

RESEARCH ARTICLE

Chronic kidney disease biomarkers and mortality among older adults: A comparison study of survey samples in China and the United States

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Abstract

Objectives

Among older adults in China and the US, we aimed to compare the biomarkers of chronic-kidney-diseases (CKD), factors associated with CKD, and the correlation between CKD and mortality.

Setting

China and the US.

Study design

Cross-sectional and prospective cohorts.

Participants

We included 2019 participants aged 65 and above from the Chinese Longitudinal Healthy Longevity Study (CLHLS) in 2012, and 2177 from US National Health and Nutrition Examination Survey (NHANES) in 2011–2014.

Outcomes

Urinary albumin, urinary creatinine, albumin creatinine ratio (ACR), serum creatinine, blood urea nitrogen, plasma albumin, uric acid, and estimated glomerular filtration rate (eGFR). CKD (ACR \geq 30 mg/g or eGFR < 60 ml/min/1.73m²) and mortality.

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Analytical approach

Logistic regression and Cox proportional hazard models. Covariates included age, sex, race, education, income, marital status, health condition, smoking and drinking status, physical activity and body mass index.

Results

Chinese participants had lower levels of urinary albumin, ACR, and uric acid than the US (mean: 25.0 vs 76.4 mg/L, 41.7 vs 85.0 mg/g, 292.9 vs 341.3 $\mu\text{mol/L}$). In the fully-adjusted model, CKD was associated with the risk of mortality only in the US group (hazard ratio [HR], 95% CI: 2.179, 1.561–3.041 in NHANES, 1.091, 0.940–1.266 in CLHLS). Compared to $\text{eGFR} \geq 90$, eGFR ranged 30–44 ml/min/1.73m^2 was only associated with mortality in the US population (HR, 95% CI: 2.249, 1.141–4.430), but not in the Chinese population (HR, 95% CI: 1.408, 0.884–2.241).

Conclusions

The elderly participants in the US sample had worse CKD-related biomarker levels than in China sample, and the association between CKD and mortality was also stronger among the US older adults. This may be due to the biological differences, or co-morbid conditions.

Introduction

Chronic kidney disease (CKD) is a public health problem around the world. It refers to kidney damage or lasting low glomerular filtration rate (GFR), regardless of causes [1]. CKD is associated with premature cardiovascular disease, and other complications of progressive CKD including anemia, bone disease, and end stage kidney disease. In high-income and middle-income countries, about one in ten people have CKD [2]. Globally, the all-age prevalence of CKD has increased by 29.3% since 1990 [3]. In 2017, 1.2 million people around the world died from CKD, and the global all-age mortality rate from CKD increased by 41.5% between 1990 and 2017 [3]. CKD lowers the quality of life and leads to catastrophic health expenditures [2]. Therefore, the prevalence and trend of CKD is a worldwide public health threat [1].

Previous studies revealed substantial difference between China and USA in the prevalence and mortality of CKD. In 2019, the estimated age-standardized prevalence of CKD in China and the US were 8125 and 8179 per 100,000, respectively. The percentage of changes in age-standardized prevalence rates between 2010 and 2019 of the two countries were 0.6% and 4% respectively. Age-standardized mortality of CKD in China in 2019 was 11.2 per 100 000 (95% CI: 9.6, 12.8), lower than that in the US (17.8 per 100 000 [95% CI: 16.1, 18.9]), and the age-standardized mortality change between 2010 and 2019 were also different (-10.1% [95% CI: -23.1, 3.1] vs. 7.1% [95% CI: 3.4, 11.3]) [4]. Previous studies found that people in China and the US share many common risk factors for CKD; however, differences were observed for the prevalences of these risk factors as well as their potential impact on CKD [5, 6]. The Chinese population had a lower prevalence of adjusted albuminuria, decreased eGFR and CKD than the US, and 65% of the difference of decreased eGFR between the countries was explained by risk factors (diabetes, hypertension, CVD, hyperuricemia, and obesity) together with age and sex [5, 6]. In a cross-sectional study, the prevalence of stage 3 and stage 4 chronic kidney disease in China was lower compared with those in the US (stage 3 [95% CI]: 1.6% [1.4–1.8] vs.

7.69% [7.02–8.38], stage 4: 0.1% [0.06–0.2] vs. 0.35% [0.25–0.45]) [7, 8]. However, these previous studies mainly focused on comparing the prevalence of CKD in the general population between China and the US, the differences in the prevalence of CKD among elderly populations between China and the US, and their association with mortality was not known yet.

Therefore, we aimed to compare the prevalence and mortality risk of CKD among elderly people between China and the US. We hypothesized that the elderly in China had a lower prevalence of CKD and a lower mortality rate compared to the US counterparts. In addition, the association between CKD and mortality might also be different among the US elderly population and the Chinese.

Methods

Study population

We used data from the Chinese Longitudinal Healthy Longevity Study (CLHLS) and National Health and Nutrition Examination Survey (NHANES) to compare the CKD-related biomarkers, CKD, and mortality among the older population, aged 65 years or older. Both CLHLS and NHANES collected data through in-person interviews, and blood and urine samples. All procedures in the NHANES survey cycles used in this study were approved by the National Center for Health Statistics Research Ethics Review Board (Protocol #2011–17), and written informed consent was obtained from all participants. The CLHLS study was approved by research ethics committees of Duke University and Peking University (IRB00001052-13074) and written informed consent was obtained from each respondent. The brief introduction of the two cohorts we used could be found in [S1 Table](#).

The Chinese participants were sampled from the Healthy Ageing and Biomarkers Cohort Study (HABCS), which is a sub-cohort of CLHLS. The study surveyed eight longevity area (Laizhou City of Shandong Province, Xiayi County of Henan Province, Zhongxiang City of Hubei Province, Mayang County of Hunan Province, Yongfu County of Guangxi Autonomous Area, Sanshui District of Guangdong Province, Chengmai County of Hainan Province and Rudong County of Jiangsu Province), covering various geographical and climatic regions of China. The study design and sampling method were described previously [9]. For the current analysis, we used data from the 2011–2012 wave. Between May and September 2012, 2354 participants aged 65 years and older received the face-to-face interview and took the blood and urine test. We excluded 94 participants without urine sample test (Urinary albumin and urine creatinine) and blood sample test (serum creatinine, BUN and plasma albumin), 214 participants with blood test but without urine test, and 28 participants with urine test but without blood test. We finally included 2019 participants with test results of the urinary albumin, urinary creatinine, serum creatinine, ACR, BUN, plasma albumin, and uric acid for the description and risk factor analysis. The CLHLS participants were followed up in 2014 and 2017/2018. We further excluded 321 participants lost in the first follow-up and included 1698 participants for the mortality analysis. In CLHLS, those who did not have the study biomarker result were older, more likely to be female, without formal education and widowed. Those lost in the first follow-up were more likely to have formal education and higher household income, less likely to do physical activity currently than those included in the follow-up study. Meanwhile, they had similar age, gender, race, marriage, smoking, alcohol drinking and BMI distribution ([S2–1 Table](#)).

The US participants were from the National Health and Nutrition Examination Survey, which is a continuous, nationally representative survey of the non-institutionalized US population of all ages [10]. NHANES uses complex sampling design recruiting people, and included a subgroup of ethnic minorities. Data from the 2011–2012 and 2013–2014 waves were used for

the current analysis. Among 2556 participants aged 65 and over, we excluded 379 subjects with missing urinary albumin, creatinine and albumin creatinine ratio (ACR), blood urea nitrogen (BUN), serum creatinine, uric acid, or plasma albumin. In NHANES, those with missing biomarker data were slightly older, more likely to be female, widowed, with lower education level and income (S2–2 Table). We eventually included 2177 participants for the current study. The participants were followed up in 2015 when 201 of them were found dead.

Participants in CLHLS were interviewed and taken urine and blood test between May and September 2012, were followed up in 2014 and 2017/2018. The recruitment and involvement of participants were organized by Center for Healthy Aging and Development Studies in Peking University National School of Development. Participants in NHANES were interviewed and examined by the US Centers for Disease Control and Prevention. The details of participants' involvement in NHANES and CLHLS were introduced in the survey documentation of NHANES [11] and CLHLS [12].

Measurement of biomarkers

In CLHLS, the urine was tested for albumin and creatinine using Siemens Microalbustix (Siemens Healthcare Diagnostic, USA). Blood plasma analyses were determined by an Automatic Biochemistry Analyzer (Hitachi 7180, Japan) using commercially available diagnostic kits (Roche Diagnostic, Mannheim, Germany), and serum creatinine was determined by the picric acid method, BUN was determined by urease ultraviolet rate method, and blood uric acid was determined by uricase colorimetric method. The central clinical laboratory at Capital Medical University conducted all laboratory analyses in Beijing. Estimated glomerular filtration rate (eGFR) was calculated by the original Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine-based equation that was validated among the Chinese population (S3 Table) [13, 14].

In NHANES, urinary albumin was measured by a solid-phase fluorescent Immunoassay described by Chavers et al. [15]. In 2011–2012, urinary creatinine was measured on the Roche/Hitachi Mod P chemistry analyzer; while in 2013–2014, it was measured on the Roche/Hitachi Cobas 6000 chemistry analyzer. Urine specimens were analyzed in the University of Minnesota, Minneapolis, MN. The urine albumin/creatinine ratio was created, with the random urine albumin in ug/mL divided by urine creatinine in mg/dL, and then multiplying 100, round to 0.01. DxC800 determined the concentration of serum creatinine, BUN, plasma albumin and uric acid by means of the Jaffe rate method, the enzymatic conductivity rate method, a bichromatic digital endpoint method and a timed endpoint method, respectively. Serum specimens were shipped to the Collaborative Laboratory Services, Ottumwa, Iowa for analysis. Estimated GFR was calculated using the original CKD-EPI creatinine-based equation as in the CLHLS part (S3 Table).

Outcomes

CKD was defined as: $ACR \geq 30$ mg/g or $eGFR < 60$ ml/min/1.73m² according to the “KDIGO clinical practice guidelines for chronic kidney disease: Evaluation, classification, and stratification” [16].

In CLHLS, the immediate family members of subjects reported the mortality information in the follow-up surveys in 2014 and 2017/2018. The survival time was entered as month counted from the month of the initial interview to the month of death or the last interview time. NHANES is linked to the National Death Index (NDI) and other data files which enable us to identify mortality. The mortality follow-up time was calculated using person-months from the mobile examination center date to the date of death. For those alive, the follow-up

time was calculated using the end of the mortality period (December 31, 2015) [17]. Among the 2019 participants included in the CLHLS part, 321 lost in the first follow-up in 2014. In the NHANES part, only 3 participants did not have available mortality data.

Covariates

We selected some available demographics, social-economic status, lifestyle and health indicators in both CLHLS and NHANES: age, sex, race/ethnicities, education, household income, marital status, health condition, smoking status, drinking status, physical activity, and body mass index (BMI), hypertension and diabetes as covariates. In CLHLS, the age was calculated as the difference between the interview dates and birth dates, and verified by the investigator. In NHANES, age was obtained at the time of screening, and participants age 80 and over were coded as 80, which led to a younger average age. In CLHLS, the ethnicity was coded as Han Chinese and ethnic minorities; while in NHANES, it was categorized into Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and other races. For participants from CLHLS, we defined having at least one year's schooling as formal education, and the others as no formal education. The educational degree in NHANES was classified as below high school, high school, and college or above. In CLHLS, annual household income of one year before the interview year was recorded and categorized into tertiles. However, family income in NHANES was indicated by the ratio of family income to poverty (PIR), which is the ratio of total family income to the poverty threshold for the year of the interview, divided into low income (0–1.85), middle income (1.86–3.50), and high income (>3.51). For the marital status, both CLHLS and NHANES included married, separated, divorced, widowed, and never married, but NHANES had an additional category of “living with partner”. The self-reported health condition included very good, good, fair, bad, and very bad in CLHLS, but were coded as excellent, very good, good, fair, and poor in NHANES. According to the CLHLS participants' answer to the questions “do you currently smoke/drink alcohol/exercise regularly?” and “did you smoke/drink alcohol/exercise regularly in the past?”, we coded the smoking and alcohol drinking status as “Current”, “Former”, and “Never”, and coded the currently exercise variable as yes or no. In NHANES, we coded smoking and alcohol drinking behavior as “Current”, “Former”, and “Never” bases on the questionnaires, and having physical activity was defined as taking vigorous or moderate work/recreational activities, or walking or using bicycle in a typical week. We calculated BMI as body weight divided by the square of the body height (unit: kg/m²). We used WHO standard of BMI in both CLHLS and NHANES, which defined a BMI of <18.5 kg/m² as underweight, a BMI of ≥18.5 to <25 kg/m² as normal weight, a BMI of ≥25 to <30 kg/m² as overweight, and a BMI of ≥30 kg/m² as obese. We defined hypertension as systolic blood pressure ≥140mmHg and/or diastolic blood pressure ≥90mmHg, and used self-reported diabetes.

Statistical analysis

We first summarized the demographic characteristics and biomarkers level and then performed logistic regression to analyze the risk factors associated with CKD. CKD was defined as: ACR ≥ 30 mg/g or eGFR < 60 ml/min/1.73m². The odds ratio (OR) and 95% confidence interval (CI) were reported. We conducted Cox proportional hazard model to evaluate the individual association of CKD-related biomarkers, eGFR levels, and CKD status with mortality. The Cox models adjusted for age, sex, race/ethnicities, education, household income, marital status, health condition, smoking status, drinking status, physical activity, and BMI. Missing value of covariates were coded as a categorical variable and included in the logistic regression and the Cox models. Besides, age was adjusted for as four separate age bins (65–69,

70–74, 75–79, 80+) in the logistic models and as continuous in the Cox models. We further ran the logistic and cox models for different age groups. We calculated hazard ratios (HR) and 95% CI to reflect the effect size. We performed all the analyses both to the Chinese and American samples. We presented results considering sample weight in [S7–1–S9](#) Tables. We used R 3.6.1 and SAS university edition for the analysis.

Data sharing statement

The NHANES data that support the findings of this study are openly available at <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx> while the CLHLS data are available on request at <https://sites.duke.edu/centerforaging/programs/chinese-longitudinal-healthy-longevity-survey-clhls/data-downloads/>.

