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Examining The Association Between Cigarette Smoking And Hypertension In Rural China

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Abstract

Cigarette smoking and hypertension are well known risk factors for cardiovascular disease, but the association between cigarette smoking and blood pressure/hypertension remains controversial. Although several existing studies have examined this association, their results are inconsistent. Therefore, this study is intended to examine the association between smoking and blood pressure/hypertension. This cross-sectional study was conducted in rural China. The study subjects were 575 volunteers with a mean age of 48.3 ± 5.6 years. They were divided into smokers and non-smokers. The effects of smoking on blood pressure and the prevalence of hypertension were examined. The results show that current smoking is associated with increased blood pressure and the prevalence of hypertension, but the associations are not statistically significant. After stratification by body mass index (BMI), smokers with BMI < 23 kg/m^2 have a 3.717 mmHg increase in diastolic blood pressure as compared to non-smokers with BMI < 23 kg/m^2 ($p=0.017$). Using non-smokers with BMI < 23 kg/m^2 as a reference, smokers with BMI < 23 kg/m^2 have a 4.712 mmHg increase in systolic blood pressure ($p=0.034$) and a 3.454 mmHg increase in diastolic blood pressure ($p=0.011$), non-smokers with BMI ≥ 23 kg/m^2 have a 9.685 mmHg increase in systolic blood pressure ($p<0.001$) and a 7.259 mmHg increase in diastolic blood pressure ($p<0.001$), and smokers with BMI ≥ 23 kg/m^2 have a 9.186 mmHg increase in systolic blood pressure ($p<0.001$) and a 7.793 mmHg increase in diastolic blood pressure ($p<0.001$). The odds of hypertension among non-smokers with BMI ≥ 23 kg/m^2 is 2.47 times those among non-smokers with BMI < 23 kg/m^2 ($p=0.003$). The odds of hypertension among smokers with BMI ≥ 23 kg/m^2 is 3.34 times those among non-smokers with BMI <23 kg/m^2 ($p=0.005$). Therefore, cigarette smoking is more likely to be associated with increased blood pressure and the prevalence of hypertension among overweight/obese people.

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1. Introduction

According to the World Health Organization (WHO), approximately 17.7 million people die from cardiovascular disease each year, and this number represents an estimated 31% of all deaths worldwide (WHO, 2018a). Both cigarette smoking and hypertension are major risk factors for cardiovascular disease. According to the WHO, cigarette smoking is one of behavioral risk factors for cardiovascular disease, and increased blood pressure is considered an effect of behavioral risk factors, or "intermediate risk factors," for cardiovascular disease (WHO, 2018a). In addition, cigarette smoking itself causes huge harm to humans. According to the data from the WHO, cigarette smoking kills more than 7 million people each year, and around 80% of cigarette smokers live in low- and middle-income countries. Approximately 6 million deaths are caused by direct cigarette use, and the remaining deaths are the result of second-hand smoking (WHO, 2018b). Hence, it is meaningful to study the harm of cigarette smoking and promote "no tobacco" worldwide.

Although cigarette smoking and hypertension are well-known risk factors for cardiovascular disease, the relationship between cigarette smoking and hypertension is still not certain. A few pathophysiological perspectives support a causal association between cigarette smoking and hypertension. Studies conclude that cigarette smoking can damage the endothelium and thereby cause endothelial dysfunction and impair endothelium-dependent coronary vasodilation (Li et al., 2017). Additionally, forearm hemodynamics may be changed by cigarette smoking, and this kind of change will impact both small and large arteries so as to damage the endothelium (Li et al., 2017). However, early studies investigating cigarette smoking and blood pressure have reached inconsistent results. Therefore, the objective of this study is to investigate the associations between smoking and blood pressure and the prevalence of hypertension. The

study hypothesis is that cigarette smoking increases blood pressure and the prevalence of hypertension. In addition, overweight and obesity are major risk factors for hypertension, and men have higher blood pressure levels and thus a higher risk of hypertension (Everett & Zajacova, 2015; Maniecka-Bryla et al., 2011). Therefore, we will also explore the potential effect modifications of BMI and gender on the associations between smoking and blood pressure and hypertension.

