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# Epidemiology of Hypertension and Chronic Kidney Disease in China

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## Abstract

**Purpose of review—**Hypertension and chronic kidney disease have become major public health challenges in China.

**Recent findings—**It is estimated that approximately 153 million Chinese adults had hypertension in 2002. It is also estimated that 2.33 million total cardiovascular deaths and 1.27 million premature cardiovascular deaths were attributable to increased blood pressure in 2005 in China. Approximately 39% of Chinese adult populations are highly sensitive to dietary sodium intake, a risk factor for hypertension and cardiovascular disease. The prevalence of chronic kidney disease varied greatly among studies due to differences in study populations and definitions of chronic kidney disease. A large prospective cohort study estimates that incidence and mortality of end-stage renal disease was 30.7 and 20.9 per 100,000 person-years among Chinese adults aged 40 years and older. Hypertension and the metabolic syndrome have been documented as risk factors for chronic kidney disease. In addition, a J-shaped association between body weight and incidence of end-stage renal disease and an inverse association between alcohol consumption and risk of end-stage renal disease were documented.

**Summary—**These results underscore the urgent need to develop national strategies for the prevention, detection, and treatment of hypertension and chronic kidney disease.

### Keywords

Hypertension; Chronic kidney disease; China

## Introduction

Hypertension is a major public health challenge worldwide because of its high prevalence and consequent increase in the morbidity and mortality of cardiovascular disease (CVD) and chronic kidney disease (CKD) (1). Kearney and colleagues pooled data from different regions of the world to estimate the overall prevalence and absolute burden of hypertension in 2000, and to project the global burden in 2025 (1). Overall, 26.4% of the world's adult population in 2000 had hypertension (26.6% of men and 26.1% of women), and 29.2% were projected to have this condition by 2025 (29.0% of men and 29.5% of women). The estimated total number of adults with hypertension in 2000 was 972 million; 333 million in economically developed countries and 639 million in economically developing countries. The number of adults with hypertension in 2025 was predicted to increase by about 60% to a

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total of 1.56 billion. Most of this rise can be attributed to an expected increase in the number of people with hypertension in economically developing regions; the number of people with hypertension in economically developing countries was projected to increase by 80% from 639 million to 1.15 billion. On the basis of these estimates, almost three-quarters of the world's hypertensive population will be in economically developing countries by 2025.

Lawes and colleagues assessed the global burden of disease attributable to systolic blood pressure (BP) ≥115 mmHg among individuals aged 30 years and older (2••). Worldwide, 7.6 million premature deaths (about 13.5% of the global total) and 92 million disability-adjusted life years (6.0% of the global total) were attributed to high BP. About 54% of stroke and 47% of ischemic heart disease worldwide were attributable to high BP. Overall, about 80% of the attributable burden occurred in low-income and middle-income economies, and over half occurred in people aged 45–69 years (2••). In addition, estimates for healthcare costs of treating non-optimal BP and its main clinical complications (stroke and myocardial infarction) for those over the age of 30 were US$370 billion globally in 2001. This represents about 10% of the world's overall healthcare expenditures (3•). Although the majority of the current absolute expenditure occurs in high-income countries, an ever-increasing proportion of the cost is going to be carried by developing countries.

## Burden of Blood Pressure-Related Disease in China

The burden of hypertension is high and increasing in the general population in China (4–6). The 2002 China National Nutrition and Health Survey reported the most recent information on the prevalence of hypertension in the general population in China (6••). Data on BP and use of antihypertensive medication were obtained from 141,892 Chinese adults aged 18 years and older. The study estimated that approximately 153 million Chinese adults were hypertensive in 2002. The prevalence of hypertension was 20% in men and 17% in women. The prevalence was higher in urban compared with rural areas in men (23% vs. 18%) and women (18% vs. 16%). Of the individuals with hypertension, only 24% were aware of their condition, 19% were treated and 5% were adequately controlled.