Patient and public involvement

There was no patient or public involvement in this study.

Results

Demographic characteristics

The proportion of older adults over 80 in CLHLS was 65.5% with a mean age of 85.7 (SD: 12.2), larger than 26.1% in NHANES with a mean age of 73.2 (SD: 5.4). Educational attainment was drastically different, in CLHLS, most of the participants had no formal education (61.3%), while in NHANES, about 70% of the participants received high school education or above. Also, more Chinese participants were widowed (56%) than US participants (25.8%). In CLHLS, more participants rated their health condition as “Good” than in NHANES (37.1% “Good” versus 23.7% “Very good”, “Fair” in CLHLS and “Very good” in NHANES were the top level of self-reported health status), while fewer Chinese participants rated as “Bad” than US participants (10% “Bad” versus 23.4% “Fair”, both were the fourth level of self-reported health condition). More Chinese participants reported that they were never smoker (72.6%) than US participants (50.3%), and more Chinese participants never drank any alcohol (75.7%) than US participants (18.0%). Besides, 39.9% of the US participants had physical activities, more than that of Chinese participants (15.4%). CLHLS had much more underweight participants (23.6%) than NHANES (1.7%), while NHANES had much more overweight and obese participants (35.4% and 34.1%, respectively) than CLHLS (10.6% and 3.1%, respectively). There were also more participants had hypertension and less participants had self-reported diabetes in CLHLS than NHANES (56.6% vs. 34.3% and 2.4% vs. 24.2% respectively) (Tables 1 and 2).

Prevalence of CKD in both countries

Among people over 65 years of age, the prevalence of CKD in CLHLS and NHANES samples were 44.4% (95% CI: 42.2%–46.6%) and 42.3% (95% CI: 40.2%–44.6%), respectively. Besides, the CKD prevalence for the participants without diabetes and hypertension were 37.8% in CLHLS and 33% in NHANES (diabetes/hypertension prevalence: 58% in CLHLS vs. 50% in NHANES). However, the prevalence in each age group of NHANES participants was higher than Chinese participants, as 27.4% vs 17.9% for those of 65–69 years old, 35.6% vs 18.3% for those aged 70–74, 49.6% vs 31.8% for 75–79 years old, and 62.3% vs 56.0% for the eldest group. In both CLHLS and NHANES, people who were aged over 80 (56.0% vs 62.3%) or widowed (54.6% vs 52.0%), or had lower educational level (51.3% of “no formal education” vs 49.0% of “below high school”) or bad health condition (52.2% of “bad” vs 51.9% of “fair”) usually had a

Table 1. Demographic characteristics and mean (SD) of biomarkers (Chinese participants: CLHLS 2012).

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μmol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (μmol/L)	eGFR (mL/min per 1.73 m ²)
Total	2019 (100)	896 (44.4)	25 (75.4)	106.6 (68.3)	41.7 (231.5)	82.1 (29.2)	6.9 (2.1)	40.3 (4.9)	292.9 (90.4)	67.5 (18.1)
Range [min, max]	/	/	[0, 991.7]	[0.02, 479.2]	[0, 6417.9]	[27, 464]	[2.3, 24.8]	[18.5, 57.1]	[0.7, 935.8]	[8.9, 116.1]
Age (mean ± SD)	85.7 ±12.2	90.5 ±10.8	/	/	/	/	/	/	/	/
Age group										
65–69	240 (11.9)	43 (17.9)	16.9 (59.8)	125.5 (68.4)	17.6 (61.3)	75.4 (20.1)	6.3 (1.6)	42.3 (4.0)	286.2 (93.4)	84.1 (14.5)
70–74	240 (11.9)	44 (18.3)	10.2 (20.3)	114.1 (67.7)	11.5 (26.0)	77.8 (18.9)	6.4 (1.7)	42.2 (4.8)	287.2 (80.5)	79.2 (13.8)
75–79	217 (10.7)	69 (31.8)	23 (82.3)	121.3 (71.4)	19.9 (63.4)	82.8 (25.9)	6.5 (1.9)	41.2 (4.5)	293.9 (99.4)	72.8 (16.0)
80+	1322 (65.5)	740 (56.0)	29.5 (82.4)	99.4 (66.8)	55.2 (282.7)	84 (32.2)	7.1 (2.3)	39.4 (5.0)	294.9 (90.0)	61.5 (16.5)
Gender										
Male	933 (46.2)	307 (32.9)	24.1 (83.2)	125.3 (70.1)	25.2 (99.7)	89.3 (31.1)	6.9 (2.1)	40.7 (4.8)	314.8 (90.5)	71.8 (17.6)
Female	1086 (53.8)	589 (54.2)	25.8 (68.0)	90.6 (62.5)	56 (301.3)	75.9 (25.8)	6.8 (2.2)	39.9 (5.0)	274 (86.0)	63.8 (17.8)
Race										
Han Chinese	1817 (90.0)	799 (44.0)	23.5 (70.8)	104.1 (66.3)	41.7 (238.4)	81.5 (27.9)	6.8 (2.1)	40.5 (4.9)	291.5 (89.4)	67.8 (18.0)
Ethnic minorities	152 (7.5)	70 (46.1)	37.3 (110.5)	137.3 (78.2)	38.5 (168.3)	90.2 (41.6)	7.1 (2.7)	38.1 (4.9)	315.2 (96.8)	64.2 (19.3)
Missing	50 (2.5)	27 (54.0)	41.7 (100.7)	106.6 (85.2)	50.3 (113.5)	79.2 (22.9)	6.8 (1.7)	39.4 (4.7)	272.9 (97.9)	66 (17.8)
Education										
No formal education	1238 (61.3)	635 (51.3)	27.2 (78.5)	97.5 (65.6)	52.3 (284.9)	79.6 (29.5)	6.9 (2.2)	39.7 (4.8)	283.3 (90.0)	64.6 (17.7)
Formal education	764 (37.8)	250 (32.7)	21.1 (70.1)	121.6 (70.2)	23.6 (95.6)	86.1 (28.4)	6.8 (2.1)	41.2 (5.1)	308.6 (89.2)	72.4 (17.9)
Missing	17 (0.8)	11 (64.7)	41.4 (69.1)	97 (60.5)	87.5 (154.5)	82.9 (19.0)	7.2 (2.0)	38 (5.8)	282.7 (78.3)	62.7 (16.1)
Household income (RMB)										
Tertile 1 (<6,000)	637 (31.6)	235 (36.9)	21.3 (72.6)	106 (67.2)	37.1 (272.9)	77.9 (23.4)	6.8 (1.9)	40 (4.5)	272.4 (83.5)	70.8 (17.3)
Tertile 2 (6,000–19,000)	661 (32.7)	291 (44.0)	24.7 (74.3)	108.6 (67.5)	42.2 (223.1)	81 (25.2)	6.9 (2.1)	40.3 (4.8)	295.6 (87.7)	67.9 (17.5)
Tertile 3 (20,000–more than 100,000)	572 (28.3)	288 (50.3)	29.8 (85.3)	108.3 (73.7)	47.2 (216.6)	87.5 (36.8)	6.9 (2.4)	40.7 (5.5)	308.8 (87.3)	64.5 (18.7)
Missing	149 (7.4)	82 (55.0)	23.8 (45.4)	94.4 (53.1)	38.4 (86.3)	84.2 (31.5)	6.9 (2.2)	39.6 (5.2)	307.2 (121.3)	63.2 (19.3)
Marital Status										
Married	774 (38.3)	229 (29.6)	20.2 (74.4)	120.8 (69.5)	19.2 (60.4)	83 (28.6)	6.6 (1.9)	41.5 (4.6)	299.6 (92.0)	74.5 (17.0)
Separated	40 (2.0)	18 (45.0)	22.6 (54.9)	117.1 (79.8)	16.3 (33.6)	87.3 (22.9)	6.5 (2.0)	38.8 (4.5)	302.5 (72.9)	68.8 (16.7)

(Continued)

Table 1. (Continued)

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μmol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (μmol/L)	eGFR (mL/min per 1.73 m ²)
Divorced	5 (0.2)	1 (20.0)	10.8 (19.0)	124.8 (113)	15.2 (28.7)	70.2 (20.2)	6.7 (1.5)	40 (3.5)	257.7 (74.3)	88.5 (16.7)
Widowed	1131 (56.0)	618 (54.6)	28.6 (78.4)	96.4 (65.5)	59 (303.8)	81.3 (29.8)	7 (2.3)	39.4 (5.0)	286 (86.5)	62.5 (17.2)
Never married	20 (1.0)	6 (30.0)	16.4 (36.8)	114.6 (52.5)	13.9 (32.8)	83.7 (25.5)	6.6 (1.3)	40.5 (5.7)	289.4 (113.2)	77.2 (21.3)
Missing	49 (2.4)	24 (49.0)	24.8 (38.9)	104 (64.4)	34.8 (72.9)	82.4 (30.6)	6.7 (2.4)	40.8 (5.2)	340.5 (130.4)	64.3 (18.5)
Health condition										
Very good	103 (5.1)	41 (39.8)	15.7 (29.8)	116.5 (68.9)	20 (48.8)	82.2 (19.6)	6.7 (1.9)	40.8 (4.7)	306.3 (86.0)	68.9 (16.5)
Good	750 (37.1)	286 (38.1)	25.7 (85.5)	109.6 (68.6)	47.3 (307.9)	82.9 (33.4)	7 (2.3)	40.5 (4.9)	292.6 (92.9)	69.3 (18.8)
Fair	775 (38.4)	367 (47.4)	24.7 (66.8)	106.3 (69.4)	40.3 (200.1)	82.2 (26.3)	6.8 (2.0)	40.6 (4.7)	291.8 (83.9)	66.9 (17.9)
Bad	201 (10.0)	105 (52.2)	24 (77.6)	103.8 (68.3)	29.3 (76.8)	84.2 (28.9)	6.6 (2.2)	39.5 (5.0)	299.6 (94.7)	65 (18.3)
Very Bad	12 (0.6)	4 (33.3)	13.7 (21.8)	79.5 (47.6)	20.9 (34.1)	68.4 (24.6)	6.2 (1.9)	37.5 (8.2)	250 (52.1)	73 (16.3)
Missing	178 (8.8)	93 (52.2)	30.7 (83.2)	95 (61.9)	52.3 (160.3)	76.8 (26.8)	7.1 (2.2)	38.3 (5.5)	286 (104.6)	64.1 (16.2)
Smoking status										
Never smoker	1465 (72.6)	700 (47.8)	26.6 (80.7)	100.9 (66.2)	48.5 (268.7)	80.5 (29.9)	6.9 (2.2)	40.2 (5.0)	286.1 (87.8)	66.3 (18.0)
Former smoker	164 (8.1)	60 (36.6)	18 (40.6)	119.2 (74.6)	27.1 (67.0)	85.6 (23.2)	7 (2.1)	39.7 (4.7)	304.5 (82.6)	69 (16.2)
Current smoker	334 (16.5)	108 (32.3)	20.8 (67.9)	127.2 (71.8)	19.6 (57.1)	87.2 (27.7)	6.5 (1.9)	40.4 (4.9)	309.2 (93.2)	72.6 (18.7)
Missing	56 (2.8)	28 (50.0)	27.9 (43.4)	97.3 (54.6)	38.9 (75.5)	82 (29.4)	6.9 (2.4)	41.7 (4.9)	338.6 (129.2)	65.3 (18.3)
Drinking status										
Never drinker	1528 (75.7)	708 (46.3)	25.8 (78.3)	103.7 (67.6)	45.8 (258)	81.5 (30.2)	6.9 (2.1)	40.2 (4.9)	285.7 (87.7)	66.5 (18.1)
Former drinker	120 (5.9)	54 (45)	34.7 (109.5)	116.4 (71.4)	40.6 (185.7)	87.6 (28.0)	7 (2.3)	39.3 (5)	313.3 (93.6)	67.7 (18.0)
Current drinker	315 (15.6)	105 (33.3)	18 (43.4)	116.6 (70.1)	24.2 (80.6)	82.8 (23.9)	6.5 (1.9)	40.9 (4.8)	310.7 (88.9)	72.7 (17.4)
Missing	56 (2.8)	29 (51.8)	22.5 (37.1)	109.4 (67.3)	31 (68.9)	83.1 (28.9)	6.9 (2.4)	40.5 (5.7)	343 (124.3)	64.9 (18.4)
Physical activity										
Yes	311 (15.4)	144 (46.3)	21.6 (58.1)	121.7 (81.0)	47.7 (368.8)	85.6 (23.4)	6.8 (2.0)	41.1 (4.8)	309.2 (86.6)	67.1 (17.4)
No	1598 (79.1)	701 (43.9)	25.9 (80.3)	103.2 (65.3)	41.5 (202.7)	81.3 (29.4)	6.9 (2.1)	40.1 (4.9)	287.4 (86.9)	67.6 (18.2)
Missing	110 (5.4)	51 (46.4)	22.3 (35.1)	113.3 (67.4)	28.1 (55.4)	82.9 (38.3)	6.6 (2.4)	40.4 (5.5)	325.6 (130.9)	67.2 (19.5)
Body mass index (kg/m²)										
Underweight (<18.5)	477 (23.6)	271 (56.8)	25.5 (71.3)	98.1 (61.2)	58.4 (377.9)	83.1 (28.1)	6.9 (2.2)	39.2 (5.0)	286 (85.0)	62.2 (18.0)

(Continued)

Table 1. (Continued)

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μmol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (μmol/L)	eGFR (mL/min per 1.73 m ²)
Normal (18.5–24.9)	1153 (57.1)	469 (40.7)	23.4 (75.3)	108.2 (69.4)	36.3 (168.8)	81.9 (29.4)	6.8 (2.1)	40.4 (4.7)	290.6 (91.4)	69.1 (17.7)
Overweight (25.0–29.9)	229 (11.3)	73 (31.9)	23.1 (66.2)	123.1 (75.4)	24.1 (71.1)	81.4 (27.2)	6.8 (1.9)	42.2 (5.0)	312.1 (90.2)	72.9 (17.9)
Obese (> = 30)	58 (2.9)	23 (39.7)	41 (112.8)	106.3 (69.7)	66 (262.4)	83.4 (38.1)	7.1 (3.1)	41.4 (5.5)	307.6 (83.3)	68.4 (18.8)
Missing	102 (5.1)	60 (58.8)	36 (87.0)	91.9 (63.5)	50.4 (138.4)	80.4 (30.1)	6.7 (2.4)	38.2 (5.1)	299.5 (102.4)	61.7 (17.6)
Hypertension										
Yes	1142 (56.6)	558 (48.9)	28.9 (81.5)	100.3 (66.9)	56.4 (300.2)	82.5 (29.8)	6.8 (2.2)	40.7 (4.8)	296.5 (87.1)	66.3 (17.9)
No	857 (42.4)	326 (38.0)	19.3 (64.1)	114.2 (68.4)	22.4 (73.8)	81.4 (28.3)	6.9 (2.1)	39.8 (5.0)	287.6 (93.9)	69.3 (18.3)
Missing	20 (1.0)	12 (60.0)	47.6 (131.9)	147 (97.2)	30.1 (72.6)	87.6 (27.8)	7.3 (1.8)	35.8 (4.3)	310.4 (116.6)	63.3 (17.9)
Diabetes										
Yes	48 (2.4)	22 (45.8)	46.5 (128.8)	111.1 (67.6)	41.5 (101.3)	84 (32.5)	6.6 (1.6)	41 (5.2)	303.4 (97.4)	71.1 (19.3)
No	1940 (96.1)	856 (44.1)	24.2 (73.6)	106.5 (68.4)	41.7 (235.5)	82 (29.0)	6.9 (2.1)	40.3 (4.9)	292.6 (90.3)	67.6 (18.1)
Missing	31 (1.5)	18 (58.1)	41.2 (72.8)	110.2 (67.7)	43.3 (63.9)	86.2 (33.2)	7.5 (2.8)	37.9 (6.3)	290.3 (85.1)	58.1 (17.8)

Abbreviations: SD = standard deviation, CKD = chronic kidney diseases, eGFR = estimated glomerular filtration rate, RMB = renminbi.

