A Population-Based, Prospective Study of Blood Pressure and Risk for End-Stage Renal Disease in China

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The association between BP and risk for ESRD has not been well characterized in Asian populations. This study examined the relationship between level of BP and incidence of ESRD in a prospective cohort study of 158,365 Chinese men and women who were 40 yr and older. Measurement of BP and covariables were made in 1991 following a standard protocol. Follow-up evaluations were conducted in 1999 to 2000 and included interviewing participants or proxies and obtaining medical records and death certificates for ESRD cases. During 1,236,422 person-years of follow-up, 380 participants initiated renal replacement therapy or died from renal failure (30.7 cases per 100,000 person-years). Compared with those with normal BP, the multivariate adjusted hazard ratios (95% confidence interval) of all-cause ESRD for prehypertension and stage 1 and stage 2 hypertension were 1.30 (0.98 to 1.74), 1.47 (1.06 to 2.06), and 2.60 (1.89 to 3.57), respectively (P < 0.001 for trend). The corresponding hazard ratios (95% confidence interval) of glomerulonephritis-related ESRD were 1.32 (0.82 to 2.11), 1.48 (0.83 to 2.61), and 3.40 (2.02 to 5.74), respectively (P <0.001 for trend). Systolic BP was a stronger predictor of ESRD than diastolic BP or pulse pressure. This study provides novel data on the incidence of ESRD and on the association between BP and glomerulonephritis-related ESRD from a nationally representative sample of adults in China. These results document the importance of high BP as a modifiable risk factor for ESRD in China. Strategies to prevent ESRD should incorporate the prevention, treatment, and control of BP.

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The number of patients who have ESRD and are treated by renal replacement therapy, dialysis, or transplantation has been increasing in the United States and worldwide (1,2). The number of incident and prevalent ESRD cases in the United States is projected to rise from 93,000 and 382,000, respectively, in 2000 to 136,166 and 712,290, respectively, by 2015 (3). The burden of ESRD in China and other economically developing countries is less well known.

Although hypertension is widely recognized as an independent risk factor for the development and progression of chronic kidney disease (4,5), few prospective studies have examined the risk for ESRD across a broad range of BP levels (6–9). Furthermore, the relationship between elevated BP and the development of ESRD has not been characterized in China, where national surveys of hypertension have indicated that the prevalence of hypertension is high and increasing (10,11). Data from the International Collaborative Study of Cardiovascular Disease in Asia indicate that 27.2% of adults (129.8 million adults) aged 35 to 74 yr in China had hypertension in 2000 to 2001 (11). At the same time, the prevalence of awareness, treatment, and control of hypertension was only 44.7, 28.2, and 8.1%, respectively (11).

In China, glomerulonephritis is the most common underlying assigned cause for ESRD, whereas in the United States, it accounts for only 8% of new cases (2,12). A better understanding of modifiable risk factors for ESRD in China is important for targeting limited health care resources and for the development and implementation of national prevention strategies. We conducted a prospective cohort study in China to determine the incidence and relative risk for ESRD across a wide range of BP levels; to compare the relative importance of systolic BP (SBP), diastolic BP (DBP), and pulse pressure on the incidence of ESRD; and to examine whether the risk that is imposed by BP is consistent for glomerulonephritis- and non–glomerulonephritis-related ESRD.

Materials and Methods

Study Population

In 1991, a multistage, random-cluster sampling design was used to select a representative sample of the general Chinese population for the China National Hypertension Survey (10). A total of 950,356 men and

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women who were 15 yr and older were selected from all 30 provinces. In 1999, 17 of the 30 provinces participated in the China National Hypertension Survey Epidemiology Follow-up Study (CHEFS). Thirteen provinces were not included in the follow-up study because participants' contact information was not available. However, sampling for the 1991 survey was conducted independently within each province, and participants who were included in the follow-up study were evenly distributed among the different geographic regions of the entire country, representing various stages of economic development. Overall, 169,871 participants (83,533 men and 86,338 women) who were 40 yr or older at the baseline examination were eligible for the follow-up study. From this population, a total of 158,666 (93.4%) participants or their proxies were identified and interviewed as part of the follow-up study. After exclusion of those with ESRD at baseline (n = 34) and those with missing BP measures (n = 267), data from 158,365 participants were included in this analysis.

