

Time Trends in Comorbidity and Management of Hypertension and Diabetes: A 15-year Nationwide Longitudinal Study of 18,380 Adults in China

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Abstract

Background: To examine time trends in comorbidity of hypertension and type 2 diabetes (T2DM) and their diagnosis, treatment, and management in China during 2000-2015 and study factors associated with these outcomes.

Methods: Longitudinal data collected from the China Health and Nutrition Survey (CHNS) during 2000-2015 were analyzed. Of the 28,204 adults, 832 had both hypertension and T2DM were selected. Average systolic blood pressure (SBP) and diastolic blood pressure (DBP) and hypertension prevalence among T2DM patients, and treatment and control of hypertension and T2DM among patients with both conditions were examined for all and by sex and weight status. Mixed effects models assessed the associations.

Results: From 2000 to 2015, among patients with T2DM, hypertension prevalence dropped from 88.4% to 83.0% and BPs decreased ($P < 0.05$). Men and overweight/obese patients had greater decreases in hypertension prevalence and DBP, while women had a larger decrease in SBP than men. Over time, among patients with both hypertension and T2DM, rates of hypertension treatment (45.3% to 57.7%), hypertension control (3.0% to 10.9%) and T2DM treatment (90.0% to 95.6%) increased, but were still very low except for T2DM treatment (all $P < 0.001$). Age, gender, smoking, drinking, household income, education, residence, and weight status were significantly associated with prevalence, treatment, and control of hypertension, and T2DM treatment among patients with both hypertension and T2DM.

Conclusion: Rates of hypertension treatment and control among patients with both hypertension and T2DM have improved in recent years, but were still low.

Background

Hypertension and type 2 diabetes mellitus (T2DM) are the most common non-communicable diseases (NCDs) and are important global public health problems [1]. Although they are two distinct medical conditions, they frequently coexist, leading to additive increases in the risk of cardiovascular diseases (CVDs). Research reported that among patients with T2DM, hypertension prevalence was 70.9% in American adults [2], 54.6% in Korean adults [3], and 49.9% to 60.6% in Chinese outpatients [4]. Epidemiological studies and clinical trials have demonstrated that lowering blood pressures (BPs) could effectively reduce CVDs mortality and morbidity in patients with T2DM [5,6].

Cross-sectional studies have indicated that compared with higher hypertension treatment rates, the control rate was relatively lower among patients with both hypertension and T2DM in the US (87.8% vs. 29.6%, respectively), the UK (54.0% vs. 28.0%, respectively), Korea (86.7% vs. 14.9% respectively) and Canada (87.7% vs. 55.5%, respectively) [2,3,7,8]. Similar patterns were observed in hypertensive patients in China [9,10]. Results from the China Kadoorie Biobank Consortium showed that among adults with a diagnosis of hypertension, only 46.4% were treated; of those treated, only 29.6% had their hypertension controlled [10]. However, most previous studies were cross-sectional studies, focused on a single disease, and were not based on long-term follow-up data.

With rapid social and economic developments during the past three decades, the prevalence of obesity and overweight in China has increased substantially [11]. Accumulating evidence has indicated that having overweight and obesity are strongly associated with hypertension, diabetes, and CVDs in many populations [12]. For example, one study reported that the hypertension rate increased with body mass (normal-weight, 15%; overweight, 25%; obese, 40%) [13]. However, few studies have examined whether time trends in hypertension prevalence, treatment, and control rates varied depending on weight status.

To fill these knowledge gaps, we analyzed the longitudinal survey data collected in the China Health and Nutrition Survey (CHNS) during 2000-2015, and aimed to: 1) describe the prevalence of hypertension and its time trend among patients with T2DM; 2) examine the rates of hypertension treatment, T2DM treatment, and hypertension control and their time trends among patients with T2DM and comorbid hypertension; and 3) prospectively identify the factors associated with hypertension prevalence, control, and treatment as well as T2DM treatment among patients with the comorbidity of hypertension and T2DM.

Methods And Materials

1. Study design and study population

This study used data from the CHNS, an ongoing large-scale longitudinal and household-based survey, which was initiated in 1989 and has been followed up every 2-4 years since then [14]. A multistage, random cluster process was used to draw samples from nine provinces in the 2000 survey (Liaoning, Shandong, Henan, Jiangsu, Hubei, Hunan, Guizhou, Guangxi and Heilongjiang) [15]. Three megacities (Beijing, Chongqing, and Shanghai) were added in 2011, and three more provinces (Shaanxi, Yunnan, and Zhejiang) were added in 2015. Extra details regarding the study design and methods have been described elsewhere [15,16] and at the website <https://www.cpc.unc.edu/projects/china>. The study data collection was approved by the Carolina Population Center at the University of North Carolina at Chapel Hill, the National Institute for Nutrition and Health (NINH), and the Chinese Center for Disease Control and Prevention (China CDC). Written informed consents were obtained from all participants before any data were collected.

Between 2000 and 2015, there were 38,752 adults who participated in the interview and medical examination. After excluding subjects younger than 18 years (n = 6,022), pregnant women (n = 178) and those who had missing data on age, sex, SBP, or DBP (n = 4,528), 28,024 subjects were eligible for the study. Of them, 995 subjects with T2DM and 832 subjects with both T2DM and hypertension records were retained.

For cross-sectional data analysis, we used the first available observation from the pooled data of the survey round during 2000-2015 to describe hypertension/T2DM status and demographic characteristics (n = 18,380), and compared them with those in 2015 (n = 3,478). For longitudinal data analysis, subjects were included if they had data both at baseline and in at least one follow-up during 2000-2015.

