Prevalence of chronic kidney disease among Chinese adults with diabetes: a nationwide population-based cross-sectional study

Weiping Jia,[a,b,o,*] Rong Yu,[a,o] Limin Wang,[c,o] Dalong Zhu,[d] Lixin Guo,[e] Jianping Weng,[f] Hong Li,[g] Mei Zhang,[c] Xiaoqi Ye,[a] Zhiguang Zhou,[h] Dajin Zou,[i] Qiuhe Ji,[j] Xiaohui Guo,[k] Yinan Zhang,[l] Dong Lang,[a] Jiarui Wu,[m,n] Jing Wu,[c,**] and Xuhong Hou,[a,***] for the China National Diabetic Chronic Complications (DiaChronic) Study Group[p]

[a]Department of Endocrinology and Metabolism, Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai Diabetes Institute, Shanghai Key Laboratory of Diabetes Mellitus, Shanghai Clinical Center for Diabetes, Shanghai Key Clinical Center for Metabolic Disease, Shanghai, China
[b]Institute for Proactive Healthcare of Shanghai Jiao Tong University, Shanghai, China
[c]National Center for Chronic and Noncommunicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing, China
[d]Department of Endocrinology, Drum Tower Hospital Affiliated to Nanjing University Medical School, Nanjing, Jiangsu Province, China
[e]Department of Endocrinology, Beijing Hospital, Beijing, China
[f]Department of Endocrinology, Institute of Endocrine and Metabolic Diseases, The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, Clinical Research Hospital of Chinese Academy of Sciences, University of Science and Technology of China, Hefei, Anhui Province, China
[g]Department of Endocrinology, The Affiliated Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University, Hangzhou, China
[h]Institute of Metabolism and Endocrinology, Key Laboratory of Diabetes Immunology, Ministry of Education, National Clinical Research Center for Metabolic Diseases, The Second Xiangya Hospital and the Diabetes Center, Central South University, Changsha, Hunan Province, China
[i]Department of Endocrinology, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[j]Department of Endocrinology, Xijing Hospital, Xi'an, Shaanxi Province, China
[k]Department of Endocrinology, Peking University First Hospital, Beijing, China
[l]Center for Translational Medicine, The Metabolic Diseases Biobank, Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai, China
[m]Key Laboratory of Systems Health Science of Zhejiang Province, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences, Hangzhou, Zhejiang Province, China
[n]Center for Excellence in Molecular Science, Chinese Academy of Sciences, Shanghai, China

The Lancet Regional Health - Western Pacific 2025;55: 101463
Published Online xxx
https://doi.org/10.1016/j.lanwpc.2024.101463

Summary

Background To date, comprehensive data on the distribution of chronic kidney disease (CKD), the most prevalent comorbidity in diabetes, among Chinese adults with diabetes is lacking. Additionally, research gaps exist in understanding the association between CKD and cardiovascular health (CVH), an integrated indicator of lifestyle and metabolic control, within a nationwide sample of Chinese adults with diabetes.

Methods A nationally community-based cross-sectional survey was conducted in 2018–2020. 58,560 residents diagnosed with diabetes aged 18–74 years nationwide were invited to participate, and 52,000 participants with complete CKD data were included in this study. CKD was identified by the presence of albuminuria (urine albumin-to-creatinine ratio ≥30 mg/g) and/or decreased estimated glomerular filtration rate (eGFR, <60 mL/min/1.73 m^2). The latter was calculated using the CKD-EPI equation incorporating serum cystatin C and creatinine. CVH was evaluated using the "life's essential 8" (LE8) score, which ranged from 0 to 100 and included 8 components: diet, sleep duration, physical activity, nicotine exposure, hemoglobin A1c, blood pressure, non–high-

*Corresponding author. Department of Endocrinology and Metabolism, Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai Diabetes Institute, Shanghai Key Laboratory of Diabetes Mellitus, Shanghai Clinical Center for Diabetes, Shanghai Key Clinical Center for Metabolic Disease, Shanghai, 200233, China.
**Corresponding author. National Center for Chronic and Noncommunicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, 27 Nanwei Road, Xicheng District, Beijing, 100050, China.
***Corresponding author. Department of Endocrinology and Metabolism, Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai Diabetes Institute, Shanghai Key Laboratory of Diabetes Mellitus, Shanghai Clinical Center for Diabetes, Shanghai Key Clinical Center for Metabolic Disease, 600 Yishan Road, Shanghai, 200233, China.
E-mail addresses: wpjia@sjtu.edu.cn (W. Jia), wujing@chinacdc.cn (J. Wu), houxuhong@sjtu.edu.cn (X. Hou).
[o]Prof Jia, Drs Yu and Wang contributed equally to this article.
[p]Listed in the Appendix pp 26–30.

density lipoprotein cholesterol, and body mass index. The total LE8 scores were categorized into low (0–49), middle (50–79), and high (80–100) according to the American Heart Association. The associations of albuminuria and decreased eGFR with potential associated factors, including CVH, socioeconomic status, clinical characteristics, sub-regional divisions, comorbidities, treatments, and metabolic controls, were evaluated using survey logistic regression.

Findings The weighted prevalence rates (95% CI) of CKD, albuminuria, and decreased eGFR were 32.6% (31.3%–33.8%), 30.8% (29.6%–32.1%), and 5.5% (5.1%–5.9%), respectively. Among those with CKD, 25.7% had diabetic retinopathy (DR) and 22.3% had cardiovascular disease (CVD). The weighted prevalence rates of albuminuria and decreased eGFR were consistently higher among southern residents, rural residents, and individuals with more severe DR and a history of CVD than their counterparts (all $p < 0.05$). After adjustment for age, sex, sub-regional division, setting, educational level, annual household income, family history of diabetes, diabetes duration, glucose-lowering treatment, any DR, CVD, and drinking status, the logistic models showed that the odds ratios (ORs) (95% CI) for albuminuria and decreased eGFR were 0.46 (0.42–0.51) and 0.61 (0.55–0.67) for the participants with moderate scores, and 0.14 (0.10–0.21) and 0.28 (0.19–0.41) for those with high scores, compared with those with low total LE8 scores. Furthermore, the restricted cubic spline curves depicted that the disparities in the odds of having albuminuria or decreased eGFR among subpopulations grouped by sex, age, setting, and geographical region, significantly decreased and even disappeared in some cases as the LE8 scores increased.

Interpretation Chinese adults with diabetes are heavily burdened by CKD. Optimized CVH is central to reducing CKD risk across different subpopulations.

Funding National Key Clinical Specialty, the Chinese Academy of Engineering.

Keywords: Diabetes; Chronic kidney disease; Prevalence; Cardiovascular health

Introduction

The global aggravated burden of diabetes has positioned it as a leading contributor to chronic kidney disease (CKD) and end-stage kidney disease (ESKD).[1] The incident cases of CKD due to type 2 diabetes increased by 74% worldwide during the past three decades.[2] Meanwhile, the proportion of incident ESKD attributed to diabetes escalated from 22.1% in 2000 to 31.3% in 2015 globally.[3] It was estimated that approximately 27% of global type 2 diabetes patients lived with CKD.[4]

CKD in diabetes imposes a disproportionately heavy burden on low- and middle-income countries, particularly China, which has the largest number of people with diabetes worldwide. In 2017, more than one-fifth of dialysis patients in China had diabetes.[5] Furthermore, the all-age mortality (per 100,000) attributed to diabetes-related CKD in China increased by 33.3%, from 4.5 in 1990 to 6.0 in 2016.[6] These challenges underscored the imperative of understanding the distribution of CKD in diabetes to curb its epidemic. However, the key information from existing data was severely limited.[7,8]

In 2021, the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) proposed a new equation for the estimated glomerular filtration rate (eGFR) that incorporated serum cystatin C (Scys) alongside creatinine (Scr).[9] Multiple professional societies have recommended this composite equation, as it has been proven to be more accurate than those using individual markers alone.[10,11] However, there is a notable paucity of data on the use of this equation in national surveys in China.

Interventions targeting improved lifestyle and better metabolic control are crucial for reducing the incidence and slowing the progression of CKD among people with diabetes.[11] The updated construct of cardiovascular health (CVH) proposed by the American Heart Association (AHA), known as "Life's Essential 8 (LE8)", has garnered widespread attention.[12] Recent studies also revealed its negative correlation with diabetes-related complications.[13,14] To date, no large-scale study has investigated the association between the LE8 scores and CKD among individuals with diabetes in China.

Using data from the first community-based survey of Chinese adults with diabetes, we systematically investigated the distribution characteristics of CKD and explored associated factors, including LE8, based on the new eGFR equation.

Methods

Study design and participants

The China National Diabetic Complications Study (China DiaChronic Study) was a nationwide community-based cross-sectional survey conducted from March 2018 to January 2020.[15,16] It aimed to

Research in context

Evidence before this study

We searched PubMed and the Wanfang Data Knowledge Service Platform for articles published in English or Chinese up to June 2024. We included MeSH and free terms related to "chronic kidney disease", "prevalence", "serum cystatin C", "diabetes", "cardiovascular health", "life's essential 8", and "China", or variations of these terms. We reviewed the titles and abstracts of these papers to identify relevant studies. We found that two large-scale surveys in China only reported the prevalence of chronic kidney disease (CKD) in subgroups with diabetes within the general population. One survey covering 13 provinces in 2009–2010 reported that among all 47,204 participants, 3488 had diabetes, and approximately 21.3% of the participants with diabetes had CKD (https://doi.org/10.1016/S0140-6736(12)60033-6; https://doi.org/10.1056/NEJMc1602469). Another survey reported that the prevalence of CKD among subgroups with previously diagnosed diabetes was 25.4% in 2018–2019 (https://doi.org/10.1001/jamainternmed.2022.6817). However, these surveys did not further analyse the distribution of CKD in diabetes nor its related factors. Additionally, multiple professional societies have recommended adopting the more accurate equation for estimated glomerular filtration rate (eGFR) that excludes the race variable and incorporates serum cystatin C alongside creatinine, as proposed by CKD-EPI, as another first-line test. However, there is a notable paucity of data on the use of this equation in large populations of Chinese people with diabetes. More importantly, no systematic survey has investigated the associations between cardiovascular health (CVH) and the distribution of CKD among nationwide Chinese adults with diabetes.