Baseline Examination

Baseline data collection occurred during a single visit to a local field center. Information on demographic characteristics, medical history, and lifestyle risk factors were obtained using a standard questionnaire that was administered by trained staff. Physical activity was assessed using a questionnaire that asked participants about their work-related activities. Leisure-time physical activity was not ascertained because it was uncommon at the time of the baseline examination. Cigarette smoking was defined as smoking at least 1 cigarette per day for ≥1 yr. Data were collected on the amount and the type of alcohol consumed during the previous year.

Body weight and height were measured once during the visit by trained observers using a standard protocol, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Overweight was defined in accordance with internationally recognized definitions as a BMI ≥25.0 kg/m^2 (13,14). Three BP measurements were obtained on a single occasion by trained nurses or doctors according to a standard protocol that was adapted from procedures that are recommended by the American Heart Association (15). BP was measured on the right arm in the sitting position using a standardized mercury sphygmomanometer after the participant had rested quietly for at least 5 min. In addition, participants were advised to avoid exercising; cigarette smoking; and consuming alcohol, coffee, or tea for at least 30 min before their BP measurement. The first and fifth Korotkoff sounds were recorded as SBP and DBP, respectively (15). The averages of all SBP and DBP measurements were used to define SBP and DBP, respectively.

Follow-Up Data Collection

Follow-up interviews were conducted in 1999 and 2000 and included tracking study participants or their proxies to a current address, performing in-depth interviews to ascertain disease status and vital information, and obtaining hospital records and death certificates. All ESRD events that were reported during the in-person/proxy interview were verified by obtaining medical records or death certificates from the local hospital, dialysis unit, public health department, or police department. ESRD was defined as renal replacement therapy (dialysis or renal transplantation) or death from renal failure. Trained study staff visited all hospitals and dialysis units where patients received their treatment. The participants' hospital records, including medical history, physical examination findings, laboratory test results, discharge diagnosis, and/or autopsy findings were abstracted by study staff using a standard form. In addition, photocopies of selected sections of the participants' inpatient record, discharge summary, and pathology reports were obtained.

An end-point assessment committee in each province reviewed and confirmed (or rejected) the hospital's discharge diagnosis and cause of death on the basis of the abstracted information using prespecified criteria. All completed abstraction forms of hospital records, death certificates, and photocopies of hospital charts were sent to the Cardiovascular Institute of the Chinese Academy of Medical Sciences in Beijing, where a study-wide end-point assessment committee independently reviewed all ESRD cases. Each ESRD case was verified by two committee members, the results were compared, and discrepancies were adjudicated by discussion involving additional committee members. The underlying causes of ESRD were largely based on hospital discharge diagnoses that were assigned by nephrologists or internists. Patients' hospital charts were reviewed to confirm a personal medical history of diabetes, hypertension, glomerulonephritis, or other causes for ESRD. Deaths were classified as being due to renal failure when one of the following *International Classification of Diseases, 9th Revision, Clinical Modification* codes was listed on the death certificate as the underlying cause: 403 to 404 (hypertensive renal disease); 250.4 (diabetes mellitus with nephropathy); 274.1 (gouty nephropathy); 275.4 (nephrocalcinosis), 593.3, 593.4, 593.5, 593.7, 593.8, 593.9 (other kidney disorders); 596 (bladder-neck obstruction); 600 (hyperplasia of prostate); 753.1 (cystic kidney disease); 580 to 589 (nephritis, nephritic syndrome, or nephrosis); 590 (infection of the kidney); 591 (hydronephrosis); and 592 (calculus of the kidney and ureter) (16).

This study was approved by the Tulane University Health Sciences Center Institutional Review Board and the Cardiovascular Institute and Fu Wai Hospital Ethics Committee. Written informed consent was obtained from all study participants at their follow-up visit.