2. Data collection and measurement

All measurements were performed by trained examiners. Mercury sphygmomanometers were used to measure SBP and DBP on the right arm with appropriate cuff sizes in triplicate after a 10 minute seated rest, and the mean of the three measurements at each wave was used in analyses [15]. Height and weight were measured without shoes and in light clothing to the nearest 0.1 cm and 0.1 kg using a portable SECA stadiometer and a calibrated beam balance, respectively [15]. BMI was calculated as weight (kg) divided by height square (m²). According to Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults [17], normal weight, overweight, and obesity were defined as $18.5 \leq \text{BMI} < 24.0$, $24.0 \leq \text{BMI} < 28.0$, and $\text{BMI} \geq 28.0$ kg/m², respectively.

Data were collected using face-to-face interviews with questionnaires. Subjects were categorized into three age groups: 18-39, 40-59 and > 60 years. Income level was divided into low, medium, and high levels according to tertiles of annual gross household income. Smoking status was defined as non-smokers, current smokers, and ever-smokers. Drinking frequencies were classified into four groups as follows: never, 3 drinks/month or less, 1–2 drinks/week, and at least 3 drinks/week.

Residence (rural, suburban/town, and urban areas), marital status (unmarried, currently married, and ever-married), educational level (illiteracy, primary/junior school, senior/secondary vocational school, college, and higher), gender (male/female), medical insurance (yes/no), nationality (Han/non-Han), and disease history (yes/no) were also considered.

3. Definitions of key outcome variables

1) T2DM was identified based on the questionnaire if an individual answered “yes” to the question “Have you ever been told by a doctor that you have diabetes?” or if an individual reported ever using insulin and/or an oral antidiabetic medication.

2) Hypertension was determined according to the Guidelines for the Prevention and Treatment of Hypertension (2018 revision) and T2DM (2017 edition) in China, issued by the Chinese Society of Cardiology (CSC) and the Chinese Diabetes Society (CDS), respectively [18,19]. Hypertension was defined as SBP ≥ 130 mmHg or DBP ≥ 80 mmHg for individuals with T2DM [19], or the threshold of 140/90 mm Hg for individuals without T2DM [18], or if an individual answered “yes” to the question, “Have you ever been told by a doctor that you have hypertension?” or if an individual was currently receiving antihypertensive medications.

3) Hypertension treatment was defined as taking any antihypertensive medications at present [18].

4) Controlled hypertension was defined as an average SBP below 130 mmHg and DBP below 80 mmHg among patients with T2DM [19]. For non-diabetic patients, control BP was defined using the target of 140/90 mmHg [18].

5) T2DM treatment was defined as taking any control and treatment measures at present (including lifestyle interventions or/and medications) [19].

4. Statistical analysis

First, demographic status, health-related outcomes, and lifestyle characteristics were described based on cross-sectional data analysis of the pooled data and the 2015 data according to T2DM status. The chi-square test and t-test were used to compare differences between groups with and without T2DM for categorical and continuous variables, respectively. A linear regression model was conducted to test time trends of comorbidity of T2DM and hypertension.

In longitudinal data analysis, we estimated the mean SBP and DBP and the hypertension prevalence among patients with T2DM, as well as hypertension treatment and control and T2DM treatment among patients with both T2DM and hypertension, which was standardized to the age distribution of CHNS data in 2015 by the direct method.

A mixed effects model was conducted to test time trends using estimated mean values, prevalence, treatment, or control rates as dependent variables and survey years as independent variables, and to assess the associations between risk factors and hypertension prevalence among patients with T2DM, and hypertension treatment/control and T2DM treatment among patients with both hypertension and T2DM. All models adjusted for age, gender, smoking status, drinking status, household income, weight status, region, education level, medical insurance and disease history. The effect size was presented as an odds ratio (OR) and a 95% confidence interval (95% CI).

All analyses were conducted using Stata software version 14 (StataCorp, College Station, Texas, USA). All statistical significance was set at $P < 0.05$.

Results

1. The demographic characteristics of Chinese adults with and without T2DM in cross-sectional data analysis of the CHNS 2000-2015 pooled data and the 2015 data

Of the total subjects in the pooled data from 2000-2015, 3.6% and 28.4% participants were diagnosed with T2DM and hypertension, respectively. Hypertension prevalence was much higher among T2DM patients than those without T2DM (83.9% vs. 26.3%, respectively).

Compared with subjects without T2DM, patients with T2DM were older, had a higher percentage of residence in urban areas (50.8% vs. 24.6%), had better income (37.5% vs. 27.7%), and had higher probabilities of receiving medical insurance coverage (79.9% vs. 65.0%). Patients with T2DM were more ever-smokers (8.8% vs. 3.1%) and less current smokers (20.7% vs. 26.0%) than their counterparts. The proportions of overweight or obesity were higher in patients with T2DM than those without T2DM (overweight: 43.5% vs. 29.9%; obesity: 23.5% vs. 10.8%).

The demographic characteristics between those with and without T2DM in 2015 were similar with the pooled data from 2000-2015, but the overall hypertension prevalence was slightly increased (30.1% vs. 28.4%) in 2015 than in the pooled 2000-2015 data.

2. The distribution and time trends of health-related outcomes among Chinese adults in CHNS 2000, 2011, and 2015

In 2000-2015 pooled data, the proportions of overweight/obesity, hypertension, and T2DM were 41.1%, 28.4% and 3.6%, respectively, in Chinese adults. Of them, 17.1% of patients had overweight/obesity and hypertension, 3.0% had hypertension and T2DM, 2.4% had overweight/obesity and T2DM, and 2.1% of the subjects had all three diseases at the same time (Figure 1). Similar distributions were also observed in 2015.