2. Literature Review

To the best of my knowledge, 14 studies have published on the topic of cigarette smoking and blood pressure. However, their results have been inconsistent. Five studies supported a positive association between smoking and blood pressure. Jena and Purohit (2017) conducted a study in India with a sample size of 111, which indicated that current smoking status increased blood pressure. Bowman et al. (2007) and Halperin et al. (2008) conducted studies in the US with sample sizes of 28,236 and 13,529, respectively, which indicated that smoking was an important risk factor for the development of hypertension, but Bowman et al. (2007) also mentioned that the risk of hypertension is related to a large amount of smoking (≥15) per day. The odds of hypertension among those who smoked more than 15 cigarettes per day was 1.1 times the odds of hypertension among those who never smoked. Abtahi et al. (2011) conducted a study in Iran with a sample size of 3,115, and Thuy et al. (2010) conducted a study in Vietnam with a sample size of 910, both of which indicated that there was no association between current smoking status and blood pressure. However, Abtahi et al. (2011) pointed out that smoking cessation or reduction significantly decreased blood pressure, and Thuy et al. (2010) pointed out that the risk of hypertension was related to the duration and amount of smoking.

Six out of the fourteen studies supported a negative association between smoking and blood pressure. Gumus et al. (2013) conducted a study in Turkey with a sample size of 712, and Okubo et al. (2004) conducted a study in Japan with a sample size of 2,871, both of which indicated that smoking would reduce the risk of hypertension and lower blood pressure. Also, a study Li et al. (2017) conducted a study in China with a sample size of 1,248 and another study by Okubo et al. (2002) with the same sample size and location indicated that current smokers had lower blood pressure levels than former smokers and those who had never smoked. The study conducted by Halimi et al. (2002) in France, with a sample size of 12,417, and the study conducted by Lee et al. (2001) in Korea, with sample size of 8,170, indicated that smoking cessation increased the risk of hypertension.

The two studies Fogari et al. (1996) conducted in Italy, with sample size of 7,109, and Jeganathan and Chowta (2012) conducted in India, with sample size of 2,190, both showed the various effects of smoking on systolic and diastolic blood pressure. They concluded that smoking would lead to higher systolic blood pressure and lower diastolic blood pressure. One study conducted by Primatesta et al. (2001) in the UK, with sample size of 33,860, showed that there is no significant association between smoking status and blood pressure.

Based on the above literature review, the existing studies have no consistent conclusions regarding the association between cigarette smoking and blood pressure, and some studies even support a negative association between smoking and blood pressure levels. Hence, this association will be examined once again in this study.

3. Methods

3.1 Data

The study population was 575 volunteers who participated in the INTERMAP study conducted by Peking University Clinical Research Institute. All participants were from three areas of China (rural Beijing, rural Shanxi, and rural Guangxi). Participants included both males (n=268) and females (n=307) aged 40 to 59 years at the time of survey (2017). All of the participants were interviewed by trained interviewers using a standardized questionnaire. The study design was cross-sectional, and the data that were available to use for this study included age, sex, body mass index, educational status, marital status, systolic blood pressure, diastolic blood pressure, anti-hypertension drug use, and smoking status.

3.2 Measurements

Systolic and diastolic blood pressure values were calculated as the mean of four measurements taken during interview period. Hypertension was defined as a mean systolic blood pressure ≥ 140 mmHg, a mean diastolic blood pressure ≥ 90 mmHg, or the taking of antihypertensive drugs. Body mass index was also calculated as the mean of four measurements taken during interview period, using the formula of BMI=weight (kg)/height (m^2). Because the participants were Chinese, WHO Asian BMI cutoff points were used: underweight (<18.5 kg/m^2), normal weight (18.6–22.9 kg/m^2), overweight (23–27.4 kg/m^2), and obesity (≥27.5 kg/m^2) (Jih et al., 2014). Because of sample size limitations, the underweight and normal weight categories were merged into non-overweight/obese (<23 kg/m^2), and the overweight and obesity categories were merged into overweight/obese (≥23 kg/m^2). Educational levels were classified based on years of education: at least some elementary school (≤ 6 years of education), at least

some middle school (7–9 years of education), and at least some high school (≥10 years of education).