Statistical Analyses

Study participants were grouped according to the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7) classification of BP as measured at the baseline examination (normal BP: SBP <120 mmHg and DBP <80 mmHg; prehypertension: SBP between 120 and 139 mmHg or DBP between 80 and 89 mmHg; stage 1 hypertension: SBP between 140 and 159 mmHg or DBP between 90 and 99 mmHg; and stage 2 hypertension: SBP ≥160 mmHg or DBP ≥100 mmHg) (17). Participants who reported current use of antihypertensive medication were included in the stage 2 hypertension category. Person-years of follow-up for each study participant were calculated from the date of the baseline examination until the date of death, development of ESRD, or the follow-up interview, whichever occurred first. Cumulative incidence of ESRD was calculated by JNC-7 BP category using the Kaplan-Meier method with differences across categories assessed using the log-rank test (18,19). Age-standardized incidence rates were calculated by JNC-7 BP category using 5-yr age and gender-specific incidence rates and the age distribution of the Chinese population from year 2000 census data as the standard.

Cox proportional hazards models were used to examine the multivariate adjusted relationship of BP categorized by JNC-7 with the incidence of ESRD. Initial models included adjustment for age and gender. Subsequent models included additional adjustment for geographic region (north *versus* south China), urbanization (urban *versus* rural residence), education, BMI, physical activity, current cigarette smoking, alcohol drinking, and history of diabetes and cardiovascular disease (stroke or coronary heart disease). History of diabetes and cardiovascular disease was modeled as a time-dependent variable in extended Cox models (20). These analyses were conducted separately for all-cause ESRD, glomerulonephritis-related ESRD, non–glomerulonephritis-related ESRD, and unknown cause of ESRD. Population-attributable risks were calculated for each BP category (21).

To explore further the association of BP with ESRD, we determined the incidence and hazard ratios of ESRD for quintile of SBP (<108.5, 108.5 to 118.5, 118.5 to 128.5, 128.5 to 141, and ≥141 mmHg), DBP (<68, 68 to 74, 74 to 80, 80 to 87, and ≥87 mmHg), and pulse pressure (<37, 37 to 42.5, 42.5 to 50, 50 to 60, and ≥60 mmHg). In addition, multivariate adjusted hazard ratios that were associated with 1 SD higher BP were used to compare the association of SBP, DBP, and pulse pressures with ESRD. Analyses of BP as a continuous variable were performed with each BP component included in the regression model separately and with both SBP and DBP simultaneously included in the regression models (or, equivalently, both pulse pressure and SBP or pulse pressure and DBP). Methods that take into account the multistage sample clustering were used to estimate variance in the Cox proportional hazards models (22). Statistical analyses were conducted using SAS statistical software (version 9.1; SAS Institute, Cary, NC).

Results

Baseline characteristics of the study participants are presented according to JNC-7 BP category in Table 1. Participants with higher BP were older and more likely to be male, to live in northern China and urban areas, to have a high school education, to drink alcohol, to be current smokers, to be physically inactive, to be overweight, and to have a history of stroke or coronary heart disease.

During an average follow-up of 8.3 yr (1,236,422 person-years of observation), 380 participants (30.7 cases per 100,000 person-years) initiated renal replacement therapy ($n = 121$) or died from renal failure ($n = 259$). Glomerulonephritis was the most common underlying assigned cause of ESRD (10.8 cases per 100,000 person-years) followed by diabetes (5.0 cases per 100,000 person-years) and hypertension (2.7 cases per 100,000 person-years; Table 2).

The cumulative incidence of all-cause ESRD after 8 yr of follow-up was 0.14, 0.23, 0.34, and 0.64% among participants with normal BP, prehypertension, stage 1 hypertension, and stage 2 hypertension, respectively ($P < 0.001$ trend; Figure 1).

The association between BP and all-cause ESRD was positive and graded after age, age–gender, and multivariate adjustment (Table 3). This association was consistent for glomerulonephritis-related ESRD, non–glomerulonephritis-related ESRD, and ESRD from unknown causes. Stage 1 and stage 2 hypertension were attributable for 6.1 and 17.3% of all ESRD cases, respectively.

