

Association between pulse pressure and body mass index in the Chinese adult population in Jilin Province 2013.

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Research article

Keywords: pulse pressure, body mass index, arterial stiffness

Posted Date: April 9th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-19797/v1>

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Abstract

Background: Pulse pressure and body mass index were associated with cardiovascular disease, and the relationship of pulse pressure and body mass index exhibited different situation in different study population. We want to access the association among pulse pressure, body mass index, and other factors in different gender Chinese population in Jilin Province.

Methods: A multi-stage stratified random cluster sampling method was used to randomly select 3789 residents who without history of taking hypertension medication for questionnaire surveys, physical examinations and laboratory tests. IBM SPSS version 24.0 was used to perform all analysis, and Chi -square test and multinomial logistic regression were applied to analysis data.

Results: For males, the multinomial logistic regression analysis shown that overweight was risk factor for other three pulse pressure groups. Besides, the older people(age \geq 60 years), and hypertension were risk factors for PP3 and PP4. In females results, aged \geq 45 years, hypertension and waist circumference was risk factor for three higher pulse pressure groups. Body mass index and pulse pressure was no significant association in three pulse pressure groups, and people with higher education level and above were protective factors in the PP3 and PP4 both in males and females.

Conclusion: the relationship between body mass index and pulse pressure in different gender displayed different situation, and the association of waist circumference and pulse pressure was stronger than the relationship between body mass index and pulse pressure for women.

Introduction

Pulse pressure(PP) is defined as the difference between systolic blood pressure(SBP) and diastolic blood pressure(DBP), and it reflects stiffness of the aorta and large arteries and pulse wave velocity^[1, 2].PP is one of the component of blood pressure, and it always combined with SBP, DBP and mean arterial pressure(MAP) predict the risk of cardiovascular disease(CVD)^[3]. PP also as a single predictor of cardiovascular disease, type 2 diabetes, myocardial infarction (MI), and congestive heart failure(CHF)^[2, 4-6].In some case, PP was a better predictor of cardiovascular disease than single SBP^[7]. Furthermore, PP has been demonstrated that it can predicts all-cause mortality, total cardiovascular mortality, and coronary mortality in normotensive and hypertensive men, although not in women^[8-10].

PP as a marker of arterial vascular properties, and has been confirmed that it associated with cardiovascular diseases and complications^[11]. Besides, PP has superior predictive capability to other component of blood pressure. Obesity has been linked with CVD risk factor, and it generally measured by BMI, waist circumference(WC), and waist-to-hip ratio^[12]. BMI was commonly used in international studies. The primary study had shown a negative relation between body mass index (BMI) and PP in older people with isolated systolic hypertension (IDH)^[13].However, the relationship between BMI and PP was different in different populations. A cross-sectional study and prospective study found that PP was associated positively with BMI in obesity people^[11]. However, the relationship among PP, BMI, and other CVD risk factors in Chinese adult population was unclear. In addition, PP has different tend between males and females, males usually have higher PP levels than females, which many previous studies have observed^[7, 14]. Therefore, we accessed the

relationship among PP, BMI and other CVD risk factors, such as smoking, drinking, and dyslipidemia in males and females, respectively.

Method

Study population

We used a multi-stage stratified random cluster sampling method to randomly select residents who lived in area for more than 6 months and aged 18 years and older in Jilin Province in 2013. The subjects we selected conducted questionnaire surveys, physical examinations, and laboratory tests. A total of 4198 cases were completed the questionnaire surveys, physical examinations and laboratory tests. The numbers of 409 subjects with a history of taking hypertensive medication were excluded. Finally, 3789 cases were included in this analysis.

Research Method

Questionnaire survey

The questionnaire survey was conducted in accordance with the China Chronic Disease Surveillance Questionnaire procedure and conducted by the uniformly and professionally trained investigators. The questionnaire included general demographic characteristics (age, gender, education level, occupation), unhealthy living habits (smoking, drinking). Occupation was including physical work, brainwork, and retirement and others. Physical work was meant that people who work on agriculture, forestry, animal husbandry, production, and business services staff. People who work on National government agencies, Party organizations, enterprises, institutions, professional and technical personnel, and students were defined as brainwork. Smoking was defined as consumption of at least one tobacco product and a history of consecutively smoking for ≥ 6 months. Drinking was defined as consumption of any type of alcohol drinking at least one week and a history of drinking for ≥ 6 months.

