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Prevalence of decreased kidney function in Chinese adults aged 35 to 74 years

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Prevalence of decreased kidney function in Chinese adults aged 35 to 74 years.

Background. Chronic kidney disease (CKD) is a major public health burden in Western countries but little is known about its impact in developing countries. We estimated the prevalence and absolute burden of CKD in the general adult population in China.

Methods. A cross-sectional survey was conducted in a nationally representative sample of 15,540 Chinese adults aged 35 to 74 years in 2000 and 2001. Serum creatinine was measured using the modified kinetic Jaffe reaction method at a central laboratory calibrated to the Cleveland Clinic Foundation laboratory. Glomerular filtration rate (GFR) was estimated using the simplified equation developed by the Modification of Diet in Renal Disease study. CKD was defined as an estimated GFR $<$60 mL/min/1.73m^2.

Results. Overall, the age-standardized prevalences of GFR 60 to 89, 30 to 59, and $<$30 mL/min/1.73m^2 were 39.4%, 2.4%, and 0.14%, respectively, in Chinese adults aged 35 to 74 years. The overall prevalence of CKD (GFR $<$60 mL/min/1.73m^2) was 2.53%, representing 11,966,653 persons (1.31% or 3,185,330 men and 3.82% or 8,781,323 women). The age-specific prevalence of CKD was 0.71%, 1.69%, 3.91%, and 8.14% among persons 35 to 44, 45 to 54, 55 to 64, and 65 to 74 years old, respectively. The age-standardized prevalence of CKD was similar in urban (2.60%) and rural (2.52%) residents but was higher in south China (3.05%) than in north China (1.78%) residents.

Conclusion. Although the prevalence of CKD in China was relatively low, the population absolute burden is substantial. These data warrant a national program aimed at detection, prevention, and treatment of CKD in China.

Key words: chronic kidney disease, prevalence, cross-sectional studies, China.

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Chronic kidney disease (CKD) is a major public health burden in Western countries. For example, according to data from the Third National Health and Nutrition Examination Survey (NHANES III), 8.3 million (4.6%) U.S. adults aged 20 years or older were estimated to have an estimated glomerular filtration rate (GFR) $<$60 mL/min/1.73m^2. In addition, 5.9 million individuals (3.3%) had persistent albuminuria with a normal GFR and 5.3 million (3.0%) had persistent albuminuria with a GFR 60 to 89 mL/min/1.73m^2. Overall, the prevalence of CKD was 11% (19.2 million) in the U.S. adult population [1, 2]. CKD is an important risk factor for end-stage renal disease (ESRD), cardiovascular disease, and premature death [3–5]. Patients with ESRD have poorer quality of life and shorter life expectancy compared to individuals of the same age in the general population [3, 4]. In addition, death from cardiovascular disease is 10 to 20 times higher among patients treated by maintenance hemodialysis or peritoneal dialysis than in the U.S. general population after controlling for age, gender, race, and presence of diabetes [5]. A number of prospective epidemiologic studies have shown that individuals with CKD are at substantially increased risk for coronary heart disease, stroke, and congestive heart failure, independent of established cardiovascular risk factors [6–12].

The burden of CKD and ESRD in economically developing countries, including China, is less well known. In 1999, the China Dialysis and Transplantation Registration Group reported a point prevalence and annual incidence of ESRD of 33.2 and 15.3 per million population, respectively [13]. These rates are likely to be underestimated since the registration response rate was low, less than 50% in most provinces [14]. The impact of ESRD in China is of particular concern since there is a shortage of healthcare resources to devote to this problem. For example, about 16% of dialysis patients died from uremia due to interruptions in their dialysis therapy, which were a result of personal financial hardships [13]. Moreover, only about 30% of hemodialysis and peritoneal dialysis patients received erythropoietin and the majority of dialysis patients had various degrees of anemia [13]. Early detection, prevention, and treatment of CKD are essential to any meaningful attempt to decrease the societal and personal burden of ESRD in China. The objectives of the present study were to estimate the prevalence and severity of CKD in the general adult population in China using serum creatinine–based equations to estimate level of kidney function. The distribution of CKD was examined by age, gender, and geographic region, as well as in rural versus urban areas. This information might be useful for healthcare policy makers to develop national strategies and to rationally plan health services for the prevention and treatment of CKD and its related complications.

METHODS

Study population

The International Collaborative Study of Cardiovascular Disease in ASIA (InterASIA) was a cross-sectional study of cardiovascular disease risk factors in a nationally representative sample of the general adult population in China [15]. A four-stage stratified sampling method was used. In stage one, 31 provinces (and municipalities) were stratified into northern and southern China, as divided by the Yangtzi River. In addition to the municipalities of Beijing in northern China and Shanghai in southern China, four provinces from northern China (Jilin, Shandong, Qinghai, and Shanxi) and four from southern China (Sichuan, Hubei, Fujian, and Guangxi) were selected to be representative of the geographic and economic characteristics in their regions (Fig. 1). In the second stage of sampling, one rural county and one city region were randomly selected from each province or municipality, providing a total of 10 city regions and 10 rural counties. In the third stage of sampling, one township or one street district (about 1000–2000 households) was randomly selected from each of the counties and city regions, respectively. In the final stage, individuals were randomly chosen from the selected township or street district. Only one participant was selected from each household, without replacement.

A total of 19,012 persons aged 35 to 74 years were randomly selected from 20 primary sampling units (street districts in urban areas or townships in rural areas) and invited to participate. A total of 15,838 persons (7684 men and 8154 women) completed the survey and examination. The overall response rate was 83.3% (82.1% in men and 84.5% in women; 82.2% in urban areas and 84.4% in rural areas). The analysis reported in this paper was restricted to study participants ($N = 15{,}209$) who had serum creatinine measurements.