Higher quintile of systolic BP, diastolic BP, and pulse pressure were each associated with an increased incidence and age-sex and multivariate adjusted hazard ratio of ESRD (Table 4). The multivariate adjusted hazard ratio associated with a similar proportional increase in BP was greatest for systolic BP

Table 1. Baseline characteristics according to JNC-7 BP category in 158,365 CHEFS participants, China 1991 to 2000[a]

Baseline Characteristics[b]	JNC-7 Classification of BP				P
	Normal ($n = 60{,}432$)	Prehypertension ($n = 54{,}654$)	Stage 1 ($n = 24{,}493$)	Stage 2 ($n = 18{,}786$)	
Age (yr)	52.5 (9.4)	55.5 (10.5)	59.3 (10.9)	61.7 (10.7)	<0.001
Male (%)	46.6	53.0	51.4	45.6	<0.001
Living in northern China (%)	51.8	63.4	66.9	66.7	<0.001
Urban residence (%)	49.7	58.6	63.9	65.9	<0.001
High school graduate (%)	21.8	25.6	24.4	20.7	<0.001
Alcohol drinkers (%)	18.0	21.8	21.8	18.6	<0.001
Current cigarette smokers (%)	31.7	35.0	33.0	28.7	<0.001
Physical activity (%)[c]					
low	30.7	35.0	41.3	47.4	<0.001
moderate	19.8	24.7	28.1	29.3	<0.001
heavy	49.5	40.4	30.6	23.2	<0.001
BMI (kg/m^2)	21.5 (3.2)	22.7 (3.5)	23.5 (3.9)	24.1 (4.2)	<0.001
Overweight (%)[d]	13.3	24.2	33.4	40.2	<0.001
Systolic BP (mmHg)	106.7 (8.2)	126.1 (7.3)	143.3 (9.3)	167.6 (21.1)	<0.001
Diastolic BP (mmHg)	67.8 (6.7)	78.0 (6.9)	85.8 (8.5)	94.5 (13.3)	<0.001
Pulse BP (mmHg)	38.9 (7.4)	48.1 (10.1)	57.5 (13.9)	73.1 (21.6)	<0.001
History of Stroke (%)	0.4	0.9	2.3	6.5	<0.001
History of CHD (%)	0.6	1.4	2.5	3.9	<0.001

[a]BP was categorized according to Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7) guidelines: Normal: systolic BP (SBP) <120 mmHg and diastolic BP (DBP) <80 mmHg; prehypertension: SBP 120 to 139 mmHg or DBP 80 to 89 mmHg; stage 1 hypertension: SBP 140 to 159 mmHg or DBP 90 to 99 mmHg; stage 2 hypertension: SBP ≥160 mmHg or SBP ≥100 mmHg or use of antihypertensive medications. BMI, body mass index; CHD, coronary heart disease; CHEFS, China National Hypertension Survey Epidemiology Follow-Up Study.

[b]All data are means (SD) or proportion.

[c]Physical activity was assessed on the basis of participants' work-related activity only.

[d]BMI ≥25.0 kg/m^2.

Table 2. Crude rates of ESRD in 158,365 CHEFS participants, China 1991 to 2000

Assigned Underlying Cause of ESRD	Incidence		Mortality[a]	
	No. of Cases	Rate per 100,000 Person-Years	No. of Cases	Rate per 100,000 Person-Years
Glomerulonephritis	133	10.8	95	7.7
Diabetic nephropathy	62	5.0	28	2.3
Hypertensive nephrosclerosis	33	2.7	19	1.5
Obstructive nephropathy	22	1.8	16	1.3
Other	15	1.2	6	0.5
Unknown	115	9.3	95	7.7
All causes	380	30.7	259	20.9

[a]A subset of incidence.

