Prevalence of and risk factors for chronic kidney disease and diabetic kidney disease in a central Chinese urban population: a cross-sectional survey

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Abstract

Background This study was conducted to evaluate and update the current prevalence of and risk factors for chronic kidney disease (CKD) and diabetic kidney disease (DKD) in a China. Methods A total of 5231 participants were randomly recruited for this study. CKD and DKD were defined according to the combination of estimated glomerular filtration rate (eGFR), presence of albuminuria and diabetes. Participants completed a questionnaire assessing lifestyle and relevant medical history, and blood and urinary specimens were taken. Serum creatinine, uric acid, total cholesterol, triglycerides, low-density lipoprotein, high-density lipoprotein and urinary albumin were assessed. The age- and gender-adjusted prevalences of CKD and DKD were calculated, and risk factors associated with the presence of reduced eGFR, albuminuria, DKD, severity of albuminuria and progression of reduce renal function were analyzed by binary and ordinal logistic regression. Results The overall adjusted prevalence of CKD was 16.8% (15.8 – 17.8%) and that of DKD was 3.5% (3.0 – 4.0%). Decreased renal function was detected in 132 participants [2.9%, 95% confidence interval (CI): 2.5 – 3.2%], whereas albuminuria was found in 858 participants (14.9%, 95% CI: 13.9 – 15.9%). In all participants with diabetes, the prevalence of reduced eGFR was 6.3% (95% CI = 3.9 – 8.6%) and that of albuminuria was 45.3% (95% CI = 40.4 – 50.1%). The overall prevalence of CKD in participants with diabetes was 48.0% (95% CI = 43.1 – 52.9%). The results of the binary and ordinal logistic regression indicated that factors independently associated with higher risk of reduced eGFR and albuminuria were older age, gender, smoking, alcohol consumption, overweight, obesity, diabetes, hypertension, dyslipidemia and hyperuricemia. Conclusions Our study shows the current prevalences of CKD and DKD in residents of Central China. The high prevalence suggests an urgent need to implement interventions to relieve the high burden of CKD and DKD in China.

Background

Chronic kidney disease (CKD) is a common public health issue with an increasing incidence and prevalence in developing countries, such as China. The burden of CKD is not restricted to only the requirement of renal replacement therapy for end-stage renal disease (ESRD), but other serious complications, such as cardiovascular events and mortality, are also highly influenced by kidney involvement [1, 2].

In the past decade, CKD has been highly prevalent in China due to the rapid increase in the prevalence of relevant risk factors, such as diabetes and hypertension [3-6]. In 2010, Yang et al reported that the prevalences of diabetes and prediabetes were 9.7% and 15.5% in China, respectively [7]. In the same year, Ho and Hwang et al demonstrated that diabetic kidney disease (DKD) was responsible for 46.2% and 43.2% of ESRD cases in Hong Kong and Taiwan [8, 9]. However, the inadequate awareness and control of diabetes and hypertension aggravated the health and socioeconomic burden of CKD and DKD in the Chinese population in several aspects, such as lower life expectancies, poor qualities of daily lives and overburdened cost of medical care [10-13]. Insufficient contract with health services, delayed health-seeking behavior and frequent use of the Chinese herb medicine are also contributed the high incidence and progression of CKD [14, 15].

Previous studies have indicated that over 60% of CKD cases could be early detected from general screening (16-18). Timely medical care is beneficial for improving the life qualities of CKD patients and reducing the morbidity and mortality caused by ESRD [18]. Nevertheless, studies reporting epidemiological features of CKD and DKD in Chinese population are still insufficient. Updating the epidemiological data and identifying the early risk factors is urgent and beneficial for developing effective strategies for the prevention of CKD, DKD and ESRD. Therefore, we conducted a cross-sectional study to provide current epidemiological data of CKD and DKD and to identify the risk factors associated with declination of renal function in Central China.

Methods

Study subjects

From December 2017 to June 2018, the subjects were recruited from 3 communities in 3 districts of Zhengzhou: the Erqi, Zhongyuan and Jinshui districts. There are 12 administrative districts with a total population of approximately 10 million in Zhengzhou (data available on http://tjj.zhengzhou.gov.cn/). A multistage, stratified cluster sampling method was employed to select participants over 18 years old from the general population. In the first stage, 3 districts were randomly selected from 6 urban districts. In the second stage, one representative community in each district was selected according to the proportion of permanent residents. In the final stage, all permanent residents who satisfied the inclusion criteria and agreed to sign the informed consent were recruited in this study. Altogether, a total of 6000 subjects aged 18 years or older were selected from 3 communities, and 5231 subjects completed the survey and examination, with a response rate of 87.2%.

Measurements and definitions

Data were collected by face-to-face interviews in examination centers at community health stations. All subjects completed a questionnaire that collected information about their sociodemographic status (e.g., age, gender, ethnicity, education, etc.), personal and family health history (e.g., diabetes, hypertension, hepatitis, etc.), lifestyle behaviors (e.g., smoking, alcohol consumption, physical activity, etc.) and awareness and control of chronic non-communicable disease (e.g., diabetes, hypertension, dyslipidemia, etc.) with assistance of trained practitioners, doctors and nurses. Anthropometric measurements, such as height, weight and blood pressure (BP), were obtained. Height and weight were measured while the participants were in light clothing without shoes, and body mass index (BMI, kg/m^2) was subsequently calculated. According to the Chinese "Criteria of weight for adults (No. WS/T 428-2013, available on http://www.nhfpc.gov.cn)", BMI was divided into four levels: underweight (< 18.5), healthy weight (18.5 – 23.9), overweight (24 – 27.9) and obesity (≥ 28). BP was measured using an electronic sphygmomanometer (Omron HEM-7071A, Japan) three times in one-minute intervals. The mean value of the three BP readings was used for statistical analysis unless the difference between the readings was higher than 10 mm Hg, in which case the mean value of the other two closest results was calculated. In addition to participants' self-reported use of antihypertension medications in the past 2 weeks, hypertension was defined as participants with an average systolic BP (SBP) ≥ 140 mm Hg and/or an average diastolic BP (DBP) ≥ 90 mm Hg [19]. Subjects with hypertension were considered to have controlled BP if SBP < 140 mm Hg and DBP < 90 mm Hg.

After at least 8 hours of overnight fasting, venous blood specimens were collected in vacuum tubes without an anticoagulant. Serum concentrations of creatinine, uric acid, total cholesterol, triglycerides, high-density lipoprotein and low-density lipoprotein were measured using enzymatic colorimetry on a Cobas C 701 (Roche). The fasting plasma glucose (FPG) level was estimated by the glucose oxidative method (GOD-PAP). Urinary albumin and creatinine were measured from a fresh morning spot urine sample. Albuminuria was measured with an immune-turbidimetric test. Urinary creatinine was evaluated by Jaffe's kinetic method. The urinary albumin to creatinine ratio (ACR, mg/g) was calculated automatically.