The Institutional Review Board at the Tulane University Health Sciences Center approved the InterASIA study. In addition, ethics committees and other relevant regulatory bodies in China approved the study. Informed consent was obtained from each study participant prior to data collection. Study participants with untreated medical conditions or elevated cholesterol or glucose levels identified during the examination were referred to a primary health care provider.

Data collection

Data were collected in examination centers at local health stations or community clinics in the participants' residential area. During the visits, trained research staff administered a standard questionnaire to obtain information on demographic characteristics, including age, sex, education, occupation, and annual household income. During the clinical examination, blood pressure and anthropometric measurements were collected by trained and certified physicians or nurses using standard protocols and techniques [16]. Blood pressure was measured three times with the participant in the seated position after five minutes of rest. Body weight and height were measured twice during the examination in light indoor clothing without shoes.

Overnight fasting blood specimens were collected for measurement of serum creatinine, lipids, and glucose. Blood specimens were processed at each field center and shipped by air to the central clinical laboratory at the Department of Population Genetics at Fuwai Hospital of the Chinese Academy of Medical Sciences in Beijing, where the specimens were stored at -70°C until laboratory assays could be performed. Serum creatinine was measured by the modified kinetic Jaffe reaction on a Hitachi 7060 Clinical Analyzer (Hitachi High-Technologies Corporation, Tokyo, Japan) using commercial reagents and reported using conventional units (1 mg/dL = 88.4 μmol/L). In addition, a random sample of 60 serum specimens was sent to the Cleveland Clinic Laboratory (Cleveland, OH, USA) for measurement of serum creatinine where the Modification of Diet in Renal Disease (MDRD) Study measured serum creatinine levels [17]. On average, serum creatinine assays on the same samples were 0.0338 mg/dL higher in the Cleveland Clinic Laboratory than in the InterASIA Study laboratory. Therefore, serum creatinine measurements among study participants were calibrated by adding this difference.

Statistical methods

The glomerular filtration rate (GFR) was estimated from the simplified equation developed using MDRD data [17]:

$$\begin{aligned}\text{Estimated GFR} = {} & 186.3 \times (\text{serum creatinine})^{-1.154} \\ & \times \text{age}^{-0.203} \times (0.742 \text{ for women}) \\ & \times (1.212 \text{ if African American}).\end{aligned}$$

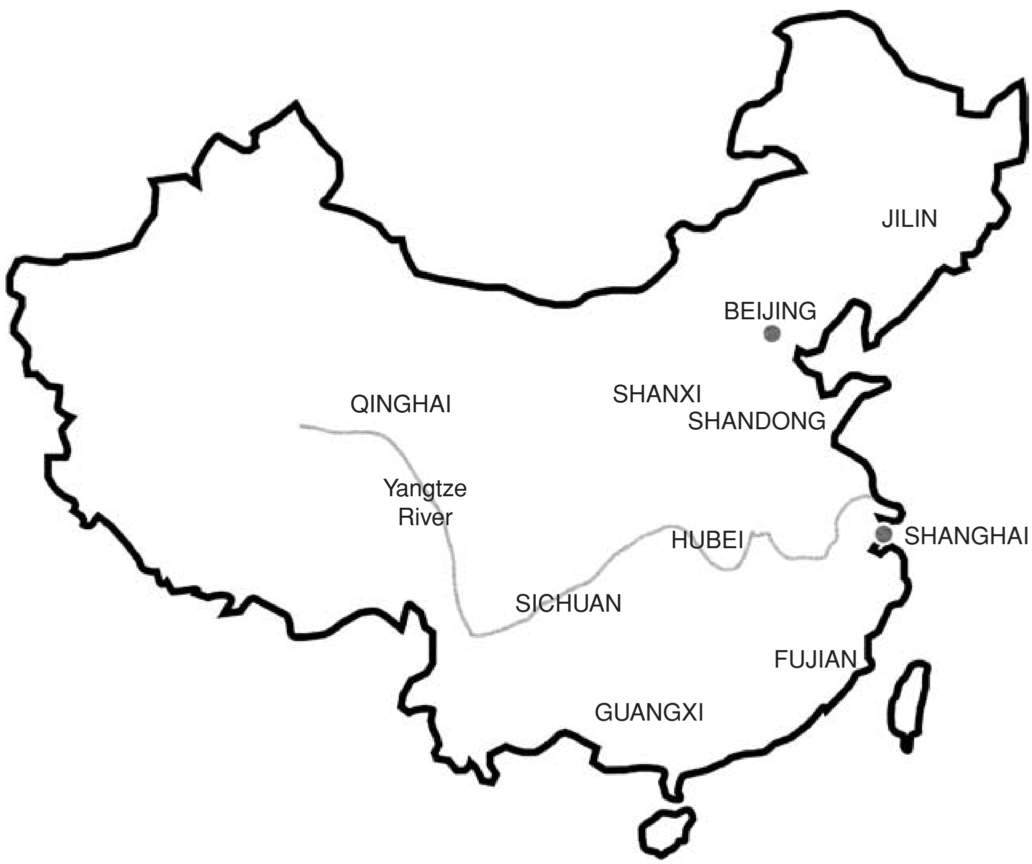

Fig. 1. A map of China with study sites (north China: Jilin, Beijing, Qinghai, Shanxi, and Shandong; south China: Sichuan, Hubei, Shanghai, Fujian, and Guangxi).

