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The Prevalence of Chronic Kidney Disease (CKD) and the Associated Factors to CKD in Urban Korea: A Population-based Cross-sectional Epidemiologic Study

Chronic kidney disease (CKD) is a worldwide problem. This study was designed to survey the prevalence and risk factors for CKD in Korea. The 2,356 subjects were selected in proportion to age, gender, and city. Subjects 35 yr of age or older were selected from 7 cities. Estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRD) Study equation, with albuminuria defined as a urine albumin to creatinine ratio of 30 mg/g or more. The overall prevalence of CKD was 13.7%. The prevalences of CKD according to stage were 2.0% stage 1, 6.7% stage 2, 4.8% stage 3, 0.2% stage 4, and 0.0% stage 5. The prevalences of microalbuminuria and macroalbuminuria were 8.6% and 1.6%, respectively. The prevalence of eGFR less than 60 mL/min/1.73 m^2 was 5.0%. Age, body mass index (BMI), hypertension, diabetes mellitus, systolic blood pressure (SBP), diastolic blood pressure (DBP), and fasting blood glucose were independent factors related to the presence of CKD. In conclusions, Korea, in which the prevalence of CKD is increasing, should prepare a policy for early detection and appropriate treatment of CKD. The present data will be helpful in taking those actions.

Key Words : *Korea; Kidney Failure, Chronic; Epidemiologic Studies*

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INTRODUCTION

Chronic kidney disease (CKD) is a worldwide problem, and its prevalence is increasing dramatically. According to data from the National Health and Nutrition Examination Surveys (NHANES), the prevalence of CKD in the United States was 13.1% between 1999 and 2004, which indicated an increase compared to the 10.0% prevalence noted during the 1994-1998 period (1). In the AusDiab kidney study, approximately 16% of Australian adults had markers of CKD, including proteinuria, hematuria, or reduced glomerular filtration rate (GFR) (2). The prevalence of CKD in Asia is not lower than that seen in Western countries. The prevalence of GFR less than 60 mL/min/1.73 m^2 in the adult Japanese population is 19.1% (3). A recent study found the prevalence of CKD in Beijing to be 13.0% (4).

CKD is a well known predictor of hospitalization (5), cardiovascular events (5-8), cardiovascular mortality (5), non-cardiac mortality (9), and all-cause mortality (5-7). Decreased renal function is also a risk factor for cognitive dysfunction (10) and poor quality of life (11). Some CKD-related metabolic complications, such as anemia and hyperparathyroidism, are observed early in stage 3 CKD (12). Despite the significant health problems associated with CKD, an English study showed that only 15.2% of patients with CKD were known to renal services and only 8.1% of patients were referred to a nephrologist during a mean follow-up period of 31.3 months (13). Late referral to a nephrologist was an important risk factor for patient mortality (13). The cost of health services for patients with CKD is 1.8 times the cost for patients without CKD. By 2010, more than 28 billion US dollars will be paid for health services in patients with end stage renal disease (ESRD) in the United States (14).

In Korea, the prevalence and incidence of ESRD have been increasing since 1986, as well (15). In 2005, the incidence of ESRD in Korea reached 173 per million population (PMP), and the prevalence reached 900 PMP (16). An international comparison of ESRD epidemiology showed Korea to rank 9th in ESRD prevalence (16). The health costs for kidney disease (defined by ICD-10 codes N18.x and N19.x) made up 3.24% of the national expenditure for health services in Korea in 2004.

Although the data for patients with ESRD has been entered into the ESRD registry in the Korean Society of Nephrology since 1986, there have been no studies detailing the nationwide prevalence of CKD in Korea. Thus, this cross-sectional epidemiologic study was designed to survey the prevalence and risk factors for CKD in the 7 major cities of Korea.

MATERIALS AND METHODS

Study population

This was a cross-sectional epidemiologic study. The sample population was made up of individuals 35 yr or older, selected in proportion to age, gender, and city in Korea. We decided to include 2,400 persons in the study. Seven cities were included (Seoul, Incheon, Daejeon, Gwangju, Daegu, Ulsan, Busan); 48.03% of Koreans age 35 yr or older live in these cities according to the 2006 Korean Population Census. Seoul and Incheon are located in the middle of the Korean peninsula; Daejeon and Gwangju are in the southwest; and Ulsan, Daegu, and Busan are in the southeast. A website was created, and an advertisement was placed in various newspapers for volunteers to participate in this survey. The number of participants was decided according to age, gender, and sub-district of city (Gu). Only one person per household could participate in this survey. The website for volunteers was closed after the planned number of participants was recruited. There were 2,413 volunteers registered to the website. Among these, 2,364 persons completed the questionnaires and laboratory tests. We analyzed the data of 2,356 participants and excluded 8 persons less than 35 yr of actual age.