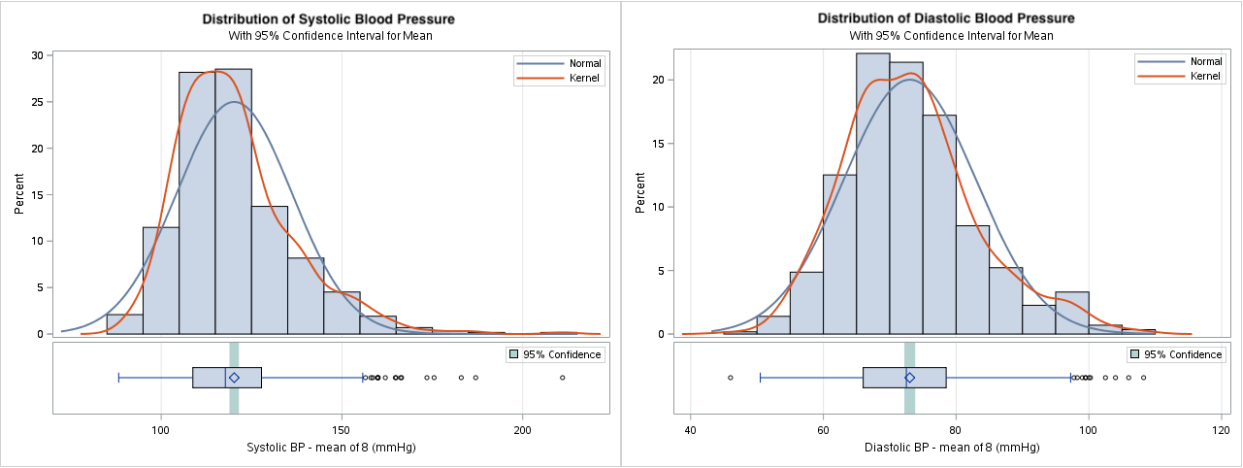
3.3 Statistical analysis

The SAS statistical software program (SAS Studio, Web-based SAS: https://odamid.oda.sas.com/) was used for all statistical calculations. Participants were categorized into one of two groups based on their smoking status: currently smoking (n=196) and non-smoking (n=379). Participants who were in the currently smoking group were those who were smokers when they were interviewed. Participants who were in the non-smoking group were those who were never smokers (n=331) or former smokers (n=48). Because of limitations regarding the sample size for former smokers (n=48), they were combined with those who had never smoked. The results are given as mean ± standard deviation (SD) for continuous variables and percentages for categorical variables.

Logistic regressions and multivariable logistic regressions were performed to assess the risk of hypertension associated with smoking status. The covariates included in the multivariable logistic regressions were sex, BMI, educational level, marital status, and smoking status. Stratified analyses were performed based on BMI (overweight/obesity) in order to test effect modification. Additionally, multiple linear regressions were performed to assess the association between blood pressure and smoking status. The covariates included in the multiple linear regressions were sex, BMI, educational level, marital status, and smoking status. Stratified analyses were performed based on BMI (overweight/obesity) and gender. Moreover, the interaction between smoking status and BMI and the interaction between smoking status and gender were also tested.

T-tests were performed to confirm that both systolic and diastolic blood pressure levels were normally distributed (Figure 1), and $p<0.05$ was regarded as statistically significant.

Figure 1. Distribution of systolic and diastolic blood pressures



4. Results

In the present study, 575 participants were included in the analysis, and the mean age was 48.3 ± 5.6 years. Table 1 shows the baseline characteristics of the study population. Smoking status was stratified into smokers (n=196) and non-smokers (n=379). Exactly 92.9% of males and 22.7% of females were smokers ($p<0.001$). The mean age of smokers was 48.1 ± 5.9 years, and the mean age of non-smokers was 48.4 ± 5.5 years. The mean BMI values of smokers and non-smokers were 22.5 ± 2.7 kg/m^2 and 23.8 ± 3.5 kg/m^2, respectively. In addition, 38.8% of smokers (n=76) and 55.7% of non-smokers (n=211) were classified as overweight/obese ($p<0.001$). Smokers had a similar mean systolic blood pressure (120.3 ± 16.0 mmHg) but a slightly greater mean diastolic blood pressure (74.2 ± 10.2 mmHg) as compared with non-smokers, who had a mean systolic blood pressure of 120.1 ± 16.0 mmHg and a mean diastolic

