Original Article

Body Mass Index and Hypertension Hemodynamic Subtypes in Yi Farmers and Migrants*

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Abstract

Objective To examine the relationship between overweight or obesity and the risk of the various hypertension hemodynamic subtypes in Yi farmers and migrants.

Methods A cross-sectional study of 2 358 Yi farmers and 1 392 Yi migrants was carried out in the Liangshan Yi autonomous prefecture, Sichuan, China in 2007.

Results The standardized prevalence of overweight in female Yi farmers (6.22%) was higher than in males (3.15%), whereas in Yi migrants 31.56% of males and 18.78% of females were overweight. The standardized prevalence of obesity was 0 and 0.61% in male and female Yi farmers, compared to 3.91% and 5.57% in male and female Yi migrants, respectively. For both genders the standardized prevalence of ISH, IDH, and SDH was higher in Yi migrants than Yi farmers. Overweight and obese Yi men and women had a higher risk for IDH and SDH (P<0.001) than non-overweight /obese individuals. However, an association of overweight or obesity with ISH was observed only in men.

Conclusion Yi migrants have substantially higher proportion of overweight and obese individuals, as well as individuals affected by ISH, IDH, and SDH, than do Yi farmers. Overweight and obesity are significant risk factors for the development of hypertension in Yi people.

Key words: Body mass index (BMI); Overweight; Obesity; Hypertension; Ethnic Yi; Migrant; China

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INTRODUCTION

Obesity is associated with cardiovascular abnormalities, including hypertension[1-2]. Hypertension is a strong predictor for cardiovascular disease and death and an important component of metabolic syndrome[3-4].

Simultaneous consideration of both systolic and diastolic blood pressure defines the following phenotypic subtypes of hypertension: isolated systolic hypertension (ISH), isolated diastolic hypertension (IDH), and systo-diastolic hypertension (SDH)[5]. These subcategorizations provide important information regarding the relative importance of the hemodynamic and/or structural abnormalities that contribute to hypertension[6-7]. ISH is predominantly associated with an increase in the stiffness of the large arteries resulting in increased pulse pressure,

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whereas IDH is predominantly associated with an increase in the mean arterial pressure[6-7].

Previous studies have shown that the prevalence of hypertension increases significantly with increasing body mass index (BMI) in both men and women[8]. Obesity is associated with increased arterial stiffness[9-10] and various hemodynamic changes[11-12] that may contribute to hypertension, and affects not only the prevalence but also the patterns of hypertension. Studies investigating the different subtypes of hypertension may yield important clues regarding the relative importance of the underlying hemodynamic abnormalities that contribute to obesity-related hypertension in the general population[13].

To our knowledge, there is no published work on the prevalence of the hemodynamic subtypes of hypertension in people of the Yi ethnic group. Furthermore, there has been little evaluation of the relationship between obesity and the hemodynamic subtypes of hypertension in China. In this study, we investigate the association between overweight or obesity and ISH, IDH, and SDH in Yi adults. In addition, the relative risk of developing hypertension in overweight and obese Yi adults is assessed in comparison with their non-overweight/obese controls.

METHODS AND PROCEDURES

Study Population

The Yi ethnic group is a minority group living in the southwest of Sichuan province. The majority of Yi people are traditional subsistence farmers living in remote mountain villages; however, in recent times many Yi farmers have migrated to urban areas. Yi farmers are very isolated and preserve their own language and lifestyle; they rarely eat meat and have a diet based on potatoes, oats and buckwheat. However, Yi migrants living in towns and in Xichang city have changed their lifestyle to one more resembling that of the Han people; they have rice as their staple food and meat and fresh vegetables as non-staple foods[14-15]. The Yi Migrant Study in 2007 surveyed a population-based sample of Yi people aged 18 years and over, including Yi farmers living in high-altitude mountainous villages in remote areas of southwestern China, and Yi migrants who were born in remote areas but had been living in towns with county administration seats for more than five years.