Hypertension is a major risk factor for CVD, stroke, CKD, and premature death in China (7–9). In a prospective cohort study of 169,871 Chinese men and women aged 40 years and older, Gu and colleagues reported a strong, linear, and independent relationship between BP levels and the risk of CVD, coronary heart disease (CHD), and stroke (7•). Systolic BP is a stronger predictor of CVD risk compared to diastolic BP. All hypertension subtypes were associated with significantly increased risk of CVD. For example, compared with normotensives, relative risks (95% CIs) of CVD incidence and mortality were 2.73 (2.60 to 2.86) and 2.53 (2.39 to 2.68) for combined systolic and diastolic hypertension, 1.78 (1.69 to 1.87) and 1.68 (1.58 to 1.78) for isolated systolic hypertension, 1.59 (1.43 to 1.76) and 1.45 (1.27 to 1.65) for isolated diastolic hypertension, 2.01 (1.64 to 2.48) and 1.61 (1.28 to 2.03) for treated hypertension with systolic BP <140 and diastolic BP <90 mm Hg, and 3.37 (3.07 to 3.69) and 2.88 (2.60 to 3.19) for treated hypertension with systolic BP ≥140 and/or diastolic BP ≥90 mm Hg, respectively, after adjustment for important covariables (8••).

In this large Chinese cohort study, prehypertension is related to an increased risk of CVD (9••). For example, compared with normotension (<120/80 mmHg), prehypertension (120–139/80–89mmHg) was significantly associated with an increased relative risk (95% CIs) of CVD incidence 1.34 (1.27, 1.42) and mortality 1.22 (1.15, 1.30). The population-attributable risk (PAR) associated with prehypertension was 10.6 and 7.1% for CVD incidence and mortality. The optimal 5-year number-needed-to-treat (NNT) to prevent a CVD event or death was 53 and 185, 17 and 51, and eight and 22 for prehypertension, stage-1 hypertension, and stage-2 hypertension, respectively. The optimal NNT to prevent a CVD

event was significantly smaller in prehypertension patients with a history of CVD or diabetes (34 for incidence and 44 for mortality) compared with those without (115 for incidence and 352 for mortality). This study indicated that treatment of prehypertension among patients with a history of CVD or diabetes was as beneficial as treatment of stage-1 hypertensive patients without a history of CVD or diabetes (9••).

He and colleagues estimated that in 2005, 2.33 million (95% CI 2.21–2.45) CVD deaths were attributable to increased BP in China: 2.11 million (2.03–2.20) in adults with hypertension and 0.22 million (0.19–0.25) in adults with prehypertension (Figure 1). Additionally, 1.27 million (1.18–1.36) premature CVD deaths were attributable to raised BP in China: 1.15 million (1.08–1.22) in adults with hypertension and 0.12 million (0.10–0.14) in adults with prehypertension. Most BP-related deaths were caused by stroke: 1.86 million (1.76–1.96) total deaths and 1.08 million (1.00–1.15) premature deaths (10••).

## Sodium-Sensitivity of Blood Pressure

Clinical trials have demonstrated that a reduced intake of dietary sodium lowers BP in both hypertensive and normotensive persons (11). BP reduction in response to a decrease in dietary sodium intake, however, may vary considerably among different individuals–a phenomenon described as sodium-sensitivity (12). The Genetic Epidemiology Network of Salt Sensitivity (GenSalt) study is a family-based dietary feeding study conducted in 1,906 Chinese adults. In GenSalt, a proportional change of mean arterial pressure (MAP) ≥5% was used to define sodium-sensitivity. Based on this criteria, the proportion with salt-sensitivity was 39% among Chinese adults (13••). Therefore, sodium-sensitivity appeared to be a common biological phenomenon in this Chinese population. In addition, sodium-sensitivity was more common in women and in persons who were older and had higher usual BP.

