# Association Between Blood Pressure Levels and Risk of Chronic Kidney Disease Among Elderly Adults in Chinese Longevity Areas: A Postprint

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## Abstract

Background: Chronic kidney disease (CKD) seriously endangers the health and longevity of the elderly, and hypertension is closely associated with CKD. However, there are few cohort studies investigating the relationship between blood pressure levels and the occurrence and progression of CKD in the elderly population.

Objective: To explore the association between blood pressure levels and the risk of CKD incidence in elderly individuals aged 65 years and above.

Methods: Based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) cohort study, 989 elderly individuals who underwent health examinations and had biomedical indicators collected in 2012 were selected as study subjects. Baseline biomedical indicators including age, sex, height, weight, blood pressure, blood lipids, blood glucose, and routine blood and urine tests were collected, and follow-up monitoring was conducted in 2014. The Cox proportional hazards regression model was employed to analyze the association between different blood pressure levels and CKD incidence risk.

Results: A total of 989 subjects were included, with a mean age of 80.2$±$12.0 years. The total follow-up duration was 2046 person-years, with a mean follow-up time of 2.07 years. There were 183 new CKD cases, with a cumulative incidence of 18.5% (95%CI: 16.1%-21.1%) during the follow-up period and an incidence density of 89.4/1000 person-years. After multivariate adjustment, elderly individuals with hypertension had a higher risk of CKD incidence compared with those with normal blood pressure [HR (95%CI) = 2.28 (1.13-4.60)]. Elderly individuals with baseline SBP $ $140 mmHg had a 1.83-fold risk of CKD incidence compared with those with SBP <120 mmHg (95%CI: 1.02-3.29); elderly individuals with baseline DBP $ $90 mmHg had a 1.55-fold risk of CKD incidence compared with those with DBP <80 mmHg (95%CI: 1.02-2.35).

Conclusion: Elevated blood pressure is an independent risk factor for CKD incidence in the elderly, and it is particularly important to enhance CKD screening and prevention for elderly individuals with predominantly systolic blood pressure elevation.

## Full Text

## Preamble

**Association of Blood Pressure Level with the Risk of Chronic Kidney Disease among the Elderly in Longevity Areas of China**

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## Abstract

**Background**: Chronic kidney disease (CKD) seriously endangers the health and longevity of the elderly, and hypertension is closely related to CKD. However, few cohort studies have examined the relationship between blood pressure levels and CKD occurrence and progression in older adults.

**Objective**: To investigate the association between blood pressure levels and CKD incidence risk among elderly individuals aged 65 years and older.

**Methods**: Based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) cohort, 989 elderly people who underwent physical examination and biomedical indicator testing in 2012 were selected as study subjects. Baseline biomedical indicators including age, sex, height, weight, blood pressure, blood lipids, blood glucose, and urinalysis were collected, and follow-up monitoring was conducted in 2014. Cox proportional hazard regression models were used to analyze the association between different blood pressure levels and CKD incidence risk.

**Results**: A total of 989 subjects were included with a mean age of 80.2$±$12.0 years, representing 2,046 person-years of follow-up. The average follow-up duration was 2.07 years, during which 183 new CKD cases were identified. The cumulative incidence of CKD during follow-up was 18.5% (95%CI: 16.1%-21.1%), with an incidence density of 89.4/1,000 person-years. After multivariate adjustment, elderly individuals with hypertension had a higher risk of CKD compared to those with normal blood pressure [HR (95%CI) = 2.28 (1.13-4.60)]. The risk of CKD among elderly individuals with baseline SBP $ $140 mmHg was 1.83 times higher than those with SBP <120 mmHg (95%CI: 1.02-3.29). Similarly, the risk for those with baseline DBP $ $90 mmHg was 1.55 times higher than those with DBP <80 mmHg (95%CI: 1.02-2.35).

**Conclusion**: Elevated blood pressure is an independent risk factor for CKD incidence in the elderly, particularly systolic hypertension. Enhanced screening and prevention of CKD are especially important for elderly individuals with elevated systolic blood pressure.