Added value of this study

To our knowledge, this study, based on a national sample of Chinese adults diagnosed with diabetes, is the first to provide comprehensive estimates of the prevalence of CKD, albuminuria, and decreased eGFR among the total and various subpopulations. Approximately 39.0 million patients with diabetes (one-third) lived with CKD in China. Among those with CKD, approximately one-fourth had diabetic retinopathy (DR) and over one-fifth had cardiovascular disease (CVD). The prevalence rates of albuminuria and decreased eGFR were consistently higher among southern residents, rural residents, individuals with more severe stages of DR, and those with a history of CVD compared with their counterparts. We calculated the "life's essential 8" (LE8) score to assess CVH, a construct recently updated by the American Heart Association, which consists of four health behaviors (diet, nicotine exposure, physical activity, sleep duration) and four health factors (hemoglobin A1c, blood pressure, non-high-density lipoprotein cholesterol, and body mass index). The odds ratios for albuminuria were inversely associated with total and individual LE8 scores. The disparities in the odds of having albuminuria or decreased eGFR among subpopulations grouped by sex, age, setting, and geographical region, significantly decreased and even disappeared in some cases as the LE8 scores increased.

Implications of all the available evidence

These findings provided a detailed distribution map of the CKD burden among Chinese adults with diabetes. Our results also showed that optimized CVH, as measured by the LE8 scores—which included four health behaviors and four health factors—was crucial to reducing CKD risk both overall and across different subpopulations. This information helps identify vulnerable populations and highlights the urgent need for targeted and multifaceted prevention strategies, such as early screening for high-risk individuals, promoting healthy lifestyles, and improving metabolic control. These enriched and systematic data from this study will significantly contribute to contemporary public health efforts to prevent the development of CKD and promote related research. Insights from China would be invaluable in guiding the global response to the challenges posed by diabetes and its complications.

investigate the epidemiological characteristics and management status of diabetes-related complications and comorbidities in Chinese adults with physician-diagnosed diabetes. Details of the design and data collection of the study have been described elsewhere.[15,16] Briefly, we selected 122 disease surveillance points (DSPs) from the China Chronic Disease and Risk Factor Surveillance, covering 65 urban districts and 57 rural counties across 31 provinces, autonomous regions, and municipalities. Next, 488 neighborhoods/villages were selected, with four neighborhoods from each urban district and four villages from each rural county. We then sampled 113 registered individuals with diabetes from each neighborhood or village. Finally, we sampled a total of 58,560 eligible individuals with diagnosed diabetes, based on the designed sex and age structure, excluding pregnant women and those with severe health conditions. Ultimately, 53,401 participants aged 18–74 took part in the survey, with a 91.2% response rate. This study included a total of 52,000 participants after excluding 822 participants with self-reported urinary tract infections and 579 lacking data on Scr, Scys, urine creatinine (Ucr), and/or urine albumin (Ualb) (Appendix p 3). Compared to the included participants, the excluded participants (n = 1401) were more likely to be female, older, residing in the northern region, and with lower education levels and household incomes. However, there were no significant differences in the

regional distribution, education levels, or household income between participants with incomplete CKD diagnosis data (n = 579) and those included in the analysis (Appendix p 4). As antibody tests to confirm diabetes phenotypes were not conducted in this study, diabetes phenotypes were determined based on self-reports. Among the 52,000 participants, 66.35% had type 2 diabetes, 2.33% had type 1 diabetes, 0.46% had a special type of diabetes, and 30.87% reported being unaware of their diabetes type.

The Ethics Review Committee of Shanghai Sixth People's Hospital approved the study protocol (Approval No: 2018–010). Each participant signed an informed consent form.

Data collection

Trained medical staff collected information on demographics, diet, physical activity (PA), sleep duration, smoking and drinking status, family history of diseases, and medication history using standardized questionnaires (Supplementary Material 2).[16] We collected data on alcohol consumption, including type (with reported alcohol content), frequency, duration, and cessation. The weekly ethanol intake (g/week) was calculated by multiplying the alcohol content of each beverage by the total weekly consumption, then by 0.8. Following a standard protocol, blood pressure (BP), height, and weight were measured. Body mass index (BMI) was calculated using the weight (kg) divided by the square of height (m^2). Each participant underwent non-mydriatic fundus examinations, with four photographs taken (two for each eye, one centered on the optic disc and the other on the macula). These photographs were assessed by two experienced ophthalmologists. For discordant diagnoses, the photographs were forwarded to a third ophthalmologist for reevaluation.

After over 10-h overnight fasting, blood samples and random urine samples were collected. Glucose indices (hemoglobin A1c [HbA1c], fasting plasma glucose, and glycated albumin), lipid profile (triglyceride, total cholesterol [TC], high-density lipoprotein cholesterol [HDL-C], and low-density lipoprotein cholesterol [LDL-C]), and renal function indicators (Scr, Scys, Ucr, Ualb, and uric acid [UA]) were measured. Non-HDL-C was calculated by subtracting HDL-C from TC. Scys was measured with Latex-enhanced immune turbidification. Scr, Ucr, and UA were all measured with the enzymatic method. Ualb was tested using immunoturbidimetry. The eGFR was calculated using the new CKD-EPI equation and named CKD-EPIcr-cys.[9] We also calculated eGFRs using three other CKD-EPI equations: the equations proposed in 2009 and in 2021 with Scr alone (named CKD-EPIcr09 and CKD-EPIcr21),[9,17] and the equation proposed in 2012 with Scys alone (named CKD-EPIcys12).[18]

Outcomes

Decreased eGFR was defined as eGFR <60 mL/min/1.73 m^2.[11] Albuminuria was defined as urine albumin-to-creatinine ratio (UACR) ≥30 mg/g.[11] Micro- and macro-albuminuria was defined as UACR 30–300 and > 300 mg/g.[11] CKD was defined as the presence of decreased eGFR and/or albuminuria.[11]

Associated factors

Ethnicity was divided into Han, Manchu, Zhuang, Uyghur, Hui, Tibetan, and other. Broad geographical regions were categorized into northern and southern areas along the Qinling-Huaihe Line, and further subdivided into seven sub-regional divisions: north, south, east, central, northwest, northeast, and southwest. Educational levels were classified into primary school or below, secondary school, high school, and college or above. Smoking status was classified as never, former, and current. Secondhand smoke exposure was defined as the average exposure to secondhand smoke for at least 15 min per week at home, workplace, or indoor public places. Drinking status was categorized as never, former, and current. Current drinking was further divided into light and heavy drinking, with heavy drinking defined as consuming over 140 g/week of alcohol for females or 210 g/week for males.

Any diabetic retinopathy (DR) was defined as the presence of non-proliferative DR (NPDR), proliferative DR (PDR), and/or diabetic maculopathy.[19,20] Vision-threatening DR was defined as the presence of severe NPDR, PDR, and/or clinically significant macular edema. Cardiovascular disease (CVD) was determined based on a physician-diagnosed history of angina pectoris, myocardial infarction, heart failure, cerebral hemorrhage, and/or cerebral infarction. Hypertension was defined as a physician-diagnosed history, taking antihypertensive treatment, and/or having an average systolic BP (SBP) over 140 mmHg and/or diastolic BP (DBP) over 90 mmHg. Metabolic control targets were defined as HbA1c <7%, BP < 130/80 mmHg, and LDL-C <100 mg/dL. The LE8 scores were categorized into low (0–49), moderate (50–79), and high (80–100).[12]

CVH

According to the AHA, the LE8 scores encompassed 8 components, including four health behaviors (diet, sleep health, nicotine exposure, and PA) and four health factors (blood glucose, BP, blood lipids, and BMI).[12] The LE8 scoring algorithms for this study participants are detailed in Appendix pp 5–7. The Dietary Approaches to Stop Hypertension (DASH) diet component's scoring algorithm was modified due to the food frequency questionnaires used, as shown in Appendix p 5. Scores for all components ranged from 0 to 100, except for the blood glucose component, which was adjusted to range from 0 to 40 due to the exclusive inclusion of the participants, as detailed in Appendix pp 6–7.

Statistical analysis

The Kolmogorov–Smirnov test was used to assess the normality of continuous variables, all of which were

skewedly distributed (all $p < 0.05$). Descriptive data were presented as medians (25th–75th percentiles) for continuous variables and frequencies (percentages) for categorical variables. Differences between groups were compared using the Wilcoxon rank sum test or Kruskal–Wallis test for continuous variables and the χ^2 test for categorical variables.