blood pressure of 72.4 ± 9.8 mmHg (p=0.908 and p=0.039, respectively). In fact, 6.6% of smokers and 8.4% of non-smokers used antihypertensive drugs. The inclusion criteria for hypertension were systolic blood pressure ≥ 140, diastolic blood pressure ≥ 90, or the use of antihypertensive drugs. Regarding hypertension, 15.8% of smokers had hypertension, while 16.6% of non-smokers had hypertension (p=0.804). Among smokers, 61.2% had at least some elementary school education, 32.7% had at least some middle school education, and 6.1% had at least some high school education; among non-smokers, 73.9% had at least some elementary school education, 21.6% had at least some middle school education, and 4.5% had at least some high school education (p=0.007). Participants who were married were classified as such, and participants who were divorced/separated, widowed, or never married were classified as not married. Most of smokers and non-smokers were married, at 98.5% and 90.8%, respectively (p<0.001).

Table 1. Baseline characteristics of 575 participants according to baseline smoking status

	Smoking Status (mean ± sd or n%)		
Population characteristic	Smokers (n=196)	Non-smokers (n=379)	p-value
Age (years)	48.1 ± 5.9	48.4 ± 5.5	0.534
Sex			<0.001
Male	182 (92.9)	86 (22.7)	
Female	14 (7.1)	293 (77.3)	
Overweight/Obesity (BMI)			<0.001

Yes (≥23 kg/m^2)	76 (38.8)	211 (55.7)	
No (<23 kg/m^2)	120 (61.2)	168 (44.3)	
Body mass index	22.5 ± 2.7	23.8 ± 3.5	<0.001
Education			0.007
At least some elementary school	120 (61.2)	280 (73.9)	
At least some middle school	64 (32.7)	82 (21.6)	
At least some high school	12 (6.1)	17 (4.5)	
Marital status[1]			<0.001
Yes	193 (98.5)	344 (90.8)	
No	3 (1.5)	35 (9.2)	
Systolic blood pressure (mmHg)	120.3 ± 16.0	120.1 ± 16.0	0.908
Diastolic blood pressure (mmHg)	74.2 ± 10.2	72.4 ± 9.8	0.039
Antihypertensive drug			0.444
Yes	13 (6.6)	32 (8.4)	
No	183 (93.4)	347 (91.6)	
Hypertension[2]			0.804
Yes	31 (15.8)	63 (16.6)	
No	165 (84.2)	316 (83.4)	

1. Marital status (Yes): married; marital status (No): divorced/separated, widowed, or never married.

2. Hypertension: systolic blood pressure ≥ 140 or diastolic blood pressure ≥ 90 or antihypertensive drugs use.

4.1 Blood Pressure

Elevated blood pressure is related to the prevalence of hypertension, so whether smoking status affected blood pressure was examined. Table 2 shows the effect of smoking status on

systolic and diastolic blood pressure after adjusting for sex, BMI, education, and marital status. Participants who smoked have a 2.412 mmHg increase in systolic blood pressure as compared to those who did not smoke. However, the p-value of 0.194 indicates that the mean difference of systolic blood pressure between those who smoked and those who did not smoke is not significant. In addition, participants who smoked have a 2.165 mmHg increase in diastolic blood pressure as compared to those who did not smoke. However, the p-value of 0.056 indicates that this result is only borderline significant.