**Keywords**: Chronic kidney disease; Blood pressure level; Risk; Elderly; Cohort study

## Introduction

Chronic kidney disease (CKD) refers to abnormalities in kidney structure, function, or markers of kidney damage that persist for more than three months and affect health, including estimated glomerular filtration rate (eGFR) <60 ml/min/1.73m$^2$ or albuminuria ($ $30 mg/24h) [1]. The incidence and mortality of CKD have increased annually, yet awareness remains low, prognosis is poor, and medical costs are high, making CKD a major public health threat [2]. Age is an independent risk factor for CKD, with incidence increasing among the elderly [3]. A 2012 epidemiological survey in China showed that the prevalence of CKD among adults over 18 years was 10.8%, affecting approximately 120 million people. Among those over 70 years old, the prevalence reached 18.5%, but awareness was only 10.0% [4]. CKD, independent of other traditional risk factors, not only increases the risk of cardiovascular disease and mortality in the elderly but may also progress to renal failure, seriously affecting quality of life and endangering health and longevity [5].

Hypertension (HTN) is the most common chronic disease and an important risk factor for end-stage renal disease and all-cause mortality [6]. In 2013, elevated blood pressure contributed to 96,600 CKD deaths in Chinese adults over 25 years, accounting for 62.11% of all CKD deaths [7]. Malignant hypertension causes rapid kidney damage, while multiple studies have shown that benign hypertension is also closely associated with CKD incidence [8-10], with even mildly elevated blood pressure increasing the risk of end-stage renal disease [11]. The prevalence of hypertension increases significantly with age [2], and from 1991-2015, the prevalence among those over 60 years remained above 40%, higher than in younger age groups [12].

However, few domestic cohort studies have examined the relationship between blood pressure levels and CKD occurrence and progression in elderly populations. Therefore, this study, based on the Chinese Longitudinal Healthy Longevity Survey, analyzes the association between baseline blood pressure levels and CKD incidence risk among individuals aged 65 and older, exploring the role of blood pressure in CKD pathogenesis and providing data to support CKD prevention and control in China' s elderly population.

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### 1.1.1 Study Population

The study selected 2,439 elderly individuals aged 65 years and older from the 2012 Chinese Longitudinal Healthy Longevity Survey (CLHLS) who underwent physical examination and biomedical indicator testing, with follow-up monitoring conducted in 2014. The CLHLS database comprises eight waves of tracking surveys conducted from 1998-2018 in randomly selected counties across 23 provinces/municipalities/autonomous regions in China, with cumulative household visits to 113,000 individuals including the oldest-old, younger elderly, and middle-aged controls. The survey collected detailed data on demographic characteristics, health status, quality of life, and medical and care costs.

### 1.1.2 Inclusion Criteria

Subjects were included if they had: (1) complete baseline blood pressure measurements; (2) complete baseline serum creatinine values; and (3) complete baseline urinary microalbumin and urinary creatinine data.

### 1.1.3 Exclusion Criteria

Subjects were excluded if they had: (1) baseline eGFR <60 ml/min/1.73m$^2$; (2) baseline ACR $ $30 mg/g; (3) a history of kidney disease; or (4) missing data on key variables. The study was approved by the Ethics Committee of Tianjin Medical University General Hospital (IRB2022-WZ-103), and all participants provided informed consent.

### 1.2.1 Data Collection

A self-designed questionnaire was used to collect sociodemographic characteristics, health status, and disease history (including hypertension, diabetes, and kidney disease) through face-to-face interviews. Physical examination data including height, weight, waist circumference, calf circumference, systolic blood pressure (SBP), and diastolic blood pressure (DBP) were collected, and body mass index (BMI) was calculated.

### 1.2.2 Biomedical Indicator Testing

Experienced medical staff collected 5 ml of venous blood samples for complete blood count and biochemical measurements, including white blood cell count (WBC), red blood cell count (RBC), platelet count (PLT), hemoglobin (HB), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG), glycated serum protein (GSP), serum uric acid (SUA), serum creatinine (Scr), blood urea nitrogen (BUN), high-sensitivity C-reactive protein (hs-CRP), vitamin D3 (VD3), and superoxide dismutase (SOD). Urine samples were collected for urinalysis and other urinary indicators including urinary microalbumin (UAlb) and urinary creatinine (Ucr), from which the urinary albumin-to-creatinine ratio (ACR) was calculated.

### 1.2.3 Blood Pressure Grouping

Normal blood pressure was defined as SBP <120 mmHg and DBP <80 mmHg. High-normal blood pressure was defined as SBP 120-139 mmHg and/or DBP 80-89 mmHg. Hypertension was defined as SBP $ $140 mmHg and/or DBP $ $90 mmHg, or a self-reported diagnosis of hypertension, or current use of antihypertensive medication [13].