Measurements and definitions

The subjects came to the specified hospital(s) in each city after overnight fasting for at least 12 hr, completed the questionnaires, and completed blood and urine tests. Baseline demographics such as age, gender, weight (kg), height (cm), area of residence, systolic blood pressure (SBP), and diastolic blood pressure (DBP) and laboratory tests such as serum blood urea nitrogen (BUN), serum creatinine (Cr), fasting serum glucose, total cholesterol, low density lipoprotein (LDL) cholesterol, and single voided fasting urine albumin to creatinine ratio (mg albumin/g creatinine: UACR) were examined. Arterial blood pressure was measured using a mercury sphygmomanometer after participants sat for at least 15 min in each specified hospital. Participants reported their respective comorbidities, such as hypertension, diabetes mellitus, coronary artery disease, cerebrovascular events, and renal disease; current smoking habits; family history of hypertension, diabetes mellitus, coronary artery disease, renal disease, cerebrovascular events, or cancer; and medications for hypertension and diabetes mellitus. The serum creatinine was measured by an automatic analyzer using the Jaffe method in all participating hospitals. Estimated GFR (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRD) Study equation (17).

Albuminuria was defined as a UACR of 30 mg/g or more. Microalbuminuria was defined as a UACR ranging from 30 to 299 mg/g, and macroalbuminuria was defined as a UACR of 300 mg/g or more. Referencing the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI) working group, CKD was defined as the presence of albuminuria or eGFR <60 mL/min/1.73 m^2. Stages of CKD were defined as follows: stage 1 (eGFR $\geq$ 90 mL/min/1.73 m^2 and UACR $\geq$30 mg/g); stage 2 (eGFR 60-89 mL/min/1.73 m^2 and UACR $\geq$30 mg/g); stage 3 (eGFR 30-59 mL/min/1.73 m^2 regardless of UACR); stage 4 (eGFR 15-29 mL/min/1.73 m^2 regardless of UACR); and stage 5 (eGFR <15 mL/min/1.73 m^2 regardless of UACR).

Hypertension was defined as SBP of 140 mmHg or greater, DBP of 90 mmHg or greater, or use of antihypertensive medications irrespective of BP. Diabetes mellitus was defined as a fasting glucose of 126 mg/dL or greater or use of hypoglycemic agents. A history of cardiovascular events was defined as a history of coronary arterial disease or cerebrovascular accident. Body mass index (BMI) was calculated based on weight and height (weight [kg]/height [m^2]). BMI groups were classified as less than the 10th percentile (BMI <20.7 kg/m^2), 10th to 50th percentile (BMI 20.7 to 24 kg/m^2), 50th to 90th percentile (BMI 24.1 to 28.0 kg/m^2), and greater than the 90th percentile (BMI >28.0 kg/m^2), as proposed in another study (18).

Statistical analyses

All analyses and calculations were performed using SPSS software (SPSS version 12.0, Chicago, IL, U.S.A.). Data are presented as the means $\pm$SDs for continuous variables and as proportions for categorical variables. Demographic and clinical data were described and compared between groups. Differences were analyzed using the chi-square test for categorical variables and the Student t test or one-way ANOVA for continuous variables according to the number of groups. The odds ratio (OR) between the factors and CKD was calculated using logistic regression analysis with or without adjustment for age, gender, BMI, hypertension, and diabetes mellitus, which are well known risk factors for CKD. *p* values less than 0.05 were considered statistically significant.

RESULTS

Characteristics of participants

The proportions of age and gender in the study group were no different compared to those in the general populations in each city (Table 1). Of the 2,356 participants, 1,151 (48.8%) were male and 1,205 (51.2%) were female. The mean participant age was 50.5±11.1 yr. The prevalences of hypertension and diabetes mellitus were 35.5% and 10.1%, respectively. The serum creatinine was 0.83±0.11 mg/dL in women and 1.09±0.45 mg/dL in men; it slightly increased with age in women ($p<0.05$), but it did not differ among the various age groups in men ($p>0.05$) (Fig. 1). The eGFR level was 79.4±12.6 mL/min/1.73 m^2 in women and 79.3±12.7 mL/min/1.73 m^2 in men. The mean eGFRs in age groups, 35-44 yr, 45-54 yr, 55-64 yr, and 65 yr or more were 85.3, 80.0, 74.6, and 70.5 mL/min/1.73 m^2 in females, respectively, and 83.0, 79.3, 77.0, and 71.9 mL/min/1.73 m^2, in males, respectively. The mean eGFR level decreased with age at a rate of 4.24 mL/min/1.73 m^2/10 yr in females and at a rate of 4.08 mL/min/1.73 m^2/10 yr in males (Fig. 1). The UACR level was 24.2±115.7 mg/g (median: 5.2 mg/g) in women and

Table 1. Comparisons of demographic characteristics of the study population and the 2006 population in 7 Korean cities