Survey weights were derived from the data on adult with diabetes from the 2018 China Chronic Disease and Risk Factors Surveillance (CCDRFS) study.[21] Briefly, the survey weights are the reciprocals of the selection probability for the participants included in the final analysis, with each participant's weight coefficient applied in analyses to represent the population with similar characteristics (gender, age, and setting). For the prevalence estimations and logistic regression analyses, the STRATA, CLUSTER, and WEIGHT statements in the SAS PROC SURVEYFREQ and PROC SURVEYLOGISTIC procedures were used to account for provinces, DSPs, and survey weights, ensuring alignment with the survey design. We also accounted for the finite population correction (FPC) by incorporating the FPC values for each stratum (totaling 2850 study sites across 31 provinces for selection) with the TOTAL = option within the PROC SURVEYFREQ and PROC SURVEYLOGISTIC statements. Differences in proportions between groups were tested using the Rao-Scott chi-square test, with results from multiple comparisons adjusted via the Bonferroni correction. The linear trend of proportions across ordinal groups was assessed by treating the median of each subgroup as a quasi-continuous variable in a binary logistic regression model. The associations of albuminuria and decreased eGFR with associated factors were evaluated using the multivariable binary logistic regression. The potential factors were selected if they were reported in the literature or related to the outcomes. These variables included age, sex, sub-regional division, setting, educational level, annual household income, family history of diabetes, drinking status, diabetes duration, glucose-lowering treatment, any DR, CVD, along with total or individual component of LE8 scores. Model 1 included age, sex, and each potential above-mentioned factor (entered separately). Model 2 included these factors simultaneously (hereafter referred to as the fully-adjusted model). We evaluated the nonlinear relationships of the outcomes with the total LE8 scores and individual component (except the nicotine exposure) using the restricted cubic spline (RCS) analyses in the fully-adjusted logistic models in the R software. The models of each LE8 individual component were further adjusted for other components. The number of knots for each spline was selected between 3 and 5, and determined based on the minimum Akaike Information Criterion. Since there is currently no standardized cut-off value for the total LE8 score, non-HDL-C, DASH diet score, and PA in the literature, the point at which the odds ratio (OR) equals 1 was used as the cut-off for the RCS analyses. The cut-off values for HbA1c, SBP, DBP, BMI, and sleep duration were set at 7%, 130 mmHg, 80 mmHg, 25 kg/m^2, and 7 h, respectively.

All analyses were conducted using SAS (version 9.4, SAS Institute) and R software (version 4.3.2). All tests were two-sided, and a $p < 0.050$ was considered statistically significant.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Characteristics of study participants

Of the 52,000 participants, half were females, and the median age was 57.7 years. Among them, 51.1% were from broad southern regions, and 53.3% resided in urban areas. Compared to people without CKD, those with CKD have a higher proportion of males, non-Han ethnicity, residents living in the broad southern region (specifically the sub-regional southwest) or rural areas, and were generally older. Participants without CKD had higher levels of education and household income. Furthermore, those without CKD also exhibited healthier lifestyle behaviors and better metabolic profiles, and had higher proportions of moderate to high overall LE8 scores than participants with CKD (Table 1, Appendix p 8). The characteristics of the study population stratified by LE8 score categories are presented in Appendix pp 9–12.

Prevalence of CKD

Overall, the weighted prevalence rates were as follows: 32.6% (95% confidence interval [CI], 31.3%–33.8%) for CKD, 30.8% (95% CI, 29.6%–32.1%) for albuminuria, which included 24.1% (95% CI, 23.2%–25.0%) for microalbuminuria and 6.8% (95% CI, 6.2%–7.3%) for macroalbuminuria, and 5.5% (95% CI, 5.1%–5.9%) for decreased eGFR. It was estimated that approximately 39.0 million adults with diabetes were living with CKD, 36.9 million with albuminuria, and 6.6 million with decreased eGFR in China (Table 2).

The prevalence of the three outcomes (albuminuria, decreased eGFR, and CKD) significantly increased with age and diabetes duration, but decreased with higher LE8 scores (all p for linear trend <0.0001).

Sex disparities in the prevalence of the three main outcomes were not observed. Tibetans had the highest prevalence of CKD and albuminuria, while Han Chinese had the lowest. The Zhuang showed the highest prevalence of decreased eGFR, whereas the Uyghur had

	Total (n = 52,000)	CKD		
		No CKD (n = 34,597)	CKD (n = 17,403)	p value[b]
Demographic				
Gender	–	–	–	0.0030
Male	26,006 (50.0)	17,143 (49.6)	8863 (50.9)	–
Female	25,994 (50.0)	17,454 (50.4)	8540 (49.1)	–
Age, median (IQR), y	57.7 (51.1–65.0)	56.9 (50.4–64.2)	59.3 (52.6–66.5)	<0.0001
Ethnicity	–	–	–	<0.0001
Han	47,524 (91.4)	31,927 (92.3)	15,597 (89.6)	–
Manchu	568 (1.1)	372 (1.1)	196 (1.1)	–
Zhuang	479 (0.9)	294 (0.8)	185 (1.1)	–
Uyghur	859 (1.7)	481 (1.4)	378 (2.2)	–
Hui	790 (1.5)	500 (1.4)	290 (1.7)	–
Tibetan	640 (1.2)	331 (1.0)	309 (1.8)	–
Other	1140 (2.2)	692 (2.0)	448 (2.6)	–
Broad geographical region[c]	–	–	–	<0.0001
North	25,429 (48.9)	17,647 (51.0)	7782 (44.7)	–
South	26,571 (51.1)	16,950 (49.0)	9621 (55.3)	–
Sub-regional division[d]	–	–	–	<0.0001
North	8852 (17.0)	6436 (18.6)	2416 (13.9)	–
South	4760 (9.2)	3099 (9.0)	1661 (9.5)	–
East	12,622 (24.3)	8511 (24.6)	4111 (23.6)	–
Central	5588 (10.7)	3510 (10.1)	2078 (11.9)	–
Northwest	6962 (13.4)	4544 (13.1)	2418 (13.9)	–
Northeast	5192 (10.0)	3507 (10.1)	1685 (9.7)	–
Southwest	8024 (15.4)	4990 (14.4)	3034 (17.4)	–
Setting	–	–	–	<0.0001
Urban	27,722 (53.3)	19,028 (55.0)	8694 (50.0)	–
Rural	24,278 (46.7)	15,569 (45.0)	8709 (50.0)	–
Socio-economic status				
Educational level	–	–	–	<0.0001
Primary school or below	22,685 (43.6)	13,914 (40.2)	8771 (50.4)	–
Secondary school	16,112 (31.0)	10,979 (31.7)	5133 (29.5)	–
High school	9020 (17.3)	6476 (18.7)	2544 (14.6)	–
College or above	4183 (8.0)	3228 (9.3)	955 (5.5)	–
Average household income per capita in 2017	–	–	–	<0.0001
<10,000¥	14,824 (28.5)	9598 (27.7)	5226 (30.0)	–
10,000¥–<20,000¥	10,398 (20.0)	6908 (20.0)	3490 (20.1)	–
≥20,000¥	14,266 (27.4)	10,179 (29.4)	4087 (23.5)	–
Unwilling to disclose	12,512 (24.1)	7912 (22.9)	4600 (26.4)	–
Lifestyle behavior[e]				
DASH diet score, median (IQR)	25.0 (22.0–29.0)	26.0 (22.0–29.0)	25.0 (21.0–28.0)	<0.0001
Physical activity				
Moderate intensity activity per week	–	–	–	<0.0001
No	8615 (16.6)	5390 (15.6)	3225 (18.5)	–
Yes	43,385 (83.4)	29,207 (84.4)	14,178 (81.5)	–
Vigorous intensity activity per week	–	–	–	<0.0001
No	42,348 (81.4)	27,968 (80.8)	14,380 (82.6)	–
Yes	9652 (18.6)	6629 (19.2)	3023 (17.4)	–
Nicotine exposure				
Smoking status	–	–	–	<0.0001
Never	35,464 (68.2)	23,862 (69.0)	11,602 (66.7)	–
Former	4516 (8.7)	2868 (8.3)	1648 (9.5)	–
Current	12,020 (23.1)	7867 (22.7)	4153 (23.9)	–

(Table 1 continues on next page)