In addition, the Cockcroft-Gault formula was used to estimate creatinine clearance (CCr) from the serum creatinine level [18]:

$$\text{Cockcroft-Gault CCr} = (140 - \text{age})/(\text{serum creatinine}) \times (\text{weight}/72) \times (0.85 \text{ for women}) \times \text{body surface area } (\text{BSA})/1.73\text{m}^2$$

BSA was estimated using the following formula for Chinese adults [19]:

$$\text{BSA}(\text{m}^2) = 0.0061 \times \text{height (cm)} + 0.0124 \times \text{weight kg}) - 0.0099$$

Estimated GFR was analyzed as both a continuous variable and a categorical variable with the following four categories: GFR $\geq$90 mL/min/1.73m^2, GFR 60 to 89 mL/min/1.73m^2, GFR 30 to 59 mL/min/1.73m^2, and GFR <30 mL/min/1.73m^2 [1]. The prevalence of chronic kidney disease, defined as an estimated GFR <60 mL/min/1.73m^2 measured by the MDRD Study and Cockcroft-Gault equations, was estimated overall, as well as by sex, age group, geographic region, and urban versus rural residence. In addition, the distribution of serum creatinine values was calculated for each gender and estimated GFR category.

Hypertension was defined as a mean systolic blood pressure $\geq$140 mm Hg and/or diastolic blood pressure $\geq$90 mm Hg and/or use of antihypertensive medication. Diabetes was defined as fasting plasma glucose $\geq$7.0 mmol/L or a self-reported history of diabetes and insulin or oral hypoglycemic treatment.

All calculations were weighted to represent the total Chinese adult population aged 35 to 74 years. Sample weights were calculated based on data from the year 2000 China Population Census and the InterASIA sampling scheme, and took into account several features of the survey, including oversampling for specific age or geographic subgroups, nonresponse, and other demographic or geographic differences between the sample and the total population. Standard errors were calculated by a technique appropriate to the complex survey design. All data analyses were conducted using SUDAAN (version 8.0; Research Triangle Institute, Research Triangle Park, NC, USA).

RESULTS

The distribution of serum creatinine levels was slightly skewed toward greater values in both men and women (Fig. 2, upper panel). The estimated GFR values using the simplified MDRD Study equation, however, were

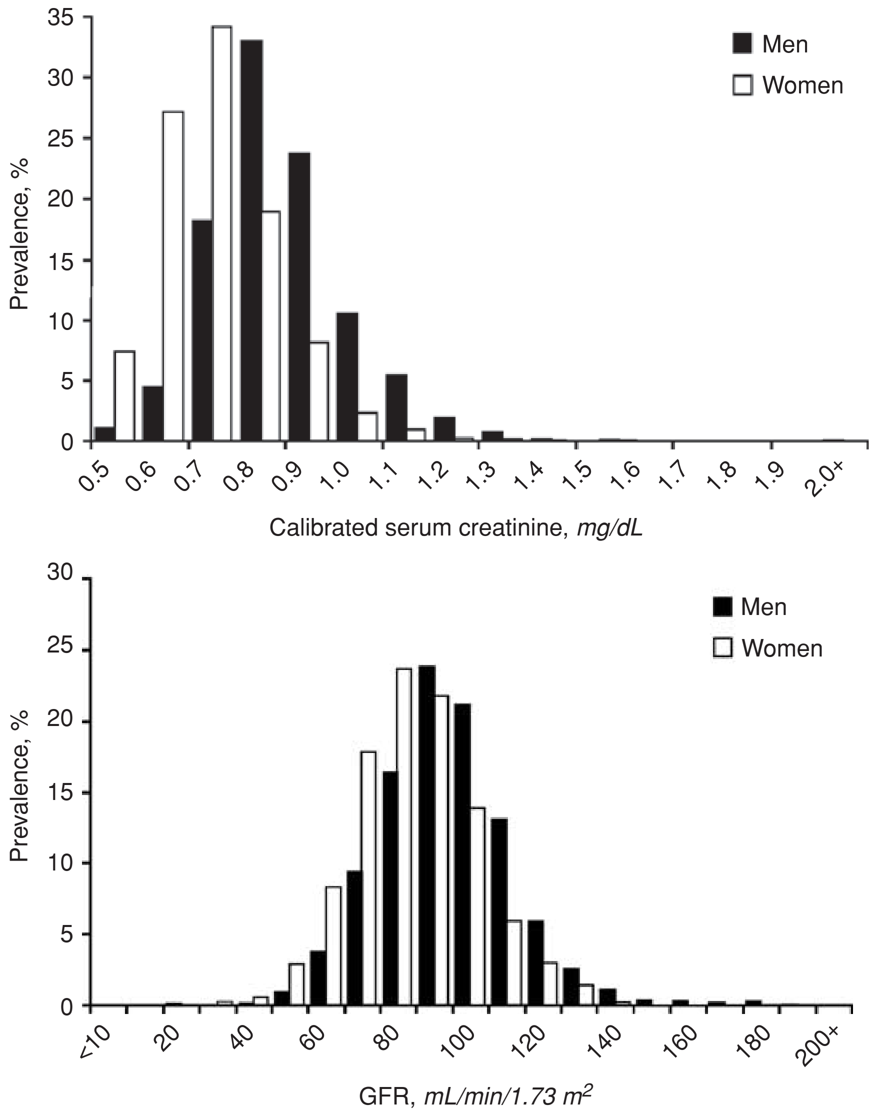

Fig. 2. Distribution of calibrated serum creatinine levels (upper panel) and estimated glomerular filtration rate (lower panel) in the general adult population aged 35 to 74 years in China, 2000 to 2001. GFR (mL/min/1.73m^2) was estimated using the simplified MDRD Study equation.

normally distributed (Fig. 2, lower panel). The distribution of serum creatinine levels was shifted toward lower values in women than that in men, and the distribution of estimated GFR using the simplified MDRD Study equation was also shifted toward lower values in women than in men. Figure 3 shows that successive categories of kidney function (GFR ≥90, 60–89, 30–59, and <30 mL/min/1.73m^2) estimated by the simplified MDRD Study equation corresponded to increasingly greater serum creatinine values. The kidney function categories overlapped at the same levels of serum creatinine, indicating the limitations of using serum creatinine level and sex alone to estimate kidney function.