The estimated glomerular filtration rate (eGFR) was calculated by the 2009 CKD-EPI creatinine equation [20]. According to the 2012 KDIGO classification, eGFR was classified into 5 stages, in which stage 3 was further divided into stage 3a and 3b with an eGFR of 45 mL/min/1.73 m^2 as the cut-off value. ACR was classified as follows: A1, < 3 mg/g; A2, 30 – 300 mg/g; and A3, > 300 mg/g [21]. Albuminuria was defined as an ACR ≥ 30 mg/g. Indicators of renal damage were the presence of an eGFR less than 60 mL/min/1.73 m^2 or albuminuria. CKD was defined as the presence of one or two indicators of renal damage.

Diabetes was defined according to the 2009 American Diabetes Association (ADA) guidelines: 1. FPG ≥ 7.0 mmol/L; 2. Self-reported use of insulin or antidiabetic medications in the past 2 weeks; and 3. Self-reported previous diagnosis of diabetes by a physician. Diabetic subjects with albuminuria and/or an eGFR less than 60 mL/min/1.73 m^2 were classified as having DKD. Control of diabetes defined as the FPG of subject with diabetes less than 7.0 mmol/L. Dyslipidemia was considered the presence of abnormal serum lipid concentrations according to the Chinese guidelines for the prevention and treatment of dyslipidemia in adults or the use of antidyslipidemia medications during the last 2 weeks [22]. Hyperuricemia was defined as a plasma uric acid concentration > 422 μmol/L for men and > 363 μmol/L for women.

Education was divided into 3 levels: 1. Primary school or lower; 2. Junior middle school; and 3. Senior high school or above. Diets rich in fruits and vegetables were considered as diets with an daily average consumption of more than 500 g of fruits and vegetables. A high-fat diet was defined as a diet with a daily average consumption of livestock and poultry of more than 75 g [23]. Physical activity was classified as low, moderate or high according to the international physical activity questionnaire (IPAQ 2001) [24].

Statistical analysis

Epidata software (version 3.1) was used for data entry and management. All statistical analyses were performed with SAS 9.1 (SAS Institute, Cary, NC, USA) and GraphPad Prism 6 (GraphPad Software, Inc., La Jolla, CA, USA) for Windows. A p-value < 0.05 was considered statistically significant. Data are expressed as the mean ± SD, median with range or frequency with percentage, as appropriate. Intergroup comparisons were performed using the Pearson *Chi-square* test for categorical variables and Student's t-test, Mann-Whitney U-test or Wilcoxon test for continuous variables, as appropriate. The standard population of this study was based on data from the China Population Sampling Census in 2009 (data available on http://www.stats.gov.cn/).

The crude and adjusted prevalences of reduced eGFR (eGFR < 60 mL/min/1.73 m^2), albuminuria, DKD and CKD were reported. Both binary and ordinal logistic regressions were employed to explore the associations between indicators of renal damage and the relevant covariates. In binary logistic regression, crude and multivariable adjusted odds ratios (ORs) with 95% confidential intervals (CIs) were calculated. The covariates involved in our multivariable logistic regression model were age (in 10-year intervals), gender (men versus women), education [≤ primary school (reference) versus junior high school versus ≥ senior high school], current smoker (yes versus no), alcohol consumption (yes versus no), BMI [healthy weight (reference) versus underweight versus overweight versus obesity], diabetes (yes versus no), hypertension (yes versus no), dyslipidemia (yes versus no), and hyperuricemia (yes versus no). According to prognosis of CKD by GFR and albuminuria category from the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) guidelines, two models were used to calculate the data in the ordinal logistic regression. In model 1, we analyzed data from subjects with an eGFR > 60 mL/min/1.73 m^2 and different levels of ACR (A1 –

A3, n=5099) [21]. In model 2, data from all participants were divided into 5 groups as follows: low risk (no CKD); moderately increased risk; high risk; and very high risk [21]. The results of the tests of parallel lines indicated that the two models were statistically executable (both *P* values > 0.05).

Results

Of the 6000 participants involved in this study, 5231 had a complete data set and were entered into our statistical analysis. Their demographic and clinical characteristics are shown in Table 1. The prevalences of hypertension, dyslipidemia, hyperuricemia and diabetes were 34.6%, 14.6%, 11.5% and 7.6%, respectively. A total of 80.3% of the participants attended senior high school. The prevalences of current smokers and habitual drinkers were similar. The mean eGFR was 92.6 ± 21.5 mL/min/1.73 m^2 and the median ACR was 14.1 with an interquartile range of 8.8 to 23 mg/g. Generally, participants with reduced eGFR or albuminuria were older, less educated, consumed less meat, performing heavy physical activity, and had higher prevalences of cardiovascular disease, hypertension, dyslipidemia, hyperuricemia and diabetes than did those without indicators of renal damage.

According to the stratification of renal indicators, there were 132 subjects performed eGFR less than 60 mL/min/1.73m^2 and 858 individuals performed albuminuria (Table 2). Totally, 945 participants were suffering from CKD, in which 192 subjects were DKD patients. The adjusted prevalence of eGFR less than 60 mL/min/1.73m^2 was 2.8% (95% CI = 2.4 – 3.3%) and that of albuminuria was 14.9% (95% CI = 13.9 – 15.9%). The overall prevalence of CKD and DKD was 16.8% (95% CI = 15.8 – 17.8%) and 3.5% (95% CI = 3.0 – 4.0%), respectively. By disease stage, the prevalence was as follows: stage 1, 6.0%; stage 2, 7.8%; stage 3a, 2.4%; stage 3b, 0.2%; and stage 5, 0.1%. As shown in figure 1, comparing with men, prevalence of reduced eGFR was much higher in women subjects who aged over 40 years old and the overall prevalence was increased with age in both men and women. The prevalence of albuminuria increased with age and was higher in women than men in all age groups except for subjects who aged 60 – 69 years old (24.7 versus 26.3%). Overall, the prevalences of CKD and DKD were increased with age in both men and women participants.

In all participants with diabetes (N = 400), comparing with those without renal damage, subjects with reduced eGFR were older, more likely to be women, insufficient consumption of meat, lack of physical activities, poor control of diabetes, higher proportion of hypertension and dyslipidemia, meanwhile, those with albuminuria performed diet rich in fruits and vegetables, lacking control of diabetes and higher proportion of dyslipidemia (Table 3). One hundred and twenty six subjects were classified as stage 3 – 5 CKD and 908 subjects had albuminuria (Table 4). The prevalence of reduced eGFR was 6.3% (95% CI = 3.9 – 8.6%) and that of albuminuria was 45.3% (95% CI = 40.4 – 50.1%). The overall prevalence of CKD in participants with diabetes was 48.0% (95% CI = 43.1 – 52.9%).