	Total (n = 52,000)	CKD		
		No CKD (n = 34,597)	CKD (n = 17,403)	p value[b]
(Continued from previous page)				
Smoking cessation duration, median (IQR), y	6.0 (2.0–15.0)	6.0 (2.0–15.0)	6.0 (2.0–14.0)	0.64
Secondhand smoke exposure	–	–	–	0.29
No	26,745 (51.4)	17,737 (51.3)	9008 (51.8)	–
Yes	25,255 (48.6)	16,860 (48.7)	8395 (48.2)	–
Drinking status	–	–	–	<0.0001
Never	35,168 (67.6)	23,298 (67.3)	11,870 (68.2)	–
Former	2670 (5.1)	1585 (4.6)	1085 (6.2)	–
Light	11,331 (21.8)	7860 (22.7)	3471 (19.9)	–
Heavy	2831 (5.4)	1854 (5.4)	977 (5.6)	–
Sleep health				
Average hours of sleep per night	–	–	–	<0.0001
7–9, h	26,162 (50.4)	17,834 (51.6)	8328 (47.9)	–
Other	25,767 (49.6)	16,722 (48.4)	9045 (52.1)	–
Clinical indicator[c]				
Family history of diabetes	–	–	–	<0.0001
No	30,749 (59.1)	20,248 (58.5)	10,501 (60.3)	–
Yes	21,251 (40.9)	14,349 (41.5)	6902 (39.7)	–
Diabetes duration, median (IQR), y	5.3 (2.5–10.1)	4.9 (2.2–9.4)	6.4 (3.2–11.3)	<0.0001
Any DR	–	–	–	<0.0001
No	40,977 (83.1)	29,088 (87.4)	11,889 (74.3)	–
Non-VTDR	6688 (13.6)	3632 (10.9)	3056 (19.1)	–
VTDR	1633 (3.3)	572 (1.7)	1061 (6.6)	–
History of CVD	–	–	–	<0.0001
No	42,248 (81.2)	28,731 (83.0)	13,517 (77.7)	–
Yes	9750 (18.8)	5864 (17.0)	3886 (22.3)	–
Hypertension	–	–	–	<0.0001
No	26,236 (50.5)	19,722 (57.0)	6514 (37.4)	–
Yes	25,739 (49.5)	14,859 (43.0)	10,880 (62.6)	–
BMI, median (IQR), kg/m^2	25.4 (23.2–27.8)	25.3 (23.1–27.6)	25.8 (23.5–28.3)	<0.0001
FPG, median (IQR), mg/dL	145.9 (118.4–188.6)	138.7 (113.9–174.1)	164.5 (130.3–219.3)	<0.0001
HbA1c, median (IQR), %	7.2 (6.3–8.7)	7.0 (6.1–8.2)	7.9 (6.7–9.5)	<0.0001
GA, median (IQR), %	18.6 (15.8–22.9)	17.9 (15.4–21.6)	20.2 (16.9–25.0)	<0.0001
SBP, median (IQR), mmHg	135.3 (123.3–149.7)	132.0 (120.7–144.7)	143.3 (130.0–158.0)	<0.0001
DBP, median (IQR), mmHg	79.7 (72.7–87.0)	78.7 (71.7–85.3)	82.3 (74.7–90.3)	<0.0001
TC, median (IQR), mg/dL	188.8 (162.5–217.0)	186.5 (161.4–213.1)	193.8 (164.9–225.1)	<0.0001
HDL-C, median (IQR), mg/dL	46.7 (39.0–56.4)	47.5 (39.8–57.1)	45.6 (37.8–55.2)	<0.0001
Non-HDL-C, median (IQR), mg/dL	139.4 (113.9–167.6)	136.7 (112.0–163.3)	145.6 (117.8–176.4)	<0.0001
LDL-C, median (IQR), mg/dL	114.3 (90.0–139.4)	113.9 (90.7–138.2)	115.1 (88.8–142.5)	0.017
TG, median (IQR), mg/dL	155.8 (108.0–235.4)	147.8 (102.7–217.7)	177.0 (121.2–273.5)	<0.0001
Scr, median (IQR), mg/dL	0.8 (0.7–0.9)	0.8 (0.7–0.9)	0.8 (0.7–1.0)	<0.0001
Scys, median (IQR), mg/L	0.9 (0.8–1.0)	0.9 (0.8–1.0)	1.0 (0.8–1.2)	<0.0001
UA, median (IQR), mg/dL	5.3 (4.3–6.4)	5.2 (4.3–6.2)	5.5 (4.5–6.7)	<0.0001
UACR, median (IQR), mg/g	13.5 (5.4–42.3)	7.5 (3.9–14.2)	74.9 (42.1–205.7)	<0.0001
eGFR, median (IQR), mL/min/1.73m^2	96.2 (81.7–108.8)	98.8 (86.4–109.9)	88.6 (67.8–105.6)	<0.0001
Life's essential 8 score[c]				
LE8 scores	–	–	–	<0.0001
Low	9875 (19.2)	5107 (14.9)	4768 (27.7)	–
Moderate	39,638 (77.0)	27,418 (79.9)	12,220 (71.1)	–
High	1994 (3.9)	1793 (5.2)	201 (1.2)	–

(Table 1 continues on next page)

	Total (n = 52,000)	CKD		
		No CKD (n = 34,597)	CKD (n = 17,403)	p value[b]
(Continued from previous page)				
Medication[e,f]				
Glucose-lowering treatment	–	–	–	<0.0001
No	11,044 (21.2)	8153 (23.6)	2891 (16.6)	–
Yes	40,956 (78.8)	26,444 (76.4)	14,512 (83.4)	–
Non-insulin therapy	34,409 (66.2)	22,775 (65.8)	11,634 (66.9)	0.020
Insulin therapy	6547 (16.0)	3669 (13.9)	2878 (19.8)	<0.0001
Antihypertensive treatment	–	–	–	<0.0001
No	31,630 (60.8)	22,799 (65.9)	8831 (50.7)	–
Yes	20,368 (39.2)	11,796 (34.1)	8572 (49.3)	–
ACEI/ARB	–	–	–	<0.0001
No	43,272 (83.2)	29,441 (85.1)	13,831 (79.5)	–
Yes	8726 (16.8)	5154 (14.9)	3572 (20.5)	–
Lipid-lowering treatment	–	–	–	0.00072
No	45,696 (87.9)	30,521 (88.2)	15,175 (87.2)	–
Yes	6302 (12.1)	4074 (11.8)	2228 (12.8)	–
Statin	–	–	–	0.0017
No	46,639 (89.7)	31,133 (90.0)	15,506 (89.1)	–
Yes	5361 (10.3)	3464 (10.0)	1897 (10.9)	–
Attainment of target[e]				
Attainment of HbA1c	–	–	–	<0.0001
No	29,438 (56.6)	17,310 (50.0)	12,128 (69.7)	–
Yes	22,555 (43.4)	17,284 (50.0)	5271 (30.3)	–
Attainment of BP	–	–	–	<0.0001
No	36,635 (70.5)	22,395 (64.8)	14,240 (81.9)	–
Yes	15,332 (29.5)	12,183 (35.2)	3149 (18.1)	–
Attainment of LDL-C	–	–	–	0.17
No	34,099 (65.6)	22,757 (65.8)	11,342 (65.2)	–
Yes	17,901 (34.4)	11,840 (34.2)	6061 (34.8)	–

CKD = chronic kidney disease. DASH = Dietary Approaches to Stop Hypertension. DR = diabetic retinopathy. VTDR = vision-threatening diabetic retinopathy. CVD = cardiovascular disease. BMI = body-mass index. FPG = fasting plasma glucose. HbA1c = hemoglobin A1c. GA = glycated albumin. SBP = systolic blood pressure. DBP = diastolic blood pressure. TC = total cholesterol. HDL-C = high-density lipoprotein cholesterol. LDL-C = low-density lipoprotein cholesterol. TG = triglycerides. Scr = serum creatinine. Scys = serum cystatin-C. UA = uric acid. UACR = urine albumin-to-creatinine ratio. eGFR = estimated glomerular filtration rate. LE8 = life's essential 8. ACEI/ARB = angiotensin-converting enzyme inhibitor or angiotensin receptor blocker. BP = blood pressure. SI conversion factors: To convert FPG to mmol/L, multiply values by 0.0555; TC, HDL-C, Non-HDL-C, LDL-C to mmol/L multiply by 0.0259; TG to mmol/L, multiply values by 0.0113; Scr to μmol/L multiply by 88.4; UA to μmol/L multiply by 59.5. [a]Data are presented as number (percentage) of participants unless otherwise specified. Due to rounding, totals may not add to 100%. [b]p-values are derived by comparing the differences in distributions or proportions of variables between the participants with and without CKD. The Wilcoxon rank sum test is used for continuous variables and the Chi–Square test for categorical variables. [c]The northern regions include Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; the Southern regions include Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, and Tibet. [d]The sub-region north includes Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia. The sub-region south includes Guangdong, Guangxi, Hainan. The sub-region east includes Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong. The sub-region central includes Henan, Hubei, Hunan. The sub-region northwest includes Shaanxi, Gansu, Qinghai, Ningxia. The sub-region northeast includes Liaoning, Jilin, Heilongjiang. The sub-region southwest includes Chongqing, Sichuan, Guizhou, Yunnan, and Tibet. [e]There are 71, 2702, 2, 25, 16, 27, 7, 5, 33, 493, 2, and 2 missing values for sleep duration, any DR, history of CVD, hypertension, BMI, FPG, HbA1c, GA, BP, LE8 scores, antihypertensive treatment, and lipid-lowering treatment, respectively. [f]Glucose-lowering treatment includes oral agent therapy and/or insulin therapy. Antihypertensive treatment includes angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, aldosterone, β-blocker, α-blocker, diuretic, calcium antagonist, and others. Lipid-lowering treatment includes statin, fibrate, and others.

Table 1: **Characteristics of study participants by the presence of chronic kidney disease.**[a]

the lowest. Regionally, people in the broad southern region consistently had higher prevalence rates of the three primary outcomes compared to their northern counterparts. In sub-regional divisions, individuals in the sub-regional central and sub-regional southwest exhibited higher prevalence rates of CKD and albuminuria compared to those in the sub-regional north. The participants in the sub-regional south had a higher prevalence of decreased eGFR, whereas those in the sub-regional north, sub-regional northwest, and sub-regional northeast had lower rates. Compared with their counterparts, the three main outcomes were consistently more prevalent among rural residents and those with lower education levels (all $p < 0.050$). CKD prevalence rates were significantly higher among participants with hypertension, more severe DR stages, and