The age-standardized and age-specific prevalence of normal and decreased kidney function (GFR categories) estimated using the simplified MDRD Study equation according to demographic characteristics is displayed in Table 1. Overall, the age-standardized prevalences of GFR 60 to 89, 30 to 59, and <30 mL/min/1.73m^2 were 39.4%, 2.4%, and 0.14%, respectively, in Chinese adults aged 35 to 74 years. The age-standardized prevalences of mildly and moderately decreased kidney function were greater in women than in men, while age-standardized prevalence of severe decreased kidney function was similar in men and women. Older age was associated with greater prevalences of mildly, moderately, and severely decreased kidney function. The age-standardized prevalences of mildly and severely decreased kidney function were higher in urban residents than in rural residents, while the age-standardized prevalence of moderately decreased kidney function was similar between urban and rural residents. The age-standardized prevalence of decreased kidney function was higher in residents living in south China than those in north China.

The prevalence of moderately and severely decreased kidney function estimated using the Cockcroft-Gault

Table 1. Age-standardized and age-specific prevalence of normal and decreased kidney Function (GFR categories) by demographic characteristics in China, 2000 to 2001

	Prevalence of GFR category (mL/min/1.73m^2)			
	≥90 Percent (SE)	60–89 Percent (SE)	30–59 Percent (SE)	<30 Percent (SE)
Total	58.1 (0.5)	39.4 (0.5)	2.4 (0.2)	0.14 (0.04)[a]
Sex				
Men	69.0 (0.6)	29.7 (0.6)	1.2 (0.2)	0.16 (0.06)[a]
Women	46.5 (0.7)	49.7 (0.7)	3.7 (0.3)	0.12 (0.06)[b]
Age *years*				
35–44	71.9 (0.7)	27.4 (0.7)	0.7 (0.1)	0.02 (0.01)[b]
45–54	59.4 (1.0)	38.9 (0.9)	1.6 (0.2)	0.14 (0.09)[b]
55–64	45.7 (1.2)	50.4 (1.2)	3.8 (0.4)	0.11 (0.05)[b]
65–74	30.3 (1.5)	61.5 (1.6)	7.6 (0.8)	0.54 (0.24)[a]
Urbanization				
Urban	47.4 (0.6)	50.0 (0.6)	2.4 (0.2)	0.24 (0.06)[a]
Rural	60.8 (0.6)	36.7 (0.6)	2.4 (0.2)	0.11 (0.05)[b]
Region				
North	62.7 (0.7)	35.6 (0.7)	1.8 (0.2)	0.03 (0.02)[b]
South	54.8 (0.6)	42.2 (0.6)	2.8 (0.2)	0.21 (0.07)[a]

GFR (mL/min/1.73m^2) estimated using the simplified MDRD study equation.
[a]Estimate is based on less than 30 individuals.
[b]Estimate is based on less than 10 individuals.

equation was much higher than the prevalence estimated using the simplified MDRD Study equation in the Chinese population. For example, the overall age-standardized prevalence of GFR 60 to 89, 30 to 59, and <30 mL/min/1.73m^2 using the Cockroft-Gault formula was 39.4%, 19.6%, and 0.8%, respectively. However, the prevalence patterns of decreased kidney function estimated using the Cockcroft-Gault equation were consistent with those estimated using the simplified MDRD Study equation according to sex, age, and other demographic characteristics (data not shown).

The overall age-standardized prevalence of CKD (defined as GFR <60 mL/min/1.73m^2) was 2.53% in the Chinese adult population aged 35 to 74 years; representing 11,966,653 persons (Table 2). The age-standardized prevalence of CKD was 1.31% (3,185,330 persons) in men and 3.82% (8,781,323 persons) in women. The prevalence of CKD was higher with increased age in both men and women. The age-standardized prevalence of CKD was higher in persons with diabetes or hypertension compared to those without. These associations were consistent among all age groups (Fig. 4).

Age-standardized and age-specific calibrated serum creatinine and estimated GFR levels by normal and decreased kidney function (estimated GFR categories) according to demographic characteristics in the Chinese adult population are shown in Table 3. The average creatinine was 0.91 mg/dL among persons with a GFR 60 to 89 mL/min/1.73m^2, 1.23 mg/dL among those with a GFR 30 to 59 mL/min/1.73m^2, and 2.86 mg/dL among those with a GFR <30 mL/min/1.73m^2. Women had significantly lower mean creatinine levels compared to men in the same ranges of GFR categories except for in the severely decreased kidney function group. Mean creatinine levels were very similar among age groups within each category of estimated GFR.

DISCUSSION

The worldwide burden of chronic kidney disease is currently unknown because there are only a few reports on the prevalence from national representative samples, primarily in Western countries. We contribute to this knowledge by reporting the prevalence of CKD in the general Chinese adult population aged 35 to 74 years. Our study indicates that the prevalence of persons with an estimated GFR <60 mL/min/1.73m^2 is approximately 2.53%, which represents approximately 12 million persons with CKD in China.