Table 2. Multiple linear regression model shows the effect of smoking status and other variables on systolic and diastolic blood pressure

Population characteristic	Systolic blood pressure		Diastolic blood pressure	
	Adjusted β (SE)	P	Adjusted β (SE)	p
Sex				
Male	-1.387 (1.824)	0.448	0.584 (1.110)	0.599
Female	Reference	--	Reference	--
Overweight/Obese (BMI)				
Yes (≥23 kg/m^2)	7.952 (1.313)	<0.001	6.288 (0.799)	<0.001
No (<23 kg/m^2)	Reference	--	Reference	--
Education				
At least some elementary school	Reference	--	Reference	--
At least some middle school	-0.400 (1.555)	0.797	1.257 (0.946)	0.185
At least some high school	-3.343 (3.071)	0.277	-1.770 (1.869)	0.344
Marital status[1]				

Yes	2.145 (2.643)	0.417	2.393 (1.608)	0.137
No	Reference	--	Reference	--
Smoking				
Yes	2.412 (1.856)	0.194	2.165 (1.129)	0.056
No	Reference	--	Reference	--

1. Marital status (Yes): married; marital status (No): divorced/separated, widowed, or never married.

Table 2 shows that only the mean difference in systolic and diastolic blood pressure levels between those who were classified as overweight/obese (≥23 kg/m^2) and those who were classified as non-overweight/obese (<23 kg/m^2) is significant (p-value < 0.001). Participants who had BMI values equal to and greater than 23 kg/m^2 have a 7.952 mmHg increase in systolic blood pressure and a 6.288 mmHg increase in diastolic blood pressure as compared to those who had BMI values less than 23 kg/m^2. In order to test whether BMI is an effect modifier, smokers and non-smokers were stratified based on their BMI. Corraini et al. (2017) indicated that the aim of the assessment of effect modification is to "separate exposure effects according to another variable." Table 3 shows that the effect of smoking status on systolic and diastolic blood pressure after stratification based on BMI. In those with BMI<23 kg/m^2 (non-overweight or obese), participants who smoked have a 4.361 mmHg increase in systolic blood pressure as compared to those who did not smoke, but the p-value of 0.073 indicates that the mean difference is not significant. In addition, participants who smoked have a 3.717 mmHg increase in diastolic blood pressure as compared to those who did not smoke, and the p-value of 0.017 indicates that the mean difference is significant. In those with BMI ≥23 kg/m^2 (overweight or obese), participants who smoked have a 0.329 mmHg decrease in systolic blood pressure and a 0.250 mmHg increase in diastolic blood pressure as compared to those who did not smoke, but the mean

differences are not significant (p=0.908 and p=0.881, respectively). The mean differences are not consistent after stratification based on BMI, so BMI is considered a potential effect modifier. However, the interactions between smoking status and BMI on the effect of systolic blood pressure (p=0.061) or diastolic blood pressure (p=0.085) are not statistically significant. Therefore, BMI cannot be considered an effect modifier.

Table 3. The effect of smoking status on the systolic and diastolic blood pressure after stratification based on BMI

Population characteristic (kg/m^2)	Systolic blood pressure model		Diastolic blood pressure model	
	Adjusted β (SE) of smoking status (Y/N)	P	Adjusted β (SE) of smoking status (Y/N)	p
BMI≥23	-0.329 (2.847)	0.908	0.250 (1.671)	0.881
BMI<23	4.361 (2.420)	0.073	3.717 (1.544)	0.017

* Adjusted for sex, education, and marital status.

* Interaction test: systolic blood pressure (p=0.061) and diastolic blood pressure (p=0.085).

In the stratified analysis, the results changed after using those who had BMI values less than 23 kg/m^2 and did not smoke as reference. Table 4 indicates that those who had BMI values less than 23 kg/m^2 and did smoke have a 4.712 mmHg increase in systolic blood pressure and a 3.454 mmHg increase in diastolic blood pressure as compared those who had BMI values less than 23 kg/m^2 and did not currently smoke, and the mean differences are significant (p=0.034 and p=0.011, respectively). Participants who had BMI values equal to and greater than 23 kg/m^2 and did not currently smoke have a 9.685 mmHg increase in systolic blood pressure and a 7.259

mmHg increase in diastolic blood pressure as compared to those who had BMI values less than 23 kg/m^2 and did not currently smoke, and the mean difference is significant ($p<0.001$). Participants who had BMI values equal to and greater than 23 kg/m^2 and did smoke have a 9.186 mmHg increase in systolic blood pressure and a 7.793 mmHg increase in diastolic blood pressure as compared to those who had BMI values of less than 23 kg/m^2 and did not currently smoke, and the mean difference is significant ($p<0.001$). Therefore, based on the above results, participants who were overweight/obese (BMI≥23 kg/m^2) have significant higher blood pressure levels, regardless of smoking status. Among those who are overweight/obese, current smoking status has more of an effect on diastolic blood pressure. In the non-overweight/obese group, current smoking status has large effects on both systolic and diastolic blood pressure.