Overall proportions of hypertension, T2DM, and their comorbidity rose during 2000 to 2015 in both men and women (all $P < 0.001$), with men having a higher proportion than women (hypertension: 31.5% vs. 25.7%; T2DM: 3.8% vs. 3.5%; both: 3.2% vs. 2.9%, respectively).

3. Time trends of hypertension prevalence and BPs levels among subjects with T2DM during 2000-2015

The age-adjusted hypertension prevalence decreased from 88.4% to 83.0% over 2000-2015, and the trends were similar in normal weight, overweight, and obese groups. Overall, hypertension prevalence decreased over time in men and women, with the lowest prevalence (81.0%) in men and the highest prevalence (88.9%) in women in 2011 (Figure 2). Age-standardized values of SBP were higher among women/overweight/obese patients, whereas DBP values were higher among men/overweight/obese patients in patients with T2DM (Figure 2).

4. Hypertension treatment and control and T2DM treatment among subjects with comorbidity of T2DM and hypertension during 2000-2015

The time trends of hypertension treatment and control as well as T2DM treatment by gender and weight status were shown in Table 3. The proportion of hypertension treatment and control increased from 45.3% to 57.7% (men, from 34.8% to 47.5%; women, from 55.3% to 68.6%) and from 3.0% to 10.9% (men, from 1.5% to 9.7%; women, from 4.3% to 12.5%), and T2DM treatment increased from 90.0% to 95.6% (men, from 93.7% to 96.3%; women, from 86.8% to 94.8%) from 2000 to 2015. These increasing trends were observed in normal weight, overweight, and obese groups (all $P < 0.001$).

5. Associated factors of hypertension among patients with T2DM, and hypertension treatment and control and T2DM treatment among subjects with both T2DM and hypertension

Mixed effect models identified several factors associated with hypertension prevalence in patients with T2DM and with hypertension treatment and control and T2DM treatment among patients with both hypertension and T2DM (Table 4). Older patients had a greater probability of being hypertensive (OR: 3.4; 95% CI: 1.1-10.6) and had higher rates of hypertension treatment (OR: 4.3; 95% CI: 1.8-10.1) and control (OR: 5.2; 95% CI: 2.0-11.1) when compared with 18-39 years group. Women had higher rates of hypertension treatment (OR: 3.1; 95% CI: 1.7-5.7) and control (OR: 3.0; 95% CI: 1.2-7.6) than men.

Living in urban areas was positively associated with hypertension prevalence (OR: 4.3; 95% CI: 1.5-12.5) and hypertension treatment (OR: 3.2; 95% CI: 1.5-7.0). Compared with those having a low income, patients who were in the high household income group were more likely to have their hypertension controlled (OR: 3.4; 95% CI: 1.0-11.7).

Ever-smoking and alcohol intake ≥ 3 drinks/week were positively associated with hypertension prevalence (ever-smoking: OR: 1.6; 95% CI: 1.0-3.8; alcohol intake: OR: 2.4; 95% CI: 1.6-3.5) and treatment (ever-smoking: OR: 3.1; 95% CI: 1.7-14.1; alcohol intake: OR: 2.3; 95% CI: 1.0-5.2). Ever- and current smokers were more likely to have their hypertension controlled (ever-smoking: OR: 3.8; 95% CI: 1.0-15.2; current smoking: OR: 3.1; 95% CI: 1.1-8.5).

Subjects with overweight and obesity had a greater probability of being hypertensive (overweight: OR: 3.6; 95% CI: 2.2-5.9; obese: OR: 7.4; 95% CI: 3.0-18.0). Subjects with obesity had higher treated hypertension (OR: 8.8; 95% CI: 2.5-30.8), whereas overweight subjects were more likely to have their hypertension controlled (OR: 3.3; 95% CI: 1.0-10.6).

Subjects who were older, had better income, and had a higher education level had higher rates of T2DM treatment (older: OR: 2.4; 95% CI: 1.2-4.5; income: OR: 2.0; 95% CI: 1.0-4.0; education: OR: 3.6; 95% CI: 1.4-9.0). Alcohol intake ≥ 3 drinks/week was positively associated with T2DM treatment (OR: 2.6; 95% CI: 1.0-7.4). Subjects with overweight and obesity had higher rates of treated T2DM (overweight: OR: 1.7; 95% CI: 1.0-3.0; obese: OR: 3.5; 95% CI: 1.7-7.5).

Discussion

Using longitudinal data collected from a nationwide study sample during 2000-2015, we examined time trends in hypertension prevalence among patients with T2DM, hypertension and T2DM treatment, and hypertension control rates among patients with both hypertension and T2DM in Chinese adults, and identified the associated factors with these rates. To our knowledge, this is the first study examining these rates in subjects with the comorbidity of hypertension and T2DM using longitudinal data from China. We found, first, that hypertension prevalence and BPs levels decreased from 2000 to 2015, but were still higher among patients with T2DM. Age and being overweight/obese were positively associated with hypertension. Second, hypertension treatment and control rates increased among patients with both hypertension and T2DM over 2000-2015, but the control rate was low at less than 30%. Older patients, women, and overweight/obese individuals were more likely to be treated and have their hypertension controlled. Third, higher social economic status, ever-smoking, and more drinking were positively associated with hypertension prevalence and its treatment or control rate among subjects with the comorbidity of hypertension and T2DM.