To our knowledge, this study is the first in China and possibly in any developing country to accurately report the national burden of CKD. The strengths of this study include a large representative sample of the Chinese adult population, a high response rate, use of standardized protocols and data collection instruments, training of data collectors, as well as ongoing quality assurance. To avoid introducing bias during the estimation of GFR, serum creatinine was measured at a central laboratory and calibrated according to Cleveland Clinic Laboratory standard, where the MDRD Study equation originated.

Our study had several limitations. First, GFR was not directly measured in the study population. We used the simplified MDRD Study equation and the Cockcroft-Gault equation to estimate GFR. These equations might over- or underestimate the actual GFR in the Chinese population because these equations were developed primarily in Caucasian populations in the U.S. Zuo et al evaluated the validity of the simplified MDRD equation and the Cockcroft-Gault equation on estimating kidney function in 261 Chinese patients with CKD [20]. They concluded that both equations overestimated GFR in patients with CKD stages 4 to 5 and underestimated GFR in those with CKD stage 1. In addition, the Cockcroft-Gault equation was more biased than the MDRD equation in Chinese patients with CKD. There are several possible reasons for this apparent discrepancy. Dual plasma sampling of technetium Tc 99m-labeled diethylene triamine pentaacetic acid plasma clearance was used to measure GFR in the Chinese study, while renal clearance of iothalamate was used in the MDRD study [17]. The dual blood sampling method may overestimate GFR at lower levels (by an average of 0.5 mL/min when GFR = 10 mL/min) and underestimate GFR at higher levels (by an average of 20 mL/min when GFR = 100 mL/min) [21]. Furthermore, plasma creatinine concentrations used in the development of the MDRD equations were measured by means of the kinetic alkalic picrate method (CX3

Table 2. Age-standardized and age-specific prevalence of chronic kidney disease in the adult population aged 35 to 74 years in China, 2000 to 2001

	Men		Women		Total	
Age *years*	Percent (SE)	Estimated population (SE)	Percent (SE)	Estimated population (SE)	Percent (SE)	Estimated population (SE)
Total	1.31 (0.17)	3,185,330 (417,036)	3.82 (0.27)	8,781,323 (638,339)	2.53 (0.16)	11,966,653 (756,537)
35–44	0.24 (0.10)	228,676 (90,385)[a]	1.20 (0.24)	1,066,518 (210,444)	0.71 (0.12)	1,295,194 (228,878)
45–54	0.71 (0.23)	523,032 (168,215)[a]	2.74 (0.44)	1,906,839 (313,094)	1.69 (0.25)	2,429,871 (354,784)
55–64	1.60 (0.37)	715,815 (164,351)	6.40 (0.81)	2,653,792 (347,103)	3.91 (0.44)	3,369,606 (383,422)
65–74	5.80 (1.09)	1,717,807 (333,826)	10.43 (1.25)	3,154,174 (391,788)	8.14 (0.83)	4,871,981 (513,043)

Chronic kidney disease was defined as GFR <60 mL/min/1.73m^2 estimated using the simplified MDRD study equation.
[a] Estimate is based on less than 30 individuals.