The prevalence of reduced eGFR was not significantly different among three tertiles of education and family income, while that of albuminuria was highest in subjects with lower tertile of education and upper tertile of family income (Table 5). The overall adjusted prevalences of CKD were 33.5% (95% CI = 27.7 – 39.3%) and 26.5% (95% CI = 22.4 – 30.6%), respectively. Prevalences of hypertension and diabetes were lower in subjects with higher education condition while they were lowest in subjects with middle tertile of family income. The worst performance of controlling hypertension and diabetes was in subjects with upper tertile of education (6.9% and 29.9%) and middle tertile of family income (9.3% and 27.4%).

The results of the binary logistic regression are shown in Table 6. Older age, higher educated, and hypertension were all independently associated with a higher risk of reduced eGFR, while being a man performed the opposite. Factors independently associated with a higher risk of albuminuria were older age, being current smoker, a diet rich in fruits and vegetables, overweight, obesity, diabetes, hypertension and dyslipidemia. Better educated and more consumption of meat had lower ORs of developing albuminuria than the other factors. In addition, being an old man, having obesity, hypertension, dyslipidemia and hyperuricemia were significantly associated with an increased risk of DKD, while a diet rich in fruits and vegetables was related to a lower risk of developing renal damage in subjects with diabetes.

In the ordinal logistic regression, data were analyzed in two models (Table 7). In model one, aging, smoking, diet rich in fruits and vegetables, heavy physical activity, high BMIs, diabetes, hypertension, and dyslipidemia were positively associated with increased severities of albuminuria in subjects with normal eGFR values, while better educated and diet rich in meat were associated with reduced severities. Similarly, in model two, better educated and high-fat diet were also negatively related to an elevated risk of renal damage, while the factors including older age, current smoking, favoring fruits and vegetables diet, obesity, diabetes, hypertension and dyslipidemia showed a positive association.

Discussion

Henan Province is one of the largest provinces in China, and its population accounts for an estimated 8% of the entire country according to the China Population Census in 2009. The city of Zhengzhou has a population of nearly 10 million people and is one of the representative urban centers in Central China. To the best of our knowledge, the present study was the first study performed with a large representative sample of an urban population in Central China to evaluate the current epidemiological features of both vital indicators of renal damage, eGFR and albuminuria, and DKD. In this study, the prevalence of CKD was 16.8% and that of DKD was 3.5%, corresponding to over 3 million adults in Henan Province. Generally, older age, sex, education, smoking, unhealthy BMIs, diabetes, hypertension, dyslipidemia and hyperuricemia were significantly associated with a higher risk for and elevated severities of reduced renal function. Compared with previous studies, these findings indicated that the prevalence of CKD was higher in the urban population in Central China than in the urban populations in South China (12.1%) and North China (13.0%) and that the prevalence of CKD increased by 6% since 2009 (10.5%) [11, 25, 26].

In 2012, Zhang et al conducted a national survey using a multistage stratified sampling method and reported that the prevalence of CKD in Chinese urban residents was 8.9%, out of which 2.3% subjects had reduced eGFR and 7.0% subjects had albuminuria [27]. Compared with our current study, the number of people with CKD increased markedly in the past six years. Older age was shown to be independently associated with a higher risk of reduced renal function, which was further supported by our present study [11, 28-32]. Aging has become a highlighted social problem in China. According to the data from the China Population Census in 2009, the proportion of residents aged over 50 and 60 years was 24.0% and 12.7% in Henan Province, respectively. In this study, the mean age of the subjects without renal damage was 40.3 years, while the mean ages of those with reduced eGFR, albuminuria and DKD were 63.0, 51.5 and 57.9 years, respectively. The age distribution partly contributed to the higher prevalence of CKD in this study population.

Diabetes and hypertension are reported to be significantly related to the high prevalence and incidence of CKD [3, 33-35]. In the past twenty years, a noteworthy increase in the prevalence of diabetes and hypertension in the Chinese population occurred. Xiang et al conducted a national survey in China and demonstrated that the prevalence of impaired glucose tolerance and diabetes mellitus was 3.2% and 4.8%, respectively [36]. In 2004, the Fourth National Health and Nutrition Examination Survey of China (NHANES) reported that the prevalence of diabetes had increased to 6.4% [37]. Even though the growth rate decelerated in the past 10 years, the results from the 2016 Global Burden of Disease study suggested that 6.6% of all-age Chinese individuals had diabetes [5]. In 2002, a national survey by Gu et al suggested that the overall prevalence of hypertension was 13.6% in residents aged over 15 years [38]. Ten years later, the results of the International Collaborative Study of Cardiovascular Disease in Asia indicated that 27.2% of middle-aged Chinese adults had hypertension [39]. A national hypertension survey conducted from 2012 to 2015 reported that there were still 23.2% of Chinese adults had hypertension [40]. The changing trajectories of prevalences of diabetes and hypertension were associated with CKD. In our study, we found that a larger proportion of subjects with both hypertension and diabetes had reduced eGFR and albuminuria than those without them. Results of the logistic regression also showed that diabetes and hypertension were independently associated with a higher risk of reduced eGFR with ORs of 1.13 and 1.81 and of albuminuria with ORs of 2.71 and 2.79, respectively. Therefore, the higher prevalence of CKD in our study population could be caused by the high proportion of subjects with diabetes (7.6%) and hypertension (34.6%).

Dyslipidemia tends to develop along with kidney function decline in patients with CKD, even in the early stages. Dyslipidemia is also associated with a higher risk of cardiovascular disease, which is the main cause of death in patients with CKD and ESRD [41]. Ji et al found that increased serum concentrations of total cholesterol and triglycerides were significantly associated with mildly reduced eGFR [42]. Thompson et al also indicated that decreased eGFR was independently associated with lower concentrations of high-density lipoprotein and higher concentrations of triglycerides in an Australian population. In a longitudinal study, Tsai et al found that the level of total cholesterol, both at baseline and over the longitudinal course, was significantly associated with a higher risk of incident ESRD [43]. Similarly, in our current study, the serum concentration of total cholesterol was much higher in subjects with reduced eGFR than in subjects without reduced eGFR, and subjects with DKD had the highest serum concentration of triglycerides. The results of both the binary and ordinal logistic regressions also indicated that dyslipidemia was significantly associated with albuminuria, DKD and severe renal damage.