Hypertension and T2DM frequently coexist, leading to additive increases of CVDs risk [20,21]. With the rapid social and economic developments during the past three decades, China is facing a growing threat from NCDs, and hypertension is one of the most common NCDs in China and many other countries [22]. We found hypertension prevalence decreased from 88.4% to 83.0% during 2000-2015, but it was still at a higher level among patients with T2DM compared with that in Western societies [2,3,8,23]. This may be the diagnosis of hypertension in patients with T2DM seems different in Guidelines from China compared to western countries, for example, the 2019 [European Society of Cardiology \(ESC\)](#)/ [European Atherosclerosis Society \(EAS\)](#) Diabetes guidelines, which is 130/80 mmHg compared to 140/90 mmHg in ESC/EAS.

Hypertension treatment and control among patients with both hypertension and T2DM play an important role in preventing morbidity and mortality from CVDs [5,6,24]. Cross-sectional studies conducted in some European countries and the U.S. had reported that the hypertension treatment rate was higher, while the control rate was lower among patients with both hypertension and T2DM than in others [2,3,7,8]. Surveys in China showed that about half of diagnosed hypertension was treated, while only less than 25% of them had their hypertension controlled [11,25]. However, those previous studies were cross-sectional studies and had focused on T2DM or hypertension. Our study using longitudinal data found that hypertension treatment and control rates among patients with both T2DM and hypertension increased from 2010 to 2015, but only 57.7% were treated and only 10.9% had their hypertension controlled. Those with better socio-economic status were more likely to receive treatment and gain control of their hypertension. This may be due to their better access to higher quality medical care services [26].

Among patients with both hypertension and T2DM, 90% of them reported having received T2DM treatment, which was much higher than two previous studies conducted in Portugal (79.7%) and China (51.3%) among T2DM patients [27,28]. The disparity may be mainly due to different subjects and definitions of T2DM treatment. The definition of T2DM treatment in those two previous studies was only persons who took hypoglycemic therapy, while in the present study "treated T2DM" was defined as taking any control and treatment measures, including lifestyle interventions or/and medications [19].

In the present study, older subjects and women were more likely to have hypertension, receive hypertension and T2DM treatment, and have their hypertension controlled, which was consistent with previous studies [11,29]. Older subjects cared for their hypertension and T2DM more and were more likely to be covered by medical insurance and have access to basic medical and public health services than younger adults [30,31]. It is reported that compared with men, women are more likely to visit doctors and receive timely treatment [32,33]. Women are also more sensitive to anti-hypertensive drug than men and might benefit from the protective effects of estrogen [34]. These factors may help explain why Chinese women have higher hypertension treatment and control rates than men.

Smoking and drinking alcohol were highly associated with T2DM and hypertension risks [35,36]. It has since long been known that smokers have lower BP and higher in ever-smokers [37]. Consistently, we observed patients who had ever smoked or drank heavily had higher hypertension prevalence and treatment rates, but only ever-/current smokers were likely to have their hypertension controlled. Previous studies also reported that ever-smokers were more likely to have hypertension due to excessive weight gain after smoking cessation [38,39]. Guo and colleagues [11] suggested that patients who were ever-/current smokers or drank frequency may experience more complications of health problems and have a stronger desire to receive relevant treatment. During hypertension treatment, ever-/current smokers with hypertension were commonly asked to reduce their cigarette consumption [40]. Compared with patients who continue to smoke, patients who quit smoking may be more health conscious and visit the physician more often after a diagnosis of hypertension, resulting in better blood pressure control than current smokers [41], which has significantly

contributed to decreased BPs as well as BP control in ever- and current smokers. In addition, subjects with a cancer history had worse control of hypertension, which might due to the severity and complexity of their medical condition and poor treatment compliance.

We found overweight and obese patients had higher hypertension prevalence and hypertension and T2DM treatment, but a lower hypertension control rate. This was in agreement with other studies [25,42]. Overweight and obesity increase hypertension and T2DM risks. There is research reporting that obese patients have received medications to lower their lipid, BPs, and plasma glucose levels, but this was correlated inversely to how well their BP was controlled [43,44].

China faces a severe threat from NCDs. Prevention of NCDs including hypertension and diabetes through promoting healthy lifestyles has become a national priority. That BP in diabetic patients is inadequately controlled may be due to many patient, clinician, and disease factors [45]. The need for intensive BP control in patients with diabetes is recognized in clinical practice guidelines. The Chinese national standards emphasize the need for diabetic patients to control their BP to $\leq 130/80$ mmHg [18,19].

This study has several strengths. First, this is the first study in China to evaluate the trends in the prevalence, treatment, and control rates of hypertension among subjects with the comorbidity of T2DM and hypertension, and to determine factors associated with these outcomes using a large longitudinal data set. Second, the longitudinal data with large sample sizes enabled us to track the dynamics of BP levels, T2DM and hypertension management during 2000-2015. However, some limitations should be noted. First, the CHNS 2000-2015 data was collected from 15 provinces across China, which amounts to less than half of all provinces. Second, T2DM status was based on self-reported questionnaires, and we cannot calculate the T2DM control rate due to lack of blood glucose data.

Conclusions

In conclusion, data collected during 2000-2015 in a nationwide study showed that although the prevalence of hypertension among patients with T2DM decreased, it is still high in China. The treatment of hypertension and T2DM among patients with both conditions has improved over time, but the hypertension control rate remains very low, especially among overweight/obese patients. More vigorous and effective intervention efforts are needed for the management of the comorbidity of hypertension and T2DM. This may include programs such as health education, health insurance, regular blood pressure monitoring, strict adherence to prescribed medication, and lifestyle modification strategies. Multiple related stakeholders including patients, their families, and medical and public health agencies need to work together well to achieve these goals.