Characteristics	Study population		2006 population in 7 cities	
	No. of participants	%	No. of participants	%
Total	2,356	100	11,298,320	100
Age in 2006 (yr)				
35-44	833	35.4	4,077,457	36.1
45-54	768	32.6	3,648,794	32.3
55-64	432	18.3	2,061,663	18.2
65 or more	257	13.7	1,510,406	13.4
Gender				
Male	1,151	48.9	5,504,445	48.7
Female	1,205	51.1	5,793,875	51.3
City				
Seoul	1,055	44.8	5,023,194	44.5
Incheon	263	11.2	1,279,035	11.3
Daejeon	142	6.0	687,389	6.1
Gwangju	133	5.6	642,447	5.7
Daegu	265	11.2	1,246,987	11.0
Ulsan	107	4.5	521,744	4.6
Busan	391	16.6	1,897,524	16.8

Table 2. Prevalence of decreased kidney function and CKD in urban Korea

Kidney function			Albuminuria within each level of eGFR (%)			CKD		
eGFR	No.	%	None	Micro	Macro	Stage	No.	%
≥90	435	18.5	89.0	9.2	1.8	1	48	2.0
60-89	1,804	76.6	91.2	7.8	0.9	2	158	6.7
30-59	112	4.8	73.2	19.6	7.1	3	112	4.8
15-29	4	0.2	0.0	0.0	100.0	4	4	0.2
<15	1	0.0	0.0	0.0	100.0	5	1	0.0
Total	2,356	100.0	89.8	8.6	1.6	All	323	13.7

eGFR, mL/min/1.73 m^2 by MDRD equation; Micro, microalubminuria; Macro, macroalbuminuria.
CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

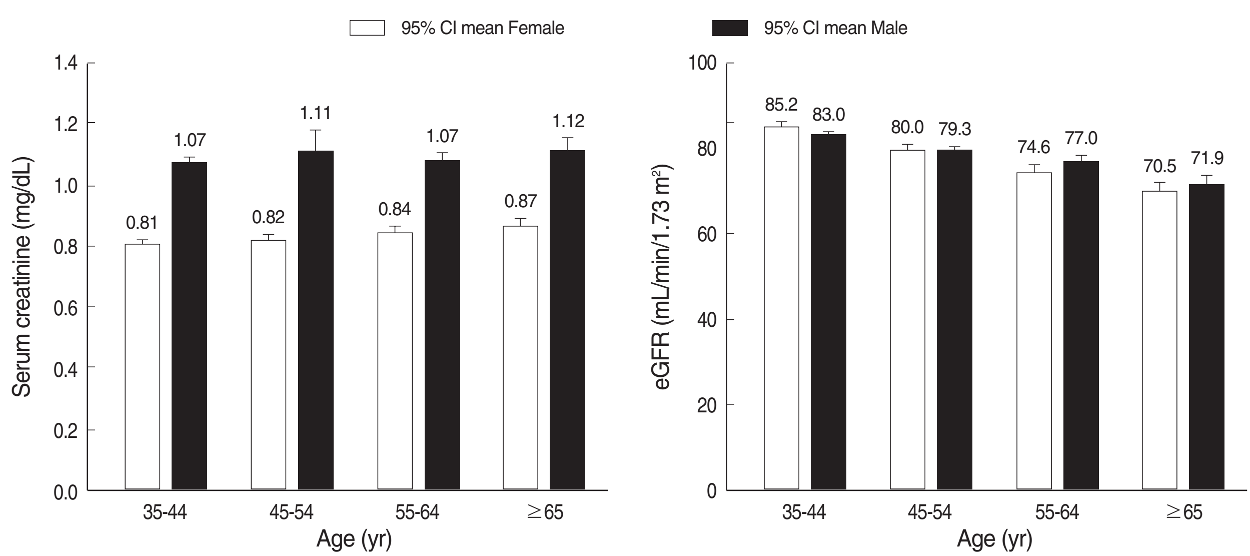

Fig. 1. The serum creatinine and eGFR with age in each gender.

26.9±132.6 mg/g (median: 3.8 mg/g) in men, with no statistical difference noted between the gender groups (p>0.05).

Prevalence of CKD

The overall prevalence of CKD was 13.7%. The prevalences of CKD according to stage were 2.0% in stage 1, 6.7% in stage 2, 4.8% in stage 3, 0.2% in stage 4, and 0.0% in stage 5 (Table 2). The prevalence increased remarkably with age (Table 3). The prevalence in subjects aged 65 yr or older (31.0%) was much higher than the prevalence in subjects 35 to 44 yr of age (8.8%) (p<0.05) (Table 3). Generally, the prevalence of CKD did not differ according to gender, but, in participants less than 50 yr of age, the prevalence was higher in men (11.4% vs. 7.0%, p=0.008); in subjects 50 yr of age or greater, the prevalence was lower in men compared to women (15.7% vs. 21.4%, p=0.014). The frequencies of hypertension and diabetes mellitus were higher in women