Table 4. Stratified analysis of the effect of smoking status on systolic and diastolic blood pressure using those who had BMI values less than 23 kg/m^2 and did not smoke as a reference

Population characteristic		Systolic blood pressure		Diastolic blood pressure	
	Smoking	Adjusted β (SE)	p	Adjusted β (SE)	p
BMI≥23 kg/m^2	Yes	9.186 (2.433)	<0.001	7.793 (1.481)	<0.001
	No	9.685 (1.603)	<0.001	7.259 (0.976)	<0.001
BMI<23 kg/m^2	Yes	4.712 (2.221)	0.034	3.454 (1.352)	0.011
	No	Reference	--	Reference	--

* Adjusted for sex, education, and marital status.

Because sex may have an effect on blood pressure, the effect of smoking status on blood pressure will be analyzed after stratification based on sex. Tables 5 and 6 show inconsistent effects on blood pressure, so sex is also considered as a potential effect modifier. Table 5 shows that female participants who currently smoke have a 3.592 mmHg increase in systolic blood pressure and a 0.659 mmHg decrease in diastolic blood pressure as compared to female participants who do not currently smoke, but the mean differences are not significant (p=0.404 and p=0.793, respectively). In addition, male participants who currently smoke have a 2.181 mmHg increase in systolic blood pressure and a 2.606 mmHg increase in diastolic blood pressure as compared to males who do not currently smoke, but the mean differences are not significant (p=0.295 and p=0.050, respectively). In Table 6, a stratified analysis is performed by using female participants without current smoking status as a reference. Female participants who smoke have a 3.291 mmHg increase in systolic blood pressure and a 0.726 mmHg decrease in diastolic blood pressure as compared to female participants who do not currently smoke, but the mean differences are not significant (p=0.440 and p=0.779, respectively). Male participants who do not smoke have a 1.212 mmHg decrease in systolic blood pressure and a 0.008 mmHg increase in diastolic blood pressure as compared to female participants who do not smoke, but the mean differences are not significant (p=0.541 and p=0.995, respectively). Male participants who do not smoke have a 0.998 mmHg increase in systolic blood pressure as compared to female participants who do not currently smoke, but the p-value of 0.517 indicates that the mean difference is not significant. Male participants who currently smoke have a 2.841 mmHg increase in diastolic blood pressure as compared to female participants who do not smoke, and the p-value of 0.003 indicates that the mean difference is significant. Thus, smoking has more of an effect on males' diastolic blood pressure than females' diastolic blood pressure. In addition,

the interactions between smoking status and sex on the effect of systolic blood pressure (p=0.819) or diastolic blood pressure (p=0.215) are not statistically significant. Therefore, sex cannot be considered an effect modifier.

Table 5. The effect of smoking status on systolic and diastolic blood pressure after stratification based on sex

Population characteristic	Systolic blood pressure model		Diastolic blood pressure model	
	Adjusted β (SE) of smoking status (Y/N)	p	Adjusted β (SE) of smoking status (Y/N)	p
Male	2.181 (2.076)	0.295	2.606 (1.325)	0.050
Female	3.592 (4.303)	0.404	-0.659 (2.506)	0.793

* Adjusted for BMI, education, and marital status.

* Interaction test: systolic blood pressure (p=0.819) and diastolic blood pressure (p=0.215).

Table 6. Stratified analysis of the effect of smoking status on systolic and diastolic blood pressure using females who do not smoke as a reference

Population characteristic		Systolic blood pressure		Diastolic blood pressure	
	Smoking	Adjusted β (SE)	p	Adjusted β (SE)	p
Male	Yes	0.998 (1.540)	0.517	2.841 (0.936)	0.003
	No	-1.212 (1.979)	0.541	0.008 (1.203)	0.995
Female	Yes	3.291 (4.257)	0.440	-0.726 (2.587)	0.779
	No	Reference	--	Reference	--

* Adjusted for BMI, education, and marital status.