### 1.2.4 CKD Diagnostic Criteria

Based on the Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines, CKD was diagnosed if any of the following were present: (1) eGFR <60 ml/min/1.73m$^2$; (2) urinary albumin-to-creatinine ratio (ACR) $ $30 mg/g [1]; or (3) new CKD diagnosis based on medical records. eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation suitable for Chinese populations [14].

### 1.2.5 Statistical Analysis

Data were analyzed using STATA 13.0 software. Continuous variables with non-normal distribution were expressed as median (P25, P75) and compared between groups using the Kruskal-Wallis H test. Categorical variables were expressed as frequencies and percentages and compared using the $^2$ test. Cox proportional hazard models were used to analyze the association between baseline blood pressure levels and CKD incidence risk, with blood pressure as the independent variable and CKD incidence as the dependent variable. Confounding factors adjusted for in the models included baseline age, sex, BMI, HDL-C, LDL-C, TC, TG, and diabetes history. All tests were two-sided, with P<0.05 considered statistically significant.

# Results

## 2.1 Baseline Characteristics of Study Subjects

A total of 989 subjects were included with a mean age of (80.2$±$12.0) years, including 550 males (55.6%). The cohort accumulated 2,046 person-years of follow-up with an average duration of 2.07 years. During follow-up, 183 new CKD cases were identified, yielding a cumulative incidence of 18.5% (95%CI: 16.1%-21.1%) and an incidence density of 89.4/1,000 person-years. Baseline characteristics including age, sex, BMI, waist circumference, GSP, TC, TG, LDL-C, VD3, BUN, UAlb, Ucr, and ACR differed significantly across blood pressure groups (all P<0.05). The hypertension group had the highest mean age, highest proportion of females, and highest levels of BMI, TC, TG, LDL-C, UAlb, and ACR, while having the lowest VD3 levels .

**Table 1 Baseline characteristics of study subjects**

| Characteristic | Normal (N=102) | High-normal (N=335) | Hypertension (N=552) | $^2$/H value | P value |
|---|---|---|---|---|---|
| Age (years) | 77 (69, 86) | 76 (69, 87) | 81 (71, 89) | - | <0.001 |
| Male | 34 (33.3%) | 143 (42.7%) | 262 (47.5%) | - | 0.007 |
| Female | 68 (66.7%) | 192 (57.3%) | 290 (52.5%) | - | - |
| BMI (kg/m$^2$) | 20.49 (18.37, 23.01) | 21.26 (19.03, 23.88) | 21.94 (19.39, 24.65) | - | <0.001 |
| Waist circumference (cm) | 78 (72, 83) | 80 (73, 87) | 82 (75, 90) | - | <0.001 |
| Calf circumference (cm) | 31 (27, 34) | 31 (27, 34) | 31 (27, 34) | - | 0.948 |
| FBG (mmol/L) | 4.31 (3.50, 5.05) | 4.41 (3.62, 5.12) | 4.42 (3.80, 5.04) | - | 0.116 |
| GSP (mmol/L) | 222.3 (205.4, 241.2) | 234.9 (221.4, 252.0) | 234.9 (217.7, 252.9) | - | <0.001 |
| TC (mmol/L) | 3.92 (3.34, 4.48) | 4.33 (3.77, 5.04) | 4.35 (3.75, 5.01) | - | <0.001 |
| TG (mmol/L) | 0.69 (0.51, 0.94) | 0.85 (0.57, 1.19) | 0.88 (0.63, 1.25) | - | <0.001 |
| HDL-C (mmol/L) | 1.22 (0.99, 1.45) | 1.28 (1.07, 1.54) | 1.24 (1.05, 1.50) | - | 0.292 |
| LDL-C (mmol/L) | 2.25 (1.81, 2.78) | 2.55 (2.05, 3.04) | 2.56 (2.10, 3.10) | - | <0.001 |