Table 3. The prevalence of CKD in adults aged 35 yr or more in urban Korea

	No-CKD	All CKD	CKD stage 1	CKD stage 2	CKD stage ≥3
Age (yr)					
35-44	760 (91.2)	73 (8.8)	18 (2.2)	49 (5.9)	6 (0.7)
45-54	683 (88.9)	85 (11.1)	18 (2.3)	49 (6.4)	18 (2.3)
55-64	367 (85.0)	65 (15.0)	10 (2.3)	26 (6.0)	29 (6.7)
65 or more	223 (69.0)	100 (31.0)	2 (0.6)	34 (10.5)	64 (19.8)
Female	1,037 (86.1)	168 (13.9)	21 (1.7)	85 (7.1)	62 (5.1)
Male	996 (86.5)	155 (13.5)	27 (2.3)	73 (6.3)	55 (4.8)
History of CVD*, no	1,974 (86.8)	299 (13.2)	45 (2.0)	150 (6.6)	104 (4.6)
History of CVD*, yes	46 (69.7)	20 (30.3)	3 (4.5)	5 (7.6)	12 (18.2)
Current non-smoking	1,548 (86.2)	248 (13.8)	29 (1.6)	120 (6.7)	99 (5.5)
Current smoking	472 (86.9)	71 (13.1)	19 (3.5)	35 (6.4)	17 (3.1)
BMI*					
Less than 10th percentile	205 (88.4)	27 (11.6)	7 (3.0)	9 (3.9)	11 (4.7)
10th-50th percentile	813 (91.5)	76 (8.5)	10 (1.1)	38 (4.3)	28 (3.1)
50th-90th percentile	819 (83.7)	159 (16.3)	25 (2.6)	73 (7.5)	61 (6.2)
Over 90th percentile	195 (76.2)	61 (23.8)	6 (2.3)	38 (14.8)	17 (6.6)
Diabetes mellitus, absent	1,859 (88.4)	244 (11.6)	34 (1.6)	118 (5.6)	92 (4.4)
Diabetes mellitus, present	161 (68.2)	75 (31.8)	14 (5.9)	37 (15.7)	24 (10.2)
Fasting Glucose (mg/dL)					
Less than 110	1,846 (88.2)	247 (11.8)	34 (1.6)	119 (5.7)	94 (4.5)
110-125	92 (78.6)	25 (21.4)	3 (2.6)	15 (12.8)	7 (6.0)
126 or more	95 (65.1)	51 (34.9)	11 (7.5)	24 (16.4)	16 (11.0)
Hypertension, no	1,367 (90.7)	140 (9.3)	21 (1.4)	73 (4.8)	46 (3.1)
Hypertension, yes	651 (78.4)	179 (21.6)	27 (3.3)	82 (9.9)	70 (8.4)
SBP (mmHg)					
Less than 110	309 (90.6)	32 (9.4)	2 (0.6)	18 (5.3)	12 (3.5)
110-119	442 (92.7)	35 (7.3)	7 (1.5)	14 (2.9)	14 (2.9)
120-129	475 (89.5)	56 (10.5)	8 (1.5)	26 (4.9)	22 (4.1)
130-139	378 (84.0)	72 (16.0)	10 (2.2)	37 (8.2)	25 (5.6)
140 or more	427 (76.9)	128 (23.1)	21 (3.8)	63 (11.4)	44 (7.9)
DBP (mmHg)					
Less than 70	403 (91.4)	38 (8.6)	3 (0.7)	16 (3.6)	19 (4.3)
70-79	607 (88.6)	78 (11.4)	12 (1.8)	35 (5.1)	31 (4.5)
80-89	700 (86.4)	110 (13.6)	16 (2.0)	58 (7.2)	36 (4.4)
90 or more	321 (76.8)	97 (23.2)	17 (4.1)	49 (11.7)	31 (7.4)
Cholesterol (mg/dL)					
Less than 200	1,424 (87.8)	197 (12.2)	34 (2.1)	102 (6.3)	61 (3.8)
200 or more	609 (82.9)	126 (17.1)	14 (1.9)	56 (7.6)	56 (7.6)
LDL-cholesterol (mg/dL)					
Less than 100	939 (87.6)	133 (12.4)	25 (2.3)	64 (6.0)	44 (4.1)
100-119	577 (87.4)	83 (12.6)	12 (1.8)	42 (6.4)	29 (4.4)
120 or more	517 (82.9)	107 (17.1)	11 (1.8)	158 (6.7)	117 (5.0)