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higher prevalence of CKD. Besides, Chinese participants who were female (54.2%) or underweight (56.8%), or had the highest household income (50.3%), never smoked (47.8%), never drank (46.3%), did physical activity (46.3%), or had hypertension (48.9%) tended to have higher CKD prevalence. However, in the US, the prevalence was higher among people who were non-Hispanic White (44.9%), former smoker (44.2%), former drinker (48.1%), obese (44.9%), had income (PIR) <1.87 (44.8%), did not do physical activity (45.6%), had hypertension (49.7%) or self-reported diabetes (57.4%).

Biomarkers' level by the demographic characteristics

The mean values of urinary albumin (mg/L), urinary creatinine (mg/dL), ACR (mg/g), serum creatinine (μmol/L), plasma albumin (g/L), uric acid (μmol/L) and eGFR (mL/min per 1.73 m²) were lower in the Chinese participants than the US sample (25.0 vs 76.4, 106.6 vs 109.4, 41.7 vs 85.0, 82.1 vs 92.0, 40.3 vs 41.8, 292.9 vs 341.3, and 67.5 vs 69.7), while the BUN (mmol/L) was higher in the Chinese sample (6.9 vs 6.1) (Tables 1 and 2). The median comparison showed the same trend (S4–1 and S4–2 Table).

The mean difference between the CLHLS and NHANES varied in different age groups. The urinary creatinine, BUN and eGFR were both higher in CLHLS participants than NHANES sample aged younger than 80 and this difference almost disappeared in participants aged 80 and older. The eGFR decreased with age increasing in both CLHLS and NHANES samples. The urinary albumin, ACR, serum creatinine, and uric acid were lower in Chinese participants than the US ones among different age groups consistently. Plasma albumin level was similar in both samples across all age groups.

Table 2. Demographic characteristics and mean (SD) of biomarkers (US participants: NHANES 2011–2014).

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μ mol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (μ mol/L)	eGFR (mL/min per 1.73 m ²)
Total	2177 (100)	921 (42.3)	76.4 (359.6)	109.4 (68.8)	85.0 (449.3)	92.0 (42.5)	6.1 (2.8)	41.8 (3.1)	341.3 (88.0)	69.7 (19.3)
Range [min, max]	/	/	[0.2, 7410.0]	[9.0, 567.0]	[0.3, 10465.1]	[35.4, 818.6]	[1.4, 33.9]	[21.0, 52.0]	[65.4, 701.9]	[5.7, 114.8]
Age (mean \pm SD)	73.2 \pm 5.4	75.0 \pm 5.1	/	/	/	/	/	/	/	/
Age group										
65–69	682 (31.3)	187 (27.4)	61.2 (297.5)	115.7 (76.3)	71.0 (494.1)	87.0 (43.1)	5.4 (2.6)	42.2 (3.0)	335.0 (86.3)	77.9 (18.3)
70–74	567 (26.1)	202 (35.6)	52.0 (218.5)	106.1 (63.6)	47.1 (180.5)	86.4 (31.7)	5.7 (2.1)	42.0 (3.0)	338.1 (81.8)	72.4 (16.8)
75–79	361 (16.6)	179 (49.6)	109.3 (484.7)	112.0 (72.5)	116.4 (524.2)	98.7 (53.9)	6.4 (2.9)	41.6 (3.1)	352.1 (95.9)	64.9 (19.0)
80+	567 (26.1)	353 (62.3)	98.0 (437.7)	103.5 (60.8)	119.9 (521.2)	99.4 (41.4)	7.1 (3.1)	41.2 (3.2)	345.1 (90.3)	60.2 (17.9)
Gender										
Male	1072 (49.2)	457 (42.6)	98.1 (412.2)	130.2 (71.4)	108.3 (567.2)	104.1 (49.5)	6.3 (2.9)	42.0 (3.2)	361.1 (83.5)	69.4 (19.2)
Female	1105 (50.8)	464 (42.0)	55.3 (298.7)	89.2 (59.6)	62.4 (291.2)	80.3 (30.2)	5.9 (2.6)	41.6 (3.0)	322.0 (88.1)	70.0 (19.3)
Race/Ethnicity										
Mexican American	169 (7.8)	58 (34.3)	120.1 (435.4)	111.7 (69.9)	142.7 (542.6)	85.6 (47.9)	5.9 (2.9)	41.8 (3.3)	319.9 (83.5)	75.8 (19.6)
Other Hispanics	188 (8.6)	69 (36.7)	69.0 (208.9)	108.3 (58.1)	55.2 (148.1)	83.7 (29.8)	5.9 (2.5)	41.6 (3.3)	326.0 (82.9)	72.8 (18.1)
Non-Hispanic White	1151 (52.9)	517 (44.9)	51.3 (261.2)	101.6 (62.0)	64.2 (369.6)	90.7 (35.3)	6.4 (2.7)	41.8 (2.9)	337.3 (87.2)	66.9 (17.8)
Non-Hispanic Black	439 (20.2)	195 (44.4)	122.5 (541.4)	140.3 (84.9)	111.1 (483.4)	104.9 (57.5)	5.8 (3.1)	41.3 (3.3)	364.5 (90.2)	71.6 (22.4)
Non-Hispanic Asian	196 (9.0)	64 (32.7)	92.2 (399.7)	86.4 (54.0)	132.6 (794.8)	82.7 (41.9)	5.7 (2.1)	42.7 (2.9)	342.3 (82.4)	75.1 (17.3)
Other races	34 (1.6)	18 (52.9)	60.4 (207.1)	103.4 (56.7)	55.4 (184.2)	102.7 (35.1)	5.8 (2.5)	41.6 (3.3)	361.3 (108.8)	62.2 (21.3)
Education										
Below high school	649 (29.8)	318 (49.0)	103.9 (440.4)	114.1 (72.8)	108.4 (437.3)	95.4 (49.4)	6.3 (3.3)	41.4 (3.3)	348.4 (90.9)	68.8 (21.3)
High school	504 (23.2)	213 (42.3)	70.3 (308.3)	114.2 (72.8)	71.2 (307.4)	92.2 (40.3)	6.0 (2.5)	41.9 (3.0)	346.7 (86.9)	69.4 (18.3)
College or above	1019 (46.8)	386 (37.9)	61.9 (324.5)	104.0 (63.7)	76.9 (512.5)	89.8 (38.7)	6.0 (2.5)	42.0 (2.9)	333.8 (86.1)	70.5 (18.3)
Missing	5 (0.2)	4 (80.0)	74.2 (70.3)	122.8 (68.2)	82.8 (90.9)	99.5 (31.8)	5.1 (2.3)	41.2 (2.2)	397.3 (93.2)	67.1 (23.8)
Income (PIR)										
Tertile 1 (0–1.87)	928 (42.6)	416 (44.8)	88.8 (415.6)	109.5 (70.3)	90.8 (412.7)	91.8 (41.5)	6.1 (2.9)	41.7 (3.0)	343.2 (89.8)	69.8 (20.1)
Tertile 2 (1.88–3.86)	582 (26.7)	251 (43.1)	65.8 (264.0)	112.8 (72.3)	76.0 (362.0)	93.7 (47.5)	6.1 (2.7)	41.6 (3.3)	341.9 (85.1)	68.4 (19.0)
Tertile 3 (>= 3.87)	474 (21.8)	176 (37.1)	50.7 (258.0)	105.4 (63.4)	64.7 (507.6)	91.1 (36.8)	6.0 (2.4)	42.1 (2.9)	336.7 (87.4)	70.6 (17.9)
Missing	193 (8.9)	78 (40.4)	111.3 (503.1)	108.7 (63.3)	134.2 (656.5)	90.4 (45.1)	6.4 (3.0)	42.2 (3.1)	341.3 (90.0)	71.3 (18.9)

(Continued)

Table 2. (Continued)

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μmol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (umol/L)	eGFR (mL/min per 1.73 m ²)
Marital Status										
Married	1173 (53.9)	450 (38.4)	77.4 (379.3)	112.0 (69.6)	91.4 (530.9)	93.2 (46.0)	6.1 (2.8)	42.1 (2.9)	343.3 (86.3)	70.7 (18.4)
Separated	44 (2.0)	15 (34.1)	134.2 (349.6)	106.5 (67.0)	146.6 (456.0)	88.5 (33.4)	5.8 (2.9)	41.8 (3.4)	330.2 (90.7)	72.7 (19.1)
Divorced	258 (11.9)	112 (43.4)	60.5 (200.8)	114.6 (72.9)	58.2 (221.0)	90.9 (40.2)	5.7 (2.6)	41.8 (2.8)	342.7 (93.0)	70.8 (20.1)
Widowed	562 (25.8)	292 (52.0)	73.2 (365.8)	99.2 (64.4)	79.1 (343.4)	90.4 (37.4)	6.4 (2.8)	41.2 (3.4)	337.4 (89.5)	66.4 (20.0)
Never married	100 (4.6)	40 (40.0)	120.7 (466.4)	115.6 (67.7)	113.6 (456.4)	93.3 (42.4)	5.9 (2.6)	42.1 (3.0)	337.3 (90.9)	71.8 (21.8)
Living with partner	39 (1.8)	11 (28.2)	18.3 (18.8)	131.0 (68.2)	15.5 (19.0)	88.5 (23.5)	5.9 (1.8)	42.1 (3.1)	345.6 (77.4)	74.4 (15.9)
Missing	1 (0.1)	1 (100.0)	14.6 (0.0)	154.9 (0.0)	9.5 (0.0)	80.4 (0.0)	6.8 (0.0)	32.0 (0.0)	410.4 (0.0)	59.8 (0.0)
Health condition										
Excellent	158 (7.3)	59 (37.3)	29.2 (94.1)	114.7 (70.8)	36.5 (151.5)	91.5 (39.2)	6.3 (2.2)	42.0 (3.0)	337.8 (79.2)	69.0 (16.4)
Very good	515 (23.7)	172 (33.4)	34.6 (185.1)	103.6 (63.3)	31.7 (127.3)	84.2 (23.3)	5.8 (2.0)	42.1 (2.9)	327.8 (85.9)	72.4 (16.7)
Good	811 (37.3)	336 (41.4)	82.5 (392.1)	108.4 (68.5)	88.1 (443.8)	92.5 (37.7)	6.0 (2.6)	42.0 (2.9)	346.6 (85.1)	69.4 (19.4)
Fair	509 (23.4)	264 (51.9)	109.5 (446.2)	115.1 (71.6)	121.3 (511.6)	96.4 (48.7)	6.4 (3.2)	41.4 (3.3)	346.8 (94.3)	68.5 (20.9)
Poor	95 (4.4)	49 (51.6)	171.8 (585.5)	112.7 (79.5)	243.9 (1152.4)	104.2 (95.1)	6.2 (3.9)	40.4 (4.3)	342.7 (97.8)	67.6 (23.4)
Missing	89 (4.1)	41 (46.1)	55.2 (144.5)	107.1 (68.7)	74.0 (242.4)	95.6 (41.5)	6.3 (3.8)	41.7 (2.6)	343.4 (87.3)	67.3 (20.3)
Smoking status										
Never smoker	1096 (50.3)	445 (40.6)	75.1 (393.7)	102.1 (63.1)	84.6 (487.0)	88.9 (42.6)	6.1 (2.6)	41.8 (3.0)	333.6 (87.3)	69.9 (19.0)
Former smoker	857 (39.4)	379 (44.2)	68.9 (292.8)	116.5 (72.1)	73.9 (353.1)	94.4 (39.4)	6.2 (2.7)	41.9 (3.1)	350.4 (90.1)	69.0 (18.8)
Current smoker	222 (10.2)	96 (43.2)	111.6 (414.9)	117.2 (78.5)	130.3 (572.4)	98.4 (51.8)	5.6 (3.5)	41.5 (3.4)	343.6 (80.4)	71.6 (22.0)
Missing	2 (0.1)	1 (50.0)	64.7 (74.0)	206.0 (52.3)	27.7 (28.9)	83.1 (1.3)	6.3 (1.3)	41.0 (2.8)	350.9 (50.5)	75.3 (26.2)
Drinking status										
Never drinker	392 (18.0)	177 (45.2)	98.0 (522.1)	103.0 (67.8)	111.5 (530.0)	91.2 (55.3)	6.2 (3.0)	41.6 (3.0)	333.8 (90.0)	68.5 (20.8)
Former drinker	318 (14.6)	153 (48.1)	84.2 (306.1)	105.3 (65.0)	93.2 (340.4)	89.3 (34.3)	6.2 (2.9)	41.5 (3.1)	335.7 (90.8)	68.1 (19.7)
Current drinker	1356 (62.3)	541 (39.9)	70.4 (324.8)	112.4 (70.1)	77.1 (460.3)	92.7 (40.3)	6.0 (2.6)	41.9 (3.1)	344.7 (86.8)	70.6 (18.6)
Missing	111 (5.1)	50 (45.1)	50.1 (131.0)	107.5 (65.7)	64.0 (218.1)	94.7 (38.9)	6.2 (3.6)	41.8 (2.8)	342.3 (87.0)	67.7 (20.1)
Physical activity										
Yes	868 (39.9)	324 (37.3)	63.6 (298.8)	111.7 (70.6)	78.3 (507.9)	90.7 (41.5)	5.9 (2.5)	42.1 (2.9)	341.9 (86.5)	71.7 (18.7)
No	1306 (60.0)	596 (45.6)	84.6 (394.9)	107.9 (67.6)	89.4 (406.4)	92.9 (43.2)	6.2 (2.9)	41.6 (3.2)	340.8 (89.2)	68.4 (19.5)