Physical examination

Height, weight, and waist circumference (WC) were measured by the uniformly trained investigator. The accuracy of height and waist circumference measuring tools are 0.1cm. The accuracy of weight measuring instrument is 0.1kg. The blood pressure was measured with an Omron HEM-7071 electronic sphygmomanometer. Waist circumference (WC) was usually measured abdominal obesity, and when male waist circumference ≥ 85 cm, female waist circumference ≥ 80 cm, it will be defined as abdominal obesity^[15]. Body mass index (BMI, kg/m^2) was calculated by weight in kilograms by the square of height in meters ($\text{weight}/\text{height}^2$). According to the recommended criteria for Chinese adults, we divided the participants into four groups. We defined $\text{BMI} < 18.5 \text{kg}/\text{m}^2$ as group1, which meant underweight. Likewise, group2 was defined as $18.5 \text{kg}/\text{m}^2 \leq \text{BMI} < 24.0 \text{kg}/\text{m}^2$, which meant normal; group3 meant overweight and was defined as $\text{BMI} \geq 24.0 \text{kg}/\text{m}^2$ ^[16]. We also divided all subjects into four groups by the quartile of PP (PP1: $\text{PP} < 41.33 \text{mmHg}$; PP2: $41.33 \text{mmHg} \leq \text{PP} < 48.33 \text{mmHg}$; PP3: $48.33 \text{mmHg} \leq \text{PP} < 56.67 \text{mmHg}$; PP4: $\text{PP} \geq 56.67 \text{mmHg}$). According to the 2018 Chinese guidelines for the management of hypertension, $\text{SBP} \geq 140 \text{mmHg}$ with or without DBP $\geq 90 \text{mmHg}$ or having been diagnosed with hypertension by a clinician were defined as hypertension^[17].

Laboratory tests

Blood samples were obtained from all participants in the morning after a 10-hours fast and were sent to the laboratory for total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C). According to the guidelines for the prevention and treatment of dyslipidemia in Chinese Adults (2016 Revision), TC ≥ 5.2 mmol/L was defined as marginal elevated total cholesterol, TG ≥ 1.7 mmol/L was defined as marginal elevated triglyceride, HDL-C < 1.04 mmol/L was defined as lower high-density lipoprotein cholesterol, and LDL-C ≥ 3.41 mmol/L was defined as marginal elevated. When any of the above conditions are met, it can be defined as dyslipidemia^[18].

Statistical analysis

Using EpiData 3.1 to establish a database and enter data, then using IBM SPSS version 24.0 to perform all analysis. The quantitative data was presented as mean and standard deviation, and the qualitative data was presented as frequencies. The quantitative data was tested with ANOVA, and the qualitative data was compared using Chi-square test. The association between PP and BMI, and other CVD risk factors using multinomial logistic regression. all analysis significance levels were 0.05.

Results

The general characteristic of participants

In our study, a total of 3789 participants were included in this analysis, including 1577 male and 2212 female adults. Based on the quartile of PP in study population, 910 participants were divided into PP1, accounting for 24.0%, and 948 participants were divided into PP2 accounting for 25.0% in our study. The numbers of PP3 and PP4 were 977 (25.8%) and 954(25.2%), respectively. BMI were divided into four groups according to the criteria of BMI in Chinese adults, and the numbers of underweight group (Group1), normal group (Group2), overweight (Group3) were 120,1703, and1966. We also found the general characteristic of participants between males and females were significant different ($P < 0.05$). All of the basic character of participants was listed in Table 1.

