. In 2007, Xu F. et al. [36] reported that, among Chinese men from 35 to older, the prevalence of overweight (BMI) was significantly lower among current smokers than in non-smokers and former smokers. Compared to non-smokers, only male former smokers were at increased risk of central obesity (WC), while

Table 5. The comparison of fat free mass among current smokers, non-smokers and former smokers in both men and women for each age bracket

	Age (years)	Current smoker		Non-smoker		Former smoker		*P value*
		Mean (kg)	SD	Mean (kg)	SD	Mean (kg)	SD	
Men								
	19-24	57.11	8.02	53.34	9.27	56.29	6.69	-a**; c**
	25-34	58.69	8.65	57.56	8.35	59.09	8.73	-a**; c**
	35-44	57.88	8.61	57.53	8.72	58.68	8.96	*P=0.124*
	45-54	56.37	8.45	56.37	8.62	58.03	8.02	b**; c**
	55-64	52.89	8.41	54.44	8.16	55.7	8.18	a**; b**; c**
	65-74	50.13	8.09	51.56	7.95	52.01	7.71	a**; b**
	75-	45.29	8.09	49.04	7.69	48.84	7.92	a**; b**
	All	54.05	8.43	54.26	8.56	55.52	8.1	b**; c**
Women								
	19-24	44.56	8.15	39.98	5.28	-	-	-a*
	25-34	45.43	9.73	42.04	5.71	-	-	-a*
	35-44	43.63	7.29	43.07	5.76	43.75	6.96	*P=0.445*
	45-54	42.93	7.33	43.65	6	40.37	7.41	-c**
	55-64	42	7.13	42.15	6.12	42.44	6.77	*P=0.912*
	65-74	39.72	6.08	40.24	6.26	41.93	5.28	*P=0.163*
	75-	35.86	7.66	37	6.31	-	-	*P=0.350*
	All	42.02	7.29	41.16	5.86	42.12	6.51	-a**

Note: -a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was lower than that of current smokers; a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was higher than that of current smokers; b= the comparison between current smokers and former smokers, and the indicator of former smokers was higher than that of current smokers; c= the comparison between non-smokers and former smokers, and the indicator of former smokers was higher than that of non-smokers; *= $P<0.05$; **= $P<0.01$; SD= standard deviation.

there was no significant association with current smokers. In 2009, Fang et al. [20] reported that, among Chinese men from 18 to older, there was a moderate negative and significant relationship between cigarette smoking and BMI, which was considerably stronger in healthy weight people than obese people. In 2011, Patel et al. [24] reported that, among both African American and Caucasian women, current smokers had decreased odds of being overweight or obese compared to normal-weight nonsmokers, and the inverse trends between current smoking and BMI held for both African American and white. In 2011, Clair et al. [19] reported that, among Switzerland Caucasian men and women from 35 to 75 years old, current smokers had lower mean BMI, WC, and body fat percentage, compared with non-smokers. Age-adjusted mean WC and body fat increased with cigarettes smoked per day among smokers, while not significantly related to BMI. In 2012, Jong et al. [22] reported that, in Korean adolescents, smoking frequency and cigarette consumption had positive effects with regard to weight loss. In 2014, de Oliveira et al. [26] reported that, among Austrian bank male and female employees from 19 to 65 years old, no differences in total body fat and/or body fat distribution were found among non-smokers, smokers and former smokers.

In conclusion, some studies suggested that smoking was negatively associated with obesity [19-25], others suggested that smoking was positively associated with obesity [27-31]. Also, there were studies demonstrating that smoking status and obesity were not significantly correlated [26]. Various factors may cause the differences in those studies. First, racial/ethnic differences have been observed in the association with obesity. For example, Asian men have lower odds of obesity relative to White men in all regions of the United States [32-34, 37]. Second, geographic regions play a substantial role in contributing to obesity. Environment encompasses a range of physical and social elements that make up the structure of a community and may influence obesity [32, 38-40]. Third, the observed gender difference in the prevalence of obesity may be attributed to gender-specific body structures, sex hormones and behavioral responses [41, 42]. All these factors including age were different in multiple studies, which may be the reason causing the different results of the relationship between smoking status and obesity.

Table 6. The comparison of fat percentage among current smokers, non-smokers and former smokers in both men and women for each age bracket

	Age (years)	Current smoker		Non-smoker		Former smoker		*P value*
		Mean (%)	SD	Mean (%)	SD	Mean (%)	SD	
Men								
	19-24	9.5	7.69	11.75	8.13	8.94	6.62	a**; -c**
	25-34	15.37	7.55	15.55	7.16	17.1	7.4	*P=0.057*
	35-44	17.04	7.03	17.58	6.92	18.12	7.22	a**
	45-54	18.17	7.02	18.94	6.96	19.65	6.24	a**; b**
	55-64	19.27	7.45	19.94	6.56	20.37	6.93	a**; b**
	65-74	20.72	7.25	21.57	6.97	22.32	7.01	a**; b**
	75-	21.6	6.99	22.79	7.47	22.66	5.99	*P=0.184*
	All	17.38	7.27	18.3	7.23	18.45	6.82	a**; b**
Women								
	19-24	20.03	5.84	22.56	5.88	-	-	a*
	25-34	22.66	5.49	23.01	6.4	-	-	*P=0.703*
	35-44	24.92	6.83	24.99	6.3	24.48	4.73	*P=0.920*
	45-54	27.23	6.63	27.23	6.43	29.02	7.78	*P=0.413*
	55-64	29.23	6.98	29.34	6.37	29.75	7.06	*P=0.907*
	65-74	28.96	6.98	30.27	6.5	30.3	7.15	*P=0.080*
	75-	31.22	8.13	30.82	6.94	-	-	*P=0.765*
	All	26.32	6.8	26.89	6.32	28.39	6.85	a**; b**; c**

Note: a= the comparison between current smokers and non-smokers, and the indicator of non-smokers was higher than that of current smokers; b= the comparison between current smokers and former smokers, and the indicator of former smokers was higher than that of current smokers; c= the comparison between non-smokers and former smokers, and the indicator of former smokers was higher than that of non-smokers; *= $P<0.05$; **= $P<0.01$; SD= standard deviation.