	N	CKD	Albuminuria			Decreased eGFR
			Total	Microalbuminuria	Macroalbuminuria	
Weighted number	119,749,193	39,032,106	36,916,869	28,827,188	8,089,681	6,601,252
Number	52,000	17,403	16,298	12,944	3354	3361
Total	52,000	32.6 (31.3–33.8)	30.8 (29.6–32.1)	24.1 (23.2–25.0)	6.8 (6.2–7.3)	5.5 (5.1–5.9)
Sex						
Male	26,006	32.1 (30.8–33.4)	30.4 (29.1–31.8)	23.3 (22.4–24.2)	7.1 (6.4–7.9)	5.4 (5.0–5.8)
Female	25,994	33.2 (31.6–34.8)	31.3 (29.7–32.9)	25.0 (23.7–26.4)	6.3 (5.7–6.9)	5.7 (5.2–6.1)
p for difference[b]	–	0.16	0.26	0.060[c]	0.21[c]	0.16
Age groups						
18–<45 y	7097	27.2 (24.6–29.8)	26.9 (24.3–29.6)	19.8 (17.7–21.9)	7.1 (5.8–8.5)	1.4 (1.1-1.7)
45–<60 y	23,259	30.8 (29.7–32.0)	29.9 (28.8–31.1)	23.7 (22.9–24.6)	6.2 (5.7–6.7)	3.7 (3.3–4.1)
≥60 y	21,644	39.7 (38.4–41.0)	35.5 (34.3–36.8)	28.4 (27.5–29.4)	7.1 (6.5–7.7)	11.5 (10.7–12.3)
p for linear trend[b]	–	<0.0001	<0.0001	<0.0001[c]	0.30[c]	<0.0001
Ethnicity						
Han	47,524	31.8 (30.5–33.1)	30.0 (28.7–31.3)	23.5 (22.6–24.4)	6.5 (5.9–7.1)	5.5 (5.1–5.9)
Manchu	568	33.5 (25.4–41.5)	32.8 (24.3–41.3)	27.5 (20.1–34.9)	5.3 (3.9–6.7)	3.9 (2.7–5.0)
Zhuang	479	36.9 (34.4–39.4)	32.1 (28.1–36.1)	24.3 (21.9–26.7)	7.8 (5.5–10.2)	12.7 (9.9–15.6)
Uyghur	859	43.6 (38.4–48.8)	43.1 (38.0–48.1)	33.6 (31.2–36.1)	9.4 (6.8–12.0)	3.7 (3.3–4.1)
Hui	790	42.0 (34.9–49.0)	40.4 (33.5–47.2)	28.8 (23.3–34.3)	11.6 (3.2–20.0)	5.3 (2.2–8.4)
Tibetan	640	46.9 (45.3–48.5)	46.2 (44.3–48.1)	33.0 (27.3–38.7)	13.2 (9.1–17.4)	4.4 (3.6–5.2)
Other	1140	38.5 (32.3–44.7)	36.6 (29.8–43.5)	28.6 (22.9–34.3)	8.0 (6.3–9.8)	6.3 (4.3–8.4)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Broad geographical region[d]						
North	25,429	30.2 (28.4–32.1)	29.1 (27.3–30.8)	23.4 (22.0–24.7)	5.7 (5.1–6.3)	3.8 (3.4–4.2)
South	26,571	35.0 (33.3–36.7)	32.6 (30.9–34.4)	24.8 (23.7–25.9)	7.8 (6.9–8.8)	7.3 (6.7–7.8)
p for difference[b]	–	0.00019	0.0051	0.090[c]	0.00020[c]	<0.0001
Sub-regional division[e]						
North	8852	26.7 (24.3–29.2)	25.2 (22.7–27.7)	20.9 (18.8–22.9)	4.4 (3.7–5.0)	3.9 (3.3–4.6)
South	4760	33.2 (30.4–35.9)	30.0 (27.1–32.9)	23.7 (21.2–26.1)	6.4 (5.3–7.4)	9.4 (8.2–10.6)
East	12,622	32.3 (29.7–34.9)	30.5 (27.9–33.0)	23.7 (22.1–25.4)	6.8 (5.4–8.1)	5.6 (4.9–6.4)
Central	5588	36.8 (32.6–41.0)	34.1 (30.1–38.1)	25.6 (23.2–27.9)	8.5 (6.4–10.6)	8.3 (6.9–9.8)
Northwest	6962	34.8 (31.1–38.4)	33.7 (30.3–37.2)	26.6 (24.3–28.9)	7.1 (5.6–8.6)	3.8 (2.9–4.7)
Northeast	5192	29.6 (24.9–34.2)	28.7 (24.1–33.3)	23.2 (19.2–27.1)	5.6 (4.4–6.7)	3.4 (2.6–4.3)
Southwest	8024	36.2 (33.2–39.2)	34.3 (31.2–37.5)	25.5 (23.3–27.7)	8.8 (7.2–10.5)	6.0 (5.2–6.8)
p for difference[b]	–	<0.0001	0.00025	0.0088[c]	<0.0001[c]	<0.0001
Setting						
Urban	27,722	29.9 (28.1–31.7)	28.3 (26.5–30.1)	22.6 (21.2–23.9)	5.7 (5.1–6.3)	4.8 (4.2–5.4)
Rural	24,278	34.7 (32.7–36.7)	32.9 (30.9–34.8)	25.3 (23.9–26.7)	7.6 (6.7–8.5)	6.1 (5.4–6.8)
p for difference[b]	–	0.0013	0.0020	0.013[c]	0.0020[c]	0.025
Education level						
Primary school or below	22,685	39.0 (37.4–40.5)	36.3 (34.7–37.9)	28.1 (27.0–29.2)	8.2 (7.4–9.0)	8.0 (7.4–8.6)
Secondary school	16,112	32.1 (30.6–33.5)	30.7 (29.2–32.2)	23.5 (22.3–24.8)	7.2 (6.3–8.1)	4.6 (4.2–5.0)
High school	9020	26.9 (25.0–28.9)	25.7 (23.8–27.7)	21.1 (19.4–22.8)	4.7 (3.9–5.5)	4.0 (3.6–4.4)
College or above	4183	20.5 (17.8–23.2)	19.8 (17.1–22.5)	16.1 (13.7–18.5)	3.8 (2.7–4.8)	1.7 (1.3–2.1)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
LE8 scores						
Low	9875	48.0 (46.2–49.9)	45.9 (44.0–47.8)	32.9 (31.6–34.1)	13.0 (11.4–14.7)	8.5 (7.8–9.2)
Moderate	39,638	29.9 (28.6–31.2)	28.2 (26.9–29.5)	22.7 (21.7–23.7)	5.5 (5.0–6.0)	4.9 (4.6–5.3)
High	1994	9.9 (6.9–13.0)	9.1 (6.1–12.1)	8.4 (5.4–11.5)	0.7 (0.3–1.0)	1.4 (0.9–1.8)
p for linear trend[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Diabetes duration						
<1 y	4659	21.5 (19.3–23.6)	20.4 (18.2–22.5)	17.2 (15.3–19.1)	3.2 (2.3–4.0)	2.4 (2.0–2.9)
1–<5 y	19,610	28.0 (26.6–29.4)	26.5 (25.1–27.9)	21.4 (20.5–22.4)	5.1 (4.2–6.0)	3.7 (3.3–4.0)
5–<10 y	14,068	35.1 (33.7–36.6)	33.3 (31.9–34.7)	26.7 (25.5–27.9)	6.6 (5.9–7.2)	5.9 (5.4–6.4)

(Table 2 continues on next page)

	N	CKD	Albuminuria			Decreased eGFR
			Total	Microalbuminuria	Macroalbuminuria	
(Continued from previous page)						
≥10 y	13,663	43.2 (41.3–45.1)	40.8 (38.8–42.7)	29.2 (27.8–30.6)	11.6 (10.4–12.8)	9.8 (9.1–10.5)
p for linear trend[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Hypertension						
No	26,236	24.1 (22.6–25.5)	23.1 (21.7–24.5)	19.1 (18.0–20.3)	3.9 (3.4–4.5)	2.7 (2.4–3.0)
Yes	25,739	43.5 (42.2–44.9)	40.8 (39.4–42.1)	30.4 (29.3–31.5)	10.4 (9.6–11.2)	9.1 (8.6–9.7)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Any DR						
No	40,977	28.0 (26.8–29.2)	26.2 (25.0–27.4)	21.9 (20.9–22.8)	4.3 (3.8–4.9)	4.2 (3.9–4.6)
Non-VTDR	6688	46.6 (44.4–48.7)	45.1 (42.9–47.3)	32.3 (30.7–34.0)	12.8 (10.8–14.7)	7.9 (7.1–8.7)
VTDR	1633	66.9 (63.7–70.1)	65.5 (62.3–68.8)	35.4 (32.5–38.3)	30.1 (26.9–33.4)	15.0 (13.1–17.0)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
CVD						
No	42,248	31.0 (29.7–32.3)	29.6 (28.3–30.9)	23.3 (22.3–24.3)	6.3 (5.7–6.9)	4.5 (4.2–4.8)
Yes	9750	41.1 (39.4–42.8)	37.6 (36.0–39.3)	28.2 (26.9–29.6)	9.4 (8.5–10.3)	11.0 (10.1–11.8)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Attainment of HbA1c						
No	29,438	41.3 (39.9–42.6)	39.8 (38.4–41.1)	30.4 (29.4–31.3)	9.4 (8.6–10.2)	5.8 (5.4–6.2)
Yes	22,555	21.5 (20.3–22.7)	19.3 (18.2–20.5)	16.0 (15.0–17.0)	3.4 (3.0–3.7)	5.2 (4.7–5.6)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	0.0037
Attainment of BP						
No	36,635	38.8 (37.6–40.0)	36.9 (35.7–38.2)	28.3 (27.4–29.2)	8.6 (7.9–9.3)	6.5 (6.1–6.9)
Yes	15,332	19.8 (18.1–21.5)	18.2 (16.6–19.9)	15.3 (14.0–16.5)	2.9 (2.3–3.6)	3.5 (3.1–3.9)
p for difference[b]	–	<0.0001	<0.0001	<0.0001[c]	<0.0001[c]	<0.0001
Attainment of LDL-C						
No	34,099	32.9 (31.6–34.3)	31.4 (30.0–32.7)	24.2 (23.3–25.2)	7.2 (6.4–7.9)	5.4 (5.0–5.8)
Yes	17,901	32.0 (30.4–33.7)	29.8 (28.2–31.5)	23.8 (22.4–25.2)	6.0 (5.3–6.8)	5.7 (5.2–6.2)
p for difference[b]	–	0.28	0.060	0.65[c]	0.039[c]	0.17