Table 1 The general characteristic of participants

Variables	Total(n=3789) N (%)	Males(n=1577) N (%)	Females(n=2212) N (%)	χ^2	P value
Age (years)				12.776	0.002
<45	981(25.9)	407(25.8)	574(26.0)		
45-60	1625(42.9)	631(40.0)	994(44.9)		
≥60	1183(31.2)	539(34.2)	644(29.1)		
Place of residence				10.983	0.001
Urban	2033(53.7)	796(50.5)	1237(55.9)		
Rural	1756(46.3)	781(49.5)	975(44.1)		
Education level				19.391	<0.001
Primary or lower	1125(29.7)	439(27.8)	686(31.0)		
Junior high school	1296(34.2)	601(38.2)	695(31.4)		
Senior high school	836(22.1)	319(20.2)	517(23.4)		
College and higher	532(14.0)	218(13.8)	314(14.2)		
Occupation				7.660	0.022
Physical work	2342(61.8)	967(61.3)	1375(62.2)		
Brainwork	727(19.2)	281(17.8)	46(20.2)		
Retirement and others	720(19.0)	329(20.9)	397(17.6)		
BMI (kg/m²)				6.603	0.037
underweight (<18.5)	120(3.2)	39(2.5)	81(3.7)		
normal (18.5-24.0)	1703(44.9)	691(43.8)	1012(45.8)		
overweight (≥24.0)	1966(51.9)	847(53.7)	1119(50.5)		
PP group (mmHg)				57.160	<0.001
PP1 (<41.33)	910(24.0)	286(18.1)	624(28.2)		
PP2 (41.33-48.33)	948(25.0)	395(25.0)	553(25.0)		
PP3 (48.33-56.67)	977(25.8)	450(28.5)	527(23.8)		
PP4 (≥56.67)	954(25.2)	446(28.3)	508(23.0)		
Waist circumference				147.973	<0.001
Normal	1945(51.3)	994(63.0)	951(43.0)		
Above normal	1844(48.7)	583(37.0)	1261(57.0)		
Drinking				878.563	<0.001

Yes	812(21.4)	707(44.8)	105(4.7)		
No	2977(78.6)	870(55.2)	2107(95.3)		
Smoking				838.574	<0.001
Yes	977(25.8)	791(50.2)	186(8.4)		
No	2812(74.2)	786(49.8)	2026(91.6)		
Dyslipidemia				23.665	<0.001
Yes	1774(53.2)	812(51.5)	962(43.5)		
No	2015(46.8)	765(48.5)	1250(56.5)		
Hypertension				93.555	<0.001
Yes	1069(28.2)	577(36.6)	492(22.2)		
No	2720(71.8)	1000(63.4)	1720(77.8)		

The difference of general characteristic among four pulse pressure groups for males

In our results, there were different in age, place of residence, education level, occupation, BMI, hypertension, and waist circumference among four PP groups for male adults ($P < 0.05$). However, we did not find difference in drinking, smoking and dyslipidemia among four PP groups ($P > 0.05$). All of the results were shown in Table 2.

Table 2 The difference of general character among four pulse pressure groups for males (N=1577)

Variables	PP1(n=286)	PP2(n=395)	PP3(n=450)	PP4(n=446)	χ^2	P value
Age group (years)					97.747	<0.001
<45	88(30.8)	108(27.3)	131(29.1)	80(17.9)		
45-60	128(44.8)	195(49.4)	172(38.2)	136(30.5)		
≥60	70(24.4)	92(23.3)	147(32.7)	230(51.6)		
Place of residence					9.392	0.025
Urban	154(53.8)	217(54.9)	223(49.6)	202(45.3)		
Rural	132(46.2)	178(45.1)	227(50.4)	244(54.7)		
Education level					44.207	<0.001
Primary and lower	65(22.7)	93(23.5)	122(27.1)	159(35.7)		
Junior high school	100(35.0)	138(34.9)	191(42.4)	172(38.6)		
Senior high school	66(23.1)	99(25.1)	81(18.0)	73(16.4)		
College and higher	55(19.2)	65(16.5)	56(12.5)	42(9.4)		
Occupation					22.117	0.001
Physical work	156(54.5)	233(59.0)	287(63.8)	291(65.2)		
Brainwork	64(22.4)	88(22.3)	74(16.4)	55(12.3)		
Retirement and others	66(23.1)	74(18.7)	89(19.8)	100(22.4)		
BMI group					38.190	<0.001
Group1	10(3.5)	7(1.8)	15(3.3)	7(1.6)		
Group2	166(58.0)	171(43.3)	182(40.4)	172(38.6)		
Group3	110(38.5)	217(54.9)	253(56.2)	267(59.8)		
Hypertension					450.300	<0.001
Yes	37(12.9)	67(17.0)	132(29.3)	341(76.5)		
No	249(87.1)	328(83.0)	318(70.7)	105(23.5)		
Waist circumference					21.562	<0.001
Normal	204(71.3)	262(66.3)	281(62.4)	247(55.4)		
Above normal	82(28.7)	133(33.7)	169(37.6)	199(44.6)		
Drinking					3.858	0.277
Yes	128(44.8)	163(41.3)	216(48.0)	200(44.8)		
No	158(55.2)	232(58.7)	234(52.0)	246(55.2)		
Smoking					4.727	0.193