Hyperuricemia generates renal injury via its crystal-independent mechanisms, such as activating the renin-angiotensin system, thereby inducing endothelial dysfunction and oxidative stress [44]. Previously, Weiner et al observed that every 1 mg/dL increase in serum uric acid from the baseline level was associated with a 7% higher risk for reduced eGFR in the Atherosclerosis Risks in Communities and the Cardiovascular Health Study [45]. In another prospective cohort study, Zhang et al demonstrated that the increased level of serum uric acid was associated with both the declination of new-onset albuminuria and eGFR, defined as its value decrease $\geq$ 20% [46]. A meta-analysis integrating 13 studies with more than 190 thousand subjects with normal baseline renal function suggested that an elevated serum concentration indicating hyperuricemia was independently associated with a twofold increased risk of new-onset CKD [47]. According to the results of present study, compared with subjects without renal damage, the prevalence of hyperuricemia was much higher in subjects with reduced eGFR and albuminuria (15.2% and 16.5%, respectively, versus 10.4%). The results of the logistic regression further supported the idea that hyperuricemia was robustly connected with a higher risk of albuminuria and DKD with ORs of 1.70 and 2.15, respectively.

Our present study reports the epidemiologic characteristics and influencing factors of CKD and DKD based on a representative urban population in Central China. Standardized survey tools, training programs and quality-control procedures ensured the reliability of the results. However, several limitations should be addressed. First, the renal indicators were acquired from single measurements, which might partly overestimate the prevalences of CKD and DKD. Second, the cross-sectional study is incapable of demonstrating causal relationships between indicators of renal damage and the relevant influencing factors.

Conclusion

The results of the present study demonstrate that the high prevalences of CKD and DKD have become a major public health burden in the Chinese urban population. The rapid increase in the prevalences of hypertension and diabetes will persistently affect the overall prevalence of CKD in the future. It is urgent to develop specific strategies aimed at reducing the burden of CKD.

List Of Abbreviations

CKD: Chronic kidney disease; ESRD: End-stage renal disease; DKD: Diabetic kidney disease; BP: Blood pressure; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; ACR: Albumin to creatinine ratio; eGFR: estimated glomerular filtration rate; KDIGO: Kidney disease improving global outcomes; ADA: American diabetes association; IPAQ: International physical activity questionnaire; SD: Standard deviation; OR: Odds ratio; CI: Confidential interval; NHANES: National health and nutrition examination survey; DM: Diabetes mellitus; HTN: Hypertension.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (No. KY-2018-LW-66). All participants provided written informed consent before data collection. The present study was performed in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors’ Contributions

Study design: ZSL, GCD, JYD; data acquisition: SKP, DKJ, ZHZ, LLL, FT; data analysis: YJQ, JYD; statistical analysis: JYD; supervision: CJW, GCD, ZSL. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved. All authors have read and approved the final manuscript.

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Tables

Table 1 General characteristics of participants according to indicators of renal damage

	Participants with eGFR < 60 mL/min/1.73 m2 (N=132)	Participants with albuminuria (N=859)	Participants with DKD (N=192)	Participants without renal damage (N=4286)	Total (N=5231)
Age	63.0 (13.8)	51.5 (14.0)	57.9 (12.5)	40.3 (16.2)	42.5 (16.5)
Men	24 (18.2%)	574 (66.8%)	132 (68.8%)	2362 (55.1%)	2945 (56.3%)
Education					
≤ Primary school	20 (15.2%)	90 (10.5%)	27 (14.1%)	156 (3.6%)	257 (4.9%)
Junior high school	32 (24.2%)	192 (22.4%)	54 (28.1%)	564 (13.2%)	774 (14.8%)
≥ Senior high school	80 (60.6%)	577 (67.2%)	111 (57.8%)	3566 (83.2%)	4200 (80.3%)
Current smoker	9 (6.8%)	295 (34.3%)	66 (34.4%)	825 (19.2%)	1125 (21.6%)
Habitual drinker	7 (5.3%)	282 (32.8%)	61 (31.9%)	817 (19.1%)	1104 (21.1%)
Dietary pattern					
Diet rich in fruits and vegetables	78 (59.1%)	419 (48.8%)	74 (38.5%)	1746 (40.7%)	2222 (42.5%)
High fat diet	11 (8.3%)	92 (10.7%)	16 (8.3%)	680 (15.9%)	779 (14.9%)
Physical activity					
Low	99 (75%)	494 (57.5%)	111 (57.8%)	2911 (67.9%)	3469 (66.3%)
Moderate	33 (25%)	330 (38.4%)	73 (38.0%)	1293 (30.2%)	1645 (31.4%)
High	0 (0%)	35 (4.1%)	8 (4.2%)	83 (1.9%)	117 (2.2%)
Self-reported HBV infection	2 (1.5%)	11 (1.3%)	3 (1.6%)	54 (1.3%)	66 (1.3%)
Cardiovascular disease	37 (28%)	112 (13%)	47 (24.5%)	247 (5.8%)	376 (7.2%)
Hypertension	79 (59.8%)	558 (65%)	142 (74.0%)	1213 (28.3%)	1812 (34.6%)
Dyslipidemia	33 (25%)	248 (28.9%)	73 (38.0%)	496 (11.6%)	765 (14.6%)
Hyperuricemia	20 (15.2%)	142 (16.5%)	21 (10.9%)	447 (10.4%)	599 (11.5%)
Diabetes	25 (18.9%)	181 (21.1%)	NA	208 (4.9%)	400 (7.6%)
Body mass index (kg/m2)	24.9 (3.6)	26.1 (3.8)	26.6 (3.3)	23.6 (3.6)	24.1 (3.8)
Waist–hip ratio	0.8 (0.05)	0.9 (0.04)	1.0 (0.03)	0.8 (0.1)	0.8 (0.1)
Total cholesterol (mmol/L)	4.8 (0.9)	4.6 (0.97)	4.6 (1.0)	4.2 (0.9)	4.3 (0.9)
Triglyceride (mmol/L)	1.7 (1.2)	2.0 (1.8)	2.5 (2.5)	1.3 (1.1)	1.4 (1.3)
LDL cholesterol (mmol/L)	2.6 (0.7)	2.5 (0.6)	2.5 (0.6)	2.3 (0.7)	2.3 (0.7)

HDL cholesterol (mmol/L)	1.4 (0.3)	1.3 (0.4)	1.2 (0.3)	1.4 (0.4)	1.3 (0.4)
Fasting blood glucose (mmol/L)	5.4 (2.3)	5.8 (2.2)	9.0 (2.9)	4.9 (1.0)	5.0 (1.3)
Uric acid (μmol/L)	285.5 (94.5)	321.7 (102.1)	295.8 (99.6)	289.7 (95.5)	294.6 (97.3)
Creatinine (μmol/L)	97.8 (92.0 – 106.7)	84.0 (39.5)	84.6 (72.3 – 96.6)	79.6 (15.2)	80.8 (25.1)
eGFR (mL/min/1.73m2)	52.4 (10.7)	86.9 (19.4)	80.9 (20.5)	94.5 (21.2)	92.6 (21.5)
ACR (mg/g)	20.1 (10.7 – 44.2)	47.8 (36.6 – 106.3)	55.5 (36.6 – 178.7)	12.3 (8.1 – 17.6)	14.1 (8.8 - 23)

Note: Data were n (%), mean (standard deviation) or median with interquartile range, as appropriate.