Study Design

The Yi Migrant Study includes three cross-sectional studies conducted in the Liangshan Yi autonomous prefecture, Sichuan province, China in 1986-1988, 1996, and 2007, respectively. Data reported here are from the 2007 Yi Migrant study. In 2007, the study population consisted of 2 358 Yi farmers living in villages in Butuo, Zhaojue, Jinyang, Puge, and Xide counties, and 1 392 Yi migrants living in the towns with county administration seats in those counties, or in Xichang city, the capital of the prefecture. The Yi farmers were selected by stratified cluster sampling from the region around each county seat; four villages were randomly selected from each region. All Yi farmers aged 18 years or over in the selected villages were surveyed. Yi migrants were defined as Yi people who had migrated to one of the county seats, or Xichang city, more than five years prior to the survey. Because the number of Yi migrants was relatively small, all of the Yi migrants found in the selected county seats and Xichang city were enrolled in the study.

Data were collected by trained physicians using standardized methods and identical examinations as reported previously[15]. A questionnaire was used to assess demographic characteristics and anthropometrical measures. Height and weight were measured with the participants in light clothing and without shoes. Blood pressure was measured using a mercury sphygmomanometer, with the participant in a sitting position after 10 min of rest. The average of three consecutive blood pressure measurements was used for data analysis. Since antihypertensive medications may have differing effects on systolic and diastolic blood pressure, the self-reported highest levels of systolic and diastolic blood pressure were used for analysis of data from participants receiving antihypertensive medications at the time of the survey. Characteristics of the participants and study procedure have been described in detail previously[14], and only the procedures and variables relevant to this analysis are presented here.

This survey was approved by the Bioethics Committee of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (No. 0152011), Beijing.

Participant Classification and Definitions

For the primary analysis, ISH was defined as a systolic blood pressure (SBP) of 140 mm Hg or higher with a diastolic blood pressure (DBP) lower than 90 mmHg. IDH was defined as a DBP of 90 mmHg or higher with a SBP lower than 140 mmHg. SDH was defined as a SBP of 140 mmHg or higher and a DBP of 90 mm Hg or higher[5,7]. Individuals with a BMI of greater than or equal to 25.0 kg/m^2 and less than

30.0 kg/m^2 were considered overweight, and those with a BMI greater than or equal to 30.0 kg/m^2 were considered obese in accordance with World Health Organization (WHO) criteria[16]. Overweight and obesity (overweight/obesity) was defined as a BMI of 25.0 kg/m^2 or higher. Physical activity included both occupational and leisure-time activity; these were considered together. Participants were classified into three categories based on activity level: 1) the light-physical activity group, who reported light levels of both occupational and leisure-time physical activity; 2) the medium-physical activity group, who reported medium levels of either occupational or leisure-time physical activity; and 3) the high-physical activity group, who reported higher levels of both occupational and leisure-time physical activity.

Statistical Analysis

Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Continuous variables are presented as means plus and minus standard deviation (SD), and differences between genders and between the Yi farmers and migrants were compared using independent sample *t*-tests. Categorical variables are presented as frequencies and percentages, and differences in the prevalence of overweight, obesity, ISH, IDH, and SDH between genders and between Yi farmers and migrants were compared using the χ^2-test. The relative risk for developing hypertension in overweight and obese Yi adults was estimated by calculating the odds ratio with the Mantel-Haenszel method. Direct standardization was performed using Yi population age and gender data from the Fifth National Population Census in 2000. Differences were considered significant at a *p*-value of less than 0.05. All data analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Demographic characteristics of the participants are described in Table 1. Men had a higher SBP and DBP than women in both the Yi farmer and Yi migrant populations (P<0.0001). BMI was significantly higher in female than in male Yi farmers (P<0.0001), but the opposite trend was observed in Yi migrants (P<0.0015). For both men and women, SBP, DBP, and BMI were significantly higher in Yi migrants than in Yi farmers (all P<0.0001). Yi migrants of both genders performed significantly less physical activity than Yi farmers (P<0.05).