Abbreviations

BP, blood pressure; CDS, Chinese Diabetes Society; CHNS, China Health and Nutrition Survey; CI, confidence interval; CSC, Chinese Society of Cardiology; CVDs, cardiovascular diseases; DBP, diastolic blood pressure; NCDs, non-communicable diseases; OR, odds ratio; SBP, systolic blood pressure; T2DM, type 2 diabetes mellitus.

Declarations

Acknowledgments

Not applicable.

Authors' contributions

Research conception and design was made by JW, YL, XJW and YW. Data analysis was conducted by YL, XS and YW. The manuscript was drafted by YL, and was critically revised by all coauthors. YW secured administration and financial support for the study. All authors have read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1.

Characteristics of Chinese adults by type 2 diabetes (T2DM) status: based on cross-sectional data analysis of the CHNS 2000, 2011 and 2015 pooled data and the 2015 data

Variables	All		Those with T2DM		Those without T2DM		<i>P</i> -value*	<i>P</i> -value†
	Pooled data 2000, 2011, 2015 (N=18,380)	2015 (N=3,478)	Pooled data 2000, 2011, 2015 (N=663)	2015 (N=152)	Pooled data 2000, 2011, 2015 (N=17,717)	2015 (N=3,326)		
Having hypertension	28.4	30.1	83.9	82.9	26.3	27.6	<0.001	<0.001
Age (years, mean ± SD)	46.8±15.8	48.2±16.0	60.0±11.6	64.4±10.3	46.3±15.7	47.4±15.8	<0.001	<0.001
Age (years)							<0.001	<0.001
18-39 years	35.3	31.7	4.7	0.7	36.5	33.2		
40-59 years	41.4	41.2	42.1	32.9	41.3	41.5		
60 + years	23.3	27.1	53.2	66.4	22.2	25.3		
Gender							0.300	0.036
Men	47.0	45.0	49.0	53.3	47.0	44.6		
Women	53.0	55.0	51.0	46.7	53.0	55.4		
Marital status							<0.001	<0.001
Unmarried	9.8	8.5	1.8	0.0	10.1	8.8		
Married	82.6	84.5	85.8	86.2	82.5	84.4		
Ever-married	7.6	7.0	12.4	13.8	7.4	6.8		
Nationality							<0.001	0.005
Han	89.7	89.8	96.5	96.6	89.4	89.5		
Non-Han	10.3	10.2	3.5	3.4	10.6	10.5		
Region							<0.001	<0.001
Rural	40.8	37.5	16.2	10.5	41.8	38.8		
Suburban/towns	33.6	32.1	33.0	23.7	33.6	32.5		
Urban	25.6	30.4	50.8	65.8	24.6	28.7		
Household income (yuan)							<0.001	0.024
Low	38.0	17.1	25.6	12.6	38.5	17.3		
Medium	33.9	30.2	36.9	23.8	33.8	30.5		
High	28.1	52.7	37.5	63.6	27.7	52.2		
Education							0.270	0.869
Illiteracy	20.7	15.4	18.8	17.8	20.7	15.3		
Primary/junior school	56.4	55.6	55.7	55.0	56.5	55.7		
Senior/secondary vocational school	22.4	28.3	25.3	26.4	22.3	28.3		
College and higher levels	0.5	0.7	0.2	0.8	0.5	0.7		
Smoking							<0.001	0.001
Never	70.8	74.7	70.5	70.4	70.9	74.9		
Ever	3.3	2.5	8.8	7.2	3.1	2.3		

Current	25.9	22.8	20.7	22.4	26.0	22.8		
Drinking							0.185	0.072
Never	69.1	73.5	72.5	75.0	69.0	73.5		
≤3 drinks/month	10.4	10.1	9.7	8.5	10.4	10.2		
1-2 drink/week	7.4	5.9	5.6	2.0	7.5	6.1		
≥3 drinks/week	13.1	10.5	12.2	14.5	13.1	10.2		
Weight status							<0.001	<0.001
Normal weight	52.4	47.4	31.0	25.5	53.1	48.4		
Overweight	30.4	32.7	43.5	44.3	29.9	32.1		
Obesity	11.2	13.3	23.5	27.5	10.8	12.7		
Medical insurance							<0.001	0.401
Yes	65.5	96.9	79.9	98.0	65.0	96.8		
No	34.5	3.1	20.1	2.0	35.0	3.2		
Disease history (cancer)							<0.001	<0.001
Yes	0.7	1.0	3.3	4.6	0.6	0.8		
No	99.3	99.0	96.7	95.4	99.4	99.2		

Abbreviation: T2DM, type 2 diabetes mellitus; CHNS, the China Health and Nutrition Survey.

Values were percentages unless otherwise indicated. Hypertension was determined according to Guidelines for the Prevention and Treatment of Hypertension (the 2018 revision) and T2DM (the 2017 edition) in China issued by the CSC and CDS, respectively. According to Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults, normal weight, overweight and obesity were defined as $18.5 \leq \text{BMI} < 24.0$, $24.0 \leq \text{BMI} < 28.0$ and $\text{BMI} \geq 28.0 \text{ kg/m}^2$, respectively.

* P-values were calculated by using χ^2 tests for categorical variables or t-tests for continuous variables between with and without T2DM group in pooled data from 2000-2015.