*History of CVD: cerebrovascular disease such as coronary arterial disease and cerebrovascular accident reported by participants; BMI: less than the 10th percentile (BMI <20.7 kg/m^2), 10th to 50th percentile (BMI 20.7 to 24 kg/m^2), 50th to 90th percentile (BMI 24.1 to 28.0 kg/m^2), and greater than the 90th percentile (BMI >28.0 kg/m^2).
CKD, chronic kidney disease; CVD, cerebrovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

than they were in men according to age. The prevalence of higher BMI (more than 90th percentile) increased in women, but decreased in men, with age (Fig. 2). Participants with middle range BMIs (10th to 50th percentile) showed the lowest prevalence of CKD; higher BMIs were related to higher CKD prevalence ($p<0.05$) (Table 3). The prevalence of CKD was increased with the presence of previous cardiovascular events, hypertension, and diabetes mellitus, and with increases in SBP, DBP, serum glucose, serum cholesterol, and serum LDL-cholesterol ($p<0.05$) (Table 3).

Prevalence of albuminuria

The prevalences of albuminuria, microalbuminuria, and macroalbuminuria were 10.2%, 8.6%, and 1.6%, respectively. The prevalence of albuminuria increased with age ($p<0.05$) (Table 4). Generally, the prevalence of albuminuria was no different according to gender, but, in participants less than 50 yr of age, the prevalence was higher in men (10.6% vs. 6.5%, $p=0.011$). In subjects 50 yr of age or greater, the prevalence was lower in men compared to women (10.1% vs. 14.0%, $p=0.043$). The prevalence of albuminuria was also increased in the presence of hypertension and diabetes mellitus and with increased SBP, DBP, and serum glucose ($p<0.05$). The albuminuria prevalence was not related to smoking, previous cardiovascular events, or serum levels of cholesterol or LDL-cholesterol ($p>0.05$).

Prevalence of decreased renal function (eGFR less than 60 mL/min/1.73 m²)

The prevalence of decreased renal function (eGFR less than 60 mL/min/1.73 m²) was 5.0% (Table 2). The frequency of decreased renal function was only 0.7% in participants aged 35 to 44 yr, but this figure increased to 19.8% in patients aged 65 yr or more ($p<0.05$) (Table 5). The prevalence of decreased renal function was no different according to gender, with or without stratification based on age 50 yr. The prevalence of decreased renal function was also increased in the presence of previous cardiovascular events, hypertension, and diabetes mellitus, as well as increased SBP, serum glucose, and serum cholesterol ($p<0.05$). However, the prevalence of decreased renal function was not related to DBP or LDL-cholesterol levels ($p>0.05$).

Factors related to the prevalence of CKD

The ORs for the prevalence of CKD are listed in Table 6. We tested the ORs of each clinical parameter with or without adjustment for age, sex, BMI, hypertension, and diabetes mellitus, which are well known risk factors for CKD. Without adjustment, the factors of age, previous cardiovas-