Abbreviations: DKD, diabetic kidney disease; HBV, hepatitis B virus; LDL, low density lipoprotein; HDL, high density lipoprotein; eGFR, estimated glomerular filtration rate; ACR, albumin: creatinine ratio; NA, not applicable.

Table 2 Adjusted prevalence of indicators of renal function and chronic kidney disease, by disease stage

Renal indicator								Chronic kidney disease (in 5231 participants)	
		eGFR (mL/min/1.73m2)		Albuminuria		Diabetic kidney disease			
Stage		n	Prevalence (95% CI)	n	Prevalence (95% CI)	n	Prevalence (95% CI)	N	Prevalence (95% CI)
1	> 90	2744	52.1 (50.7 - 53.4)	370	11.5 (10.3 – 12.7)	63	1.9 (1.4 – 2.5)	370	6.0 (5.3 – 6.6)
2	60 – 89	2355	42.4 (41.1 – 43.8)	443	18.4 (16.8 – 20.0)	104	4.5 (3.7 – 5.4)	443	7.8 (7.1 – 8.5)
3	30 – 59	124	2.6 (2.2 – 3.1)	40	37.0 (28.8 – 45.1)	22	20.3 (13.5 – 27.1)	124	2.6 (2.2 – 3.1)
3a	45 – 59	115	2.4 (2.0 – 2.8)	33	32.8 (24.5 – 41.1)	19	18.4 (11.5 – 25.3)	115	2.4 (2.0 – 2.8)
3b	30 – 44	9	0.2 (0.1 – 0.4)	7	76.9 (50.4 – 93.4)	3	38.5 (7.9 – 69.1)	9	0.2 (0.1 – 0.4)
4	15 – 29	5	0.2 (0.1 – 0.4)	4	46.2 (14.8 – 77.5)	2	23.1 (6.6 – 39.5)	5	0.2 (0.1 – 0.4)
5	< 15	3	0.1 (0.1 – 0.2)	1	14.3 (9.4 – 29.2)	1	14.3 (9.4 – 29.2)	3	0.1 (0.1 – 0.2)
Total		5231	100	858	14.9 (13.9 – 15.9)	192	3.5 (3.0 – 4.0)	945	16.8 (15.8 – 17.8)

Note: Albuminuria was defined as urinary albumin to creatinine ratio ≥ 30mg/g creatinine. CKD was defined as an eGFR less than 60 mL/min/1.73m2 or presence of albuminuria. All prevalences were adjusted for synthesized weights.

Abbreviations: eGFR, estimated glomerular filtration rate.

Table 3 General characteristics of participants with diabetes according to indicators of renal damage

	Participants with eGFR < 60 mL/min/1.73 m2 (N= 25)	Participants with albuminuria (N= 181)	Participants without renal damage (N= 208)	Total (N= 400)
Age	68.4 (11.3)	57.6 (12.4)	57.2 (10.6)	57.5 (11.5)
Men	5 (20.0%)	132 (72.9%)	123 (59.1%)	255 (63.8%)
Education				
≤ Primary school	2 (8.0%)	26 (14.4%)	21 (10.1%)	48 (12.0%)
Junior high school	9 (36.0%)	51 (28.2%)	67 (32.2%)	121 (30.3%)
≥ Senior high school	14 (56.0%)	104 (57.5%)	120 (57.7%)	231 (57.8%)
Current smoker	1 (4.0%)	66 (36.5%)	55 (26.4%)	121 (30.3%)
Habitual drinker	1 (4.0%)	61 (33.7%)	35 (16.8%)	96 (24.0%)
Dietary pattern				
Diet rich in fruits and vegetables	9 (36.0%)	69 (38.1%)	100 (48.1%)	174 (43.5%)
High fat diet	1 (4.0%)	16 (8.8%)	22 (10.6%)	38 (9.5%)
Physical activity				
Low	19 (76.0%)	101 (55.8%)	131 (63.0%)	242 (60.5%)
Moderate	6 (24.0%)	72 (39.8%)	74 (35.6%)	147 (36.8%)
High	0 (0.0%)	8 (4.4%)	3 (1.4%)	11 (2.8%)
Awareness of diabetes	24 (96.0%)	130 (71.8%)	164 (78.8%)	305 (76.3%)
Control of diabetes	9 (36.0%)	38 (21.0%)	89 (42.8%)	133 (33.3%)
Self-reported HBV infection	0 (0.0%)	3 (1.7%)	11 (5.3%)	14 (3.5%)
Hypertension	18 (72.0%)	136 (75.1%)	106 (51.0%)	248 (62.0%)
Dyslipidemia	13 (52.0%)	67 (37.0%)	40 (19.2%)	113 (28.3%)
Hyperuricemia	3 (12.0%)	21 (11.6%)	19 (9.1%)	40 (10.0%)
Body mass index (kg/m2)	26.2 (3.0)	26.7 (3.3)	25.5 (3.4)	26.0 (3.4)
Total cholesterol (mmol/L)	4.7 (0.9)	4.6 (1.0)	4.4 (1.0)	4.5 (1.0)
Triglyceride (mmol/L)	2.2 (1.2)	2.6 (2.5)	1.3 (0.9 – 2.0)	2.2 (2.3)
LDL cholesterol (mmol/L)	2.5 (0.6)	2.6 (0.7)	2.4 (0.7)	2.5 (0.7)
HDL cholesterol (mmol/L)	1.2 (0.3)	1.2 (0.3)	1.2 (0.3)	1.2 (0.3)
Fasting plasma glucose (mmol/L)	8.6 (3.7)	9.1 (2.9)	7.6 (2.3)	8.3 (2.7)
Uric acid (μmol/L)	282.0 (203.0 – 347.0)	300.4 (99.1)	272.3 (93.3)	283.6 (97.0)
Creatinine (μmol/L)	97.5 (89.0 – 111.3)	8.4 (71.6 – 96.5)	77.8 (17.2)	82.9 (40.0)

eGFR (mL/min/1.73m2)	48.8 (12.9)	82.4 (20.1)	85.6 (16.5)	83.3 (18.6)
ACR (mg/g)	34.6 (12.4 – 172.7)	62.7 (39.4 – 196.7)	16.3 (7.5)	27.8 (14.5 – 53.5)

Note: Data were n (%), mean (standard deviation) or median with interquartile range, as appropriate.

Abbreviations: DKD, diabetic kidney disease; HBV, hepatitis B virus; LDL, low density lipoprotein; HDL, high density lipoprotein; eGFR, estimated glomerular filtration rate; ACR, albumin: creatinine ratio.