† P-values were calculated by using χ^2 tests for categorical variables or t-tests for continuous variables between with and without T2DM group in 2015.

Table 2.

Prevalence (%) and time trends of hypertension, type 2 diabetes (T2DM) and the comorbidity among adults in China: China Health and Nutrition Survey during 2000-2015

	All (N=18,380)			Men (N=8,647)			Women (N=9,733)		
	Comorbidity*	Hypertension	T2DM	Comorbidity*	Hypertension	T2DM	Comorbidity*	Hypertension	T2DM
Pooled data	3.0	28.4	3.6	3.2	31.5	3.8	2.9	25.7	3.5
2000	1.9	26.9	2.3	2.1	29.4	2.4	1.8	24.4	2.2
2011	3.9	29.2	4.6	3.7	32.1	4.6	4.0	26.7	4.5
2015	3.6	30.1	4.4	4.5	35.1	5.2	2.9	25.9	3.7
Time trend, P_{trend}	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Had both hypertension and T2DM.

Time trends were examined by liner regression model based on cross-sectional data of the CHNS 2000, 2011 and 2015 pooled data.

Table 3.

Time trends in age-adjusted hypertension treatment and control and type 2 diabetes treatment rates (%) among subjects with both type 2 diabetes (T2DM) and hypertension by gender and weight status based on the 2000, 2011, and 2015 CHNS data

Variables	N	2000 (N=143)	2011 (N=351)	2015 (N=338)	Over time change	Time trend, P trend
1. Hypertension treatment, (% 95% CI)						
All	456	45.3 (32.1, 58.5)	56.5 (49.3, 63.7)	57.7 (50.4, 65.0)		<0.001
Man	188	34.8 (16.4, 53.2)	52.3 (41.3, 63.3)	47.5 (37.1, 57.9)	-	<0.001
Woman	268	55.3 (36.5, 74.1)	59.9 (50.2, 69.6)	68.6 (58.9, 79.5)		<0.001
Normal weight	99	38.9 (14.6, 63.2)	44.1 (29.8, 58.5)	50.4 (34.9, 66.0)		<0.001
Overweight	194	40.7 (18.8, 62.5)	60.0 (49.6, 71.3)	53.1 (41.5, 64.6)	-	<0.001
Obesity	151	64.3 (35.0, 93.5)	63.8 (49.3, 78.3)	69.0 (56.6, 81.4)	-	<0.001
2. Hypertension control, (% 95% CI)						
All	74	3.0 (-1.3, 7.2)	8.9 (4.7, 13.1)	10.9 (6.4, 15.5)		<0.001
Man	31	1.5 (-0.6, 3.6)	7.8 (1.8, 13.7)	9.7 (3.6, 15.7)		<0.001
Woman	43	4.3 (-3.4, 11.9)	9.8 (3.8, 15.8)	12.5 (5.3, 19.9)		<0.001
Normal weight	25	5.3 (-5.9, 16.5)	12.9 (3.0, 22.8)	12.9 (2.5, 23.3)		<0.001
Overweight	29	1.8 (-0.7, 4.2)	6.7 (1.2, 12.2)	11.3 (4.0, 18.6)		<0.001
Obesity	20	1.5 (-1.6, 4.6)	9.7 (0.8, 18.7)	9.5 (1.6, 17.3)	-	<0.001
3. T2DM treatment, (%) (95% CI)						
All	792	90.0 (82.4, 97.7)	95.4 (92.3, 98.5)	95.6 (92.5, 98.7)		<0.001
Man	390	93.7 (84.2, 103.2)	96.5 (92.4, 100.6)	96.3 (92.3, 100.2)	-	<0.001
Woman	402	86.8 (74.5, 99.0)	94.8 (90.6, 99.1)	94.8 (89.7, 99.9)		<0.001
Normal weight	204	85.2 (71.0, 99.4)	93.5 (86.3, 100.8)	91.4 (82.9, 99.9)	-	<0.001
Overweight	343	92.1 (80.2, 104.0)	94.8 (89.9, 99.8)	95.6 (90.5, 100.6)		<0.001
Obesity	223	93.0 (77.7, 108.3)	97.7 (93.1, 102.3)	98.2 (94.5, 101.8)		<0.001

Abbreviations: BMI, Body Mass Index; CI, confidence interval; CHNS, China Health and Nutrition Survey.

These analyses were conducted using mixed effects models based on longitudinal data collected in CHNS 2000, 2011 and 2015.

Hypertension treatment was defined as taking any antihypertensive medications at present. Hypertension control was defined as an average SBP below 130 mmHg and DBP below 80 mmHg among diabetic patients. Diabetes treatment was defined as taking any control and treatment measures at present (including lifestyle interventions or/and medications). According to Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults, normal weight, overweight and obesity were defined as $18.5 \leq \text{BMI} < 24.0$, $24.0 \leq \text{BMI} < 28.0$ and $\text{BMI} \geq 28.0 \text{ kg/m}^2$, respectively.

indicates that hypertension treatment, hypertension control or type 2 diabetes treatment continue to rise; - indicates that hypertension treatment, hypertension control or type 2 diabetes treatment rises first and then falls; ~ indicates that hypertension treatment, hypertension control or type 2 diabetes treatment falls first and then rises.

Table 4.