4.2 Hypertension

According to the World Health Organization, "hypertension is a condition in which the blood vessels have persistently raised pressure" (WHO, 2018c). Table 7 shows that 15.8% of smokers (n=196) and 16.6% of non-smokers (n=379) had hypertension. The odds of hypertension among smokers is 0.94 times the odds of hypertension among non-smokers, but the association is not significant (p=0.804). After adjusting for other variables, the odds of hypertension among smokers is 1.25 times the odds of hypertension among non-smokers, but the association is still not significant (p=0.518). Among the 287 overweight or obese participants, 22.7% had hypertension, and among the 288 non-overweight or non-obese participants, 10.1% had hypertension. Based on unadjusted OR, the odds of hypertension among overweight or obese participants is 2.62 times the odds of hypertension among non-overweight or non-obese participants. Based on the adjusted OR, the odds of hypertension among overweight or obese participants is 2.67 times the odds of hypertension among non-overweight or non-obese participants. Both the unadjusted and adjusted associations are significant (p<0.001). Therefore, a stratified analysis will be performed again to determine whether BMI is an effect modifier.

Table 7. Multivariable logistic regression model showing the effect of smoking status and other variables on the risk of hypertension

Population characteristic	N	% Hypertension[1]	Unadjusted OR (95% CI)	p	Adjusted OR (95% CI)	p

Sex						
Male	268	14.9	0.82 (0.53, 1.28)	0.390	0.78 (0.40, 1.49)	0.445
Female	307	17.6	1.00	--	1.00	--
Overweight/Obese (BMI)						
Yes (≥23 kg/m^2)	287	22.7	2.62 (1.63, 4.20)	<0.001	2.67 (1.65, 4.32)	<0.001
No (<23 kg/m^2)	288	10.1	1.00	--	1.00	--
Education						
At least some elementary school	400	15.8	1.00	--	1.00	--
At least some middle school	146	19.9	1.33 (0.81, 2.16)	0.257	1.41 (0.84, 2.36)	0.191
At least some high school	29	6.9	0.40 (0.09, 1.71)	0.215	0.42 (0.09, 1.86)	0.252
Marital status[2]						
Yes	537	16.8	1.71 (0.59, 4.94)	0.321	1.83 (0.62, 5.41)	0.272
No	38	10.5	1.00	--	1.00	--
Smoking						
Yes	196	15.8	0.94 (0.59, 1.51)	0.804	1.25 (0.64, 2.43)	0.518
No	379	16.6	1.00	--	1.00	--

1. Hypertension: systolic blood pressure ≥ 140, diastolic blood pressure ≥ 90, or antihypertensive drug use.

2. Marital status (Yes): married; marital status (No): divorced/separated, widowed, or never married.

Table 8 shows that 10.0% of smokers with BMI values less than 23 kg/m^2 have hypertension. In the non-overweight/non-obese group (BMI<23 kg/m^2), the odds of hypertension among smokers is 0.91 times the odds of hypertension among non-smokers, but the association is not significant (p=0.864). In addition, 25.0% of smokers with BMI values equal to or greater than 23 kg/m^2 have hypertension. In the overweight/obese group (BMI≥23 kg/m^2), the odds of

hypertension among smokers is 1.54 times the odds of hypertension among non-smokers, but the association is still not significant (p=0.326). Because the results are not consistent, BMI is considered an effect modifier. However, the interaction test shows that these is no interaction effect between smoking status and BMI (p=0.679) on the risk of hypertension.

Table 8. The effect of smoking status on the risk of hypertension after stratification by BMI

	Smoking	N	% Hypertension[1]	OR (95% CI)	p
BMI≥23 kg/m^2	Yes	76	25.0	1.54 (0.65, 3.62)	0.326
	No	211	21.8	1.00	--
BMI<23 kg/m^2	Yes	120	10.0	0.91 (0.31, 2.66)	0.864
	No	168	10.1	1.00	--

* Adjusted for sex, education, and marital status.