Yes	153(53.5)	192(48.6)	237(52.7)	209(46.9)		
No	133(46.5)	203(51.4)	213(47.3)	237(53.1)		
Dyslipidemia					3.643	0.303
Yes	141(49.3)	202(51.1)	223(49.6)	246(55.2)		
No	145(50.7)	193(48.9)	227(50.4)	200(44.8)		

The difference of general character among four pulse pressure groups for females

For females, there were different in age, place of residence, education level, occupation, and BMI and other factors, such as drinking, smoking and dyslipidemia, among four PP groups($P<0.05$). The results were listed in Table 3.

Table 3 The difference of general character among four pulse pressure groups for females (N=2122)

Variables	PP1	PP2	PP3	PP4	χ^2	P value
Age group					297.351	<0.001
<45	246(39.4)	168(30.4)	105(19.9)	55(10.8)		
45-60	295(47.3)	268(48.5)	256(48.6)	175(34.4)		
≥60	83(13.3)	117(21.1)	166(31.5)	278(54.7)		
Place of residence					18.283	<0.001
Urban	383(61.4)	315(57.0)	291(55.2)	248(49.8)		
Rural	241(38.6)	238(43.0)	236(44.8)	260(51.2)		
Education level					154.802	<0.001
Primary and lower	124(19.9)	141(25.5)	182(34.5)	239(47.0)		
Junior high school	199(31.9)	176(31.8)	171(32.4)	149(29.3)		
Senior high school	160(25.6)	140(25.3)	124(23.5)	93(18.3)		
College and higher	141(22.6)	96(17.4)	50(9.5)	27(5.3)		
Occupation					79.762	<0.001
Physical work	354(56.7)	323(58.4)	347(65.8)	351(69.1)		
Brainwork	181(29.0)	135(24.4)	80(15.2)	50(9.8)		
Retirement and others	89(14.3)	95(17.2)	100(19.0)	107(21.1)		
BMI group					47.961	<0.001
Group1	24(3.8)	25(4.5)	16(3.0)	16(3.1)		
Group2	348(55.8)	256(46.3)	212(40.2)	196(38.6)		
Group3	252(40.4)	272(49.2)	299(56.7)	296(58.3)		
Hypertension					758.643	<0.001
Yes	33(5.3)	42(7.6)	80(15.2)	337(66.3)		
No	591(94.7)	511(92.4)	447(84.8)	171(33.7)		
Waist circumference					82.400	<0.001
Normal	351(56.3)	247(44.7)	195(37.0)	158(31.1)		
Above normal	273(43.7)	306(55.3)	332(63.0)	350(38.9)		
Drinking					7.968	0.047
Yes	23(3.7)	37(6.7)	27(5.1)	18(3.5)		
No	601(96.3)	516(93.3)	500(94.9)	490(96.5)		
Smoking					12.265	0.007

Yes	34(5.4)	45(8.1)	53(10.1)	54(10.6)		
No	590(94.6)	508(91.9)	474(89.9)	454(89.4)		
Dyslipidemia					49.198	<0.001
Yes	232(37.2)	214(38.7)	230(43.6)	286(56.3)		
No	392(62.8)	339(61.3)	297(56.4)	222(43.7)		

The multinomial logistic regression for males

The forward stepwise multinomial logistic regression was utilized to analysis the association between some factors, which had significantly statistical difference conducted Chi-square test above, and pulse pressure for males. In our results, PP1 was defined as the reference group, and place of residence, occupation and waist circumference (WC) were not contained in the model. We also found that overweight was risk factor for other three PP groups($P<0.05$). Besides, the older people(age \geq 60 years), overweight, and hypertension were risk factors, and people with senior high school education level and above were protective factors in the PP3 and PP4. The results were shown in Table 4.