Longitudinal data analysis: Factors associated with hypertension, its treatment and control, and type 2 diabetes (T2DM) treatment among patients with both T2DM and hypertension: China Health and Nutrition Survey during 2000-2015

Variables	Hypertension† OR (95% CI)	Hypertension treatment‡ OR (95% CI)	Hypertension control‡ OR (95% CI)	T2DM treatment‡ OR (95% CI)
Age (years) (ref: 18-39 years)				
40-59 years	2.6 (1.0, 7.9)*	3.9 (1.7, 9.1)*	2.8 (1.2, 8.3)*	1.5 (1.0, 3.8)*
60+ years	3.4 (1.1, 10.6)*	4.3 (1.8, 10.1)*	5.2 (2.0, 11.1)*	2.4 (1.2, 4.5)*
Gender (ref: Man)				
Woman	0.9 (0.5, 1.7)	3.1 (1.7, 5.7)*	3.0 (1.2, 7.6)*	1.6 (0.4, 6.1)
Ethnicity (ref: Han)				
Non-Han	1.4 (0.4, 4.3)	1.0 (0.5, 2.1)	0.4 (0.1, 1.1)	0.2 (0.1, 1.2)
Region (ref: Rural)				
Suburban/town	2.3 (1.1, 4.8)*	1.6 (0.8, 3.1)	1.2 (0.4, 3.3)	1.4 (0.6, 3.0)
Urban	4.3 (1.5, 12.5)*	3.2 (1.5, 7.0)*	1.4 (0.5, 4.0)	1.0 (0.4, 2.6)
Household income (yuan) (ref: Low)				
Medium	1.1 (0.5, 2.6)	1.1 (0.5, 2.4)	1.9 (0.6, 6.1)	1.7 (0.8, 3.4)
High	1.0 (0.4, 2.5)	1.3 (0.6, 3.0)	3.4 (1.0, 11.7)*	2.0 (1.0, 4.0)*
Education (ref: Illiteracy)				
Primary/junior school	1.5 (0.7, 3.2)	0.3 (0.1, 2.4)	0.4 (0.1, 2.0)	3.5 (1.6, 7.7)*
Senior/secondary vocational school	0.7 (0.3, 1.7)	0.5 (0.1, 5.1)	0.9 (0.3, 2.8)	3.6 (1.4, 9.0)*
Smoking (ref: Never)				
Ever	1.6 (1.0, 3.8)*	3.1 (1.7, 14.1)*	3.8 (1.0, 15.2)*	1.4 (0.6, 3.0)
Current	0.9 (0.5, 1.8)	1.5 (0.5, 4.8)	3.1 (1.1, 8.5)*	1.3 (0.3, 5.1)
Drinking (ref: Never)				
≤3 drinks/month	1.0 (0.4, 2.2)	1.6 (0.5, 5.2)	1.1 (0.4, 3.3)	1.2 (0.5, 2.9)
1-2 drink/week	1.3 (0.5, 3.2)	3.0 (1.7, 12.7)*	0.7 (0.2, 2.0)	1.5 (0.5, 4.8)
≥3 drinks/week	2.4 (1.6, 3.5)*	2.3 (1.0, 5.2)*	0.4 (0.1, 2.4)	2.6 (1.0, 7.4)*
Weight status (ref: Normal weight)				
Overweight	3.6 (2.2, 5.9)*	2.5 (0.9, 7.0)	3.3 (1.0, 10.6)*	1.7 (1.0, 3.0)*
Obesity	7.4 (3.0, 18.0)*	8.8 (2.5, 30.8)*	1.7 (0.5, 5.5)	3.5 (1.7, 7.5)*
Having medical insurance (ref: No)				
Yes	0.9 (0.5, 1.8)	1.3 (0.5, 3.1)	1.1 (0.6, 2.0)	1.0 (0.4, 2.9)
Having cancer history (ref: No)				
Yes	1.5 (0.6, 3.9)	0.7 (0.4, 1.3)	0.3 (0.1, 0.8)*	0.8 (0.1, 4.8)

Abbreviations: OR, odd ratio; CI, confidence interval.

According to Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults, normal weight, overweight and obesity were defined as $18.5 \leq \text{BMI} < 24.0$, $24.0 \leq \text{BMI} < 28.0$ and $\text{BMI} \geq 28.0 \text{ kg/m}^2$, respectively.

* $P < 0.05$.

† Hypertension rate in diabetic patient; ‡ treatment and control rates in among patients with both type 2 diabetes and hypertension.

All mixed effect model adjusted for age, gender, smoking status, drinking status, household income, weight status, region, education level, medical insurance and cancer history. Separate models were fit for the four outcomes, respectively.