(Continued)

Table 2. (Continued)

Characteristics	n (%)	CKD n (%)	Urinary albumin (mg/L)	Urinary creatinine (mg/dL)	Albumin creatinine ratio (mg/g)	Serum creatinine (μ mol/L)	Blood urea nitrogen (mmol/L)	Plasma albumin (g/L)	Uric acid (μ mol/L)	eGFR (mL/min per 1.73 m ²)
Missing	3 (0.1)	1 (33.3)	198.6 (339.0)	106.0 (53.9)	120.3 (201.7)	82.5 (11.9)	5.1 (1.0)	40.3 (2.9)	343.0 (44.6)	80.3 (9.7)
Body mass index (kg/m²)										
Underweight (<18.5)	36 (1.7)	16 (44.4)	79.0 (261.2)	106.1 (67.9)	81.2 (238.0)	77.5 (20.2)	5.2 (2.0)	42.1 (4.1)	270.8 (74.1)	75.8 (16.3)
Normal (18.5–24.9)	579 (26.6)	228 (39.4)	79.2 (388.4)	97.7 (67.3)	103.8 (601.0)	89.3 (45.6)	6.0 (2.7)	42.3 (3.0)	319.4 (84.0)	71.8 (19.8)
Overweight (25.0–29.9)	776 (35.7)	316 (40.7)	44.9 (171.6)	110.0 (67.0)	46.3 (190.6)	91.7 (30.8)	6.0 (2.3)	42.2 (2.8)	338.1 (84.1)	69.3 (18.1)
Obese (>= 30)	746 (34.3)	335 (44.9)	104.7 (470.7)	117.6 (70.4)	107.0 (507.8)	94.8 (50.5)	6.3 (3.1)	41.1 (3.2)	363.7 (89.6)	68.4 (19.7)
Missing	40 (1.8)	26 (65.0)	116.6 (253.3)	116.7 (73.2)	159.6 (404.3)	100.0 (41.6)	7.4 (4.1)	40.2 (3.7)	363.6 (84.4)	65.3 (23.8)
Hypertension										
Yes	746 (34.3)	371 (49.7)	131.6 (526.2)	102.2 (67.1)	159 (696.9)	94.6 (46.8)	6.2 (2.9)	41.8 (3.1)	341 (86.7)	68.4 (20.4)
No	1431 (65.7)	550 (38.4)	47.6 (224.0)	113.2 (69.4)	46.5 (223.4)	90.7 (40.0)	6.1 (2.7)	41.8 (3.1)	341.4 (88.8)	70.4 (18.6)
Diabetes										
Yes	526 (24.2)	302 (57.4)	177.7 (612.9)	112.6 (69.2)	210.1 (810.0)	104.3 (62.3)	6.9 (3.4)	41.3 (3.2)	357.8 (93.4)	65.3 (21.8)
No	1650 (75.8)	618 (37.5)	44.1 (216.2)	108.4 (68.7)	45.2 (225.8)	88.1 (33.0)	5.9 (2.5)	42 (3.0)	336 (85.6)	71.2 (18.1)
Missing	1 (0.0)	1 (100.0)	3.2 (0.0)	74 (0.0)	4.3 (0.0)	99.9 (0.0)	7.1 (0.0)	37 (0.0)	404.5 (0.0)	47 (0.0)

Abbreviations: SD = standard deviation, CKD = chronic kidney diseases, eGFR = estimated glomerular filtration rate, PIR = ratio of family income to poverty.

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There was a large difference in the urinary albumin between the two samples. The mean of urinary albumin level of CLHLS participants was 25.0 mg/L (SD: 75.4), much lower than that of NHANES participants (76.4 mg/L, SD: 359.6). Among Chinese participants, higher urinary albumin level usually appeared along with factors like age over 80 (29.5 mg/L), female (25.8 mg/L), high household income (29.8 mg/L), widowed (28.6 mg/L), good health condition (25.7 mg/L), never smoker (26.6 mg/L), and former drinker (34.7 mg/L) (Table 1). However, among NHANES participants, people had higher urinary albumin were more likely to be aged 75–79 (109.3 mg/L), male (98.1 mg/L), with low household income (88.8 mg/L), separated (134.2 mg/L), with poor health condition (171.8 mg/L), current smoker (111.6 mg/L), and never drinker (98.0 mg/L) (Table 2). Besides, some characteristics were found related to higher urinary albumin level in both samples, including lower education, obese, insufficient physical activity, hypertension, and diabetes (Tables 1 and 2).

In addition to urinary albumin, the mean level of ACR in Chinese participants (41.7 mg/g, SD: 231.5) was also significantly lower than that in the US (85.0 mg/g, SD: 449.3). In both countries, the subgroups with the lowest ACR were those were aged 70–74, with formal education, drinking currently, overweight, or without hypertension. However, we did not find a similar pattern in the two samples in terms of the relationship between ACR and other demographic or lifestyle characteristics.

Moreover, Chinese participants (292.9 $\mu\text{mol/L}$, SD: 90.4) also showed a lower mean level of uric acid than the US (341.3 $\mu\text{mol/L}$, SD: 88.0). Besides, male presented a higher mean level than female in both Chinese (male: 314.8 $\mu\text{mol/L}$, female: 274.0 $\mu\text{mol/L}$) and the US participants (male: 361.1 $\mu\text{mol/L}$, female: 322.0 $\mu\text{mol/L}$). Also, people who were younger, never smoker, never drinker, not taking physical activity, underweight, without diabetes tended to have lower uric acid in both CLHLS and NHANES group.

Factors associated with CKD

There were different factors associated with CKD between CLHLS and NHANES samples. In China, CKD was found more common in participants who were older, female, with higher household income, self-rated bad health, or had physical activities. However, in the US, participants with older age, education below high school, self-rated bad health, belonging to white or other races, were not married, or currently smoking were more likely to have CKD. The effect size of risk factors for CKD was also different between CLHLS and NHANES. Compared to those aged 65–69, the ORs (95% CI) of 70–74, 75–80, and 80+ years old for CKD in CLHLS was 0.918 (0.568, 1.484), 2.080 (1.322, 3.300), and 4.187 (2.839, 6.283), lower than those in NHANES, as 1.492 (1.154, 1.928), 2.45 (1.839, 3.263), and 4.557 (3.441, 6.034) (Tables 3 and 4). In the Chinese sample, women were more closely related to CKD (OR: 1.625, 95% CI: 1.266, 2.088) compared to men, while the same pattern did not present in the US participants. US participants who were white had greater OR of CKD (1.555) than the Mexican American, and those with college or above educational level had a lower prevalence of CKD, compared to participants with educational level below high school. In CLHLS, the presence of CKD was found associated with higher household income, which was opposite to the situation in the NHANES participants. In both countries, ORs of CKD increased with worse health condition, but insignificantly in most cases. Only participants in the US who rated their health condition as “Fair” or “Poor” had a significant association with CKD (OR: 1.533, 95% CI: 1.024, 2.295). Among NHANES participants, current smokers also showed about 40% greater odds of having CKD. Besides, in the Chinese sample, those who had no physical activities had lower odds of CKD (0.708, 95% CI: 0.534, 0.938) than the others.

In the age stratified analysis, the association between most of the above risk factors and CKD only persisted in participants aged 80 or older in CLHLS. Former drinker was associated with higher odds of CKD only in Chinese participants aged younger than 80 (Table 3). The CKD risk factors were also different among different age groups in NHANES except hypertension and diabetes. Education and health condition were still significantly associated with CKD only in participants aged 80 or older in NHANES. Current smoker had a higher odds of CKD only in those aged 65–69 in NHANES (Table 4).

Most risk factors associated with CKD were also associated with abnormal eGFR and ACR when using abnormal eGFR or ACR as the dependent variable separately. Of note, obesity was risk factor for abnormal eGFR but not for CKD or abnormal ACR in NHANES. Older age was associated with CKD and abnormal eGFR but not with abnormal ACR in CLHLS (S5 and S6 Tables).

The mortality risk of CKD biomarkers

The CLHLS participants were followed up from 2012 to 2018, with a total of 6307 person-years and 817 deaths. The participants in NHANES were followed up in 2015, with 6059 person-year and 201 deaths. In both CLHLS and NHANES, the level of BUN was positively correlated with all-cause mortality risk in the elderly [HR (95%CI): 1.041 (1.008, 1.075) in CLHLS, 1.106 (1.070, 1.143) in NHANES], plasma albumin was negatively associated with all-cause

Table 3. Odds ratio (95% CI) of factors associated with CKD in Chinese participants (CLHLS 2012).

Factors	Total population			Age<80			Age≥80		
	mean(sd) / n (%)	OR (95% CI) *	P value	mean(sd) / n (%)	OR (95% CI) *	P value	mean(sd) / n (%)	OR (95% CI) *	P value
Total	2019 (100)								
Age (mean ± SD)	85.7 (12.2)	\	\	71.8 (4.29)	1.09 (1.04, 1.14)	<0.001	93.0 (7.88)	1.04 (1.03, 1.06)	<0.001
Age group									
65–69	240 (11.9)	Ref	\	240 (34.4)	\	\	0 (0)	\	\
70–74	240 (11.9)	0.92 (0.57, 1.48)	0.727	240 (34.4)	\	\	0 (0)	\	\
75–79	217 (10.7)	2.08 (1.32, 3.30)	0.002	217 (31.1)	\	\	0 (0)	\	\
80+	1322 (65.5)	4.19 (2.84, 6.28)	<0.001	0 (0)	\	\	1322 (100)	\	\
Gender									
Male	933 (46.2)	Ref	\	457 (65.6)	Ref	\	476 (36.0)	Ref	\
Female	1086 (53.8)	1.63 (1.27, 2.09)	<0.001	240 (34.4)	1.53 (0.95, 2.48)	0.084	846 (64.0)	1.61 (1.19, 2.19)	0.002
Race									
Han Chinese	1817 (90.0)	Ref	\	622 (89.2)	Ref	\	1195 (90.4)	Ref	\
Ethnic minorities	152 (7.5)	1.21 (0.84, 1.76)	0.304	62 (8.9)	1.07 (0.54, 2.02)	0.849	90 (6.8)	1.25 (0.79, 2.01)	0.342
Missing	50 (2.5)	1.31 (0.71, 2.46)	0.389	13 (1.9)	2.57 (0.70, 8.69)	0.134	37 (2.8)	1.17 (0.58, 2.43)	0.663
Education									
No formal education	1238 (61.3)	Ref	\	239 (34.3)	Ref	\	999 (75.6)	Ref	\
Formal education	764 (37.8)	1.06 (0.82, 1.38)	0.654	456 (65.4)	1.22 (0.78, 1.92)	0.392	308 (23.3)	1.16 (0.83, 1.61)	0.388
Missing	17 (0.8)	1.61 (0.55, 5.19)	0.396	2 (0.3)	4.02 (0.14, 111.83)	0.352	15 (1.1)	1.25 (0.40, 4.40)	0.713
Household income (RMB)									
Tertile 1 (<6,000)	637 (31.6)	Ref	\	233 (33.4)	Ref	\	404 (30.6)	Ref	\
Tertile 2 (6,000–19,000)	661 (32.7)	1.36 (1.07, 1.74)	0.012	236 (33.9)	0.99 (0.62, 1.59)	0.966	425 (32.1)	1.50 (1.12, 2.00)	0.006
Tertile 3 (20,000-over 100,000)	572 (28.3)	1.89 (1.46, 2.44)	<0.001	202 (29.0)	1.00 (0.61, 1.66)	0.986	370 (28.0)	2.32 (1.70, 3.17)	<0.001
Missing	149 (7.4)	1.64 (1.06, 2.56)	0.029	26 (3.7)	1.10 (0.36, 2.98)	0.856	123 (9.3)	1.85 (1.13, 3.07)	0.016
Marital Status									
Married	774 (38.3)	Ref	\	499 (71.6)	Ref	\	275 (20.8)	Ref	\
Not married	1196 (59.2)	1.25 (0.98, 1.60)	0.075	189 (27.1)	0.77 (0.49, 1.21)	0.262	1007 (76.2)	1.22 (0.88, 1.69)	0.226
Missing	49 (2.4)	0.75 (0.22, 2.39)	0.636	9 (1.3)	0.63 (0.03, 4.77)	0.708	40 (3.0)	0.51 (0.11, 2.24)	0.378
Health condition									
Very good	103 (5.1)	Ref	\	48 (6.9)	Ref	\	55 (4.2)	Ref	\
Good	750 (37.1)	0.88 (0.55, 1.42)	0.592	312 (44.8)	1.07 (0.49, 2.55)	0.876	438 (33.1)	0.95 (0.51, 1.74)	0.866
Fair	775 (38.4)	1.25 (0.78, 2.01)	0.365	260 (37.3)	1.51 (0.68, 3.65)	0.333	515 (39.0)	1.35 (0.73, 2.47)	0.331
Bad/Very bad	213 (10.6)	1.33 (0.78, 2.28)	0.294	69 (9.9)	2.03 (0.80, 5.46)	0.144	144 (10.9)	1.40 (0.71, 2.75)	0.333