Table 4 The multinomial logistic regression for males(N=1577)

Variables	Categories	PP2		PP3		PP4	
		β	OR (95%CI)	β	OR (95%CI)	β	OR (95%CI)
Constant	-	0.007	-	0.140	-	-0.900	
Age group	<45						
	45-60	0.137	1.147(0.791-1.663)	-0.299	0.742(0.511-1.076)	-0.514	0.598(0.380-0.940)
	≥ 60	0.039	1.040(0.672-1.609)	0.219	1.245(0.821-1.887)	0.730	2.076(1.292-3.337)
Education level	Primary and lower						
	Junior high school	-0.039	0.962(0.633-1.462)	0.069	1.072(0.717-1.602)	-0.091	0.913(0.586-1.421)
	Senior high school	-0.043	0.958(0.608-1.508)	-0.493	0.611(0.386-0.966)	-0.728	0.483(0.289-0.807)
	College and higher	-0.332	0.717(0.434-1.186)	-0.759	0.468(0.281-0.779)	-1.120	0.326(0.181-0.589)
BMI	Normal						
	Underweight	-0.387	0.679(0.251-1.833)	0.369	1.446(0.621-3.366)	-0.143	0.867(0.273-2.751)
	Overweight	0.665	1.944(1.408-2.683)	0.773	2.167(1.572-2.988)	0.691	1.995(1.387-2.871)
Hypertension	No						
	Yes	0.173	1.188(0.763-1.851)	0.940	2.561(1.695-3.869)	2.996	19.996(13.055-30.626)

The multinomial logistic regression for females

The forward stepwise multinomial logistic regression model also applied for females, and place of residence, occupation, drinking, smoking, BMI, and dyslipidemia were not contained in the forward stepwise multinomial logistic regression model. In order to access the relationship between BMI and PP groups, we entered BMI into the forward stepwise multinomial logistic regression model. There were different from results of males, BMI and PP was no significant association for females, and waist circumference was associated with PP in three PP groups. The results were listed in Table 5.

Table 5 The multinomial logistic regression for females(N=2122)

Variables	Categories	PP2		PP3		PP4	
		β	OR (95%CI)	β	OR (95%CI)	β	OR (95%CI)
Constant	-	-0.412	-	-0.703	-	-1.731	-
Age group	<45						
	45-60	0.191	1.210(0.924-1.586)	0.460	1.584(1.176-2.135)	0.479	1.615(1.074-2.428)
	≥ 60	0.555	1.742(1.210-2.507)	1.157	3.179(2.193-4.609)	1.952	7.041(4.476-11.077)
Education level	Primary and lower						
	Junior high school	-0.175	0.840(0.608-1.159)	-0.382	0.682(0.496-0.939)	-0.526	0.591(0.408-0.858)
	Senior high school	-0.165	0.848(0.605-1.189)	-0.453	0.636(0.453-0.893)	-0.660	0.517(0.344-0.778)
	College and higher	-0.273	0.761(0.522-1.109)	-0.899	0.407(0.267-0.620)	-1.112	0.329(0.188-0.577)
BMI	Normal						
	Underweight	0.393	1.482(0.818-2.686)	0.092	1.096(0.550-2.185)	0.033	1.033(0.449-2.377)
	Overweight	0.119	1.126(0.834-1.522)	0.246	1.279(0.935-1.748)	-0.187	0.830(0.566-1.216)
WC	Normal						
	Above normal	0.348	1.416(1.048-1.914)	0.426	1.531(1.116-2.100)	0.528	1.695(1.149-2.500)
Hypertension	No						
	Yes	0.232	1.261(0.782-2.033)	0.878	2.407(1.558-3.718)	3.296	27.006(17.799-40.975)

Discussion

In our study, the higher PP group was associated with overweight, age, education level, and hypertension, and PP2 was merely associated with overweight (OR = 1.995, 95%CI: 1.387–2.871) in males. In the results of female adults, there were not association between PP groups and BMI. Besides that, PP2 was merely associated with above normal waist circumference, and the higher PP groups were also associated with age, education level, and hypertension in addition to above normal waist circumference.