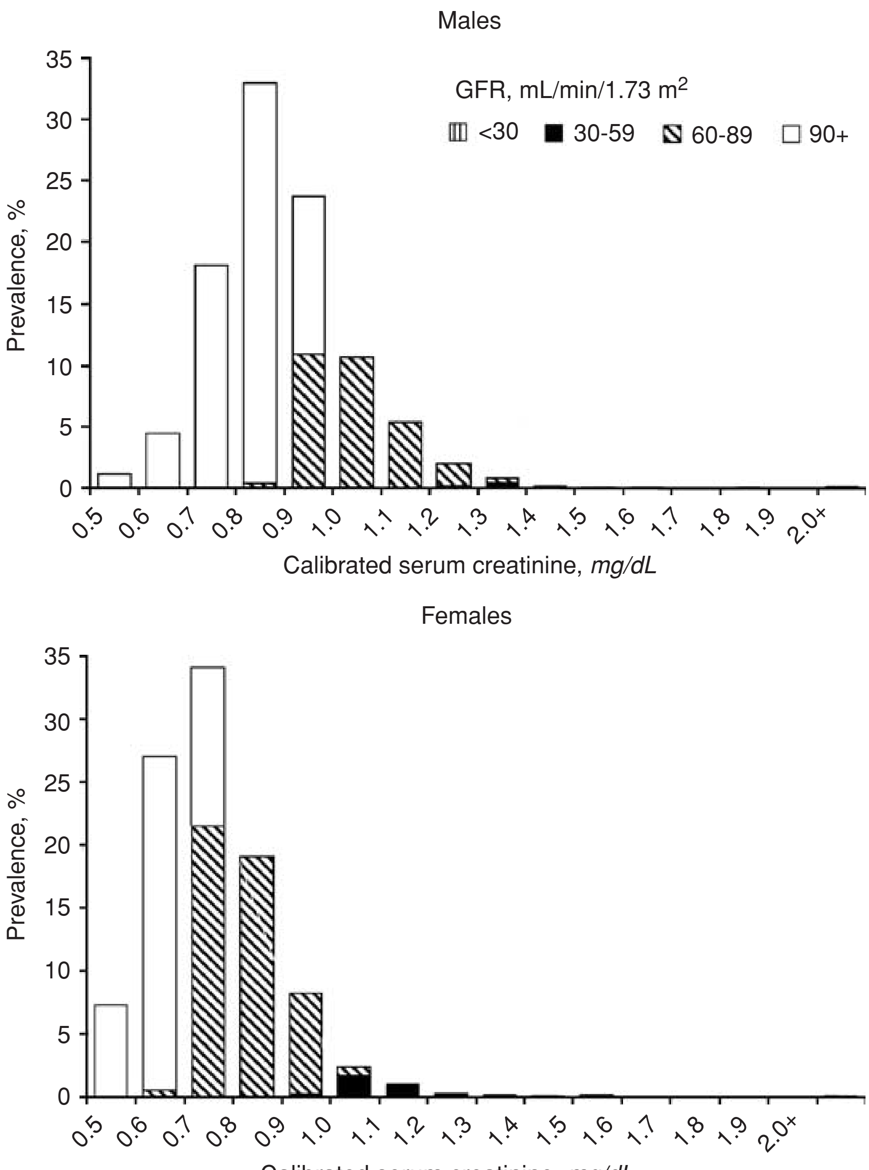

Fig. 3. Joint distribution of calibrated serum creatinine levels and estimated glomerular filtration rate in the general adult population aged 35 to 74 years in China, 2000 to 2001. Within each serum creatinine level, the proportion of individuals with normal and decreased kidney function (GFR categories) is calculated using the simplified MDRD Study equation.

Beckman method) and in the Chinese study by the alkalic picrate acid (Hitachi) method, which has been reported to overestimate plasma creatinine concentrations by approximately 8% [22]. The differences in the GFR and plasma creatinine measurement methods might introduce systematic error and cause inconsistency. In the present study, we have recalibrated serum creatinine levels based on the standard of the Cleveland Clinic laboratory, where the MDRD equation was developed. Furthermore, our findings on gender and age differences

Table 3. Age-standardized and age-specific mean calibrated serum creatinine and GFR levels according to kidney function (GFR categories) by demographic characteristics in China, 2000 to 2001

	GFR category *mL/min/1.73m*^{2}				
	≥90	60–89	30–59	<30	Total
Serum creatinine *mg/dL* Mean (SE)					
Total	0.76 (0.00)	0.91 (0.00)	1.23 (0.02)	2.86 (0.10)	0.83 (0.00)
Sex					
Men	0.82 (0.00)	1.05 (0.00)	1.46 (0.02)	2.72 (0.06)	0.90 (0.00)
Women	0.66 (0.00)	0.83 (0.00)	1.17 (0.01)	3.18 (0.28)	0.76 (0.00)
Age *years*					
35–44	0.77 (0.00)	0.93 (0.00)	1.24 (0.03)	2.78 (0.08)	0.82 (0.00)
44–54	0.76 (0.00)	0.90 (0.00)	1.26 (0.03)	2.73 (0.10)	0.83 (0.00)
55–64	0.75 (0.00)	0.90 (0.00)	1.18 (0.02)	3.30 (0.45)	0.85 (0.00)
65–74	0.75 (0.01)	0.90 (0.01)	1.20 (0.03)	2.80 (0.18)	0.89 (0.01)
Urbanization					
Urban	0.78 (0.00)	0.92 (0.00)	1.26 (0.02)	2.83 (0.09)	0.86 (0.00)
Rural	0.76 (0.00)	0.91 (0.00)	1.22 (0.02)	2.74 (0.10)	0.83 (0.00)
Region					
North	0.76 (0.00)	0.90 (0.00)	1.21 (0.02)	3.63 (0.61)	0.81 (0.00)
South	0.76 (0.00)	0.92 (0.00)	1.24 (0.02)	2.80 (0.07)	0.85 (0.00)
GFR *mL/min/1.73m*^{2} Mean (SE)					
Total	105.73 (0.21)	79.29 (0.11)	53.36 (0.51)	24.03 (1.23)	94.10 (0.18)
Sex					
Men	107.44 (0.29)	80.20 (0.19)	54.60 (0.67)	26.87 (0.55)	98.83 (0.27)
Women	103.05 (0.26)	78.73 (0.15)	53.07 (0.58)	17.38 (0.99)	89.12 (0.23)
Age *years*					
35–44	107.91 (0.30)	80.39 (0.20)	54.22 (0.95)	26.84 (1.02)	100.00 (0.30)
44–54	105.82 (0.42)	79.78 (0.21)	51.97 (1.06)	23.06 (3.39)	94.73 (0.38)
55–64	103.95 (0.44)	77.99 (0.24)	53.74 (0.69)	20.53 (2.22)	88.87 (0.41)
65–74	101.45 (0.66)	76.65 (0.33)	53.55 (0.72)	22.79 (2.85)	82.12 (0.54)
Urbanization					
Urban	103.01 (0.26)	79.81 (0.12)	52.61 (0.75)	25.46 (0.61)	90.07 (0.20)
Rural	106.28 (0.24)	79.10 (0.15)	53.59 (0.58)	22.92 (2.74)	95.14 (0.22)
Region					
North	106.56 (0.28)	79.51 (0.17)	53.16 (0.76)	17.12 (2.88)	96.04 (0.28)
South	106.01 (0.30)	78.54 (0.16)	53.46 (0.51)	23.35 (1.97)	92.68 (0.26)

GFR (mL/min/1.73m^2) estimated using the simplified MDRD Study equation.