CKD = chronic kidney disease. eGFR = estimated glomerular filtration rate. LE8 = life's essential 8. DR = diabetic retinopathy. VTDR = vision-threatening diabetic retinopathy. CVD = cardiovascular diseases. HbA1c = hemoglobin A1c. BP = blood pressure. LDL-C = low-density lipoprotein cholesterol. [a]Data are presented as weighted percentages (95% confidence interval), which are weighted by gender-, age-, and setting structure of adults with diabetes aged 18–74 years old in China in 2018 from the China Chronic Disease and Risk Factors Surveillance. [b]p for difference is calculated using the Rao-Scott Chi-Square test. p for linear trend is calculated by the median of each group representing their levels in the regression model. [c]p value is adjusted using the Bonferroni correction by multiplying the original p value by the number of comparisons. [d]The Northern regions include Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; the Southern regions include Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, and Tibet. [e]The sub-region north includes Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia. The sub-region south includes Guangdong, Guangxi, Hainan. The sub-region east includes Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong. The sub-region central includes Henan, Hubei, Hunan. The sub-region northwest includes Shaanxi, Gansu, Qinghai, Ningxia. The sub-region northeast includes Liaoning, Jilin, Heilongjiang. The sub-region southwest includes Chongqing, Sichuan, Guizhou, Yunnan, and Tibet.

Table 2: **Weighted prevalence of chronic kidney disease among Chinese adults with diabetes by sociodemographic and clinical characteristics.**[a]

CVD than those without these conditions. Moreover, for all three outcomes, participants who met target levels for HbA1c or BP had lower prevalence rates, while those who achieved LDL-C targets showed no significant difference in prevalence compared to those who did not (all $p < 0.050$) (Table 2).

Using the CKD-EPIcr09, CKD-EPIcr21, and CKD-EPIcys12 equations, the prevalence of decreased eGFR and CKD was 5.3% and 32.6%, 4.2% and 32.1%, and 10.2% and 35.0%, respectively. The distributions of decreased eGFR among subgroups evaluated by the three equations were similar to those evaluated by the CKD-EPIcr-cys equation (Appendix p 13–14).

Factors associated with albuminuria and decreased eGFR

Age- and sex-adjusted logistic models are presented in Appendix pp 15–16. In the fully-adjusted logistic regression model, females had higher odds of having albuminuria but lower odds of having decreased eGFR. Age was associated with a higher risk of decreased eGFR but not albuminuria. Notably, compared with residents in the sub-regional north, those in other sub-regions had a higher risk of albuminuria (odds ratios [ORs] ranged from 1.22 to 1.58), while residents in other sub-regions except for the northwest and northeast also had a higher risk of decreased eGFR (ORs

ranged from 1.33 to 2.58). However, the urban-rural disparity disappeared. The odds of having albuminuria and decreased eGFR declined with a higher educational level. Longer diabetes duration, the presence of more severe stages of DR, and a history of CVD were associated with higher risks of both outcomes (Fig. 1).

Notably, compared with those with low overall LE8 scores, participants with moderate and high scores had a significantly lower risk of albuminuria (OR, 0.46 [95% CI, 0.42–0.51]; OR, 0.14 [95% CI, 0.10–0.21]) and decreased eGFR (OR, 0.61 [95% CI, 0.55–0.67]; OR, 0.28 [95% CI, 0.19–0.41]) (Fig. 1).

Based on the minimum Akaike information criterion, we used 4 and 3 knots to examine the associations between the total LE8 score with albuminuria and decreased eGFR. The cut-off value of the LE8 score was 60 for both outcomes, as the according OR equals 1 at this point. Notably, all RCS curves for the total LE8 score, across both the total population and subgroups, displayed a consistent L-shape with a monotonic decrease. The curves depicted a non-linear relationship between albuminuria and LE8 scores (p for nonlinear <0.0001), but a linear relationship between decreased eGFR and LE8 scores (p for nonlinear = 0.092). When stratified, the risks of the two outcomes were initially higher among the elderly, and rural residents than their counterparts. However, these disparities gradually decreased and even disappeared as the LE8 scores approached 100 (Fig. 2).

There were inverse relationships of albuminuria and decreased eGFR with the component of the DASH diet, PA, nicotine exposure, blood lipids, and BP scores of

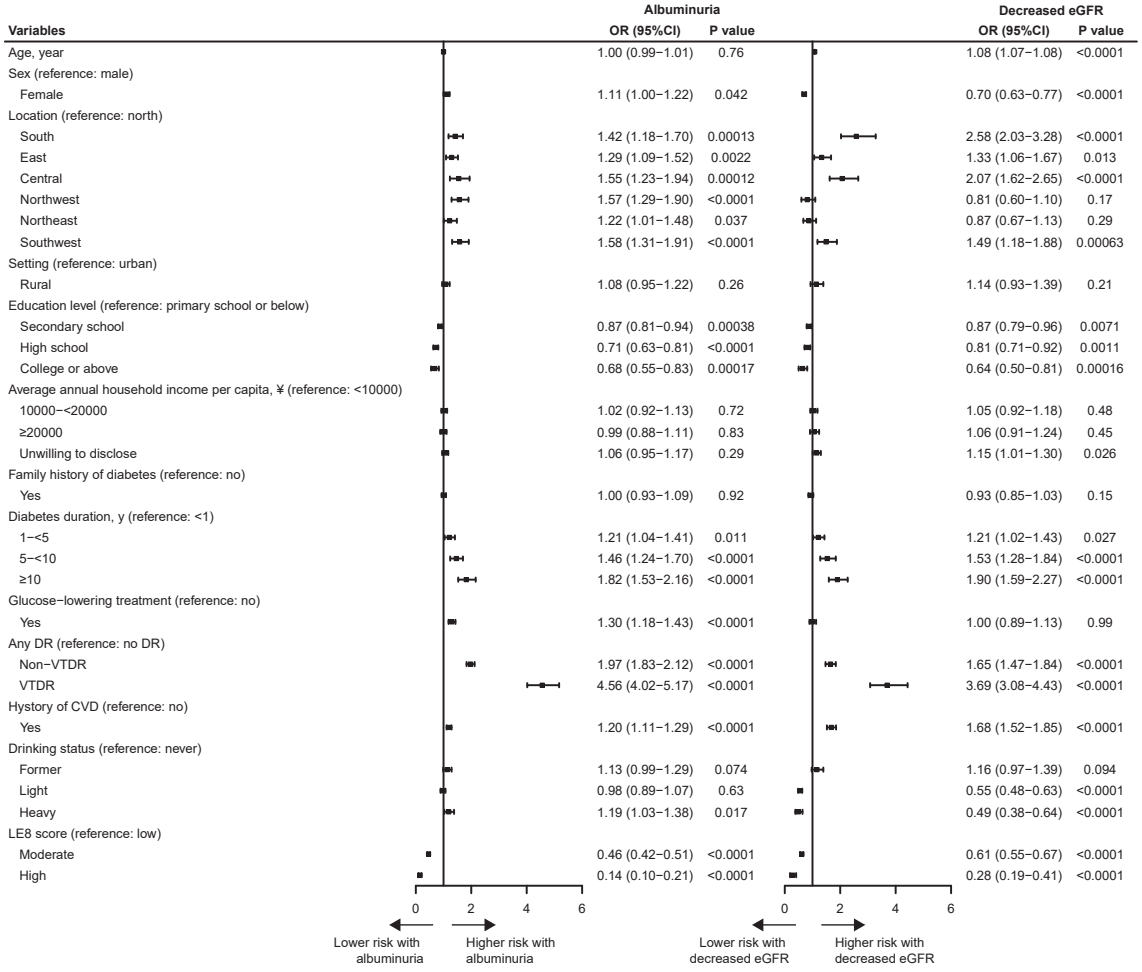
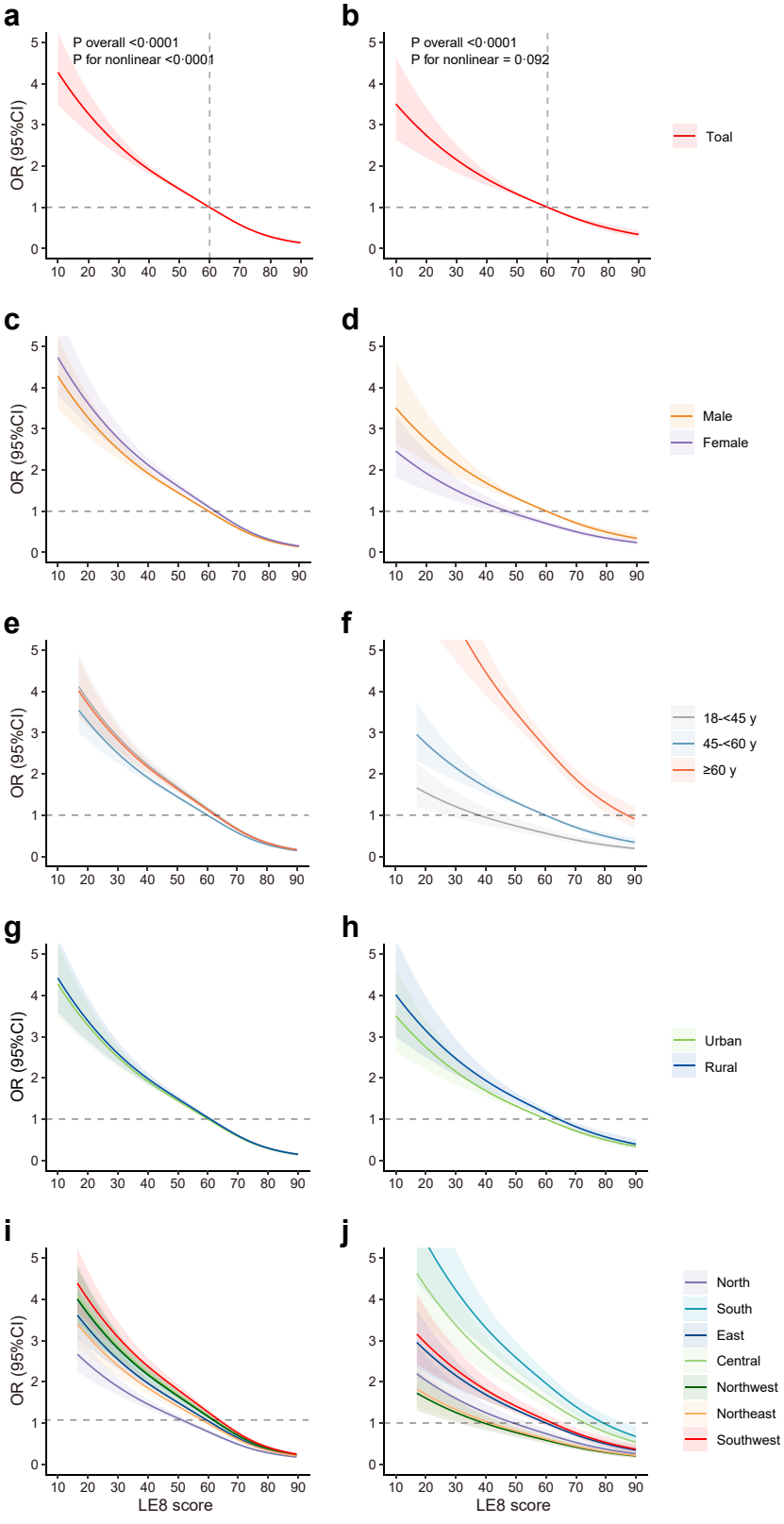