* Interaction test: p=0.679

In stratified analysis, the results change after using non-smokers with BMI values less than 23 kg/m^2 as reference. Table 9 shows that the odds of hypertension among smokers with BMI values less than 23 kg/m^2 is 1.10 times the odds of hypertension among non-smokers with BMI values less than 23 kg/m^2, but the association is not significant (p=0.842). The odds of hypertension among non-smokers with BMI values equal to or greater than 23 kg/m^2 is 2.47 times the odds of hypertension among non-smokers with BMI values less than 23 kg/m^2, and the p-value of 0.003 indicates that the association is significant. Also, the odds of hypertension among smokers with BMI values equal to or greater than 23 kg/m^2 is 3.34 times the odds of hypertension among non-smokers with BMI values less than 23 kg/m^2, and a p-value of 0.005

indicates that the association is significant. Therefore, we can conclude that for those with BMI values equal to or greater than 23 kg/m^2, smoking is related to the prevalence of hypertension.

Table 9. Stratified analysis on the effect of smoking status on the risk of hypertension using those who had BMI values of less than 23 kg/m^2 and did not smoke as a reference

	Smoking	N	% Hypertension[1]	OR (95% CI)	p
BMI≥23 kg/m^2	Yes	76	25.0	3.34 (1.44, 7.77)	0.005
	No	211	21.8	2.47 (1.35, 4.51)	0.003
BMI<23 kg/m^2	Yes	120	10.0	1.10 (0.44, 2.71)	0.842
	No	168	10.1	1.00	--

* Adjusted for sex, education, and marital status.

5. Conclusions

This cross-sectional study suggests that overweight and obesity are significantly associated with increased blood pressure and the prevalence of hypertension. However, the associations between smoking status and blood pressure and the prevalence of hypertension are not statistically significant. After the stratification of smoking status by BMI, smokers with BMI values less than 23 kg/m^2 have significantly higher diastolic blood pressure than non-smokers with BMI values less than 23 kg/m^2. Using non-smokers with BMI values less than 23 kg/m^2 as a reference, smokers with BMI values of less than 23 kg/m^2, non-smokers with BMI values equal to or greater than 23 kg/m^2, and smokers with BMI values equal to or greater than 23 kg/m^2 have significant higher systolic and diastolic blood pressure. Body mass index has large effects on

both smokers' and non-smokers' systolic and diastolic blood pressure, and among those with BMI values equal to or greater than 23 kg/m^2, smoking status significantly increases diastolic blood pressure. Male smokers have significantly higher diastolic blood pressure than female non-smokers. In addition, this study suggests that using non-smokers with BMI values less than 23 kg/m^2 as a reference, the risk of hypertension in both of smokers and non-smokers with BMI values equal to and greater than 23 kg/m^2 will significantly increase. Also, smokers with BMI values equal to and greater than 23 kg/m^2 have significantly higher risks of hypertension. Although the p-value for interaction is not statistically significant, the associations between smoking and blood pressure/hypertension varied based on BMI, and a stronger effect on the part of smoking on diastolic blood pressure and the risk of hypertension was observed among the overweight and obese population in our study.

This study has certain limitations. The data in this study were all obtained at the same point in time, so the temporal relationship between smoking status and blood pressure or hypertension is difficult to establish, and whether these is causality between cigarette smoking and increased blood pressure or the risk of hypertension cannot be determined. In addition, the data were obtained from interviews, so recall bias and interviewer bias may have occurred, leading to differential misclassification. The sample size of this study was relatively small, so the significance of study may have been affected. Also, all of study subjects were volunteers and from rural China, so they may not represent the general population. There are also limitations regarding the findings. First, because the sample size was small, the participants were classified into two groups, smokers and non-smokers. Thus, the association between former smoking status and blood pressure or hypertension cannot be determined. Additionally, because of the small

simple size, overweight and obese participants were combined into one group. Thus, the different effects of overweight and obesity cannot be determined.

In further studies, the association between smoking status and blood pressure/hypertension should be examine in a larger sample. In addition, in order to determine causality or a temporal relationship, a perspective cohort study must be performed. Moreover, pathophysiological perspectives regarding cigarette smoking and blood pressure/hypertension are still limited, so further animal and human studies are needed.

6. References

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