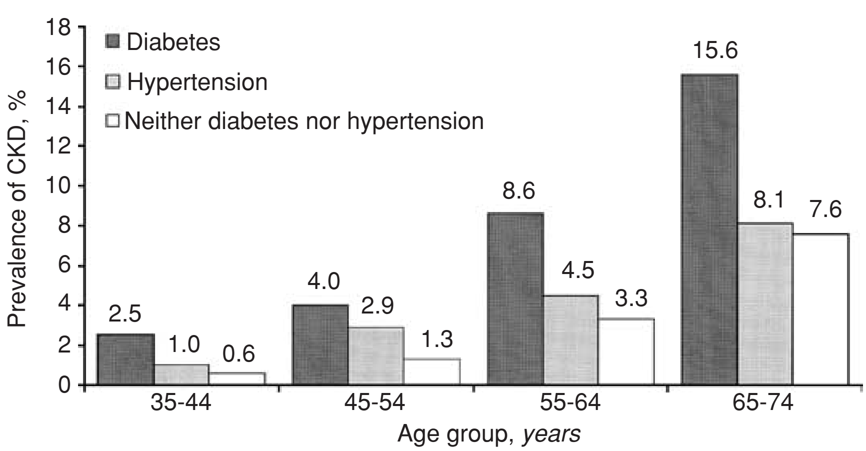

Fig. 4. Age-standardized prevalence of chronic kidney disease (GFR <60 mL/min/1.73 m^2) by the status of diabetes and hypertension, 2000 to 2001. GFR (mL/min/1.73m^2) was estimated using the simplified MDRD Study equation.

in CKD prevalence are consistent with data from the U.S. population, in which GFR was also estimated using the same equation [2]. Another limitation of our study was that urinary protein was not measured and persons with albuminuria or microalbuminuria were not included in the estimated prevalence of CKD. Therefore, our findings certainly underestimate the prevalence of CKD in the Chinese adult population.

The GFR values estimated by the Cockcroft-Gault formula were much lower than those estimated by the simplified MDRD Study equation in our study population. Similarly, GFR was underestimated by the Cockcroft-Gault formula in the African-American Study of Hypertension and Kidney Disease (AASK) participants [23]. In contrast, the MDRD and Cockcroft-Gault formulas provided similar GFR estimates in the NHANES III study population [2]. Levey et al reported that using the MDRD Study equation to estimate GFR was more accurate than either measuring creatinine clearance or using the Cockcroft-Gault equation among patients with moderately or severely decreased kidney function [24]. The validity of the MDRD Study equation and the Crockcroft-Gault equation for assessing kidney function in the Chinese population needs to be further evaluated.

Data from the U.S. NHANES III indicated that the prevalence of moderate and severe CKD (estimated GFR <60 mL/min/1.73m^2) was 4.7% in the U.S. adult population aged 20 years or older, representing 8.3 million CKD patients [2]. Our study only included Chinese adults aged 35 to 74 years. Therefore, our results are not directly comparable with NHANES III, which included a wider age range. Keeping these cautions in mind, the prevalence of moderate and severe CKD was lower in China compared to the U.S., but the actual number of patients with CKD was much greater. If applying our estimates to the full Chinese adult population aged 20 years or older, the absolute burden of CKD should be even higher. The reasons for a substantially lower prevalence of CKD in the Chinese population compared to the U.S. population are not fully understood. A lower prevalence of diabetes in Chinese population than the U.S. population might partially explain this difference [25].

Our study shows that the burden of CKD in China is lower in men than in women, and in younger than in older individuals. The reasons for a higher prevalence of CKD in women are not clear. The prevalence of ESRD was higher in men compared to women in the U.S. and China [1, 26, 27]. According to data from the China Registration of Dialysis and Transplantation program, the ratio of men to women among dialysis patients in Beijing was 1.2:1 in 1999 [26]. Zheng et al reported that the ratio of men to women was 1.3:1 among 10,002 CKD patients with renal biopsy in China [27]. The potential explanation for a higher prevalence of CKD but lower prevalence of ESRD in women might be due to a slower progression of kidney disease in women. An alternative explanation might be that the simplified MDRD Study equation underestimated GFR in women. Some investigators have suggested that the MDRD Study equation might not perform well in the general population because the formula was developed among patients with CKD [28–31].

The prevalence of CKD was significantly higher in south compared to north China, which is consistent with data from the China Registration of Dialysis and Transplantation program, which indicated a higher prevalence of ESRD in south compared to north China [13, 26, 32]. This finding was unexpected because the prevalence of hypertension and diabetes has been shown to be much higher in north than in south China [25, 33] The data from the current study suggest that hypertension and diabetes increase the risk of CKD in the Chinese population. However, there was substantial prevalence among persons without diabetes or hypertension, possibly because of the increased importance of glomerulonephritis as a major cause of CKD in China [13, 14]. It has been reported that glomerulonephritis was more common in south than in north China [13, 14].

CONCLUSION

Our study indicates that CKD is a substantial health burden in the Chinese adult population. The actual prevalence of CKD in China is probably higher than reported here because CKD patients with proteinuria and normal or mildly decreased GFR were not included in our prevalence estimates. These results underscore the need to establish a national program for the detection, prevention, and treatment of CKD aimed at reducing morbidity and mortality from ESRD, cardiovascular disease, and premature death in China.