Table 4 Prevalence of indicators of renal damage in participants with diabetes, by disease stage

Renal indicator						Diabetic kidney disease (in 400 participants)	
	eGFR (mL/min/1.73m2)			Albuminuria			
Stage		n	Prevalence (95% CI)	n	Prevalence (95% CI)	N	Prevalence (95% CI)
1	> 90	143	35.8 (31.0 – 40.5)	63	15.8 (12.2 – 19.3)	63	15.8 (12.2 – 19.3)
2	60 – 89	232	58.0 (53.1 – 62.9)	104	26.0 (21.7 – 30.3)	104	26.0 (21.7 – 30.3)
3	30 – 59	22	5.5 (3.3 – 7.7)	11	2.8 (1.1 – 4.4)	22	5.5 (3.3 – 7.7)
3a	45 – 59	19	4.8 (2.7 – 6.8)	8	2.0 (0.6 – 3.4)	19	4.8 (2.7 – 6.8)
3b	30 – 44	3	0.8 (0.1 – 1.6)	3	0.8 (0.1 – 1.6)	3	0.8 (0.1 – 1.6)
4	15 – 29	2	0.5 (0.1 – 1.2)	2	0.5 (0.1 – 1.2)	2	0.5 (0.1 – 1.2)
5	< 15	1	0.3 (0.1 – 0.7)	1	0.3 (0.1 – 0.7)	1	0.3 (0.1 – 0.7)
Total		400	100	181	45.3 (40.4 – 50.1)	192	48.0 (43.1 – 52.9)

Note: Albuminuria was defined as urinary albumin to creatinine ratio ≥ 30mg/g creatinine. Diabetic kidney disease was defined as a combination of diabetes and an eGFR less than 60 mL/min/1.73m2 or presence of albuminuria.

Abbreviations: eGFR, estimated glomerular filtration rate.

Table 5 Adjusted prevalence of indicators of renal damage, hypertension and diabetes, by education and family income

	eGFR < 60mL/min/1.73m2	Albuminuria	CKD	Hypertension	Control of hypertension	Diabetes	Control of diabetes	DKD
Education								
≤ Primary school, tertile 1	2.3 (0.5 – 4.2)	31.9 (26.2 – 37.6)	33.5 (27.7 – 39.3)	51.8 (45.6 – 57.9)	15.8 (9.5 – 22.1)	18.7 (13.9 – 23.5)	33.3 (19.5 – 47.2)	4.7 (2.1 – 7.3)
Junior high school, tertile 2	2.1 (1.1 – 3.1)	29.6 (26.4 – 32.8)	31.0 (27.7 – 34.3)	47.9 (44.4 – 51.5)	15.6 (11.9 – 19.3)	15.6 (13.1 – 18.2)	39.7 (30.8 – 48.5)	7.1 (5.3 – 8.9)
≥ Senior high school, tertile 3	3.2 (2.7 – 3.7)	16.1 (15.0 – 17.2)	17.9 (16.7 – 19.0)	31.1 (29.7 – 32.5)	6.9 (5.5 – 8.3)	5.5 (4.8 – 6.2)	29.9 (23.9 – 35.8)	3.7 (3.1 – 4.2)
**P* trend	0.20	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.18	< 0.001
Family monthly income (RMB)								
≤ 5000, tertile 1	3.7 (2.0 – 5.5)	18.2 (14.6 – 21.7)	20.6 (16.8 – 24.3)	55.1 (50.6 – 59.7)	21.3 (16.3 – 26.4)	19.3 (15.6 – 22.9)	44.3 (33.7 – 54.9)	5.5 (3.4 – 7.6)
5000 –, tertile 2	2.6 (1.9 – 3.3)	18.1 (16.3 – 19.9)	20.0 (18.2 – 21.8)	35.4 (33.2 – 37.6)	9.3 (7.1 – 11.6)	6.7 (5.6 – 7.9)	27.4 (19.5 – 35.4)	3.1 (2.3 – 3.9)
≥ 7000, tertile 3	2.4 (1.0 – 3.9)	25.2 (21.2 – 29.2)	26.5 (22.4 – 30.6)	39.3 (34.8 – 43.8)	12.9 (7.9 – 17.9)	11.9 (8.9 – 14.9)	33.3 (20.3 – 46.3)	5.5 (3.4 – 7.6)
**P* trend	0.38	0.002	0.01	< 0.001	< 0.001	< 0.001	0.04	0.01

Note: Albuminuria was defined as urinary albumin to creatinine ratio ≥ 30mg/g creatinine. CKD was defined as an eGFR less than 60 mL/min/1.73m2 or presence of albuminuria. All prevalences were adjusted for synthesized weights.

Abbreviations: eGFR, estimated glomerular filtration rate; CKD, chronic kidney disease; DKD, diabetic kidney disease.

**P* trend was calculated by Cochran-Armitage test

Table 6 Factors associated with indicators of renal damage and diabetic kidney disease