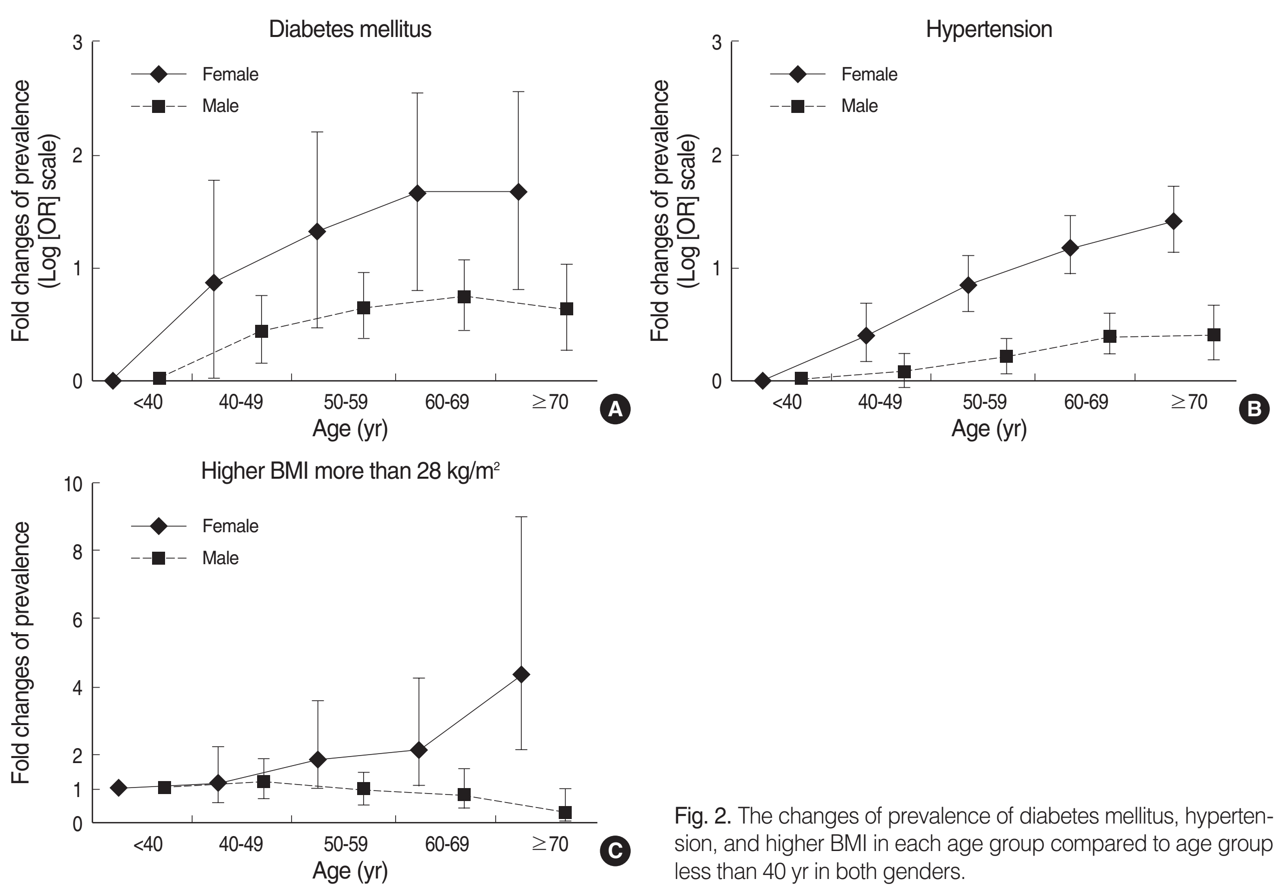

Fig. 2. The changes of prevalence of diabetes mellitus, hypertension, and higher BMI in each age group compared to age group less than 40 yr in both genders.

Table 4. The prevalence of albuminuria in adults aged 35 yr or more in urban Korea

	No albuminuria	All albuminuria	Micro*	Macro*
Age (yr)				
35-44	764 (91.7)	69 (8.3)	57 (6.8)	12 (1.4)
45-54	696 (90.6)	72 (9.4)	60 (7.8)	12 (1.6)
55-64	387 (89.6)	45 (10.4)	37 (8.6)	8 (1.9)
65 or more	268 (83.0)	55 (17.0)	49 (15.2)	6 (1.9)
Female	1,083 (89.9)	122 (10.1)	107 (8.9)	15 (1.2)
Male	1,032 (89.7)	119 (10.3)	96 (8.3)	23 (2.0)
History of CVD*, no	2,044 (89.9)	229 (10.1)	191 (8.4)	38 (1.7)
History of CVD*, yes	57 (86.4)	9 (13.6)	9 (13.6)	0 (0.0)
Current non-smoking	1,619 (90.1)	177 (9.9)	147 (8.2)	30 (1.7)
Current smoking	482 (88.8)	61 (11.2)	53 (9.8)	8 (1.5)
BMI*				
Less than 10th percentile	212 (91.4)	20 (8.6)	18 (7.8)	2 (0.9)
10th-50th percentile	831 (93.5)	58 (6.5)	51 (5.7)	7 (0.8)
50th-90th percentile	865 (88.4)	113 (11.6)	98 (10.0)	15 (1.5)
Over 90th percentile	206 (80.5)	50 (19.5)	36 (14.1)	14 (5.5)
Diabetes mellitus, absent	1,928 (91.7)	175 (8.3)	152 (7.2)	23 (1.1)
Diabetes mellitus, present	173 (73.3)	63 (26.7)	48 (20.3)	15 (6.4)
Fasting Glucose (mg/dL)				
Less than 110	1,916 (91.5)	177 (8.5)	153 (7.3)	24 (1.1)
110-125	96 (82.1)	21 (17.9)	17 (14.5)	4 (3.4)
126 or more	103 (70.5)	43 (29.5)	33 (22.6)	10 (6.8)
Hypertension, no	1,407 (93.4)	100 (6.6)	84 (5.6)	16 (1.1)
Hypertension, yes	692 (83.4)	138 (16.6)	116 (14.0)	22 (2.7)
SBP (mmHg)				
Less than 110	318 (93.3)	23 (6.7)	20 (5.9)	3 (0.9)
110-119	454 (95.2)	23 (4.8)	20 (4.2)	3 (0.6)
120-129	490 (92.3)	41 (7.7)	32 (6.0)	9 (1.7)
130-139	401 (89.1)	49 (10.9)	43 (9.6)	6 (1.3)
140 or more	450 (81.1)	105 (18.9)	88 (14.5)	17 (3.1)
DBP (mmHg)				
Less than 70	420 (95.2)	21 (4.8)	19 (4.3)	2 (0.5)
70-79	629 (91.8)	56 (8.2)	49 (7.2)	7 (1.0)
80-89	727 (89.8)	83 (10.2)	69 (8.5)	14 (1.7)
90 or more	337 (80.6)	81 (19.4)	66 (15.8)	15 (3.6)
Cholesterol (mg/dL)				
Less than 200	1,464 (90.3)	157 (9.7)	135 (8.3)	22 (1.4)
200 or more	651 (88.6)	84 (11.4)	68 (9.3)	16 (2.2)
LDL-cholesterol (mg/dL)				
Less than 100	968 (90.3)	104 (9.7)	86 (8.0)	18 (1.7)
100-119	599 (90.8)	61 (9.2)	56 (8.5)	5 (0.8)
120 or more	548 (87.8)	76 (12.2)	61 (9.8)	15 (2.4)