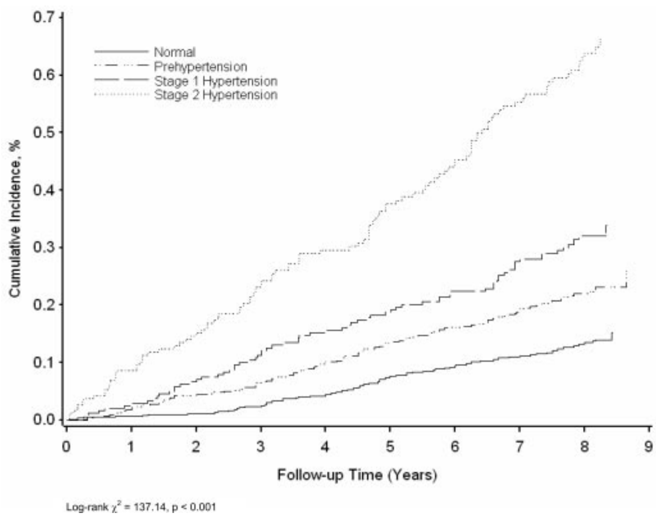

Figure 1. Cumulative incidence of all-cause ESRD according to Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7) BP category among 158,365 China National Hypertension Survey Epidemiology Follow-Up Study (CHEFS) participants, China 1991 to 2000.

and lowest for diastolic BP. For example, compared with the lowest quintile, the multivariate-adjusted hazard ratio of ESRD for the highest quintile of BP was 2.32 for systolic BP, 1.58 for diastolic BP, and 2.05 for pulse pressure.

The multivariate adjusted hazard ratio of all-cause ESRD associated with each 1-SD increase of BP (22.4 mmHg, SBP; 12.1 mmHg, DBP; 16.1 mmHg, pulse pressure) was higher for SBP compared with DBP and pulse pressure (Table 5). In multivariate models that included SBP and DBP simultaneously or included SBP and pulse pressure simultaneously, only SBP was significantly associated with an increased risk for all-cause ESRD. In a multivariate model that included DBP and pulse pressure simultaneously, both pressures were associated with increased risk for all-cause ESRD.

Discussion

This study contributes to our knowledge of ESRD in China in several ways. First, our study documents an incidence rate for all-cause ESRD of 30.7 per 100,000 in Chinese men and women who are 40 yr and older. The burden of ESRD in China and other economically developing countries is largely unknown. China does not have a national registration system of ESRD, and previous reports reflected only information that was collected from selected physicians and hospitals. According to the Chinese Dialysis and Transplantation Registration Group and other hospital-based studies, ESRD incidence in China ranged from 1.5 to 14.8 per 100,000 population (12,23,24). These low rates may reflect an incomplete ascertainment of ESRD cases. To the best of our knowledge, this study is the first to provide information on the incidence of ESRD among a nationally representative sample of the adult population in China.

Second, our study observed a strong, independent, and graded association between BP and risk for all-cause ESRD and cause-specific ESRD in the Chinese population. Only a few longitudinal studies have examined the relationship of BP with the risk for ESRD (6–9). Klag *et al.* (6) identified a graded, continuous, and strong relationship between BP and risk for all-cause ESRD during an average of 16 yr of follow-up among 332,544 middle-aged men who had been screened for the Multiple Risk Factor Intervention Trial (MRFIT). More recently, Hsu *et al.* (9) reported similar findings among 316,675 men and women who were members of Kaiser Permanente in northern California and participated in health check-ups between 1964 and 1985. Higher DBP was significantly related with an increased risk for ESRD in 107,192 Japanese men and women who were 18 yr or older and followed for 11 yr (25), and after 17 yr, both SBP and DBP were found to be independent risk factors for ESRD (8). Perry *et al.* (7) found that SBP was associated with an increased risk of ESRD in 5730 black and 6182 nonblack male veterans with hypertension.