(Continued)

Table 3. (Continued)

Factors	Total population			Age<80			Age≥80		
	mean(sd) / n (%)	OR (95% CI) *	P value	mean(sd) / n (%)	OR (95% CI) *	P value	mean(sd) / n (%)	OR (95% CI) *	P value
Missing	178 (8.8)	0.90 (0.51, 1.60)	0.716	8 (1.1)	0.64 (0.02, 7.00)	0.743	170 (12.9)	0.82 (0.41, 1.60)	0.557
Smoking status									
Never smoker	1465 (72.6)	Ref	\	432 (62.0)	Ref	\	1033 (78.1)	Ref	\
Former smoker	164 (8.1)	0.75 (0.51, 1.12)	0.160	58 (8.3)	0.92 (0.43, 1.87)	0.822	106 (8.0)	0.68 (0.42, 1.09)	0.106
Current smoker	334 (16.5)	1.00 (0.73, 1.37)	0.990	197 (28.3)	0.92 (0.55, 1.53)	0.741	137 (10.4)	1.08 (0.71, 1.66)	0.709
Missing	56 (2.8)	1.02 (0.36, 2.84)	0.970	10 (1.4)	0.48 (0.02, 3.87)	0.564	46 (3.5)	1.28 (0.36, 4.72)	0.700
Drinking status									
Never drinker	1528 (75.7)	Ref	\	495 (71.0)	Ref	\	1033 (78.1)	Ref	\
Former drinker	120 (5.9)	1.25 (0.81, 1.93)	0.321	44 (6.3)	2.29 (1.09, 4.71)	0.026	76 (5.7)	1.03 (0.60, 1.76)	0.927
Current drinker	315 (15.6)	0.87 (0.64, 1.18)	0.368	146 (20.9)	0.94 (0.53, 1.64)	0.832	169 (12.8)	0.83 (0.57, 1.21)	0.333
Missing	56 (2.8)	1.61 (0.56, 4.59)	0.367	12 (1.7)	1.00 (0.11, 5.63)	0.997	44 (3.3)	2.36 (0.57, 11.75)	0.258
Physical activity									
Yes	311 (15.4)	Ref	\	137 (19.7)	Ref	\	174 (13.2)	Ref	\
No	1598 (79.1)	0.71 (0.53, 0.94)	0.016	533 (76.5)	0.58 (0.36, 0.94)	0.024	1065 (80.6)	0.68 (0.47, 0.98)	0.038
Missing	110 (5.4)	0.68 (0.38, 1.20)	0.183	27 (3.9)	0.69 (0.20, 2.03)	0.527	83 (6.3)	0.69 (0.34, 1.37)	0.286
Body mass index (kg/m²)									
Underweight (<18.5)	477 (23.6)	Ref	\	70 (10.0)	Ref	\	407 (30.8)	Ref	\
Normal (18.5–24.9)	1153 (57.1)	0.74 (0.58, 0.94)	0.013	465 (66.7)	0.66 (0.36, 1.24)	0.186	688 (52.0)	0.83 (0.63, 1.08)	0.161
Overweight (25.0–29.9)	229 (11.3)	0.60 (0.41, 0.87)	0.008	132 (18.9)	0.64 (0.31, 1.36)	0.243	97 (7.3)	0.63 (0.39, 1.02)	0.063
Obese (>= 30)	58 (2.9)	0.67 (0.36, 1.23)	0.199	24 (3.4)	0.31 (0.06, 1.12)	0.098	34 (2.6)	0.90 (0.42, 1.98)	0.797
Missing	102 (5.1)	0.88 (0.55, 1.41)	0.586	6 (0.9)	3.31 (0.51, 22.08)	0.197	96 (7.3)	0.75 (0.46, 1.23)	0.247
Hypertension									
yes	1142 (56.6)	Ref	\	342 (49.1)	Ref	\	800 (60.5)	Ref	\
no	857 (42.4)	0.71 (0.58, 0.87)	0.001	350 (50.2)	0.77 (0.52, 1.14)	0.192	507 (38.4)	0.67 (0.53, 0.86)	0.001
missing	20 (1.0)	1.41 (0.54, 3.93)	0.492	5 (0.7)	0.25 (0.01, 2.66)	0.318	15 (1.1)	1.90 (0.60, 7.33)	0.303
Diabetes									
yes	48 (2.4)	Ref	\	29 (4.2)	Ref	\	19 (1.4)	Ref	\
no	1940 (96.1)	0.62 (0.33, 1.19)	0.150	665 (95.4)	0.66 (0.28, 1.64)	0.348	1275 (96.4)	0.36 (0.12, 0.99)	0.056
missing	31 (1.5)	0.57 (0.21, 1.57)	0.274	3 (0.4)	1.24 (0.05, 19.36)	0.877	28 (2.1)	0.29 (0.08, 1.07)	0.065

Abbreviations: OR = odds ratio, CI = confidence interval, CKD = chronic kidney diseases.

* The multi-variate analysis contained all the variables listed above in the logistic regression models.

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Table 4. Odds ratio (95% CI) of factors associated with CKD in US participants (NHANES 2011–2014).

Factors	Total			Age: 65–69			Age: 70–74			Age: 75–79			Age: 80+		
	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value
Total	2177 (100)	\	\	682 (100)	\	\	567 (100)	\	\	361 (100)	\	\	567 (100)	\	\
Age	73.2 (5.4)	\	\	66.9 (1.4)	1.12 (0.99, 1.28)	0.082	71.9 (1.4)	1.15 (1.01, 1.31)	0.034	76.8 (1.4)	1.04 (0.89, 1.23)	0.612	80.0(0) ^b	NA	NA
Age group															
65–69	682 (31.3)	Ref	\	682 (100)	\	\	0	\	\	0	\	\	0	\	\
70–74	567 (26.1)	1.49 (1.15, 1.93)	0.002	0	\	\	567 (100)	\	\	0	\	\	0	\	\
75–79	361 (16.6)	2.45 (1.84, 3.26)	< .001	0	\	\	0	\	\	361 (100)	\	\	0	\	\
80+	567 (26.1)	4.56 (3.44, 6.03)	< .001	0	\	\	0	\	\	0	\	\	567 (100)	\	\
Gender															
Male	1072 (49.2)	Ref	\	341 (50.0)	Ref	\	264 (46.6)	Ref	\	190 (52.6)	Ref	\	277 (48.9)	Ref	\
Female	1105 (50.8)	0.94 (0.76, 1.16)	0.543	341 (50.0)	0.92 (0.61, 1.39)	0.682	303 (53.4)	0.91 (0.60, 1.39)	0.658	171 (47.4)	1.12 (0.66, 1.91)	0.667	290 (51.2)	0.95 (0.63, 1.44)	0.813
Race/Ethnicity															
Mexican American	169 (7.8)	Ref	\	84 (12.3)	Ref	\	44 (7.8)	Ref	\	23 (6.4)	Ref	\	18 (3.2)	Ref	\
Other Hispanics	188 (8.6)	1.07 (0.67, 1.72)	0.770	86 (12.6)	1.28 (0.60, 2.71)	0.519	50 (8.8)	1.56 (0.61, 4.02)	0.355	25 (6.9)	0.29 (0.08, 1.11)	0.070	27 (4.8)	0.72 (0.18, 2.96)	0.653
Non-Hispanic White	1151 (52.9)	1.56 (1.05, 2.31)	0.028	234 (34.3)	1.43 (0.73, 2.80)	0.302	304 (53.6)	2.14 (0.95, 4.85)	0.068	193 (53.5)	0.59 (0.20, 1.72)	0.331	420 (74.1)	0.99 (0.31, 3.18)	0.985
Non-Hispanic Black	439 (20.2)	1.49 (0.99, 2.24)	0.054	183 (26.8)	1.57 (0.80, 3.06)	0.187	103 (18.2)	2.45 (1.04, 5.77)	0.041	87 (24.1)	0.61 (0.20, 1.85)	0.385	66 (11.6)	0.67 (0.19, 2.32)	0.529
Non-Hispanic Asian	196 (9.0)	1.12 (0.68, 1.82)	0.664	85 (12.5)	1.44 (0.64, 3.26)	0.378	55 (9.7)	0.90 (0.31, 2.58)	0.841	26 (7.2)	0.70 (0.19, 2.59)	0.592	30 (5.3)	0.62 (0.15, 2.49)	0.496
Other races	34 (1.6)	2.28 (1.02, 5.09)	0.045	10 (1.5)	5.78 (1.36, 24.51)	0.017	11 (1.9)	2.93 (0.68, 12.59)	0.148	7 (1.9)	0.69 (0.10, 4.59)	0.701	6 (1.1)	0.75 (0.09, 6.50)	0.792
Education															
Below high school	649 (29.8)	Ref	\	200 (29.3)	Ref	\	161 (28.4)	Ref	\	116 (32.1)	Ref	\	172 (30.3)	Ref	\
High school	504 (23.2)	0.80 (0.61, 1.04)	0.097	147 (21.6)	1.10 (0.65, 1.86)	0.732	136 (24)	0.77 (0.45, 1.32)	0.340	83 (23)	1.11 (0.57, 2.15)	0.760	138 (24.3)	0.51 (0.30, 0.87)	0.012
College or above	1019 (46.8)	0.78 (0.60, 0.996)	0.047	334 (49.0)	0.90 (0.55, 1.49)	0.689	269 (47.4)	0.88 (0.52, 1.48)	0.624	162 (44.9)	1.04 (0.56, 1.94)	0.908	254 (44.8)	0.54 (0.33, 0.89)	0.017

(Continued)

Table 4. (Continued)

Factors	Total			Age: 65–69			Age: 70–74			Age: 75–79			Age: 80+		
	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value
Missing	5 (0.2)	2.37 (0.26, 21.84)	0.448	1 (0.2)	NA	0.996	1 (0.2)	NA	0.980	0	\	\	3 (0.5)	1.40 (0.11, 17.16)	0.793
Income (PIR)															
Tertile 1 (0–1.87)	928 (42.6)	Ref	\	294 (43.1)	Ref	\	230 (40.6)	Ref	\	158 (43.8)	Ref	\	246 (43.4)	Ref	\
Tertile 2 (1.88–3.86)	582 (26.7)	1.14 (0.89, 1.44)	0.298	171 (25.1)	1.12 (0.69, 1.81)	0.646	148 (26.1)	1.16 (0.70, 1.93)	0.553	104 (28.8)	0.66 (0.38, 1.17)	0.154	159 (28)	1.60 (1.00, 2.57)	0.050
Tertile (> = 3.87)	474 (21.8)	1.13 (0.86, 1.50)	0.382	163 (24.0)	1.11 (0.63, 1.97)	0.714	134 (23.6)	1.36 (0.77, 2.38)	0.290	68 (18.8)	0.86 (0.43, 1.72)	0.674	109 (19.2)	1.15 (0.67, 1.98)	0.606
Missing	193 (8.9)	0.90 (0.63, 1.27)	0.530	54 (7.9)	0.80 (0.38, 1.70)	0.559	55 (9.7)	1.11 (0.56, 2.19)	0.772	31 (8.6)	0.75 (0.33, 1.73)	0.498	53 (9.4)	0.83 (0.43, 1.61)	0.587
Marital Status															
Married	1173 (53.9)	Ref	\	383 (56.2)	Ref	\	345 (60.9)	Ref	\	197 (54.6)	Ref	\	248 (43.7)	Ref	\
Not married	1003 (46.1)	1.21 (0.99, 1.49)	0.061	299 (43.8)	0.92 (0.61, 1.39)	0.679	222 (39.2)	1.65 (1.09, 2.49)	0.017	164 (45.4)	0.92 (0.55, 1.54)	0.754	318 (56.1)	1.14 (0.76, 1.69)	0.534
Missing	1 (0.1)	NA	0.978	0	\	\	0	\	\	0	\	\	1 (0.2)	NA	0.986
Health condition															
Excellent	158 (7.3)	Ref	\	45 (6.6)	Ref	\	46 (8.1)	Ref	\	22 (6.1)	Ref	\	45 (7.9)	Ref	\
Very good	515 (23.7)	0.78 (0.52, 1.15)	0.209	154 (22.6)	0.52 (0.23, 1.17)	0.114	141 (24.9)	0.57 (0.27, 1.21)	0.141	82 (22.7)	0.57 (0.20, 1.61)	0.290	138 (24.3)	1.28 (0.63, 2.59)	0.495
Good	811 (37.3)	1.05 (0.72, 1.54)	0.810	261 (38.3)	0.57 (0.26, 1.24)	0.154	207 (36.5)	0.95 (0.47, 1.93)	0.888	136 (37.7)	0.66 (0.25, 1.80)	0.422	207 (36.5)	2.14 (1.07, 4.29)	0.032
Fair/Poor	604 (27.7)	1.53 (1.02, 2.30)	0.038	204 (29.9)	0.89 (0.39, 2.01)	0.779	154 (27.2)	1.46 (0.69, 3.09)	0.317	98 (27.2)	1.18 (0.40, 3.45)	0.760	148 (26.1)	3.00 (1.40, 6.43)	0.005
Missing	89 (4.1)	2.26 (0.78, 6.53)	0.132	18 (2.6)	1.47 (0.10, 21.63)	0.780	19 (3.4)	NA	0.980	23 (6.4)	3.48 (0.15, 81.36)	0.438	29 (5.1)	4.07 (0.91, 18.20)	0.067
Smoking status															
Never smoker	1096 (50.3)	Ref	\	317 (46.5)	Ref	\	298 (52.6)	Ref	\	163 (45.2)	Ref	\	318 (56.1)	Ref	\
Former smoker	857 (39.4)	1.13 (0.91, 1.40)	0.279	251 (36.8)	1.72 (1.10, 2.68)	0.018	212 (37.4)	0.71 (0.46, 1.10)	0.123	165 (45.7)	1.31 (0.77, 2.23)	0.324	229 (40.4)	1.09 (0.72, 1.65)	0.699
Current smoker	222 (10.2)	1.48 (1.05, 2.08)	0.025	114 (16.7)	1.85 (1.05, 3.26)	0.034	56 (9.9)	0.91 (0.45, 1.82)	0.785	33 (9.1)	2.20 (0.90, 5.41)	0.085	19 (3.4)	2.26 (0.65, 7.81)	0.198
Missing	2 (0.1)	0.67 (0.03, 16.00)	0.802	0	\	\	1 (0.2)	NA	0.980	0	\	\	1 (0.2)	NA	0.988
Drinking status															