Figures

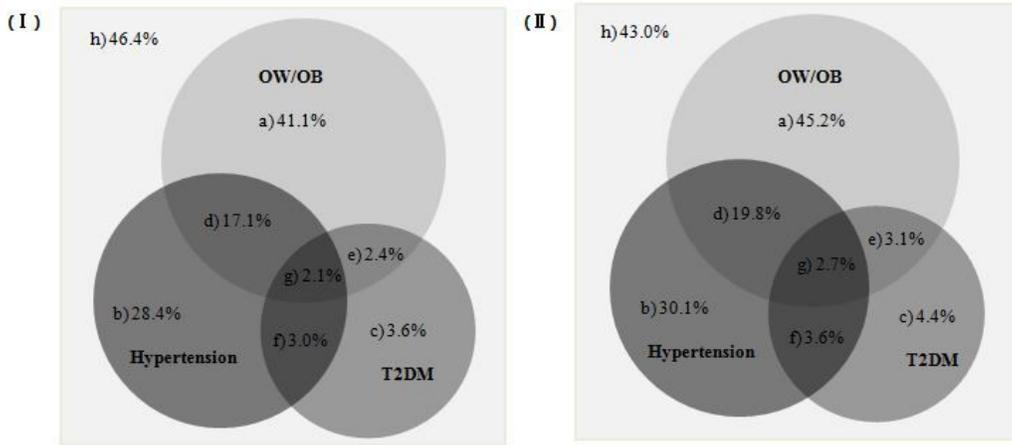


Figure 1

Hypertension, type 2 diabetes, overweight/obesity proportions among Chinese adults: based on pooled data from the CHNS 2000, 2011 and 2015 (N=18,380) (I) and only 2015 data (n=3,478) (II). a) Patients only had OW/OB, but not hypertension and T2DM. b) Patients only had hypertension, but not OW/OB and T2DM. c) Patients only had T2DM, but not OW/OB and hypertension. d) Patients had OW/OB and hypertension, but not T2DM. e) Patients had OW/OB and T2DM, but not hypertension. f) Patients had hypertension and T2DM, but not OW/OB. g) Patients had OW/OB, hypertension and T2DM. h) Patients not had any of the conditions. Abbreviation: OW/OB, overweight/obese; T2DM, type 2 diabetes mellitus. T2DM was defined based on the questions of CHNS. Hypertension was determined according to Guidelines for the prevention and treatment of hypertension (the 2018 revision) and T2DM (the 2017 edition) in China issued by the CSC and CDS, respectively.

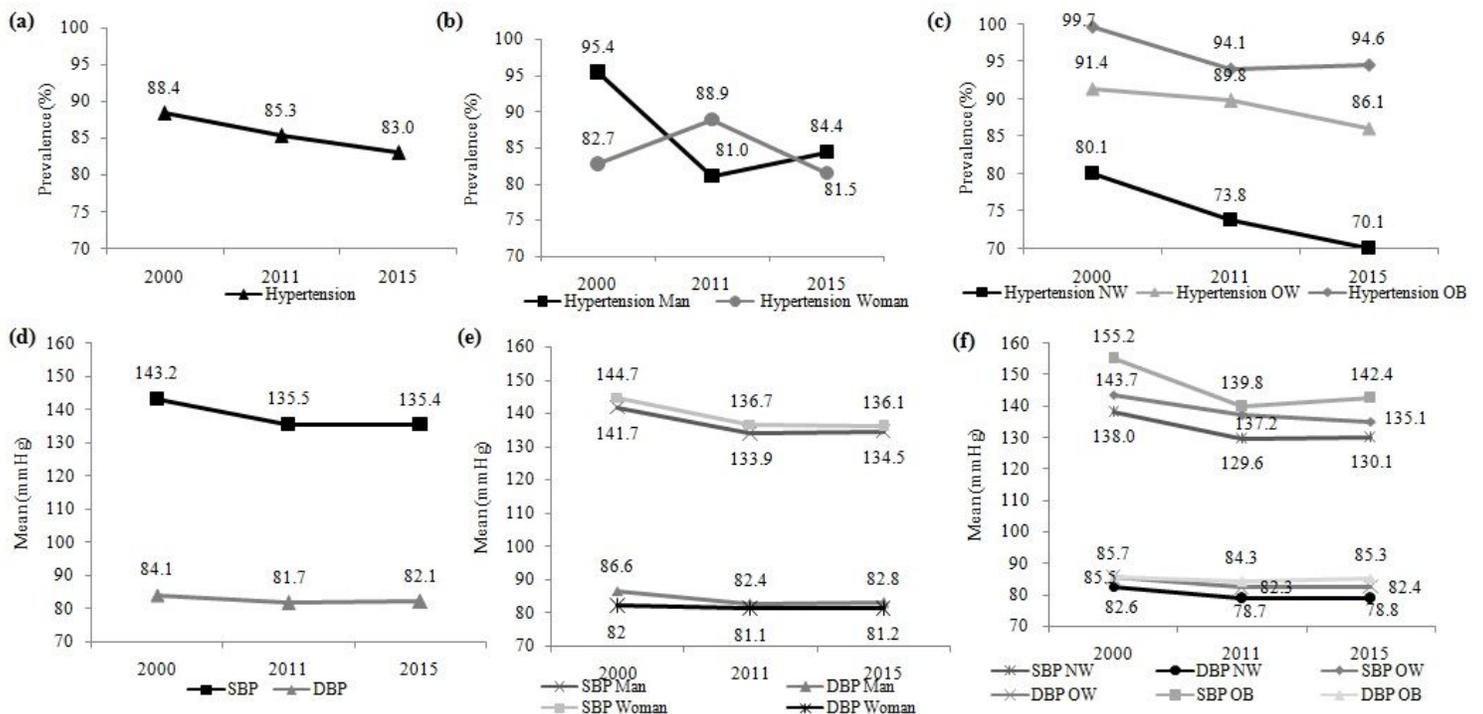


Figure 2

Time trends in age-adjusted hypertension prevalence (a-c) and blood pressure levels (d-f) among type 2 diabetes patients by gender and weight status (based on BMI) in Chinese adults over 2000-2015 (N=995). Abbreviation: SBP, systolic blood pressure; DBP, diastolic blood pressure; NW, normal weight; OW, overweight; OB, obese. (a)-(e): all time trends $p < 0.05$; (f) time trends $p < 0.05$ except for the DBP of obese group. These analyses were used mixed effects model based on longitudinal data analysis of the CHNS 2000, 2011 and 2015 pooled data. Hypertension was determined according to Guidelines for the prevention and treatment of hypertension (the 2018 revision) and T2DM (the 2017 edition) in China issued by the CSC and CDS, respectively.

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