In the GenSalt study, a dose-response relationship between BP responses to the cold pressor test (CPT) and to dietary sodium interventions was identified (14••). After adjustment for important covariates, there were statistically significant associations between the quartiles of BP response to the CPT and BP response to the dietary sodium interventions (all $p<0.0001$). The GenSalt study also identified a strong, positive, and significant association between the metabolic syndrome and salt-sensitivity of BP among persons without diabetes (15••). Compared to those with zero, participants with 4 or 5 risk factors for the metabolic syndrome had a 3.54-fold increased odds (95% CI: 2.05, 6.11) of high sodium-sensitivity during the low-sodium intervention and a 3.13-fold increased odds (1.80, 5.43) of high sodium-sensitivity during the high-sodium intervention. This association was independent of age, gender, body-mass index (BMI), physical inactivity, cigarette smoking, alcohol consumption, and baseline dietary intake of sodium and potassium. In addition, the association between the metabolic syndrome and salt-sensitivity remained after the participants with hypertension were excluded (15••).

The association between genetic variants and sodium-sensitivity of BP has been examined in several studies (16,17). In the GenSalt study, several genetic variants were associated with sodium sensitivity in the Chinese population. For example, Kelly and colleagues reported a significant association between the rare α-adducin variant rs17833172 and systolic, diastolic, and MAP responses to high-sodium (p-values <0.0001) and diastolic BP response to low-sodium (p-value=0.002) (18•). Participants homozygous for the variant A allele of this marker had systolic, diastolic and MAP responses (95% CI) to high-sodium diet of 1.6 (−1.8, 4.9), −0.8 (−5.6, 4.0), and −0.1 (−4.0, 3.9) mmHg, respectively, vs. corresponding responses of 4.6 (2.5, 6.6), 1.7 (−0.2, 3.6), and 2.7 (0.9, 4.4) mmHg, respectively, for those who were heterozygous or homozygous for the G allele. In addition, participants with at least one copy of the A allele of SNP rs1129649 of the G protein β-polypeptide 3 (GNB3)

gene had significantly decreased MAP response to low-sodium diet compared to homozygotes for the C allele (P value = 0.004) with responses of −3.4 (−3.8, −3.0) vs. −4.2 (−4.6, −3.8) mmHg, respectively. These data support a role for the ADD1 and GNB3 genes in sodium-sensitivity.

## Burden of Chronic Kidney Disease in China

Several cross-sectional studies examined the prevalence of CKD in the general Chinese population (19–21). Chen and colleagues estimated the prevalence and absolute burden of CKD in a nationally representative sample of 15,540 adults aged 35 to 74 years in China (19). Glomerular filtration rate (GFR) was estimated using the simplified equation developed by the Modification of Diet in Renal Disease study. CKD was defined as an estimated GFR <60 mL/min/1.73m$^2$. Overall, the age-standardized prevalences of CKD (GFR <60 mL/min/1.73m$^2$) was 2.53%, representing 11,966,653 persons (1.31% or 3,185,330 men and 3.82% or 8,781,323 women). Although the prevalence of CKD in China was relatively low, the population absolute burden is substantial.

A more recent study on CKD prevalence was conducted in a representative sample of 13,925 adults in Beijing, China. CKD was defined as estimated-GFR <60 mL/min/1.73m$^2$ or persistent albuminuria and hematuria. The prevalence of CKD in adults aged 18 years and older in Beijing was 13.0% from this study (20). In another population-based study among 6,311 residents aged 20 years and older from Guangzhou in south China, the prevalence of albuminuria, hematuria, reduced estimated GFR (<60 <60 mL/min/1.73m$^2$), and overall CKD was 6.6%, 3.8%, 3.2%, and 12.1%, respectively (21). These data indicated that the prevalence of CKD was high in urban Chinese populations.