	eGFR < 60 ml/min/1.73m2		Albuminuria		Diabetic kidney disease	
Age	Crude OR	Adjusted OR	Crude OR	Adjusted OR	Crude OR	Adjusted OR
18-	1.00	1.00	1.00	1.00	1.00	1.00
Age changed by 10 years	2.71 (2.34 – 3.13)	2.77 (2.32 – 3.32)	1.61 (1.52 – 1.71)	1.18 (1.08 – 1.28)	2.06 (1.84 – 2.31)	1.84 (1.58 – 2.13)
Gender						
Women	1.00	1.00	1.00	1.00	1.00	1.00
Men	0.17 (0.11 – 0.26)	0.16 (0.09 – 0.29)	1.70 (1.46 – 1.98)	1.18 (0.96 – 1.47)	1.74 (1.28 – 2.37)	1.57 (1.04 – 2.35)
Education						
≤ Primary school	1.00	1.00	1.00	1.00	1.00	1.00
Junior high school	0.51 (0.92 – 0.91)	1.23 (0.65 – 2.30)	0.61 (0.45 – 0.83)	0.60 (0.42 – 0.84)	0.64 (0.39 – 1.04)	0.81 (0.48 – 1.36)
≥ Senior high school	0.23 (0.14 – 0.38)	2.59 (1.41 – 4.77)	0.30 (0.23 – 0.39)	0.48 (0.35 – 0.68)	0.23 (0.15 – 0.36)	0.67 (0.40 – 1.14)
Current smoker	3.80 (1.92 – 7.50)	1.21 (0.50 – 2.93)	2.23 (1.90 – 2.62)	1.44 (1.17 – 1.78)	1.97 (1.45 – 2.67)	1.33 (0.90 – 1.97)
Alcohol consumption	4.90 (2.28 – 10.51)	1.81 (0.71 – 4.63)	2.11 (1.80 – 2.48)	1.16 (0.94 – 1.44)	1.78 (1.31 – 2.44)	1.01 (0.67 – 1.50)
Diet rich in fruits and vegetables	1.99 (1.40 – 2.83)	1.42 (0.96 – 2.10)	1.36 (1.17 – 1.57)	1.27 (1.07 – 1.50)	0.84 (0.63 – 1.14)	0.70 (0.51 – 0.97)
High fat diet	0.51 (0.28 – 0.96)	0.60 (0.30 – 1.18)	0.64 (0.51 – 0.81)	0.75 (0.58 – 0.96)	0.51 (0.30 – 0.86)	0.79 (0.46 – 1.37)
Physical activity						
Low	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.70 (0.47 – 1.04)	1.08 (0.69 – 1.68)	1.51 (1.30 – 1.76)	1.06 (0.89 – 1.27)	1.41 (1.04 – 1.90)	1.16 (0.83 – 1.62)
High	NA	NA	2.57 (1.71 – 3.86)	1.47 (0.93 – 2.30)	2.22 (1.06 – 4.67)	1.56 (0.71 – 3.44)
Body mass index						
Healthy weight	1.00	1.00	1.00	1.00	1.00	1.00
Underweight	0.54 (0.17 – 1.73)	1.26 (0.37 – 4.32)	0.61 (0.35 – 1.06)	0.91 (0.51 – 1.62)	0.21 (0.03 – 1.56)	0.34 (0.05 – 2.55)
Overweight	1.19 (0.80 – 1.77)	0.71 (0.45 – 1.11)	2.81 (2.35 – 3.37)	1.54 (1.26 – 1.88)	2.57 (1.78 – 3.72)	1.24 (0.83 – 1.83)
Obesity	1.75 (1.11 – 2.78)	1.05 (0.62 – 1.78)	4.99 (4.06 – 6.13)	2.30 (1.82 – 2.90)	4.98 (3.37 – 7.35)	2.20 (1.44 – 3.37)
Diabetes	2.94 (1.88 – 4.61)	1.13 (0.68 – 1.90)	5.06 (4.09 – 6.26)	2.71 (2.14 – 3.43)	NA	NA
Hypertension	2.90 (2.03 – 4.12)	1.81 (1.20 – 2.73)	4.61 (3.95 – 5.38)	2.79 (2.35 – 3.31)	5.73 (4.13 – 7.95)	2.80 (1.97 – 3.99)
Dyslipidemia	1.99 (1.33 – 2.97)	1.51 (0.96 – 2.36)	3.03 (2.54 – 3.60)	1.74 (1.43 – 2.12)	3.85 (2.85 – 5.21)	2.58 (1.86 – 3.58)
Hyperuricemia	1.39 (0.86 – 2.26)	1.57 (0.89 – 2.78)	1.70 (1.38 – 2.08)	0.96 (0.76 – 1.21)	0.95 (0.60 – 1.50)	2.15 (1.31 – 3.52)

Note: Data were crude and multivariable-adjusted odds ratio (95% Confidence Interval).

Abbreviation: DKD, diabetic kidney disease; NA, not applicable

Reference level: Gender = Woman; Education = Junior high school; Alcohol consumption = No; Diet rich in fruits and vegetables = No; High fat diet = No; Physical activity = Low; Body mass index = Healthy weight; Diabetes = No; Hypertension = No; Dyslipidemia = No; Hyperuricemia = No.

Table 7 Results of ordinal logistic regression for two Models

	Model 1 (N=5099)		Model 2 (N=5231)	
Age	Adjusted OR	*P*	Adjusted OR	*P*
18-	1.00		1.00	
Age changed by 10 years	1.11 (1.02 – 1.21)	0.01	1.32 (1.22 – 1.43)	< 0.001
Gender				
Women	1.00		1.00	
Men	1.18 (0.95 – 1.47)	0.13	0.88 (0.72 – 1.08)	0.23
Education				
≤ Primary school	1.00		1.00	
Junior high school	0.60 (0.42 – 0.85)	0.004	0.68 (0.49 – 0.93)	0.02
≥ Senior high school	0.46 (0.32 – 0.65)	< 0.001	0.61 (0.45 – 0.84)	0.002
Current smoker	1.44 (1.17 – 1.79)	< 0.001	1.41 (1.15 – 1.74)	0.001
Alcohol consumption	1.15 (0.93 – 1.43)	0.20	1.10 (0.89 – 1.36)	0.39
Diet rich in fruits and vegetables	1.30 (1.10 – 1.54)	0.002	1.32 (1.13 – 1.55)	0.001
High fat diet	0.73 (0.56 – 0.95)	0.02	0.73 (0.57 – 0.93)	0.01
Physical activity				
Low	1.00		1.00	
Moderate	1.07 (0.89 – 1.28)	0.49	1.07 (0.90 – 1.27)	0.42
High	1.57 (1.01 – 2.44)	0.05	1.46 (0.94 – 2.27)	0.09
Body mass index				
Underweight	1.00		1.00	
Healthy weight	1.21 (0.66 – 2.20)	0.54	1.13 (0.66 – 1.95)	0.66
Overweight	1.82 (1.00 – 3.33)	0.05	1.52 (0.88 – 2.64)	0.13
Obesity	2.71 (1.47 – 5.00)	< 0.001	2.34 (1.34 – 4.11)	< 0.001
Diabetes	2.98 (2.35 – 3.77)	< 0.001	2.72 (2.18 – 3.40)	< 0.001
Hypertension	2.80 (2.35 – 3.34)	< 0.001	2.73 (2.32 – 3.22)	< 0.001
Dyslipidemia	1.81 (1.49 – 2.20)	< 0.001	1.79 (1.48 – 2.15)	< 0.001
Hyperuricemia	0.99 (0.78 – 1.25)	0.93	1.09 (0.87 – 1.36)	0.45

Note: Data were multivariable-adjusted odds ratio (95% Confidence Interval) and *P* value for each variable.

Abbreviation: NA, not applicable

Reference level: Gender = Woman; Education = Primary school; Current smoker = No; Alcohol consumption = No; Diet rich in fruits and vegetables = No; High fat diet = No; Physical activity = Low; Body mass index = Underweight; Diabetes = No; Hypertension = No; Dyslipidemia = No; Hyperuricemia = No.