(Continued)

Table 4. (Continued)

Factors	Total			Age: 65–69			Age: 70–74			Age: 75–79			Age: 80+		
	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value
Never drinker	392 (18.0)	Ref	\	100 (14.7)	Ref	\	97 (17.1)	Ref	\	70 (19.4)	Ref	\	125 (22.1)	Ref	\
Former drinker	318 (14.6)	1.16 (0.83, 1.61)	0.383	87 (12.8)	1.44 (0.71, 2.92)	0.311	90 (15.9)	1.13 (0.59, 2.17)	0.720	48 (13.3)	1.02 (0.45, 2.30)	0.967	93 (16.4)	1.15 (0.62, 2.13)	0.656
Current drinker	1356 (62.3)	0.89 (0.67, 1.18)	0.420	471 (69.1)	0.78 (0.42, 1.42)	0.412	360 (63.5)	1.12 (0.63, 2.01)	0.695	218 (60.4)	0.53 (0.27, 1.06)	0.072	307 (54.1)	1.05 (0.63, 1.76)	0.854
Missing	111 (5.1)	0.49 (0.20, 1.23)	0.129	24 (3.5)	0.44 (0.04, 4.69)	0.499	20 (3.5)	NA	0.980	25 (6.9)	0.14 (0.01, 2.65)	0.188	42 (7.4)	0.68 (0.21, 2.19)	0.513
Physical activity															
Yes	868 (39.9)	Ref	\	334 (49.0)	Ref	\	244 (43.0)	Ref	\	140 (38.8)	Ref	\	150 (26.5)	Ref	\
No	1306 (60.0)	1.02 (0.84, 1.25)	0.810	347 (50.9)	1.10 (0.76, 1.59)	0.626	322 (56.8)	0.96 (0.65, 1.41)	0.822	220 (60.9)	1.22 (0.76, 1.96)	0.412	417 (73.5)	0.89 (0.58, 1.35)	0.571
Missing	3 (0.1)	0.96 (0.08, 11.34)	0.975	1 (0.2)	NA	0.995	1 (0.2)	NA	0.978	1 (0.3)	NA	0.991	0	\	\
Body mass index (kg/m²)															
Underweight (<18.5)	36 (1.7)	Ref	\	8 (1.2)	Ref	\	9 (1.6)	Ref	\	4 (1.1)	Ref	\	15 (2.7)	Ref	\
Normal (18.5–24.9)	579 (26.6)	1.02 (0.49, 2.14)	0.958	178 (26.1)	1.83 (0.20, 17.03)	0.596	129 (22.8)	0.65 (0.15, 2.76)	0.557	92 (25.5)	4.10 (0.34, 49.48)	0.267	180 (31.8)	0.75 (0.23, 2.51)	0.643
Overweight (25.0–29.9)	776 (35.7)	1.15 (0.55, 2.41)	0.712	225 (33.0)	1.69 (0.18, 15.90)	0.645	208 (36.7)	0.65 (0.16, 2.76)	0.563	127 (35.2)	6.98 (0.57, 85.61)	0.129	216 (38.1)	1.05 (0.31, 3.51)	0.940
Obese (>= 30)	746 (34.3)	1.33 (0.63, 2.81)	0.451	265 (38.9)	2.34 (0.25, 21.75)	0.455	212 (37.4)	0.90 (0.21, 3.83)	0.889	134 (37.1)	4.70 (0.38, 57.71)	0.227	135 (23.8)	1.24 (0.36, 4.29)	0.732
Missing	40 (1.8)	2.07 (0.75, 5.72)	0.159	6 (0.9)	NA	0.987	9 (1.6)	2.87 (0.37, 22.42)	0.314	4 (1.1)	4.13 (0.15, 110.30)	0.398	21 (3.7)	2.65 (0.47, 15.12)	0.272
Hypertension															
Yes	746 (34.3)	Ref	\	211 (30.9)	Ref	\	174 (30.7)	Ref	\	132 (36.6)	Ref	\	229 (40.4)	Ref	\
No	1431 (65.7)	0.67 (0.55, 0.81)	<0.001	471 (69.1)	0.46 (0.31, 0.68)	<0.001	393 (69.3)	0.93 (0.62, 1.39)	0.728	229 (63.4)	0.83 (0.51, 1.35)	0.453	338 (59.6)	0.57 (0.39, 0.84)	0.004
Diabetes															
Yes	526 (24.2)	Ref	\	163 (23.9)	Ref	\	137 (24.2)	Ref	\	108 (29.9)	Ref	\	118 (20.8)	Ref	\
No	1650 (75.8)	0.46 (0.37, 0.57)	<0.001	519 (76.1)	0.33 (0.22, 0.51)	<0.001	430 (75.8)	0.47 (0.30, 0.74)	0.001	252 (69.8)	0.47 (0.27, 0.80)	0.005	449 (79.2)	0.55 (0.33, 0.91)	0.020

(Continued)

Table 4. (Continued)

Factors	Total			Age: 65–69			Age: 70–74			Age: 75–79			Age: 80+		
	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) *	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value	mean (sd) / n (%)	OR (95% CI) ^a	P value
Missing	1 (0)	NA	0.980	0	\	\	0	\	\	1 (0.3)	NA	0.991	0	\	\

Abbreviations: OR = odds ratio, CI = confidence interval, CKD = chronic kidney diseases, PIR = ratio of family income to poverty.

* The multi-variate analysis contained all the variables listed above in the logistic regression models.

Abbreviations: OR = odds ratio, CI = confidence interval, CKD = chronic kidney diseases, PIR = ratio of family income to poverty.

a. The multi-variate analysis contained all the variables listed above in the logistic regression models.

b. In NHANES, the age of people over 80 years old was all coded as 80.

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mortality [HR (95%CI): 0.971 (0.956, 0.986) in CLHLS, 0.893 (0.856, 0.933) in NHANES], and urinary creatinine was not significantly associated with mortality after adjusted for all covariates (Tables 5 and 6). The level of urinary albumin was related to higher mortality in CLHLS [HR (95%CI): 1.001 (1.000, 1.002)], whereas this association was statistically significant but clinically meaningless in NHANES [HR (95%CI): 1.000 (1.000, 1.000)]. In NHANES, increased uric acid was associated with greater odds of death [HR (95%CI): 1.003 (1.001, 1.004)], while the effect was not significant in CLHLS after adjusted for all covariates. Serum creatinine increased the mortality risk in both CLHLS and NHANES.

In both CLHLS and NHANES, the elderly with CKD had higher mortality risk than those without CKD [crude HRs (95% CI): 1.955 (1.703, 2.245) in CLHLS, 3.646 (2.679, 4.963) in NHANES] (Tables 5 and 6 and Fig 1). However, after adjusted for age and sex, the effect size diminished, and became insignificant in the Chinese group, while in the US group remained significant [CLHLS: 1.136 (0.983, 1.312, $p > 0.05$), NHANES: 2.470 (1.796, 3.396, $p < 0.001$)].

After stratified by the CKD stages, the population with low eGFR had higher odds of death than those with high eGFR in both CLHLS and NHANES (Tables 5 and 6 and Fig 2). After adjusted for all covariates, compared with the group with $eGFR \geq 90$ mL/min per 1.73 m^2 , the HRs (95% CI) of the elderly whose eGFR under 30 remained significant in both CLHLS and NHANES [1.786 (1.047, 3.049) in CLHLS, 3.564 (1.712, 7.420) in NHANES], while eGFR of 30–45 mL/min per 1.73 m^2 did not increase mortality risk significantly in CLHLS [HRs (95% CI): 1.408 (0.884, 2.241)], but had doubled the mortality risk compared with those with $eGFR \geq 90$ in NHANES [HRs (95% CI): 2.249 (1.141, 4.430)]. Those with abnormal ACR (≥ 30) had higher mortality risk than those with normal ACR in both CLHLS and NHANES.

In the age-stratified analyses, biomarkers were associated with mortality risk only in participants aged 80 or older except for the abnormal ACR. In NHANES, most biomarkers were consistently associated with mortality risk in all age groups, but the effect were mostly less significant in the group aged 70–74.

Discussion

In the current study, we found that the prevalence of CKD was 44.4% in the Chinese participants, and 42.3% in the NHANES sample. The level of ACR and eGFR in the US participants were unhealthier than the Chinese in most age groups. Older age, female, higher household income, and hypertension were found associated with CKD in the Chinese participants. In the US sample, gender was not associated with CKD, while high household income and low education level were associated with a higher prevalence of CKD. Furthermore, the association

Table 5. Hazard ratio (95% CI) of biomarkers on mortality in Chinese participants (CLHLS 2012).

Model	Factor	CLHLS		
		Crude	Age-sex adjusted	All covariates adjusted †
Total population				
Model A	Urinary albumin (mg/L)	1.002 (1.001, 1.002)***	1.001 (1.000, 1.002)*	1.001 (1.000, 1.002)*
Model B	Urinary creatinine (mg/dL)	0.997 (0.995, 0.998)***	0.999 (0.998, 1.000)	0.999 (0.998, 1.000)
Model C	Blood urea nitrogen (mmol/L)	1.11 (1.07, 1.14)***	1.03 (0.997, 1.06)	1.04 (1.01, 1.08)*
Model D	Plasma albumin (g/L)	0.92 (0.91, 0.94)***	0.97 (0.96, 0.99)***	0.97 (0.96, 0.99)***
Model E	Uric acid (umol/L)	1.00 (0.999, 1.001)	1.001 (1.000, 1.002)	1.001 (1.000, 1.002)
Model F	Serum creatinine (μmol/L)	1.004 (1.002, 1.006)***	1.002 (1.000, 1.004)	1.003 (1.000, 1.005)*
Model G	Albumin creatinine ratio (mg/g)	1.0003 (1.0002, 1.0005)***	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	1.75 (1.50, 2.04)***	1.24 (1.06, 1.45)**	1.25 (1.07, 1.47)**
Model I	eGFR	0.98 (0.97, 0.98)***	0.997 (0.992, 1.001)	0.996 (0.992, 1.001)
Model J	Categorical eGFR			
	<30	7.88 (4.80, 12.95)***	1.45 (0.86, 2.46)	1.79 (1.05, 3.05)*
	30~	7.14 (4.65, 10.96)***	1.36 (0.86, 2.15)	1.41 (0.88, 2.24)
	45~	5.15 (3.45, 7.70)***	1.10 (0.71, 1.69)	1.07 (0.69, 1.65)
	60~	3.53 (2.39, 5.20)***	1.10 (0.73, 1.66)	1.16 (0.77, 1.75)
	90~	Ref	Ref	Ref
Model K	CKD			
	No	Ref	Ref	Ref
	Yes	1.96 (1.70, 2.25)***	1.14 (0.98, 1.31)	1.09 (0.94, 1.27)
Age<80				
Model A	Urinary albumin (mg/L)	1.003 (1.000, 1.006)	1.003 (0.999, 1.006)	1.002 (0.998, 1.006)
Model B	Urinary creatinine (mg/dL)	0.999 (0.996, 1.003)	0.999 (0.995, 1.002)	0.999 (0.995, 1.003)
Model C	Blood urea nitrogen (mmol/L)	0.99 (0.87, 1.13)	0.99 (0.87, 1.12)	1.02 (0.88, 1.17)
Model D	Plasma albumin (g/L)	0.94 (0.89, 0.99)*	0.96 (0.91, 1.01)	0.96 (0.90, 1.02)
Model E	Uric acid (umol/L)	1.000 (0.998, 1.003)	1.000 (0.997, 1.002)	1.000 (0.997, 1.003)
Model F	Serum creatinine (μmol/L)	1.01 (0.996, 1.02)	1.001 (0.99, 1.01)	0.998 (0.99, 1.01)
Model G	Albumin creatinine ratio (mg/g)	1.004 (1.000, 1.007)*	1.003 (1.000, 1.007)*	1.004 (1.000, 1.008)
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	1.95 (1.09, 3.49)*	1.94 (1.08, 3.48)*	1.89 (1.01, 3.54)*
Model I	eGFR	0.99 (0.98, 1.01)	1.001 (0.99, 1.02)	1.004 (0.99, 1.02)
Model J	Categorical eGFR			
	<30	2.33 (0.31, 17.57)	1.53 (0.20, 11.71)	1.06 (0.12, 9.48)
	30~	1.00 (0.13, 7.55)	0.55 (0.07, 4.20)	0.43 (0.05, 3.71)
	45~	1.34 (0.55, 3.25)	0.80 (0.32, 2.02)	0.77 (0.29, 2.05)
	60~	1.37 (0.78, 2.40)	0.92 (0.51, 1.68)	0.94 (0.50, 1.74)
	90~	Ref	Ref	Ref
Model K	CKD			
	No	Ref	Ref	Ref
	Yes	1.53 (0.92, 2.52)	1.35 (0.81, 2.25)	1.25 (0.72, 2.16)
Age≥80				
Model A	Urinary albumin (mg/L)	1.001 (1.000, 1.002)*	1.001 (1.000, 1.001)	1.001 (1.000, 1.002)
Model B	Urinary creatinine (mg/dL)	0.998 (0.997, 0.999)**	0.999 (0.998, 1.000)	0.999 (0.998, 1.000)
Model C	Blood urea nitrogen (mmol/L)	1.06 (1.03, 1.10)***	1.03 (0.998, 1.06)	1.04 (1.01, 1.08)*

(Continued)

Table 5. (Continued)

Model	Factor	CLHLS		
		Crude	Age-sex adjusted	All covariates adjusted †
Model D	Plasma albumin (g/L)	0.95 (0.94, 0.96)***	0.97 (0.96, 0.99)***	0.97 (0.95, 0.99)***
Model E	Uric acid (umol/L)	1.000 (0.999, 1.001)	1.001 (1.000, 1.002)	1.001 (1.000, 1.001)
Model F	Serum creatinine (umol/L)	1.002 (0.999, 1.004)	1.002 (0.999, 1.004)	1.002 (1.000, 1.005)
Model G	Albumin creatinine ratio (mg/g)	1.000 (1.000, 1.000)*	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	1.30 (1.11, 1.53)**	1.19 (1.02, 1.40)*	1.21 (1.02, 1.43)*
Model I	eGFR	0.99 (0.99, 0.996)***	0.998 (0.99, 1.003)	0.998 (0.99, 1.003)
Model J	Categorical eGFR			
	<30	1.55 (0.79, 3.04)	0.85 (0.43, 1.69)	0.98 (0.49, 1.98)
	30~	1.39 (0.74, 2.59)	0.80 (0.42, 1.51)	0.82 (0.43, 1.55)
	45~	1.08 (0.59, 1.98)	0.64 (0.35, 1.19)	0.61 (0.33, 1.14)
	60~	0.98 (0.54, 1.78)	0.65 (0.35, 1.19)	0.67 (0.36, 1.23)
	90~	Ref	Ref	Ref
Model K	CKD			
	No	Ref	Ref	Ref
	Yes	1.24 (1.07, 1.44)**	1.09 (0.94, 1.26)	1.04 (0.89, 1.21)

Abbreviations: HR = Hazard ratio CI = confidence interval, eGFR = estimated glomerular filtration rate, CKD = chronic kidney diseases.