| Characteristic | Normal (N=102) | High-normal (N=335) | Hypertension (N=552) | $^{2}$/H value | P value |
|---|---|---|---|---|---|
| SUA ( mol/L) | 256.4 (217.7, 310.3) | 268.9 (215.2, 326.0) | 274.1 (228.5, 328.3) | - | 0.054 |
| hs-CRP (mg/L) | 0.67 (0.32, 2.20) | 0.72 (0.33, 1.66) | 0.75 (0.37, 1.80) | - | 0.361 |
| BUN (mmol/L) | 6.78 (5.61, 7.91) | 6.19 (5.25, 7.29) | 6.19 (5.16, 7.27) | - | <0.001 |
| RBC ($10^{12}$/L) | 4.28 (3.83, 4.80) | 4.48 (4.06, 5.13) | 4.42 (4.02, 5.03) | - | 0.002 |
| WBC ($10^{9}$/L) | 5.13 (4.45, 5.86) | 5.20 (4.20, 6.30) | 5.30 (4.40, 6.50) | - | 0.249 |
| SOD (IU/ml) | 56.44 (50.28, 61.47) | 57.35 (52.61, 61.65) | 56.56 (50.66, 61.33) | - | 0.238 |
| VD3 (ng/ml) | 43.08 (31.01, 53.77) | 44.43 (31.50, 59.06) | 39.80 (29.06, 53.40) | - | 0.002 |
| PLT ($10^{9}$/L) | 187 (144, 253) | 202 (152, 260) | 199 (150, 262) | - | 0.226 |
| UAlb (mg/L) | 1.78 (0.02, 6.67) | 1.63 (0.16, 6.12) | 2.50 (0.47, 8.08) | - | <0.001 |
| ACR (mg/g) | 1.63 (0.02, 4.84) | 1.68 (0.16, 5.17) | 2.64 (0.45, 8.03) | - | <0.001 |
| Ucr ( mol/L) | 116.3 (76.5, 163.9) | 108.1 (70.6, 147.3) | 98.4 (63.1, 143.7) | - | <0.001 |

Note: BMI, body mass index; FBG, fasting blood glucose; GSP, glycated serum protein; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SUA, serum uric acid; hs-CRP, high-sensitivity C-reactive protein; SOD, superoxide dismutase; VD3, vitamin D3; WBC, white blood cell count; RBC, red blood cell count; PLT, platelet count; BUN, blood urea nitrogen; UAlb, urinary microalbumin; Ucr, urinary creatinine; ACR, albumin-to-creatinine ratio.

### 2.2 Association Between Blood Pressure Levels and CKD Incidence Risk

Multivariate-adjusted Cox proportional hazard regression analysis showed that, compared with the normal blood pressure group, the high-normal blood pressure group was not significantly associated with CKD incidence risk (HR=1.63, 95%CI: 0.78-3.42, P=0.193). In contrast, the hypertension group showed a significantly increased risk (HR=2.28, 95%CI: 1.13-4.60, P=0.021) .

**Table 2 Cox proportional hazard regression model analysis of blood pressure level and CKD risk**

| Blood pressure group | Model 1 HR (95%CI) | Model 2 HR (95%CI) | Model 3 HR (95%CI) |
|---|---|---|---|
| Normal | 1.00 (reference) | 1.00 (reference) | 1.00 (reference) |
| High-normal | 1.48 (0.75, 2.93) | 1.35 (0.68, 2.68) | 1.63 (0.78, 3.42) |
| Hypertension | 2.37 (1.24, 4.51) | 2.02 (1.06, 3.87) | 2.28 (1.13, 4.60) |

Note: Model 1 was unadjusted; Model 2 adjusted for age and sex; Model 3 adjusted for age, sex, BMI, waist circumference, calf circumference, FBG, GSP, TC, TG, HDL-C, LDL-C, SUA, SOD, VD3, WBC, RBC, PLT, BUN, blood glucose, creatinine, serum uric acid, and diabetes history.

### 2.3 Association Between SBP, DBP and CKD Incidence Risk

Multivariate-adjusted Cox proportional hazard regression analysis revealed that, compared with the SBP <120 mmHg group, the SBP $ $140 mmHg group had an HR of 1.83 (95%CI: 1.02-3.29, P=0.042). Similarly, compared with the DBP <80 mmHg group, the DBP $ $90 mmHg group had an HR of 1.55 (95%CI: 1.02-2.35, P=0.039) .

**Table 3 Cox proportional hazard regression model analysis of SBP and DBP with CKD risk**

| Blood pressure category | Model 1 HR (95%CI) | Model 2 HR (95%CI) | Model 3 HR (95%CI) |
|---|---|---|---|
| **SBP (mmHg)** | | | |
| <120 | 1.00 (reference) | 1.00 (reference) | 1.00 (reference) |
| 120-139 | 1.44 (0.82, 2.53) | 1.26 (0.71, 2.22) | 1.39 (0.75, 2.56) |
| $ $140 | 2.05 (1.19, 3.51) | 1.67 (0.97, 2.88) | 1.83 (1.02, 3.29) |
| **DBP (mmHg)** | | | |
| <80 | 1.00 (reference) | 1.00 (reference) | 1.00 (reference) |
| 80-89 | 1.17 (0.83, 1.66) | 1.23 (0.87, 1.75) | 1.33 (0.91, 1.93) |
| $ $90 | 1.18 (0.81, 1.70) | 1.28 (0.88, 1.85) | 1.55 (1.02, 2.35) |

Note: SBP, systolic blood pressure; DBP, diastolic blood pressure. Model 1 was unadjusted; Model 2 adjusted for age and sex; Model 3 adjusted for age, sex, BMI, waist circumference, calf circumference, FBG, GSP, TC, TG, HDL-C, LDL-C, SUA, SOD, VD3, WBC, RBC, PLT, BUN, blood glucose, creatinine, serum uric acid, and diabetes history.