Table 1. Demographic Characteristics of the Study Participants, 2007 (mean±SD, percentages in brackets)

Characteristics	Yi Farmers		Yi Migrants		*P* value
	Males (*n*=1088)	Females (*n*=1270)	Males (*n*=824)	Females (*n*=568)	
Age range (years)	18–76	18–78	18–76	18–76	—
Age (years)	38.59±12.44	40.11±11.61	40.50±11.73	37.91±11.88	*,**,#,##
Height (m)	163.70±5.93	152.89±5.45	167.47±5.90	157.22±5.11	*,**,#,##
Weight (kg)	56.01±7.02	50.61±7.12	67.25±11.26	57.56±10.73	*,**,#,##
BMI (kg/m^2)	20.68±2.07	21.19±2.58	23.94±3.56	23.28±4.11	*,**,#,##
Systolic blood pressure (mmHg)	111.14±14.12	106.61±13.56	119.53±19.49	110.19±18.25	*,**,#,##
Diastolic blood pressure (mmHg)	72.56±11.06	68.97±9.96	79.70±13.44	73.07±12.35	*,**,#,##
Participants with heavy physical activity, n (%)	1 034 (95.04)	1 110 (87.40)	47 (5.70)	39 (6.87)	*,#,##

Note. Abbreviations: BMI, body mass index; *n*, number of participants; SD, standard deviation. $^*P$<0.05 for difference between males and females in Yi farmers. $^{**}P$<0.05 for difference between males and females in Yi migrants. $^{\#}P$<0.05 for difference between Yi farmers and Yi migrants in males. $^{\#\#}P$<0.05 for difference between Yi farmers and Yi migrants in females.

The standardized and crude prevalence of overweight, obesity, and hypertension hemodynamic subtypes are presented in Table 2. The standardized prevalence of overweight in females (6.22%) was higher than in males (3.15%) in the Yi farmers, whereas in Yi migrants overweight in males (31.56%) was higher than in females (18.78%). The standardized prevalence of obesity was zero and 0.61 percent in Yi farmer men and women, respectively, compared with 3.91 and 5.57 percent of Yi migrant men and women, respectively. The standardized prevalence of both overweight and obesity were significantly higher in Yi migrants than in Yi farmers in both of genders. The standardized prevalences of ISH, IDH, and SDH were greater in males than in females in both the Yi farmer and

migrant populations. The standardized prevalences of ISH, IDH, and SDH for both genders were all higher in Yi migrants than in Yi farmers.

The relative risk for developing hypertension from overweight/obesity in the combined Yi farmer and migrant populations is presented in Table 3. Overweight and obese men and women had a higher risk of developing IDH and SDH (P<0.001) than the non-overweight/obese men and women did. However, an association between overweight/obesity and ISH was observed only in males.

Figure 1 shows the relative proportions of ISH, IDH, and SDH in all hypertensive study participants by gender and overweight/obesity status in the combined Yi farmer and migrant study populations. The proportion of SDH was greater in overweight/obese individuals, whereas the proportion of hypertensive participants with IDH was less in the overweight/obese category than in those with a BMI <25 kg/m^2; this was true for both men and women. The trend of proportion change of ISH with increasing BMI differed between men and women. The proportion of hypertensive study participants with ISH did not change with overweight/obesity status in men, but was less in overweight/obese women than in non-overweight/obese women. Stratified analysis showed that the highest proportion of overweight/obese hypertensive participants of both genders were affected by SDH, followed by IDH, and then ISH. In non-overweight/obese hypertensive participants, the proportion affected by IDH was greatest, followed in decreasing

Table 2. Crude and Standardized[†] Prevalence of Obesity, Overweight and Hypertension Hemodynamic Subtypes among Yi farmers and Migrants by Gender, 2007