*History of CVD: cerebrovascular disease such as coronary arterial disease and cerebrovascular accident reported by participants; BMI: less than the 10th percentile (BMI <20.7 kg/m^2), 10th to 50th percentile (BMI 20.7 to 24 kg/m^2), 50th to 90th percentile (BMI 24.1 to 28.0 kg/m^2), and greater than the 90th percentile (BMI >28.0 kg/m^2).
CVD, cerebrovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

cular events, hypertension, diabetes mellitus, SBP, DBP, BMI, fasting blood glucose, serum cholesterol, and serum LDL-cholesterol were related to the presence of CKD.

Age, BMI, hypertension, diabetes mellitus, SBP, DBP, and fasting blood glucose were independent factors related to the higher prevalence of CKD after adjustment of traditional risk factors for CKD.

Patients aged 65 yr or more showed the highest risk and had a 3.174-fold increase in risk for CKD compared to participants less than 45 yr of age. Adjusted ORs for CKD were 1.591 for BMI less than 10th percentile (p=0.059), 1.856 for BMI 50th to 90th percentile (p<0.001), and 2.441 for BMI 90th percentile or more (p<0.001), compared to participants with BMIs in the 10th to 50th percentile. Diabetes mellitus and hypertension were also related to increased ORs for CKD. The prevalence of CKD was increased in subjects with SBPs 130 mmHg to 139 mmHg (1.818 folds, p=0.010) and in subjects with SBPs 140 mmHg or more (1.874 folds,

Table 5. The prevalence of eGFR groups in adults aged 35 yr or more in urban Korea

	eGFR ≥90	eGFR 60-89	eGFR <60
Age (yr)			
35-44	182 (21.8)	645 (77.4)	6 (0.7)
45-54	160 (20.8)	590 (76.8)	18 (2.3)
55-64	82 (19.0)	321 (74.3)	29 (6.7)
65 or more	11 (3.4)	248 (76.8)	64 (19.8)
Female	240 (19.9)	903 (74.9)	62 (5.1)
Male	195 (16.9)	901 (78.3)	55 (4.8)
History of CVD*, no	421 (18.5)	1,748 (76.9)	104 (4.6)
History of CVD*, yes	12 (18.2)	42 (63.6)	12 (18.2)
Current non-smoking	330 (18.4)	1,367 (76.1)	99 (5.5)
Current smoking	103 (19.0)	423 (77.9)	17 (3.1)
BMI*			
Less than 10th percentile	64 (27.6)	157 (67.7)	11 (4.7)
10th-50th percentile	173 (19.5)	688 (77.4)	28 (3.1)
50th-90th percentile	161 (16.5)	756 (77.3)	61 (6.2)
Over 90th percentile	37 (14.5)	202 (78.9)	117 (6.6)
Diabetes mellitus, absent	395 (18.8)	1,616 (76.8)	92 (4.4)
Diabetes mellitus, present	38 (16.1)	174 (73.7)	24 (10.2)
Fasting Glucose (mg/dL)			
Less than 110	390 (18.6)	1,609 (76.9)	94 (4.5)
110-125	17 (14.5)	93 (79.5)	7 (6.0)
126 or more	28 (19.2)	102 (69.9)	16 (11.0)
Hypertension, no	286 (19.0)	1,175 (78.0)	46 (3.1)
Hypertension, yes	147 (17.7)	613 (73.9)	70 (8.4)
SBP (mmHg)			
Less than 110	69 (20.2)	260 (76.2)	12 (3.5)
110-119	97 (20.3)	366 (76.7)	14 (2.9)
120-129	90 (16.9)	419 (78.9)	22 (4.1)
130-139	80 (17.8)	345 (76.7)	25 (5.6)
140 or more	99 (17.8)	412 (74.2)	44 (7.9)
DBP (mmHg)			
Less than 70	98 (22.2)	324 (73.5)	19 (4.3)
70-79	123 (18.0)	531 (77.5)	31 (4.5)
80-89	129 (15.9)	645 (79.6)	36 (4.4)
90 or more	85 (20.3)	302 (72.2)	31 (7.4)
Cholesterol (mg/dL)			
Less than 200	336 (20.7)	1,224 (75.5)	61 (3.8)
200 or more	99 (13.5)	580 (78.9)	56 (7.6)
LDL-cholesterol (mg/dL)			
Less than 100	217 (20.2)	811 (75.7)	44 (4.1)
100-119	131 (19.8)	500 (75.8)	29 (4.4)
120 or more	87 (13.9)	493 (79.0)	44 (7.1)