In our study, we explored the relationship between smoking status and obesity using data from a large scale, cross-sectional study in China (2006-2011), including both men (18,589) and women (27,478), with multiple indicators including BMI, WC, fat percentage, fat mass, and fat free mass. In our study, we focused on the role of age played on the association between smoking status and obesity. In men, from 19 to 24 years old, BMI, WC and fat free mass of current smokers were higher than that of non-smokers. However, fat mass and fat percentage of current smokers were lower than that of non-smokers but higher than that of former smokers. From 25 to 34 years old, BMI and fat mass of former smokers were higher than non-smokers and current smokers. In addition, WC and fat free mass of non-smokers were lower than that of current smokers and former smokers. From 55 to older, BMI, WC, fat mass, fat free mass and fat percentage of current smokers were lower than that of non-smokers, indicating that cigarette smoking might have positive effects with regard to weight loss. From 45 to older, BMI, WC, fat mass, fat free mass and fat percentage of former smokers were higher than that of current smokers, indicating that smoking cessation might have a strong effect on obesity. According to these results, cigarette smoking might have different effects on obesity depending on different age. For young men (from 19 to 24 years old), cigarette smoking might have an effect on increasing fat free mass and decrease fat mass, which might make an increase of BMI and WC, and a decrease of fat percentage. For middle and older men (from 45 to older), cigarette smoking might have an effect on decreasing both fat free mass and fat mass, which might make a decrease of BMI, WC, and fat percentage. And these different results depending on different age range might be another important reason for the contradictory of multiple studies. In women, smoking status might not be significantly related to obesity.

Various hypotheses may explain the association between smoking status and obesity. First, studies indicated that resting energy expenditure increased in both obese and normal-weight current smokers after smoking, which may be a possible reason for the negative effect of smoking on obesity [43]. Second, smoking status may modify genetic effects on obesity. For example, rs6548238/TMEM18 and rs9939609/FTO were two risk alleles of obesity, and the association between these two risk alleles and BMI was different depending on the different smoking status [44]. Third,

various aspects of nicotine dependence are mediated by close interactions of the glutamatergic, dopaminergic and γ-aminobutyric acidergic systems in the mesocorticolimbic system, which may affect metabolism of smokers [45].

Our study has some advantages in the research of smoking status and obesity. First, we use weighing scale, height meter, and measuring scale for waistline, instead of self-reported weight and height, to measure BMI and WC. Self-reported data may lead to under or over estimation of the accurate indicators. Second, compared with other two studies in China [20, 36], we measured other indicators besides BMI and WC. These factors - fat mass, fat free mass, and fat percentage - were measured by Biodynamics BI-310 Body Composition Analyzer. BMI is a useful index of nutritional status, and a recommended indicator to determinate obesity and overweight. However, besides fat mass, BMI also reflects fat free mass, such as muscular and bone mass, resulting in numerous variations of these body components within the same body mass [46, 47]. Considering all of these, BMI is not an accurate indicator to define the total body fat mass. However, fat mass, fat free mass and fat percentage can represent body composition, and are more close to the current concept of obesity [35]. Fat free mass is predictive of self-determined meal size, daily energy intake, and ad-libitum food intake [48, 49]. In BMI-defined normal people, an increased fat percentage indicates cardiometabolic dysregulation, body adiposity and type 2 diabetes [49, 50]. Third, we focused on the role of age played on the association between smoking status and obesity by an analysis for different age ranges. According to the results, cigarette smoking might have a positive effect on increasing weight for young men while a negative effect on obesity for middle and older men. Last, besides men, we also studied the association between smoking status and obesity in women.

However, our study has some limitations that should be acknowledged. First, we divided participants into three groups: current smokers, non-smokers and former smokers. But, among current smokers, the relationship between cigarettes smoked per day and obesity was not studied. Several studies indicated that among current smokers, cigarettes smoked per day were positively associated with central obesity [19, 36]. Second, there were several confounding factors that may affect the association between smoking status and obesity, such as alcohol consumption, physical work, education level, total energy intake and total energy expenditure. Third, although Chinese women have been first enrolled in our study compared with other studies, the percentage of former smokers in women was small. Therefore, direction of the causality between obesity and smoking cessation for women may be disputable. Forth, the present study enrolled only Chinese, whose results may not be consistent with other racial/ethnic groups.

Conclusion

For young men, cigarette smoking might have an effect on increasing fat free mass and decrease fat mass, which might make an increase of BMI and WC, and a decrease of fat percentage. For middle and older men, cigarette smoking might have an effect on decreasing both fat free mass and fat mass, which might make a decrease of BMI, WC, and fat percentage. In addition, these associations were stronger in former smokers, therefore, obesity risk should be paid more attention in smoking cessation programs.

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Disclosure of conflict of interest

None.

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