	Yi Farmers			Yi Migrants		
	Males %[a] (%[b])	Females %[a] (%[b])	Total %[c] (%[b])	Males %[a] (%[b])	Females %[a] (%[b])	Total %[c] (%[b])
Overweight	3.15(3.40)	6.22(6.38)	4.65(5.00)	31.56(35.32)	18.78(20.60)	25.31(29.31)
Obesity	0(0)	0.61(0.71)	0.30(0.38)	3.91(4.25)	5.57(5.99)	4.72(4.96)
ISH	1.05(1.10)	0.77(1.02)	0.91(1.06)	2.20(2.18)	1.33(1.23)	1.77(1.80)
IDH	3.68(3.95)	1.05(1.18)	2.39(2.46)	6.05(7.52)	2.01(2.46)	4.07(5.46)
SDH	2.14(2.11)	0.53(0.71)	1.35(1.36)	7.15(9.59)	5.24(5.11)	6.22(7.76)

Note. Abbreviations: ISH, isolated systolic hypertension; IDH, isolated diastolic hypertension; SDH, systo-diastolic hypertension. [†]Standardized using age and gender structure of Yi population aged 20~70 years according to data of the Fifth National Population Census in 2000. Overweight was defined as BMI=25.0~29.9 kg/m^2. Obesity was defined as BMI⩾30 kg/m^2. [a]Age-standardized prevalence. [b]Crude prevalence. [c]Age- and gender-standardized prevalence.

Table 3. Relative Risk for Developing Hypertension from Overweight/obesity in the Combined Yi Farmer and Migrant Populations, 2007

Gender	Overweight/obese		Non-overweight/obese		Odds Ratio[#] (95% CI)
	SDH cases	Non-SDH controls	SDH cases	Non-SDH controls	
Males	57	306	45	1 504	6.23*** (4.13-9.38)
Femalse	24	217	14	1 583	12.51*** (6.37-24.54)
	Overweight/obese		**Non-overweight/obese**		
	ISH cases	Non-ISH controls	ISH cases	Non-ISH controls	
Males	15	348	15	1 534	4.41*** (2.13-9.10)
Femalse	4	237	16	1 581	1.67 (0.55-5.03)
	Overweight/obese		**Non-overweight/obese**		
	IDH cases	Non-IDH controls	IDH cases	Non-IDH controls	
Males	41	322	64	1 485	2.95*** (1.96-4.45)
Femalse	11	230	18	1 579	4.20*** (1.96-9.00)

Note. Abbreviations: SDH, systo-diastolic hypertension; ISH, isolated systolic hypertension; IDH, isolated diastolic hypertension. Overweight/obesity is defined as BMI⩾25 kg/m^2. $^{*}P$<0.05; $^{**}P$<0.01; $^{***}P$<0.001.

order by SDH and ISH in men, and by ISH and SDH in women. The ISH subtype represented only a small proportion of the total hypertension in overweight/obese men (13.27%) and women (10.26%), with the majority suffering from either IDH or SDH.

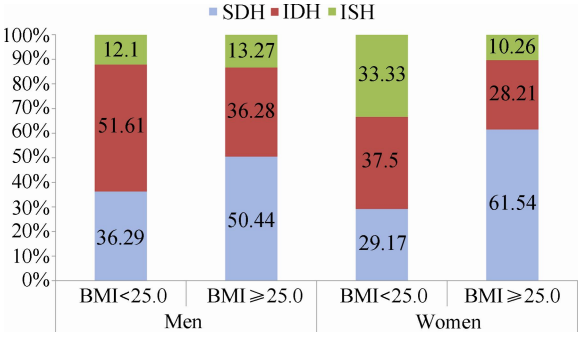

Figure 1. Proportions of isolated systolic hypertension (ISH), isolated diastolic hypertension (IDH) and systo-diastolic hypertension (SDH) in all hypertensives by BMI in Yi men and women.