Third, our study found that higher BP was associated with an increased risk for glomerulonephritis-related and non–glomerulonephritis-related ESRD. Participants with stage 2 hypertension had a 3.4-fold greater risk for developing glomerulonephritis-related ESRD and 2.2-fold greater risk for developing non–glomerulonephritis-related ESRD compared with their counterparts with normal BP. Previous prospective cohort studies have not reported on the association between BP and glomerulonephritis-related ESRD (6–9). Glomerulonephritis is

Table 3. Incidence rates and HR of ESRD by JNC-7 BP category in 158,365 CHEFS participants, China 1991 to 2000[a]

BP Category[b]	Person-Years	No. with ESRD	Age-Standardized Rate per 100,000 Person-Years[c]	Age- and Gender-Adjusted HR (95% CI)[d]	*P*	Multivariate Adjusted HR (95% CI)[e]	*P*	Population-Attributable Risk (%)
All-cause ESRD								
normal	482,905	81	17.8	1.00		1.00		
prehypertension	430,209	119	24.5	1.33 (1.00 to 1.77)	0.052	1.30 (0.98 to 1.74)	0.073	N/A
hypertension								
stage 1	186,958	73	27.8	1.56 (1.13 to 2.17)	0.008	1.47 (1.06 to 2.06)	0.023	6.1
stage 2	136,350	107	84.8	2.97 (2.19 to 4.02)	<0.001	2.60 (1.89 to 3.57)	<0.001	17.3
P for trend					<0.001		<0.001	
Glomerulonephritis-related ESRD								
normal	482,905	32	6.8	1.00		1.00		
prehypertension	430,209	42	9.0	1.26 (0.79 to 2.02)	0.332	1.32 (0.82 to 2.11)	0.253	N/A
hypertension								
stage 1	186,958	22	11.4	1.37 (0.78 to 2.39)	0.278	1.48 (0.83 to 2.61)	0.182	N/A
stage 2	136,350	37	44.3	3.05 (1.84 to 5.04)	<0.001	3.40 (2.02 to 5.74)	<0.001	19.6
P for trend					<0.001		<0.001	
Non–glomerulonephritis-related ESRD								
normal	482,905	21	4.9	1.00		1.00		
prehypertension	430,209	47	9.4	1.84 (1.09 to 3.11)	0.022	1.65 (0.98 to 2.80)	0.062	N/A
hypertension								
stage 1	186,958	27	8.5	1.95 (1.08 to 3.51)	0.026	1.44 (0.79 to 2.64)	0.240	N/A
stage 2	136,350	37	23.1	3.50 (2.00 to 6.12)	<0.001	2.17 (1.21 to 3.88)	0.009	15.1
P for trend					<0.001		0.022	
Unknown cause of ESRD								
normal	482,905	28	6.1	1.00		1.00		
prehypertension	430,209	30	6.0	1.00 (0.59 to 1.69)	0.997	1.04 (0.61 to 1.75)	0.899	N/A
hypertension								
stage 1	186,958	24	8.0	1.47 (0.84 to 2.59)	0.181	1.57 (0.88 to 2.80)	0.127	N/A
stage 2	136,350	33	17.4	2.52 (1.48 to 4.30)	0.001	2.72 (1.56 to 4.76)	<0.001	18.1
P for trend					<0.001		<0.001	

[a]N/A, not applicable; population-attributable risks were calculated for significant associations. HR, hazard ratio; CI, confidence interval.

[b]BP was categorized according to JNC-7 guidelines: Normal: SBP <120 mmHg and DBP <80 mmHg; prehypertension: SBP 120 to 139 mmHg or DBP 80 to 89 mmHg; stage 1 hypertension: SBP 140 to 159 mmHg or DBP 90 to 99 mmHg; stage 2 hypertension: SBP ≥160 mmHg or DBP ≥100 mmHg or use of antihypertensive medications.

[c]Rates were standardized according to the 2000 census data for China's population.

[d]HR, with normal BP as the reference category were calculated using a Cox proportional hazards model adjusted for baseline age and gender and stratified by sampling clusters.

[e]HR, with normal BP as the reference category, were calculated using a Cox proportional hazards model adjusted for baseline age, gender, geographic region (north *versus* south), urbanization (urban *versus* rural), education, BMI, physical activity, current cigarette smoking, alcohol drinking, and history of diabetes and cardiovascular disease and stratified by sampling clusters.

reported to be the primary cause of ESRD in China and other Asian populations (12,26). Our investigation provides novel data that BP may be an important risk factor for glomerulonephritis-related ESRD.