## Discussion

This study utilized data from elderly participants in the Chinese Longitudinal Healthy Longevity Survey who underwent physical examination and biomedical indicator testing to analyze the association between baseline blood pressure levels and CKD incidence risk among individuals aged 65 years and older. The findings demonstrate that elevated baseline blood pressure, particularly systolic hypertension, is closely associated with increased CKD risk, providing scientific evidence for the relationship between blood pressure and CKD incidence in the elderly.

Age is an independent risk factor for CKD, with detection rates increasing progressively alongside multiple comorbidities that add to treatment burden and affect quality of life and survival. Early screening and prevention of CKD are therefore essential in elderly populations [15-16]. Hypertension is a well-established independent risk factor for CKD development and progression, and represents a primary cause of end-stage renal disease [17]. The prevalence of hypertension among Chinese non-dialysis CKD patients ranges from 67.3% to 71.2%, increasing with CKD severity [18]. Characteristic pathological features of hypertensive renal damage include glomerulosclerosis, renal tubular atrophy, and interstitial fibrosis, primarily resulting from ischemic changes due to renal arteriolar lesions, with glomerular hypertension-induced epithelial cell injury and autoimmune damage also contributing to CKD pathogenesis in hypertensive patients [19-20]. Our results indicate that elevated systolic blood pressure has a more pronounced effect on CKD incidence than diastolic pressure. Similarly, Reynolds et al. found that systolic blood pressure was a stronger predictor of end-stage renal disease than diastolic pressure or pulse pressure [21]. Since elderly individuals often have isolated systolic hypertension due to atherosclerosis [22], intensive management of systolic blood pressure is particularly crucial for CKD prevention in this population.

Our study found no significant association between high-normal blood pressure and CKD risk among individuals aged 65 and older (HR: 1.63, 95%CI: 0.78-3.42). Current evidence on this relationship remains inconsistent. Chen et al. conducted a cross-sectional study of 15,160 Chinese adults aged 35-74 and found no significant association between blood pressure $ $130/85 mmHg and CKD prevalence or elevated serum creatinine [23]. Similarly, Wu et al. found that only abdominal obesity and low HDL-C were positively associated with CKD risk, while blood pressure $ $130/85 mmHg showed no significant association [24]. In contrast, Reynolds' prospective cohort study of 158,365 Chinese adults aged 40 and older followed for an average of 8.3 years demonstrated that prehypertension (high-normal blood pressure) increased the risk of all-cause end-stage renal disease by 30% compared with normal blood pressure [21]. These findings suggest that while high-normal blood pressure has a milder impact on kidneys than hypertension, whether it leads to clinically significant kidney disease requires further investigation.

This study has several limitations. First, the participants were from longevity areas in China with a relatively high mean age, limiting generalizability to younger elderly populations. Second, the high mortality rate among the oldest-old participants may have resulted in selection bias, as some individuals could not be followed for CKD outcomes. Finally, the follow-up duration for participants who underwent physical examination and biomedical testing was relatively short, and longer-term follow-up is needed to validate these findings.

In conclusion, this study provides data supporting the association between hypertension and CKD incidence risk among Chinese individuals aged 65 years and older, indicating that elevated blood pressure, particularly systolic hypertension, significantly increases CKD risk. Against the backdrop of China’ s aging population, greater attention to blood pressure changes in the elderly is warranted to enable earlier prevention and management of chronic kidney disease and improve quality of life.

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## Author Contributions

ZHANG Yunsheng was responsible for data analysis and manuscript writing; JIN Yujing contributed to data organization and analysis; ZHANG Peng conducted content review and manuscript revision; GAO Ying conceptualized the study, supervised quality control, and was accountable for the overall manuscript. All authors approved the final version.

## Conflict of Interest

All authors declare no conflicts of interest.

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*Note: Figure translations are in progress. See original paper for figures.*