DISCUSSION

From a hemodynamic standpoint, blood pressure is determined by both steady component (mean pressure) and pulsatile phenomena in each cardiac cycle. Stiffness of the large arteries is thought to be the main underlying arterial abnormality of older individuals with ISH. In contrast, IDH is more closely correlated with increases in mean arterial pressure. Large-artery stiffness increases in obese individuals of any age[17-18], and independently predicts an increased cardiovascular disease risk in various populations[19-20]. Obesity produces hemodynamic abnormalities that may affect hypertension subtypes. Studies on the hemodynamic subtypes of hypertension provide important information regarding the relative importance of the hemodynamic abnormalities that contribute to obesity-related hypertension.

In this study, we report the prevalence of overweight, obesity and the hemodynamic subtypes of hypertension, and examine the relationship between overweight/obesity and hypertension and its hemodynamic subtypes, in Yi farmers and migrants. Our results show that both the crude and standardized prevalences of ISH, IDH, and SDH were low when compared with the other studies. For example, two previous studies[21-22] of adult Chinese populations reported that the crude prevalence of ISH, IDH, and SDH was 7.16, 7.09, and 13.61 percent respectively in Tianjin and 5.7, 14.3, and 26.4 percent in those of Korean nationality, respectively. A study among young adults in Nigeria reported that the observed prevalence of ISH, IDH, and SDH was 14, 13, and 17 percent in males and 10, 13, and 14 percent in females, respectively[23].

Our study further indicated that the crude (standardized) prevalence of overweight and obesity were, respectively, 35.52 (31.56) and 4.25 (3.91) percent in male and 20.60 (18.78) and 5.99 (5.57) percent in female Yi migrants, compared with 3.40 (3.15) percent and 0 (0) in male and 6.38 (6.22) and 0.71 (0.61) percent in female Yi farmers. Yi migrants had a high prevalence of overweight/obesity, whereas Yi farmers had a very low prevalence of overweight/obesity, relative to that reported by other studies in China. Previous studies among Chinese populations have shown that the prevalence of overweight/obesity increased tremendously in all age groups, in both rural and urban areas, during the 1990s[24]. A study conducted in rural areas in China from 1993 to 1997 reported that the combined prevalence of overweight and obesity was only 5.3 percent in men and 6.9 percent in women[25] during that time period. Another study in rural adults in China during 2004-2005 showed that prevalence of overweight was 18.6 percent (15.1 percent in men and 22.1 percent in women), and the prevalence of obesity was 1.7 percent (1.2 percent in men and 2.2 percent in women)[26].

Although an increasing prevalence of overweight and obesity has been reported at the national level, few studies have been done to evaluate the link between overweight/obesity and hypertension hemodynamic subtypes in migrant populations moving within the country. Our data show that, of 102 Yi males with SDH, 57 (55.89%) were overweight or obese. The same trend was observed in the 38 Yi females with SDH, 24 (63.16%) of them were overweight or obese. Given these results, and the known association between overweight/obesity and hypertension, we investigated the association between hypertension and overweight and obesity in Yi people. We found that overweight/obese Yi men and women were 6.23 and 12.51 times more likely to develop SDH than non-overweight/obese Yi men and women, respectively. Furthermore, overweight/obese Yi people of both genders also had a significantly higher risk of developing IDH than did non-obese controls. Overweight/obese Yi males also had a higher risk of developing ISH than non-overweight/obese controls, but this relationship was not seen in Yi females. Our results were similar to those

previously reported by Jiang et al., who found that both systolic and diastolic blood pressure were significantly and positively associated with body mass, even after adjustment for several important covariables including urinary sodium, potassium, calcium and magnesium. Their results strongly suggest that body mass index is an independent predictor of blood pressure and that this effect is not dependent on a high salt diet[27].