Fourth, our study indicated that SBP was a stronger predictor of all-cause ESRD than DBP or pulse pressure. In this study, SBP was a more potent predictor of ESRD than DBP or pulse pressure. The predictive power of SBP and DBP in relation to the risk for ESRD was studied in men who were screened for the MRFIT with greater predictive power being noted for SBP (6). Young *et al.* (27) found that both SBP and pulse pressure were predictors of a decline in kidney function (a rise in serum creatinine ≥0.4 mg/dl) among older adults with isolated systolic hypertension. In that study, SBP had the greatest ability to predict a decline in kidney function.

Additional strengths of this study include the high follow-up rate over 8 yr and the use of stringent training and quality control processes, standard protocols, and criteria for assessing the presence or absence of ESRD. Furthermore, this cohort provided a unique opportunity to study the relationship of BP with ESRD because of the wide range of BP and limited use of antihypertensive medications. Only 2.8% of the study population was taking antihypertensive medications at baseline, thereby limiting the potential for confounding by treatment.

There are several potential limitations to this study. First, BP was measured three times on a single occasion. Because BP measurements are subject to random variation within person, use of a single-day baseline BP could have resulted in an underestimation of the association between usual BP and ESRD incidence (28). Second, baseline serum creatinine concentrations and urinary protein excretion were not mea-

Table 4. Incidence rates and HR of all-cause ESRD according to quintiles of SBP, DBP, and pulse pressure in 158,365 CHEFS participants, China 1991 to 2000

BP Quintile (Range)	Person-Years	No. with ESRD	Age-Standardized Rate per 100,000 Person-Years[a]	Age- and Gender-Adjusted HR (95% CI)[b]	*P*	Multivariate Adjusted HR (95% CI)[c]	*P*
SBP (mmHg)							
1 (<108.5)	259,385	38	17.6	1.0		1.0	
2 (108.5 to 118.5)	251,520	42	16.5	1.08 (0.69 to 1.67)	0.739	1.07 (0.69 to 1.66)	0.758
3 (118.5 to 128.5)	255,362	56	20.4	1.25 (0.83 to 1.90)	0.285	1.22 (0.80 to 1.85)	0.357
4 (128.5 to 141)	235,020	93	32.6	1.91 (1.30 to 2.81)	0.001	1.82 (1.23 to 2.69)	0.003
5 (≥141)	235,087	151	64.0	2.73 (1.88 to 3.95)	<0.001	2.32 (1.58 to 3.41)	<0.001
P for trend					<0.001		<0.001
DBP (mmHg)							
1 (<68)	247,500	61	21.6	1.0		1.0	
2 (68 to 74)	258,917	47	16.2	0.78 (0.53 to 1.14)	0.203	0.77 (0.53 to 1.13)	0.181
3 (74 to 80)	236,001	73	26.8	1.27 (0.90 to 1.79)	0.175	1.22 (0.86 to 1.72)	0.266
4 (80 to 87)	252,030	74	26.1	1.12 (0.79 to 1.58)	0.531	1.05 (0.74 to 1.50)	0.780
5 (≥87)	241,892	125	45.5	1.81 (1.32 to 2.48)	<0.001	1.58 (1.13 to 2.20)	0.007
P for trend					<0.001		0.001
Pulse pressure (mmHg)							
1 (<37)	261,533	43	17.6	1.0		1.0	
2 (37 to 42.5)	251,394	47	20.9	1.07 (0.71 to 1.62)	0.756	1.05 (0.69 to 1.58)	0.828
3 (42.5 to 50)	244,232	54	20.3	1.16 (0.78 to 1.74)	0.467	1.13 (0.76 to 1.69)	0.548
4 (50 to 60)	242,126	77	30.0	1.43 (0.98 to 2.09)	0.067	1.38 (0.94 to 2.03)	0.096
5 (≥60)	237,007	159	64.0	2.45 (1.71 to 3.52)	<0.001	2.05 (1.42 to 2.97)	<0.001
P for trend					<0.001		<0.001