Fig. 1: **Multivariable-adjusted odds ratio for factors associated with albuminuria and decreased estimated glomerular filtration rate.** OR = odds ratio. CI = confidence interval. DR = diabetic retinopathy. VTDR = vision-threatening diabetic retinopathy. CVD = cardiovascular diseases. LE8 = life's essential 8. eGFR = estimated glomerular filtration rate. The models are adjusted for age, sex, sub-regional division, setting, educational level, annual household income, family history of diabetes, diabetes duration, glucose-lowering treatment, any DR, CVD, drinking status, and total LE8 score.


a
P overall <0·0001
P for nonlinear <0·0001
b
P overall <0·0001
P for nonlinear = 0·092
OR (95%CI)
Toal
c
d
Male
Female
e
f
18-<45 y
45-<60 y
≥60 y
g
h
Urban
Rural
i
j
North
South
East
Central
Northwest
Northeast
Southwest
LE8 score
LE8 score

LE8. Additionally, blood glucose scores were negatively associated with albuminuria but positively associated with decreased eGFR (Appendix p 17).

The RCS plots displayed U-shaped relationships of the two outcomes with DBP (both p for nonlinear <0.0001), non-HDL-C (both p for nonlinear <0.0001), BMI (both p for nonlinear <0.0001), and sleep duration (both p for nonlinear <0.0001), as well as between albuminuria and SBP (p for nonlinear <0.0001). An inverted U-shaped relationship was found between HbA1c and decreased eGFR (p for nonlinear = 0.0060). Notably, the odds of having albuminuria were low before HbA1c and SBP increased up to the threshold values, but rose shapely after (both p for nonlinear <0.0001) (Appendix pp 18–25).

Discussion

Based on the first and largest national data and utilizing the CKD-EPIcr-cys equation, this study systematically depicted the distribution of CKD and explored potential determinants, with a particular focus on the LE8 scores among Chinese adults with diagnosed diabetes.

Prevalence of CKD

Our study demonstrated that approximately one-third of patients with diabetes lived with CKD in China. Comparing the prevalence from different studies was challenging due to various underlying determinants. Based on the same eGFR equations, we crudely compared the prevalence rates with those from other surveys. Although the CKD prevalence among U.S. adults with diabetes during almost the same period (2017–2020) was higher than in our study (38.0% vs. 32.6%),[22] our study reported a higher overall CKD prevalence compared to several cross-sectional studies conducted in mainland China and in the UK.[7,8,23,24] For example, a study based on 3488 people with diabetes from 13 provinces and using a modified eGFR equation for Chinese patients reported a CKD prevalence of 21.3% in 2009–2010, whereas our study reported 32.1% (data not shown).[8,23] Another study, based on 12,945 people with previously diagnosed diabetes, reported prevalence rates of 25.4% and 21.6% for CKD and albuminuria in 2018–2019,[7] compared to 32.6% and 30.8% in our study. Compared to the prevalence reported from routine clinical care data in the UK in 2019, our study revealed a higher CKD prevalence (32.6% vs. 29.1%) but a lower decreased eGFR prevalence (5.3% vs. 16.3%).[24] Additionally, we noted that our study population was younger (57.7 vs. 66.1 years old), had a lower proportion of hypertension (49.5% vs. 72.4%), but had a higher average BP level (135.3 vs. 131.5 mmHg). Although numerous associations have advocated for angiotensin-converting enzyme inhibitors or angiotensin receptor blockers for hypertensive populations to delay CKD progression,[10,11] their usage in our population was notably lower (16.8% vs. 50.3%). Therefore, it is necessary to target awareness campaigns highlighting the crucial role of medications in improving their prognosis in this population.

Distribution of CKD

For the first time, our study, utilizing uniform disease diagnostic criteria, centralized lab tests, and a national population-based sample, reported that among Chinese adults with diabetes, sub-regional north residents persistently exhibited a lower albuminuria risk than those in other areas, while individuals in the sub-regional north, sub-regional northwest, and sub-regional northeast showed a lower decreased eGFR risk than other participants. A meta-analysis of thirty studies also revealed a similar north-south variation among patients with diabetes in China.[25] By contrast, the prevalence of CKD was reported to be lower among the general population in sub-regional south China.[7] However, similar to the previous study,[7] the Han Chinese had a lower prevalence of CKD and albuminuria than non-Han minorities. Besides lifestyles, metabolic control, and comorbidities, other possible underlying causes, such as genetic variations, environmental factors, and medical resources and healthcare management conditions may also contribute to the disparities.

Although the sex disparities in the weighted prevalence of the three main outcomes were not statistically significant, point estimates suggested slightly higher rates in females. However, the multivariable logistic regression showed lower odds of having decreased eGFR in females. This discrepancy may be attributed to the variation in age distribution between females and males. When we applied the direct age standardization to calculate prevalence for males and females and used the age-adjusted logistic regression to assess the ORs for males versus females, these results consistently showed higher odds of decreased eGFR in males (data not shown), aligning with results from multivariable logistic

Fig. 2: **Restricted cubic spline analysis of albuminuria and decreased estimated glomerular filtration rate with life's essential 8 scores across the total population (a, b), stratified by gender (c, d), age groups (e, f), setting (g, h), and sub-regions (i, j)**. The solid line is odds ratio estimate, with shaded areas showing 95% CIs. The cut-off value of LE8 score was 60 for both outcomes. The RCS curve for albuminuria was ploted with 4 knots at 40th, 55th, 65th, and 79th, and the curve for decreased eGFR was ploted with 3 knots at 44th, 60th, and 74th. All analyses are conducted by logistic regression models adjusted for age, sex, sub-region, setting, educational level, annual household income, family history of diabetes, diabetes duration, glucose-lowering treatment, any DR, CVD, and drinking status. eGFR = estimated glomerular filtration rate. LE8 = life's essential 8. OR = odds ratio.

regression. Our study also demonstrated that the prevalence of CKD increased significantly with the presence and severity of any DR or a history of CVD. Particular attention should be given to individuals with multiple complications, as they face significantly higher risks of premature morbidity and mortality.[26] Moreover, DR, CKD, and CVD in diabetes were characterized by pathophysiological interactions. A meta-analysis of 20 cohorts showed that the presence of DR increased the risk of diabetic kidney disease by 31%.[27] Meanwhile, the kidney is also a target organ for CVD, and conversely, CKD may hasten and exacerbate the progression of CVD. The concept of "Cardiovascular-Kidney-Metabolic (CKM) Syndrome" has been defined as a systematic disorder and has received widespread attention.[28] The AHA states that the CKM staging construct provided a framework for identifying individuals at the early stages of CKM syndrome to prevent progression to CVD.[28] Therefore, holistic approaches are needed to fully and equitably prevent and manage micro- and macrovascular complications. Our study underscored the importance of identifying and prioritizing attention toward vulnerable subpopulations timely.

CVH and CKD

The AHA recommends using the LE8 scores to evaluate CVH. Two cohort studies showed that LE8 scores were negatively associated with the risk of CKD among patients with diabetes.[13,14] One study used data from Caucasian participants from the UK Biobank and determined outcomes by hospital-diagnosed ICD-10 codes.[14] Another study was conducted among Chinese workers of a coal mining company, with diabetes diagnosed using fasting blood glucose.[13]

Similarly, our study demonstrated inverse associations of the total LE8 scores and its individual components with CKD risk. For example, the DASH diet score, akin to a predominantly plant-based dietary pattern, is recommended to reduce CKD progression, manage CKD-related risks and complications, and enhance metabolic control.[29] Managing blood glucose, BP, and blood lipids, three critical metabolic factors of the LE8 scores, was essential for patients with diabetes to delay the onset and progression of CKD and extend their health span. Unfortunately, in our study, the target achievement rates were 43.4% for glycemic control, 29.5% for BP control, and 34.4% for LDL-C control, indicating larger room for improvement. Therefore, multifaceted and tailored efforts, including actively promoting these zero-cost health behaviors and enhancing the achievement of metabolic targets, were crucial for reducing the risk of CKD among diabetes patients.