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REFERENCES

1. National Kidney Foundation: K/DOQI Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification and Stratification. *Am J Kidney Dis* 39(Suppl 1):S1–S266, 2002
2. Coresh J, Astor BC, Greene T, *et al*: Prevalence of chronic kidney disease and decreased kidney function in the adult US population: Third National Health and Nutrition Examination Survey. *Am J Kidney Dis* 41:1–12, 2003
3. He J, Whelton PK: Epidemiology of end-stage renal disease, in Brenner BM, Kurokawa K, editors. *International Handbook of Hypertension*, Haslemere, UK, Euromed Communications Ltd., 1999
4. US Renal Data System: USRDS 2004 Annual Data Report. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD, 2004
5. Foley RN, Parfrey PS, Sarnak MJ: Clinical epidemiology of cardiovascular disease in chronic renal disease. *Am J Kidney Dis* 32:S112–119, 1998
6. Culleton BF, Larson MG, Wilson PW, *et al*: Cardiovascular disease and mortality in a community-based cohort with mild renal insufficiency. *Kidney Int* 56:2214–2219, 1999
7. Mann JF, Gerstein HC, Pogue J, *et al*: Renal insufficiency as a predictor of cardiovascular outcomes and the impact of ramipril: The HOPE randomized trial. *Ann Intern Med* 134:629–636, 2001
8. Shlipak MG, Simon JA, Grady D, *et al*: Renal insufficiency and cardiovascular events in postmenopausal women with coronary heart disease. *J Am Coll Cardiol* 38:705–711, 2001
9. Shlipak MG, Heidenreich PA, Noguchi H, *et al*: Association of renal insufficiency with treatment and outcomes after myocardial infarction in elderly patients. *Ann Intern Med* 137:555–562, 2002
10. Muntner P, He J, Hamm L, *et al*: Renal insufficiency and subsequent death resulting from cardiovascular disease in the United States. *J Am Soc Nephrol* 13:745–753, 2002
11. Garg AX, Clark WF, Haynes RB, House AA: Moderate renal insufficiency and the risk of cardiovascular mortality: Results from the NHANES I. *Kidney Int* 61:1486–1494, 2002
12. Go AS, Chertow GM, Fan D, *et al*: Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. *N Engl J Med* 351:1296–1305, 2004
13. Dialysis and Transplantation Registration Group: The report about the registration of dialysis and transplantation in China 1999. *Chin J Nephrol* 17:77–78, 2001

14. Lin S: Nephrology in China: A great mission and momentous challenge. *Kidney Int* Suppl 83:S108–S110, 2003
15. He J, Neal B, Gu D, *et al*: International collaborative study of cardiovascular disease in Asia: Design, rationale, and preliminary results. *Ethnic Dis* 14:260–268, 2004
16. Perloff D, Grim C, Flack J, *et al*: Human blood pressure determination by sphygmomanometer. *Circulation* 88:2460–2470, 1993
17. Levey AS, Greene T, Kusek JW, *et al*: A simplified equation to predict glomerular filtration rate from serum creatinine. *J Am Soc Nephrol* 11:155A, 2001
18. Cockcroft DW, Gault MH: Prediction of creatinine clearance from serum creatinine. *Nephron* 16:31–41, 1976
19. Hu YM, Wu XL, Hu ZH, *et al*: Study of formula for calculating body surface areas of the Chinese adults. *Acta Physiol Sinica* 51:45–48, 1999
20. Zuo L, Ma YC, Zhou YH, *et al*: Application of GFR-estimating equations in Chinese patients with chronic kidney disease. *Am J Kidney Dis* 45:463–472, 2005
21. Waller DG, Keast CM, Fleming JS, *et al*: Measurement of glomerular filtration rate with technetium-99m DTPA: Comparison of plasma clearance techniques. *J Nucl Med* 28:372–377, 1987
22. Coresh J, Astor BC, McQuillan G: Calibration and random variation of the serum creatinine assay as critical elements of using equation to estimate glomerular filtration rate. *Am J Kidney Dis* 39:920–929, 2002
23. Lewis J, Agodoa L, Cheek D, *et al*: African-American Study of Hypertension and Kidney Disease. Comparison of cross-sectional renal function measurements in African Americans with hypertensive nephrosclerosis and of primary formulas to estimate glomerular filtration rate. *Am J Kidney Dis* 38:744–753, 2001
24. Levey AS, Bosch JP, Lewis JB, *et al*: A more accurate method to estimate glomerular filtration rate from serum creatinine: A new prediction equation. *Ann Intern Med* 130:461–470, 1999
25. Gu D, Reynolds K, Duan X, *et al*: Prevalence of diabetes and impaired fasting glucose in the Chinese adult population: International Collaborative Study of Cardiovascular Disease in Asia (InterASIA). *Diabetologia* 46:1190–1198, 2003
26. Beijing Dialysis and Transplantation Registration Group: The report about the registration of dialysis and transplantation in Beijing 1999. *Chin J Nephrol* 17:79–81, 2001
27. Zeng C, Chen H, Yu Y, *et al*: Clinical epidemiologic of renal disease in China based on 10002 renal biopsy data. *Chin J Nephrol Dialy Transplant* 10:3–7, 2001
28. Rule AD, Gussak HM, Pond GR, *et al*: Measured and estimated GFR in healthy potential kidney donors. *Am J Kidney Dis* 43:112–119, 2004
29. Vervoort G, Willems HL, Wetzels JF: Assessment of glomerular filtration rate in healthy subjects and normoalbuminuric diabetic patients: Validity of a new (MDRD) prediction equation. *Nephrol Dial Transplant* 17:1909–1913, 2002
30. Lin J, Knight EL, Hogan ML, Singh AK: A comparison of prediction equations for estimating glomerular filtration rate in adults without kidney disease. *J Am Soc Nephrol* 14:2573–2580, 2003
31. Clase CM, Garg AX, Kiberd BA: Prevalence of low glomerular filtration rate in nondiabetic Americans: Third National Health and Nutrition Examination Survey (NHANES III). *J Am Soc Nephrol* 13:1338–1349, 2002
32. Shanghai Dialysis and Transplantation Registration Group: The report about the registration of dialysis and transplantation in Shanghai 1999. *Chin J Nephrol* 17:83–85, 2001
33. Gu D, Reynolds K, Wu X, *et al*: Prevalence, awareness, treatment, and control of hypertension in china. *Hypertension* 40:920–7, 2002