[a]Rates were standardized according to the 2000 census data for China's population.
[b]HR, with normal BP as the reference category, were calculated using a Cox proportional hazards model adjusted for baseline age and gender and stratified by sampling clusters.
[c]HR, with normal BP as the reference category, were calculated using a Cox proportional hazards model adjusted for baseline age, gender, geographic region (north *versus* south), urbanization (urban *versus* rural), education, BMI, physical activity, antihypertensive medication use, current cigarette smoking, alcohol drinking, and history of diabetes and cardiovascular disease and stratified by sampling clusters.

Table 5. HR of all-cause ESRD associated with a 1-SD higher SBP, DBP, or pulse pressure in 158,365 CHEFS participants, China 1991 to 2000

BP Component (SD)	Age- and Gender-Adjusted HR (95% CI)[a]	*P*	Multivariate Adjusted HR (95% CI)[b]	*P*
Individual component				
SBP, 22.4 mmHg	1.46 (1.34 to 1.59)	<0.001	1.38 (1.25 to 1.51)	<0.001
DBP, 12.1 mmHg	1.35 (1.24 to 1.48)	<0.001	1.28 (1.16 to 1.41)	<0.001
pulse pressure, 16.1 mmHg	1.36 (1.25 to 1.48)	<0.001	1.29 (1.18 to 1.41)	<0.001
Two components simultaneously				
SBP and DBP				
SBP, 22.4 mmHg	1.41 (1.24 to 1.60)	<0.001	1.35 (1.19 to 1.54)	<0.001
DBP, 12.1 mmHg	1.05 (0.92 to 1.20)	0.456	1.03 (0.90 to 1.18)	0.684
SBP and pulse pressure				
SBP, 22.4 mmHg	1.54 (1.30 to 1.83)	<0.0001	1.42 (1.18 to 1.71)	<0.001
pulse pressure, 16.1 mmHg	0.94 (0.79 to 1.11)	0.410	0.96 (0.80 to 1.15)	0.684
DBP and pulse pressure				
DBP, 12.1 mmHg	1.26 (1.15 to 1.39)	<0.0001	1.21 (1.09 to 1.34)	<0.001
pulse pressure, 16.1 mmHg	1.28 (1.17 to 1.40)	<0.0001	1.24 (1.13 to 1.36)	<0.001

[a]HR, with normal BP as the reference category, were calculated using a Cox proportional hazards model adjusted for baseline age and gender and stratified by sampling clusters.
[b]HR were calculated using a Cox proportional hazards model adjusted for baseline age, gender, geographic region (north *versus* south), urbanization (urban *versus* rural), education, BMI, physical activity, antihypertensive medication use, current cigarette smoking, alcohol drinking, and history of diabetes and cardiovascular disease and stratified by sampling clusters.

sured. Furthermore, the baseline questionnaire did not assess personal history of chronic kidney disease. Consequently, it is unknown whether chronic kidney disease was already present in those for whom ESRD subsequently developed. Therefore, our study cannot establish a causal relationship between BP and ESRD. However, our investigation is a prospective cohort study, and individuals with ESRD at baseline (those on renal replacement therapy or with a kidney transplant) were excluded from the analysis. Finally, the cause of ESRD was not known for a high proportion of the ESRD cases. Therefore, power was limited in ascertaining the association between elevated BP levels and cause-specific ESRD.

These findings have important clinical and public health implications. Recent national data from China indicate that the prevalence of hypertension increased 42% in men and 35% in women during the past decade (11). Moreover, only 8.1% of adults in China with hypertension have their BP controlled to <140/90 mmHg (11). Our findings suggest that the prevention and control of hypertension could reduce the incidence of ESRD by 23% in the general population in China. Strategies that aim to prevent ESRD in China need to incorporate the prevention, treatment, and control of high BP.

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Disclosures

None.

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