Figures

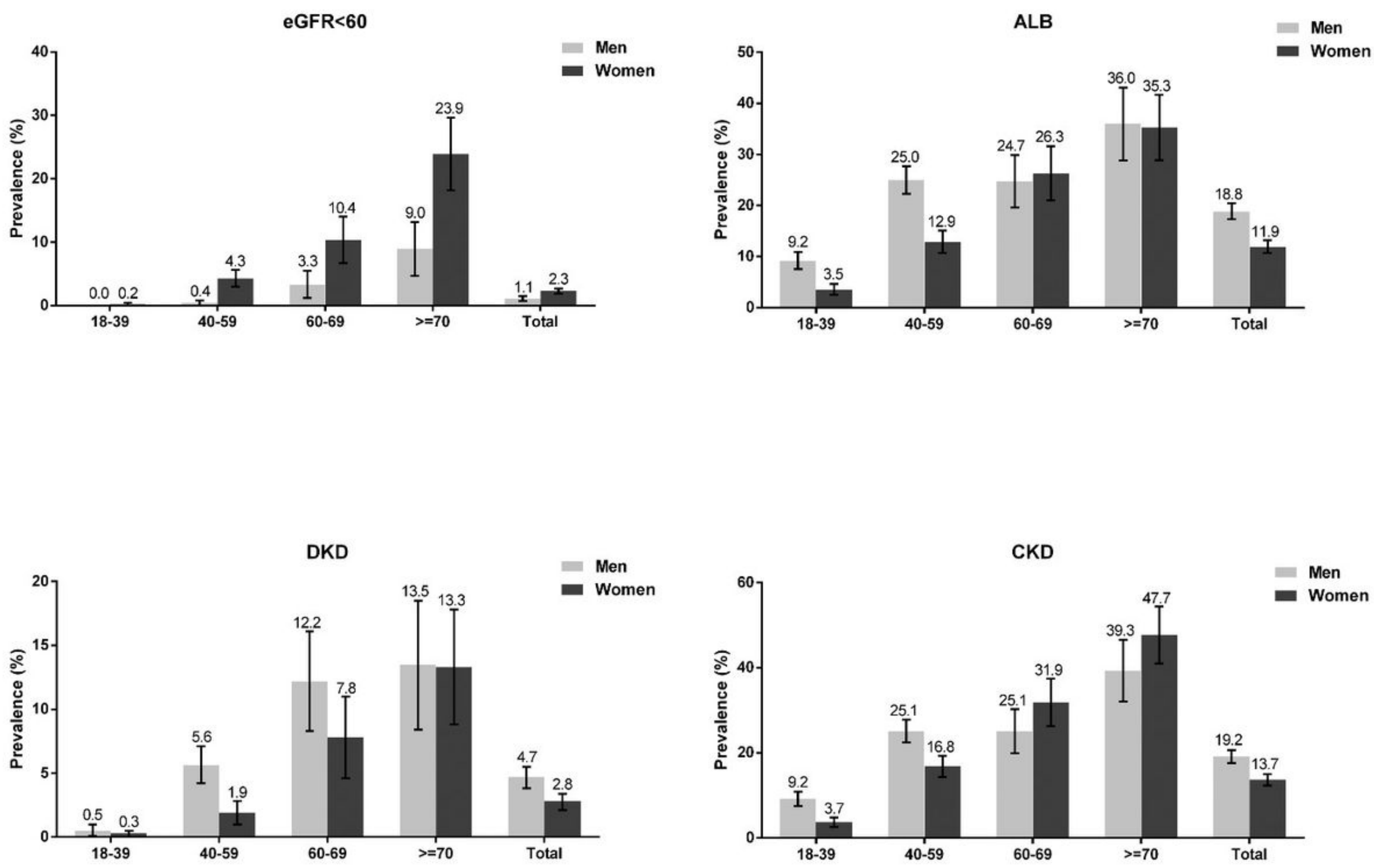

Figure 1

Adjusted prevalence of indicators of renal damage, DKD and CKD, stratified by sex and age. Adjusted prevalences of eGFR less than 60 mL/min/1.73m2 (eGFR < 60), albuminuria (ALB), diabetic kidney disease (DKD) and chronic kidney disease (CKD). Data expresses as prevalence and bars are 95% CIs.

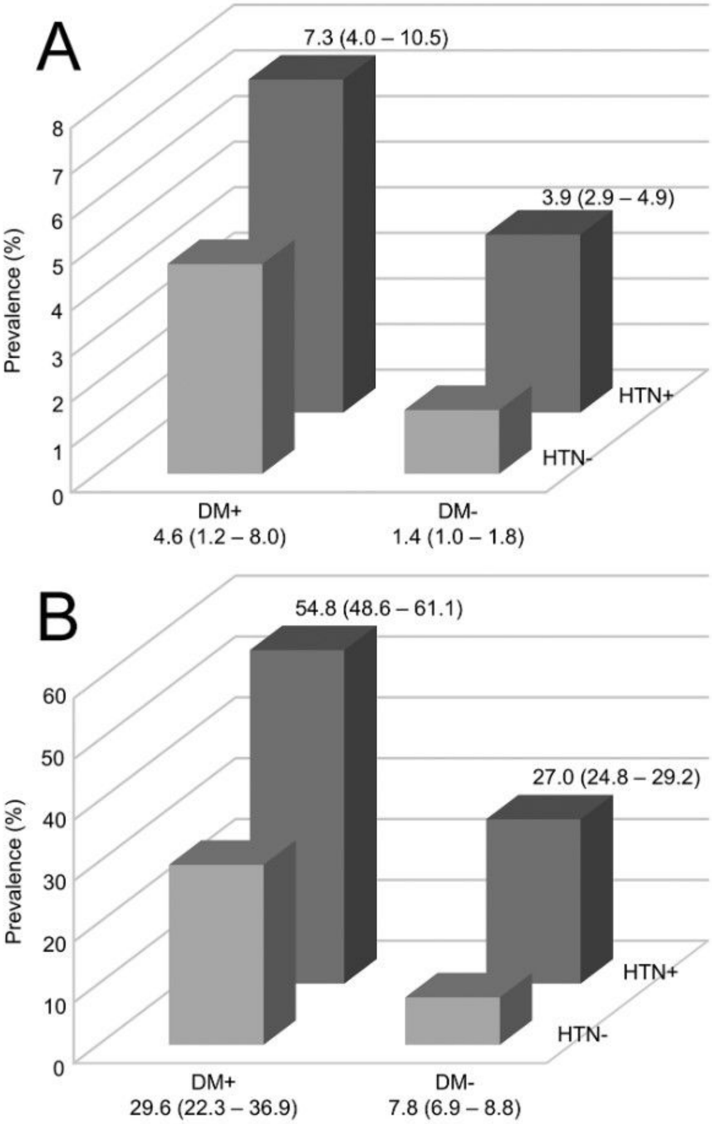

Figure 2

Prevalence of indicators of renal damage according to hypertension and diabetes. Prevalences of eGFR less than 60 mL/min/1.73m2 (A) and albuminuria (B). Data expresses as prevalence (95% CI for prevalence). DM refers to diabetes mellitus and HTN refers to hypertension.