The number of patients who have end-stage renal disease (ESRD) and are treated by renal replacement therapy, dialysis, or transplantation has been increasing worldwide but the burden of ESRD in China is less well known. Reynolds and colleagues examined the incidence of ESRD in 158,365 Chinese men and women aged 40 year and older during an average follow-up of 8.3 years (22). The overall incidence and mortality of ESRD was 30.7 and 20.9 per 100,000 person-years among Chinese adults. The leading causes of ESRD were glomerulonephritis, diabetic nephropathy, and hypertensive nephrosclerosis (22).

## Risk Factors for Chronic Kidney Disease

The risk factors for CKD and ESRD have been examined in several cross-sectional studies and one prospective cohort study in China (20–25). Chen and colleagues examined the relationship between the metabolic syndrome and risk of CKD in a cross-sectional survey in a nationally representative sample of 15,160 Chinese adults aged 35–74 years (23). The metabolic syndrome was defined as the presence of three or more of the following risk factors: elevated BP, low HDL-cholesterol, high triglycerides, elevated plasma glucose and abdominal obesity. CKD was defined as an estimated GFR<60 ml/min/1.73m$^2$. The multivariate-adjusted odds ratios (95% CI) of CKD in participants with compared to those without the metabolic syndrome were 1.64 (1.16, 2.32). Compared to participants without any components of the metabolic syndrome, the multivariate-adjusted odds ratios (95% CI) of CKD were 1.51 (1.02, 2.23), 1.50 (0.97, 2.32), 2.13 (1.30, 3.50) and 2.72 (1.50, 4.93) for those with 1, 2, 3, and 4 or 5 components, respectively (23). These findings suggest that the metabolic syndrome is an important risk factor for CKD in Chinese adults.

Reynolds and colleagues 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 years and older at their baseline examination (22). 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. Compared with those with normal BP, the multivariate adjusted hazard ratios (95% CI) 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% CI) 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.

In the same study, a J-shaped association between BMI and all-cause ESRD was observed (24). Compared with those with normal body weight (BMI, 18.5 to 24.9 $kg/m^2$), multivariate-adjusted relative risks (95% CI) for all-cause ESRD for underweight (BMI <18.5 $kg/m^2$), overweight (BMI, 25.0 to 29.9 $kg/m^2$), and obese subjects (BMI ≥30 $kg/m^2$) were 1.39 (1.02 to 1.91), 1.21 (0.92 to 1.59), and 2.14 (1.39 to 3.29), respectively. The J-shaped association existed even after additional adjustment for systolic blood pressure and history of diabetes and cardiovascular disease. In addition, an inverse relationship between alcohol consumption and risk of ESRD was observed in this cohort study (25). Compared to non-drinkers, the relative risk of ESRD was 0.67 among men consuming less than 21 drinks per week and 0.52 among men consuming this amount or more after adjustment for age, geographic region, urbanization, education, BMI, physical activity, and cigarette smoking. The inverse association between alcohol consumption and ESRD existed even after adjustment for systolic BP, and history of diabetes and CVD.

## Conclusion

Hypertension is the most common and leading preventable risk factor for premature deaths in China. It is estimated that approximately 153 million Chinese adults were hypertensive in 2002. It is also estimated that 2.33 million total CVD deaths and 1.27 million premature CVD deaths were attributable to increased BP in China. Sodium sensitivity, a risk factor for hypertension and CVD, is common in Chinese adult populations (approximately 39%). The prevalence of CKD varied greatly among studies due to differences in study population, methods for GFR estimation, and definition of CKD. A large prospective cohort study estimates that incidence and mortality of ESRD was 30.7 and 20.9 per 100,000 person-years among Chinese adults. Hypertension and the metabolic syndrome have been documented as risk factors for CKD. In addition, a J-shaped association between BMI and incidence of ESRD and inverse association between alcohol consumption and risk of ESRD were documented.