As one part of the Yi migrant study, Jiang He reported the independent effect of migration on the risk of hypertension. The result showed that migration was associated with an increased risk of definite hypertension (SBP⩾160 mmHg or DBP⩾95 mmHg), even after adjustment for age, body mass index, heart rate, alcohol use, and smoking. Migration was also associated with an increased risk of hypertension (SBP⩾140 mmHg or DBP⩾90 mmHg) in men, but not in women, after adjustment for all other covariables. Because migration was strongly associated with years of education (r=0.74 in men and r=0.79 in women) and physical activity (r=–0.88 in men and r=–0.91 in women), it was difficult to separate the effect of education level and physical activity from the effect of migration. These results suggest that the effect of migration on blood pressure differs by age, sex, length of time since migration, and whether systolic pressure or diastolic pressure is the outcome variable[14].

The Yi ethnic group is one of the minority groups of China. In 1986, a sample of Yi men participated in more detailed studies of diet, physical activity and blood pressure. Yi farmers rarely eat meat; instead they consume a low fat and low cholesterol diet with potatoes, oats, and buckwheat as their staple food. Compared to Yi farmers, Yi migrants changed their diet to include more meat, eggs, sweets, and fresh vegetables—this diet is similar to that of the native Han residents of the same towns. Approximately 10 percent of the energy in the Yi farmer diet is derived from fat, whereas almost 40 percent of dietary energy is derived from fat in the Yi migrant diet[28]. Yi migrants have experienced urbanization, which has had a noticeable effect on their food availability, dietary habits and lifestyles. In addition, Yi migrants also perform less physical activity than Yi farmers. Even in modern times, Yi farmers are still very isolated and maintain their traditional dietary patterns and keep non-mechanized agricultural labor by heavy physical activity as their main occupation.

An overview of published observations suggests that both genetic predisposition and environment work together to produce obesity and hypertension in most people. Twin and family studies show that susceptibility to obesity is heritable, with 50%-90% of the variance in BMI explained by genetic factors[29-30]. Estimates of the proportion of the variance in blood pressure attributable to all genetic factors (heritability) vary from 25% in pedigree studies to 65% in twin studies[31-33]. Some studies have concluded that genes contribute much more than shared environment to the well-recognized familial correlation of blood pressure and body mass index[34]. The ethnic background of Yi migrants is similar to that of Yi farmers; however, our study indicates that Yi migrants are substantially more likely to be overweight or obese, and to suffer from ISH, IDH, or SDH, relative to Yi farmers. We therefore suggest that these differences are likely due to the differences in diet-related factors and lifestyle, which in turn are associated with cultural and environmental differences. This implies that a healthier diet and more active lifestyle may be still effective, at least in part, in the prevention of obesity and hypertension in subjects with a genetic predisposition to obesity and hypertension.

There were some limitations in this study. Our study is limited by its cross-sectional nature, and we did not investigate the mechanistic and biological pathways that may affect blood pressure in obese subjects. In addition, no detailed information about specific, individual changes in dietary components was available in this study. However, dramatic difference between Yi farmers and migrants in both diet and lifestyle allowed us to assess the relevant public health implications of these factors.

In conclusion, this study indicates that a substantially higher proportion of Yi migrants are overweight or obese, and suffer from ISH, IDH, and SDH, in comparison with Yi farmers. We also show that overweight and obesity are risk factors for developing hypertension in Yi people. In addition, the hypertension hemodynamic subtype prevalence varies between overweight/obese and non-overweight/obese Yi people. The SDH subtype is the most prevalent form of hypertension in overweight/obese Yi people, but IDH is the most prevalent form of hypertension in those who are not overweight/obese. Changes in lifestyle may contribute to the higher risk of overweight/obesity, and the altered prevalence of the hemodynamic subtypes of hypertension, in Yi migrants. These findings add to our understanding of the development of obesity-related cardiovascular abnormalities with changes of lifestyle and dietary

patterns in rural-to-urban migrants, and indicate the need for preventing obesity early in life to avoid its life-threatening consequences in later-life.

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