*** p<0.001

**p<0.01

*p<0.05.

† Adjusted for age, gender, race, educational level, income, marital status, health condition, smoking status, drinking status, physical activity, body mass index, hypertension and diabetes.

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between CKD/eGFR and mortality was found stronger in the US sample. Notably, the biomarker level and these associations varied in different age groups.

CKD-related biomarkers comparison between China and the US

Some prior studies compared the CKD-related biomarker levels between China and the US among adults aged ≥20 years old. They found that the prevalence of albuminuria, defined as elevated ACR, was 8.1% in the US adults versus 9.5% in China, with the median of ACR as 5.97 mg/g in the US and 6.7 mg/g in China in 2009–2010 [5]. This finding was opposite to ours, which might be caused by the different age ranges of participants. However, another study comparing the prevalence of CKD found that the weighted mean of ACR was 15.67 mg/g in Chinese in 2006, while 22.81 mg/g, 53.44 mg/g, 32.89 mg/g in Whites, African Americans, and Hispanics, respectively, in 1999–2006 [6]. Interestingly, some also found that the ACR of Chinese adults in 2007–2010 and that of participants from the US in 2005–2010 were the same, about 6.3 mg/g [18]. As for serum creatinine, studies showed the same results as ours that the level in the US was higher than that in China, though all within the normal range [5, 18]. Previous studies comparing CKD between China and the US did not take BUN as an index. Moreover, some studies indicated that eGFR of Chinese was higher than that of US population, especially the Whites [5, 6]. Nevertheless, a study had the same finding as ours that eGFR in China was lower than that in the NHANES participants [18]. Although the mean

Table 6. Hazard ratio (95% CI) of biomarkers on mortality in US participants (NHANES 2011–2014).

Model	Factor	NHANES		
		Crude	Age-sex adjusted	All covariates adjusted †
Total				
Model A	Urinary albumin (mg/L)	1.000 (1.000, 1.001)***	1.000 (1.000, 1.000)***	1.000 (1.000, 1.000)***
Model B	Urinary creatinine (mg/dL)	1.001 (0.999, 1.003)	1.002 (0.999, 1.004)	1.001 (0.998, 1.003)
Model C	Blood urea nitrogen (mmol/L)	1.14 (1.12, 1.17)***	1.12 (1.09, 1.15)***	1.11 (1.07, 1.14)***
Model D	Plasma albumin (g/L)	0.87 (0.84, 0.90)***	0.88 (0.85, 0.92)***	0.89 (0.86, 0.93)***
Model E	Uric acid (umol/L)	1.003 (1.002, 1.005)***	1.003 (1.001, 1.004)***	1.003 (1.001, 1.004)**
Model F	Albumin creatinine ratio (mg/g)	1.000 (1.000, 1.000)***	1.000 (1.000, 1.000)***	1.000 (1.000, 1.001)***
Model G	Serum creatinine (umol/L)	1.005 (1.004, 1.006)***	1.004 (1.003, 1.006)***	1.004 (1.003, 1.006)***
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	3.01 (2.28, 3.97)***	2.31 (1.74, 3.05)***	2.11 (1.55, 2.86)***
Model I	eGFR	0.97 (0.96, 0.98)***	0.98 (0.97, 0.99)***	0.98 (0.97, 0.99)***
Model J	CKD			
	No	Ref	Ref	Ref
	Yes	3.65 (2.68, 4.96)***	2.47 (1.80, 3.40)***	2.18 (1.56, 3.04)***
Model K	Categorical eGFR			
	<30	10.09 (5.08, 20.04)***	4.59 (2.26, 9.32)***	3.56 (1.71, 7.42)***
	30~	6.37 (3.39, 11.97)***	2.40 (1.24, 4.66)**	2.25 (1.14, 4.43)*
	45~	3.41 (1.85, 6.29)***	1.46 (0.77, 2.77)	1.44 (0.75, 2.76)
	60~	1.90 (1.06, 3.42)*	1.07 (0.59, 1.96)	1.11 (0.60, 2.06)
	90~	Ref	Ref	Ref
Age: 65–69				
Model A	Urinary albumin (mg/L)	1.001 (1.000, 1.001)***	1.001 (1.000, 1.001)***	1.001 (1.000, 1.002)**
Model B	Urinary creatinine (mg/dL)	1.005 (1.001, 1.01)*	1.005 (1.000, 1.010)*	1.004 (0.999, 1.010)
Model C	Blood urea nitrogen (mmol/L)	1.12 (1.02, 1.236)*	1.12 (1.01, 1.23)*	1.08 (0.95, 1.23)
Model D	Plasma albumin (g/L)	0.87 (0.80, 0.95)**	0.87 (0.80, 0.95)**	0.84 (0.74, 0.95)*
Model E	Uric acid (umol/L)	1.002 (0.997, 1.007)	1.001 (0.996, 1.01)	1.002 (0.996, 1.010)
Model F	Albumin creatinine ratio (mg/g)	1.000 (1.000, 1.001)	1.000 (1.000, 1.000)	1.000 (1.000, 1.001)
Model G	Serum creatinine (umol/L)	1.006 (1.001, 1.01)**	1.005 (1.001, 1.01)*	1.004 (0.998, 1.010)
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	3.17 (1.31, 7.64)*	3.07 (1.27, 7.44)*	3.49 (1.23, 9.91)*
Model I	eGFR	0.97 (0.96, 0.99)**	0.97 (0.96, 0.99)**	0.98 (0.96, 0.998)*
Model J	CKD			
	No	Ref	Ref	Ref
	Yes	3.64 (1.54, 8.65)**	3.59 (1.51, 8.54)**	4.10 (1.39, 12.08)*
Model K	Categorical eGFR			
	<30	6.85 (1.25, 37.39)*	6.64 (1.20, 36.85)*	5.15 (0.72, 36.82)
	30~	5.07 (0.93, 27.73)	5.04 (0.90, 28.12)	12.09 (1.55, 94.16)*
	45~	3.85 (1.04, 14.38)*	3.73 (0.99, 13.98)	5.94 (1.00, 35.33)*
	60~	1.20 (0.36, 3.98)	1.16 (0.35, 3.88)	2.21 (0.57, 8.53)
	90~	Ref	Ref	Ref
Age: 70–74				
Model A	Urinary albumin (mg/L)	1.001 (1.000, 1.002)*	1.001 (1.000, 1.002)*	1.001 (1.000, 1.002)*
Model B	Urinary creatinine (mg/dL)	1.002 (0.996, 1.01)	1.002 (0.995, 1.01)	1.001 (0.995, 1.01)
Model C	Blood urea nitrogen (mmol/L)	0.98 (0.81, 1.18)	0.97 (0.80, 1.17)	0.95 (0.77, 1.18)

(Continued)

Table 6. (Continued)

Model	Factor	NHANES		
		Crude	Age-sex adjusted	All covariates adjusted †
Model D	Plasma albumin (g/L)	0.84 (0.76, 0.94)**	0.84 (0.75, 0.93)**	0.87 (0.77, 0.98)*
Model E	Uric acid (umol/L)	0.999 (0.995, 1.004)	0.999 (0.994, 1.004)	0.999 (0.994, 1.004)
Model F	Albumin creatinine ratio (mg/g)	1.001 (1.000, 1.002)	1.001 (1.000, 1.002)	1.001 (1.000, 1.003)
Model G	Serum creatinine (umol/L)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.98, 1.02)
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	2.65 (1.24, 5.67)*	2.60 (1.22, 5.58)*	2.13 (0.88, 5.15)
Model I	eGFR	1.00 (0.98, 1.02)	1.00 (0.98, 1.03)	1.01 (0.98, 1.03)
Model J	CKD			
	No	Ref	Ref	Ref
	Yes	2.23 (1.06, 4.69)*	2.18 (1.03, 4.60)*	1.79 (0.76, 4.20)
Model K	Categorical eGFR			
	<30	2.90 (0.34, 25.02)	2.65 (0.30, 23.31)	20.27 (1.30, 316.77)*
	30~	NA	NA	NA
	45~	1.54 (0.49, 4.89)	1.46 (0.46, 4.67)	0.94 (0.26, 3.44)
	60~	0.85 (0.31, 2.35)	0.82 (0.29, 2.27)	0.67 (0.22, 2.01)
	90~	Ref	Ref	Ref
Age: 75–79				
Model A	Urinary albumin (mg/L)	1.000 (1.000, 1.001)***	1.001 (1.000, 1.001)***	1.001 (1.000, 1.001)***
Model B	Urinary creatinine (mg/dL)	1.002 (0.997, 1.01)	1.001 (0.996, 1.006)	0.999 (0.99, 1.01)
Model C	Blood urea nitrogen (mmol/L)	1.11 (1.06, 1.17)***	1.11 (1.05, 1.16)***	1.12 (1.04, 1.20)**
Model D	Plasma albumin (g/L)	0.79 (0.72, 0.87)***	0.80 (0.73, 0.87)***	0.80 (0.71, 0.90)***
Model E	Uric acid (umol/L)	1.005 (1.002, 1.008)**	1.005 (1.001, 1.008)**	1.004 (1.000, 1.009)*
Model F	Albumin creatinine ratio (mg/g)	1.001 (1.000, 1.001)***	1.001 (1.000, 1.001)***	1.001 (1.000, 1.001)***
Model G	Serum creatinine (umol/L)	1.004 (1.002, 1.006)***	1.004 (1.002, 1.006)***	1.004 (1.002, 1.007)**
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	4.00 (1.95, 8.20)***	4.07 (2.00, 8.44)***	5.25 (2.23, 12.37)***
Model I	eGFR	0.97 (0.95, 0.99)***	0.97 (0.95, 0.99)***	0.96 (0.94, 0.98)***
Model J	CKD			
	No	Ref	Ref	Ref
	Yes	2.75 (1.23, 6.14)*	2.88 (1.29, 6.47)*	2.95 (1.25, 6.97)*
Model K	Categorical eGFR			
	<30	10.51 (1.29, 85.59)*	11.22 (1.37, 91.68)*	20.21 (1.86, 219.37)*
	30~	2.38 (0.26, 21.38)	2.55 (0.28, 22.94)	4.41 (0.41, 47.68)
	45~	1.25 (0.15, 10.75)	1.27 (0.15, 10.95)	1.37 (0.13, 14.47)
	60~	1.54 (0.20, 11.73)	1.52 (0.20, 11.63)	1.91 (0.20, 18.10)
	90~	Ref	Ref	Ref
Age: 80+				
Model A	Urinary albumin (mg/L)	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)	1.000 (1.000, 1.001)
Model B	Urinary creatinine (mg/dL)	1.002 (0.999, 1.005)	1.001 (0.998, 1.004)	1.000 (0.996, 1.003)
Model C	Blood urea nitrogen (mmol/L)	1.13 (1.09, 1.18)***	1.14 (1.09, 1.19)***	1.13 (1.08, 1.19)***
Model D	Plasma albumin (g/L)	0.93 (0.88, 0.99)*	0.93 (0.88, 0.98)*	0.95 (0.89, 1.01)
Model E	Uric acid (umol/L)	1.004 (1.002, 1.006)***	1.003 (1.002, 1.005)***	1.004 (1.002, 1.006)***
Model F	Albumin creatinine ratio (mg/g)	1.000 (1.000, 1.000)*	1.000 (1.000, 1.000)*	1.000 (1.000, 1.001)**
Model G	Serum creatinine (umol/L)	1.007 (1.004, 1.009)***	1.006 (1.004, 1.009)***	1.007 (1.004, 1.01)***

(Continued)

Table 6. (Continued)

Model	Factor	NHANES		
		Crude	Age-sex adjusted	All covariates adjusted †
Model H	Categorical ACR			
	<30	Ref	Ref	Ref
	≥30	1.80 (1.26, 2.57)**	1.79 (1.26, 2.56)**	1.85 (1.24, 2.77)**
Model I	eGFR	0.98 (0.97, 0.99)***	0.98 (0.97, 0.99)***	0.98 (0.97, 0.99)***
Model J	CKD			
	No	Ref	Ref	Ref
	Yes	2.15 (1.39, 3.31)***	2.15 (1.39, 3.32)***	2.06 (1.29, 3.29)**
Model K	Categorical eGFR			
	<30	3.49 (0.98, 12.37)	3.95 (1.11, 14.04)*	3.37 (0.86, 13.21)
	30~	2.56 (0.78, 8.36)	2.54 (0.78, 8.30)	2.45 (0.68, 8.83)
	45~	1.38 (0.42, 4.52)	1.38 (0.42, 4.50)	1.43 (0.40, 5.12)
	60~	1.10 (0.34, 3.55)	1.11 (0.34, 3.58)	1.21 (0.34, 4.35)
	90~	Ref	Ref	Ref

Abbreviations: HR = Hazard ratio CI = confidence interval, eGFR = estimated glomerular filtration rate, CKD = chronic kidney diseases.

*** p<0.001

**p<0.01

*p<0.05.