Strengths and limitations

Our study has several strengths. First, it was the first national population-based survey of microvascular complications of diabetes, which gave a comprehensive depiction of the distribution of CKD in China. Second, UACR, Scys, and Scr were centrally tested. Additionally, we employed the more accurate CKD-EPIcr-cys equation to estimate GFR.

Several limitations require consideration. First, this was a cross-sectional study where a temporal relationship between exposure and outcome cannot be made. Second, questionnaire data were self-reported, with inevitable misreporting and recall bias. Third, the diagnosis of CKD was based on a single random sample, but could be a feasible alternative in large-sample national surveys.[23,30] Fourth, we excluded those with urinary tract infection within 7 days before the survey and incomplete CKD diagnosis data, this may have introduced some selection bias. We mitigated this bias to some extent by considering survey weight in prevalence calculation and logistic regression analysis. Fifth, we did not consider the clustering effects among the same neighborhoods (or districts) in our analyses. However, given the large number and broad geographic coverage of sampled neighborhoods and districts, we believe that the potential impact of group-level differences on the results may be minimized to some extent.

Conclusion

In conclusion, approximately one-third of patients with diabetes in China had CKD, with approximately one-quarter of these patients also having DR, and over one-fifth having CVD, representing a heavy burden for these individuals. Higher LE8 scores were associated with a lower risk of CKD. These results were pivotal for developing public health programs focused on improving CKD outcomes among patients with diabetes. Experience from China would be invaluable in guiding the world's response to the challenges posed by diabetes and its complications.

Contributors

WJ conceptualised and designed the study. WJ, RY, LW, and XH contributed to the statistical analysis, interpretation, and writing of the report. Ye contributed to statistical analysis. WJ, DZ (Dalong Zhu), LG, JW (Jianping Weng), HL, MZ, ZZ, DZ (Dajin Zou), QJ, XG, YZ, and DL coordinated the collection of clinical data and critically reviewed the report. WJ, LM, and JW (Jiarui Wu) raised the funding. WJ, JW (Jing Wu), and XH verified the data in the study and take full responsibility for the integrity of the data. All authors had full access to all the data in this study and provided final approval to submit the manuscript for publication.

Data sharing statement

All data requests should be submitted to the corresponding author (Prof. Jia at wpjia@sjtu.deu.cn) for consideration. Access to anonymised data might be granted following review.

Declaration of interests

All authors declare no competing interests.

Acknowledgements

This survey was supported by the Bethune Charitable Foundation. This work was also supported by grants from the Shanghai Science and

Technology Committee (grant No. 19692115900 and 17411952600), Shanghai Municipal Key Clinical Specialty, Shanghai Key Discipline of Public Health Grants Award (grant No. GWVI-11.1-20), Shanghai Research Center for Endocrine and Metabolic Diseases (grant No. 2022ZZ01002), National Key Clinical Specialty (grant No. Z155080000004) and the Chinese Academy of Engineering (grant No. 2022-XY-08) to Prof Jia, the National Key Research and Development Program of China (grant No. 2021YFC2500201) to Prof Wang, and the Strategic Priority Research Program of the Chinese Academy of Sciences (grant No. XDB38020000) to Prof Jiarui Wu. We want to thank all investigators and all participants for their contributions to the China National Diabetic Chronic Complications (DiaChronic) Study. The DiaChronic Study Group members are listed in the appendix (pp 26–30).

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101463.

References

1 International Diabetes Federation. IDF atlas reports: diabetes and kidney disease. https://diabetesatlas.org/atlas/diabetes-and-kidney-disease/; 2023. Accessed May 15, 2024.
2 Li H, Lu W, Wang A, Jiang H, Lyu J. Changing epidemiology of chronic kidney disease as a result of type 2 diabetes mellitus from 1990 to 2017: estimates from Global Burden of Disease 2017. *J Diabetes Investig*. 2021;12:346–356.
3 Cheng HT, Xu X, Lim PS, Hung KY. Worldwide epidemiology of diabetes-related end-stage renal disease, 2000-2015. *Diabetes Care*. 2021;44:89–97.
4 Fenta ET, Eshetu HB, Kebede N, et al. Prevalence and predictors of chronic kidney disease among type 2 diabetic patients worldwide, systematic review and meta-analysis. *Diabetol Metab Syndr*. 2023;15:245.
5 Yang C, Yang Z, Wang J, et al. Estimation of prevalence of kidney disease treated with dialysis in China: a study of insurance claims data. *Am J Kidney Dis*. 2021;77:889–897.e1.
6 Liu M, Liu SW, Wang LJ, et al. Burden of diabetes, hyperglycaemia in China from to 2016: findings from the 1990 to 2016, global burden of disease study. *Diabetes Metab*. 2019;45:286–293.
7 Wang L, Xu X, Zhang M, et al. Prevalence of chronic kidney disease in China: results from the Sixth China chronic disease and risk factor surveillance. *JAMA Intern Med*. 2023;183:298–310.
8 Zhang L, Long J, Jiang W, et al. Trends in chronic kidney disease in China. *N Engl J Med*. 2016;375:905–906.
9 Inker LA, Eneanya ND, Coresh J, et al. New creatinine- and cystatin C-based equations to estimate GFR without race. *N Engl J Med*. 2021;385:1737–1749.
10 11. Chronic Kidney Disease and Risk Management. Standards of care in diabetes-2024. *Diabetes Care*. 2024;47:S219–S230.
11 Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2024 Clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int*. 2024;105:S117–S314.
12 Lloyd-Jones DM, Allen NB, Anderson CAM, et al. Life's essential 8: updating and enhancing the American heart association's construct of cardiovascular health: a presidential advisory from the American Heart Association. *Circulation*. 2022;146:e18–e43.
13 Gao J, Liu Y, Ning N, et al. Better life's essential 8 is associated with lower risk of diabetic kidney disease: a community-based study. *J Am Heart Assoc*. 2023;12:e029399.
14 Huang ZG, Gao JW, Zhang HF, et al. Cardiovascular health metrics defined by Life's Essential 8 scores and subsequent macrovascular and microvascular complications in individuals with type 2 diabetes: a prospective cohort study. *Diabetes Obes Metab*. 2024;26:2673–2683.
15 Hou X, Wang L, Zhu D, et al. Prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy in adults with diabetes in China. *Nat Commun*. 2023;14:4296.
16 Hou XH, Wang LM, Chen SY, et al. Data resource profile: a protocol of China national diabetic chronic complications study. *Biomed Environ Sci*. 2022;35:633–640.
17 Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med*. 2009;150:604–612.
18 Inker LA, Schmid CH, Tighiouart H, et al. Estimating glomerular filtration rate from serum creatinine and cystatin C. *N Engl J Med*. 2012;367:20–29.
19 Wilkinson CP, Ferris FL 3rd, Klein RE, et al. Proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales. *Ophthalmology*. 2003;110:1677–1682.
20 Photocoagulation for diabetic macular edema. Early treatment diabetic retinopathy study report number 1. Early treatment diabetic retinopathy study research group. *Arch Ophthalmol*. 1985;103:1796–1806.
21 Wang L, Peng W, Zhao Z, et al. Prevalence and treatment of diabetes in China, 2013-2018. *JAMA*. 2021;326:2498–2506.
22 United States Renal Data System. *2023 USRDS annual data report: Epidemiology of kidney disease in the United States, 2023*. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2023.
23 Zhang L, Wang F, Wang L, et al. Prevalence of chronic kidney disease in China: a cross-sectional survey. *Lancet*. 2012;379:815–822.
24 Cook S, Schmedt N, Broughton J, Kalra PA, Tomlinson LA, Quint JK. Characterising the burden of chronic kidney disease among people with type 2 diabetes in England: a cohort study using the Clinical Practice Research Datalink. *BMJ Open*. 2023;13:e065927.
25 Zhang XX, Kong J, Yun K. Prevalence of diabetic nephropathy among patients with type 2 diabetes mellitus in China: a meta-analysis of observational studies. *J Diabetes Res*. 2020;2020:2315607.
26 Zoccali C, Mallamaci F, Adamczak M, et al. Cardiovascular complications in chronic kidney disease: a review from the European renal and cardiovascular medicine working group of the European renal association. *Cardiovasc Res*. 2023;119:2017–2032.
27 Jiang W, Wang J, Shen X, et al. Establishment and validation of a risk prediction model for early diabetic kidney disease based on a systematic review and meta-analysis of 20 cohorts. *Diabetes Care*. 2020;43:925–933.
28 Ndumele CE, Neeland IJ, Tuttle KR, et al. A synopsis of the evidence for the science and clinical management of cardiovascular-kidney-metabolic (CKM) syndrome: a scientific statement from the American heart association. *Circulation*. 2023;148:1636–1664.
29 Carrero JJ, González-Ortiz A, Avesani CM, et al. Plant-based diets to manage the risks and complications of chronic kidney disease. *Nat Rev Nephrol*. 2020;16:525–542.
30 Hemmati R, Gharipour M, Khosravi A, Jozan M. A cost-benefit and accurate method for assessing microalbuminuria: single versus frequent urine analysis. *Int J Hypertens*. 2013;2013:752903.