As we all known that the change of PP in physiology is determined by arterial stiffness, ventricular ejection, and by wave reflections^[19]. Furthermore, some factors, such as estrogenic hormone levels, heart rate, stroke volume, arterial compliance and distensibility^[20], which caused the change of SBP or DBP also effect the change of PP. In our results, Men who aged 45–60 years was negatively associated with PP4, and aged ≥ 60 years was

positively associated with PP4 in males. It was similar with the previous study^[7, 13, 21]. Many previous studies have confirmed that SBP and DBP increase with age, and after aged 50 years SBP retain tend as before, but DBP will show decrease tend, so it causes PP rise steeply^[19, 22]. In contrast with the results of males, women aged 45–60 years and ≥ 60 years was positively associated with the higher PP groups than PP1. As similar studies mentioned above, SBP increase with age, and SBP was higher in males than females before menopause, and the tendency of SBP was turned over after menopause^[23]. Therefore, aged ≥ 45 years females were more likely to have higher PP values than women who aged less than 45 years old. In our results, age played a very different role in PP of males and females, and the older women especially women after menopause were more likely have higher PP value than men.

Body mass index as an index was always utilized to access whether people occurred the change of weight, such as underweight, overweight, and obesity. The elevated weight increased the prevalence of elevated blood pressure, and previous studies proved that the change of body mass index was positively associated with change in blood pressure^[14, 24]. Besides that, there were sex difference in change of body mass index, particularly in elevated body mass index^[25]. There is an obvious feature of obesity that is chronic low-grade inflammatory state, and this state causes increase of arterial stiffness^[26]. PP and arterial stiffness were strongly correlation, and increased arterial stiffness can cause isolated systolic hypertension and lead to increased PP^[27]. Some previous studies proved that people with overweight and obesity after 8-week swimming training, which play beneficial effects on their arterial stiffness and SBP^[28]. In our study, compared with normal body mass index, overweight was positively associated with the higher PP groups in males, and the relationship of BMI and PP was completely different in females. In the results of female multinomial logistic regression, the relationship between elevated body weight and PP groups was reflected by waist circumference not BMI. It is well known that WC is an indicator used to measure abdominal obesity, and BMI is an overall obesity indicator. There was significant difference in the association between WC and BMI and arterial stiffness, and previous study confirmed that WC was correlated with central arterial stiffness rather than BMI^[29].

In our study, hypertension was associated with higher PP groups (PP3 and PP4) both in males and females. The relationship between hypertension and arterial stiffness was complicated. On the one hand, arterial stiffness is positively associated with systolic hypertension, coronary artery disease, stroke, and heart failure, which are the leading causes of mortality in developed countries. On the other hand, the increased arterial stiffness can reduce the increase of systolic blood pressure and PP^[30, 31]. It was obvious that hypertension occurred leader to the increase of PP level.

The results of multinomial logistic regression analysis shown that the high level of education was negatively associated with PP both in male and females. It was recommended people who have higher education level may pay attention to their physical health, and easily acquired health knowledge.

The major limitation of our study is that data we collected was from a cross-sectional study, which determined that we can not draw a causal inference. However, the analysis that we conducted was based on a large size simple and uniform trained investigator.

Conclusion:

There was different situation that association between BMI and PP in different gender, the association between WC and PP was stronger than the association between BMI and PP in females. However, overweight and obesity was positively associated with elevated PP.

Abbreviations

PP	Pulse pressure
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
MAP	Mean arterial pressure
CVD	Cardiovascular disease
MI	Myocardial infarction
CHF	Congestive heart failure
WC	Waist circumference
BMI	Body mass index
TC	Total cholesterol
TG	Triglyceride
HDL-C	High-density lipoprotein cholesterol
LDL-C	Low density lipoprotein cholesterol

Declarations

Acknowledgements

The authors gratefully acknowledge the financial support received from Ministry of Finance, National Health and Family Planning Commission (grant number: [2016]50). We express our gratitude to the participants and colleagues who were involved in the study. The authors have no competing interests.

Funding

The work was supported by funding from Ministry of Finance, National Health and Family Planning Commission (grant number: [2016]50).

Availability of data and materials

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

Author Contributions

MZ had the original idea for the study, and, with all co-authors, carried out the design. JL and PS provided valuable insight regarding the methodological approach and organization of the manuscript. MZ and JHL was responsible for data cleaning, YG, SL, and YS carried out the analyses. MZ drafted the manuscript, which was revised by all authors. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The ethics were approved by the Ethics Committee of Fuwai Hospital of Chinese Academy of Medical Sciences (project identification code: 2014-574), and written informed consent was obtained from all of the participants before data collection.

Consent for publication

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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