† Adjusted for age, gender, race, educational level, income, marital status, health condition, smoking status, drinking status, physical activity, body mass index, hypertension and diabetes.

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eGFR in our study was lower in in the Chinese sample, it may result from the larger proportion of participants aged 80 and above in CLHLS than NHANES. The age-specific eGFR was higher in the Chinese participants, except for the eldest group.

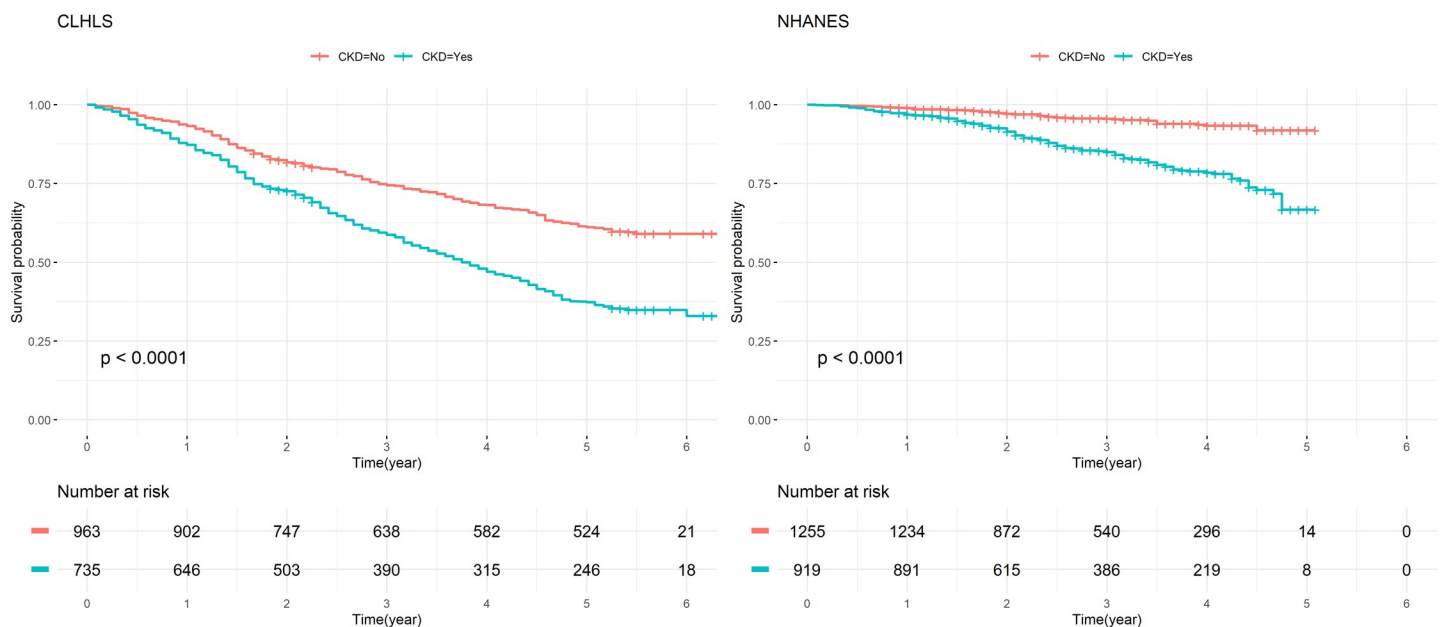


Fig 1. Kaplan-Meier Curve of CKD. CLHLS: 2012–2018. NHANES: 2011/2013–2015.

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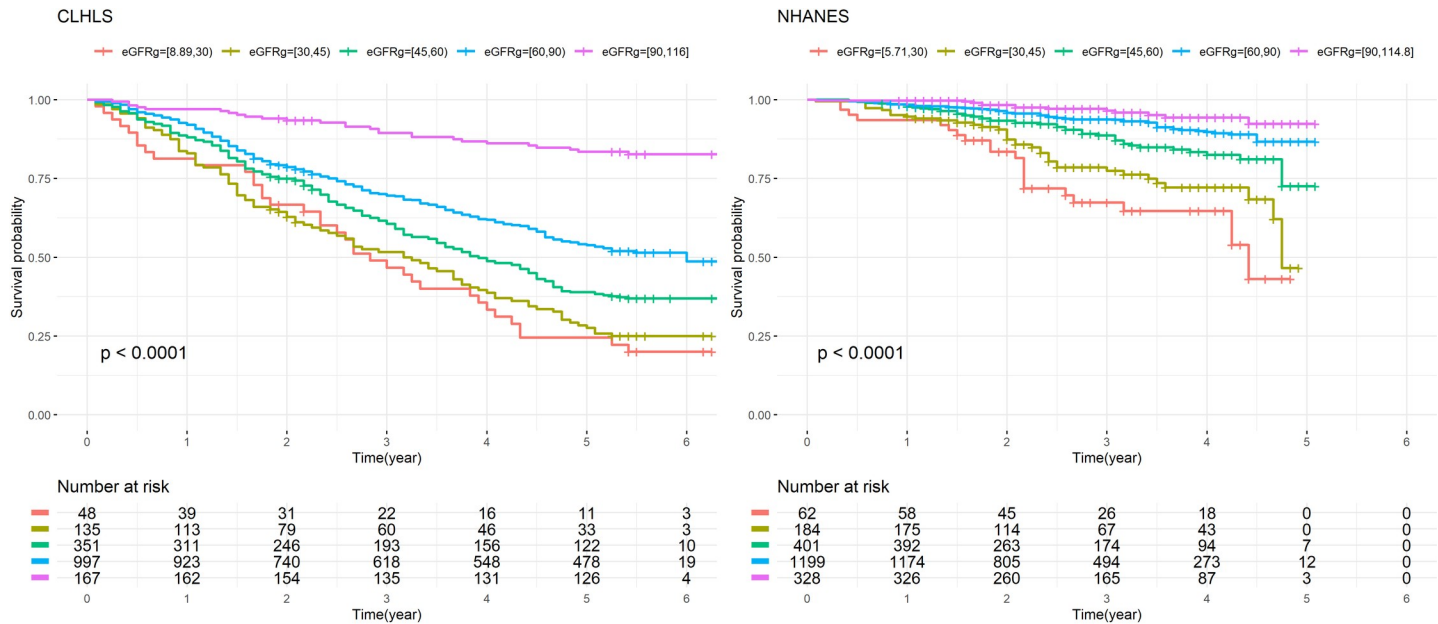


Fig 2. Kaplan-Meier Curve of CKD stage. CLHLS: 2012–2018. NHANES: 2011/2013–2015.

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Risk factors for CKD

In a previous study, it was suggested that CKD was associated with increased age, hypertension, diabetes, cardiovascular diseases, and hyperuricemia in both Chinese and the US population [5]. This study also suggested that being female was associated with decreased eGFR in CLHLS participants but not in the NHANES sample, which is consistent with our results. Besides, central obesity was also indicated associated with CKD. Another study illustrated that diabetes is more closely related to CKD in Whites, African Americans, and Hispanics, with Chinese as reference, and overweight was less associated with CKD in Whites [6]. We additionally adjusted for more variables like household income than these previous studies. The weaker relationship between higher BMI and CKD may be reasonable considering the huge gap between the proportion of overweight people in the Chinese and the US samples. Furthermore, contrary to the positive health effect of physical activity in general, we found no physical activity was associated to lower risk of having CKD among Chinese participants. We speculated that the presence of CKD might be more related to age than to physical activity. It is possible that doing exercise enable people to live longer but, thus, have CKD. This may also explain why never smokers among Chinese elderly showed a higher prevalence of CKD.

CKD and mortality risk

A previous comprehensive meta-analysis established the association of reduced eGFR with all-cause mortality in the general population [19]. Our findings are consistent with the previous result that all-cause mortality increased at eGFRs lower than 60 mL/min/1.73 m². The meta-analysis showed that the adjusted HRs for all-cause mortality were 1.57 (95% CI: 1.39–1.78) for eGFR 45 mL/min/1.73 m², and 3.14 (2.39–4.13) for eGFR 15 mL/min/1.73 m², which was similar to the HRs of NHANES group in our study. As for the different effect size between the two populations, a study found that the linear association between eGFR and all-cause mortality appeared clearer in US general population compared with the Chinese population, and the association was insignificant even in the lowest eGFR spline, which was potentially caused by

the limited death events or sample size [18]. Our findings present a similar disparity of effect size. Another study suggested that the relative mortality of lower eGFR was largely similar among Asians, whites, and blacks [20].

Possible reasons for the differences between the China sample and US sample

There are a number of possible reasons for the racial disparities in CKD. First, African Americans might have a higher prevalence of poverty compared to whites, and low socioeconomic status (SES) was found to have a stronger association with CKD among African Americans than among whites. It was indicated that the impact of SES may lead to the racial differences in biology [21]. Second, higher prevalences of comorbidities and obesity in the US population could explain their mortality rate of more than double that in China [18]. In a retrospective population-based cohort study of 530,771 adults with CKD residing in Alberta, Canada between 2003 and 2011, it was found that a number of comorbidities could increase the risk of hospitalization, including not only hypertension and diabetes, but also mental health, chronic pain, dementia and cancer [22]. By contrast, the most common risk factor of CKD in China was chronic glomerulonephritis [23], and nontraditional risk factors such as fetal and maternal factors, infections, environmental factors, and acute kidney injury were also major threats [24]. These risk factors may be linked to social deprivation and poverty in developing countries, working directly through the accessibility of predisposition, diagnosis, and management or indirectly through the increased health care burden [8]. Therefore, we assumed the elder women in China might have a high rate of reproductive tract infection several decades ago, which might have led to CKD later, as poor personal hygiene and low living standard at that time. However, we did not examine the comprehensive comorbidity condition including chronic glomerulonephritis among participants, so further studies may need to explore the gap of comorbidities in the Chinese elderly and those in the US. Apart from that, a study of patients on dialysis found a higher prevalence of cardiovascular disease at the start of dialysis in whites compared with other racial groups. Because atherosclerosis is a common and significant cause of morbidity and mortality for patients with end-stage renal disease, it is understandable that whites with more atherosclerosis might have a higher risk of death with CKD, especially in the end-stage [25]. Moreover, the cumulative dose of cigarette smoking and additional risk factors in various racial groups are also possible to result in the survival disparities of patients with end-stage renal disease [25]. In addition, the difference of the findings between the two countries varied among different age groups. There were a much larger proportion of the population aged 80 or older in the China sample than the US sample (65.5% vs. 26.1%). There may be survivor bias caused by a relatively healthier Chinese population.

Study strengths and limitations

Our study has several strengths. First, the cohort size of CLHLS and NHANES was quite large, and represented an older population which was less studied before. Second, the survey methods of CLHLS and NHANES were appropriate and time-tested. We used the data of recent waves which could best estimate the current situation about CKD. Additionally, we took a diverse group of variables to assess. Besides, we applied the same definition of CKD (original CKD-EPI creatinine equation) which have been validated in both populations, and proved more accurate than other equations, allowing eGFR levels between the two populations to be comparable.

However, our study had some limitations as well. First, CLHLS sample weight is calculated based on the total cohort and not the biomarker cohort, and only considered the age-sex-

urban/rural residence-specific distribution of the population. A previous CLHLS study suggested not including weight in multivariate analyses since the weight does not capture other important compositional variables like economic and education status and weighted regressions will unnecessarily increase standard errors [26]. We excluded sample weights from CLHLS for this reason and from NHANES for consistency, and we present results incorporating the sample weights for both studies in S7–1–S9 Tables. Lack of appropriate weight data limited the representativeness to the general population; CLHLS oversampled rural residents in China while NHANES oversampled minorities and lower SES individuals in the US. Second, the measuring technique for biomarkers may differ in NHANES and CLHLS, which made the value of biomarkers less comparable. For example, serum creatinine in NHANES was standardized to IDMS while it was measured by the picric acid method in CLHLS. Thirdly, the definition of the covariates in NHANES and CLHLS were not exactly the same due to the different questionnaire in surveys. The heterogeneity in variable definition did not permit pooling of data and evaluation of an interaction. Moreover, the age distributions were different across the two populations. Most Chinese participants aged 80 or older. Therefore, we also reported the age stratified analyses and identified some difference across the age groups. This may explain part of the difference between the two populations. Last but not least, there was a much higher loss to follow-up in the CLHLS sample, compared to that in NHANES. This might decrease the credibility of the mortality results in CLHLS and make the results of two countries less comparable to a small extent.

Conclusion

In conclusion, the elderly population in the NHANES have worse CKD-related biomarker levels than in CLHLS, and the factors associated with CKD from demo-social to lifestyle factors vary in the two cohorts. Moreover, the mortality rate from CKD and the association between CKD and mortality was higher in the NHANES than in CLHLS. Further studies are warranted to validate our findings and elucidate the biological mechanisms.

Supporting information

S1 Table. Cohorts' characteristics of this study.

(PDF)

S2 Table. 1. Characteristics of the included and excluded participants in CLHLS. 2. Characteristics of the included and excluded participants in NHANES.

(ZIP)

S3 Table. Equations used to estimate glomerular filtration rate eGFR (CKD-EPI: Chronic Kidney Disease Epidemiology Collaboration).

(PDF)

S4 Table. 1. Demographic characteristics and median (P25-P75) of biomarkers (Chinese participants: CLHLS 2012). 2. Demographic characteristics and median (P25-P75) of biomarkers (US participants: NHANES 2011–2014).

(ZIP)

S5 Table. Odds ratio (95% CI) of factors associated with abnormal eGFR (<60) in CLHLS and NHANES.

(PDF)

S6 Table. Odds ratio (95% CI) of factors associated with abnormal ACR (≥ 30 mg/g) in CLHLS and NHANES.

(PDF)

S7 Table. 1. Demographic characteristics and weighted mean (SD) of biomarkers (Chinese participants: CLHLS 2012). 2. Demographic characteristics and weighted mean (SD) of biomarkers (US participants: NHANES 2011–2014).

(ZIP)

S8 Table. Odds ratio (95% CI) of factors associated with CKD in Chinese and US population (weighted).

(PDF)

S9 Table. Hazard ratio (95% CI) of CKD biomarkers on mortality in Chinese and US population (weighted).

(PDF)

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