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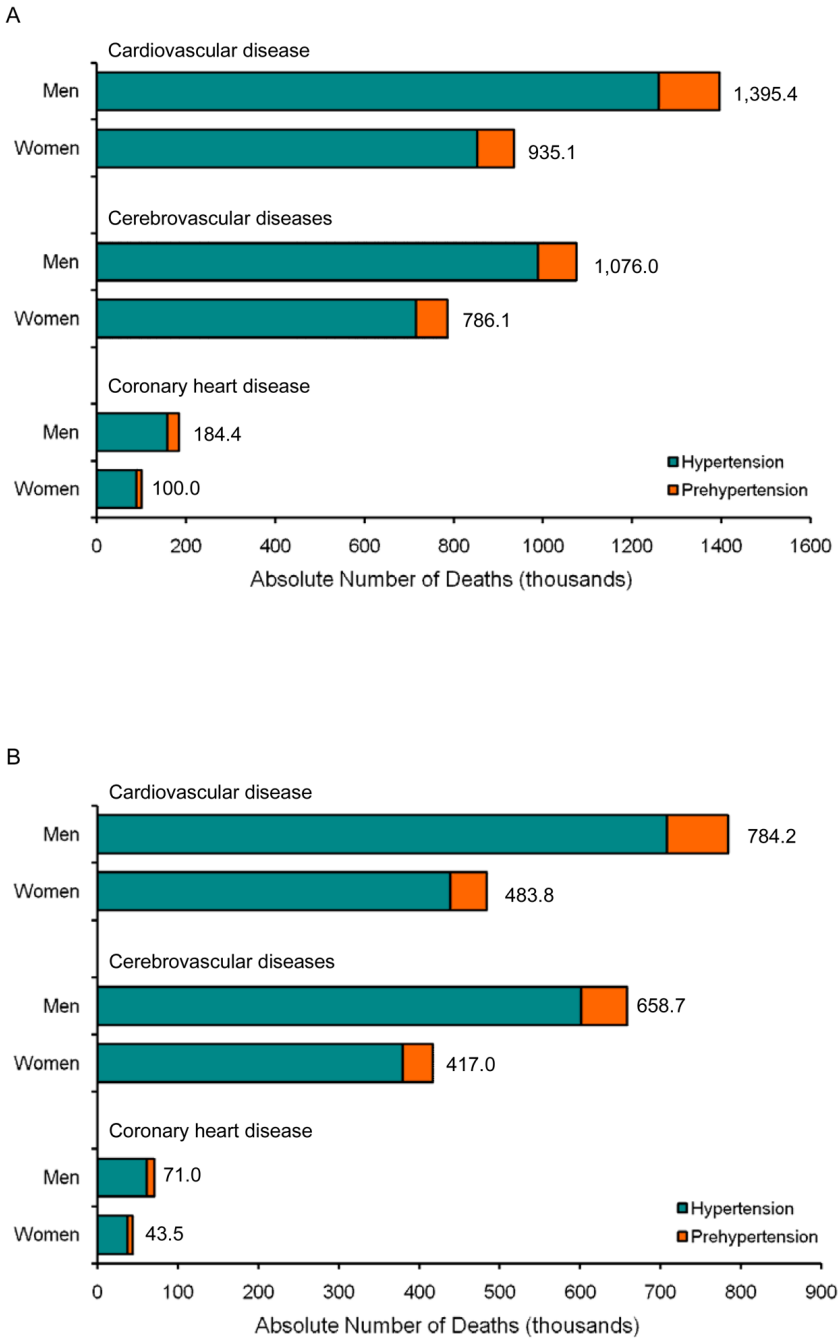


**Figure 1.**

Absolute number of deaths from cardiovascular disease, cerebrovascular disease, and coronary heart disease attributable to hypertension and prehypertension by sex in China in 2005 (A) Total deaths. (B) Premature deaths. From He J, Gu D, Chen J, et al. Premature deaths attributable to blood pressure in China: a prospective cohort study. Lancet. 2009; 374:1765–72.