*History of CVD: cerebrovascular disease such as coronary arterial disease and cerebrovascular accident reported by participants; BMI: less than the 10th percentile (BMI <20.7 kg/m^2), 10th to 50th percentile (BMI 20.7 to 24 kg/m^2), 50th to 90th percentile (BMI 24.1 to 28.0 kg/m^2), and greater than the 90th percentile (BMI >28.0 kg/m^2).

eGFR, estimated glomerular filtration rate; CVD, cerebrovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

p=0.019), compared to subjects with SBPs 110 to 119 mmHg. The adjusted OR for CKD in subjects with DBPs 90 mmHg or more was 2.308 (p=0.002) compared to subjects with DBP less than 70 mmHg. The prevalence of CKD in subjects with fasting glucose levels of 126 mg/dL or more was 2.169 times that in subjects with fasting glucose less than 110 mg/dL (p=0.015).

DISCUSSION

Based on the results of this study, we report the prevalence of CKD to be 13.7% in urban Koreans, and we estimate that 3.2 million urban Koreans age 35 yr or older may have chronic kidney disease. Factors such as older age, high BMI, hypertension, diabetes, high blood pressures, and high fasting blood glucose were associated with an increased prevalence of CKD. Although the participants in this study were volunteers, they were representative of the overall urban Korean population age 35 yr or greater for the following reasons. First, we matched the age, gender, and sub-district of origin for participants to those in the general population. Second, we only allowed one study participant per family to exclude confounding by genetic effects. Third, almost half of Koreans age 35 yr or greater live in the 7 selected cities according to the 2006 Korean Population Census.

The prevalence of CKD differs in various ethnic groups. In the National Health and Nutrition Examination Survey (NHANES) III, conducted from 1988 to 1994, the prevalence of CKD was 11.0%, and the prevalence of decreased renal function (eGFR less than 60 mL/min/1.73 m^2) was 4.7% (19). In an Australian survey, the prevalences of CKD and decreased renal function were 13.1% and 11.2%, respectively (2). In Japan, the prevalence of decreased renal function was as high as 19.2%, with estimation of eGFR using Japanese coefficient 0.881 (3). Among Chinese patients more than 40 yr of age living in Beijing, the prevalences of CKD and decreased renal function were calculated to be 12.6% and 4.9%, respectively, based on the simplified MDRD equation (20). These findings were similar to our results (13.7% and 5.0%). However, the simplified MDRD equation is not easily applied in all races, especially in Asians (17). There are modifications of the MDRD equation for Japanese and the Chinese populations (21, 22). With support from the Korean Society of Nephrology, the study is proceeding to determine if the MDRD equation is applicable in Korean patients and to determine if a modification coefficient is needed in the Korean equation. Hence, the eGFR in this study was limited in its estimate of the prevalence of CKD. When we calculated the eGFR using the Cockcroft-Gault equation divided by the body surface area (CG/BSA), described in a previous report by Coresh et al. (19), the overall prevalence of CKD was 17.0% (401/2,356), and the prevalence of CKD stage 3 or more was 8.6% (203/2,356). These figures were higher than those obtained using the MDRD equation. Other studies have also shown a higher prevalence of CKD using the CG/BSA equation, compared to the MDRD equation (23, 24). There is still debate concerning which is the more

Table 6. Crude and adjusted odds ratios for CKD in adults aged 35 yr or more in urban Korea

	Crude OR [95% CI]	*p*	Adjusted OR [95% CI][†]	*p*
Age (yr)				
35-44	1.000	–	1.000	–
45-54	1.296 [0.932-1.801]	0.123	1.100 [0.784-1.545]	0.581
55-64	1.844 [1.291-2.634]	0.001	1.263 [0.862-1.849]	0.230
65 or more	4.669 [3.334-6.537]	<0.001	3.174 [2.202-4.574]	<0.001
Female	1.000	–	1.000	–
Male	0.961 [0.759-1.215]	0.737	0.887 [0.687-1.145]	0.359
History of CVD*, no	1.000	–	1.000	–
History of CVD*, yes	2.870 [1.675-4.920]	<0.001	1.471 [0.818-2.645]	0.197
Current non-smoking	1.000	–	1.000	–
Current smoking	0.939 [0.707-1.246]	0.663	1.111 [0.792-1.558]	0.541
BMI*				
Less than 10th percentile	1.409 [0.885-2.243]	0.149	1.591 [0.983-2.575]	0.059
10th-50th percentile	1.000	–	1.000	–
50th-90th percentile	2.077 [1.554-2.776]	<0.001	1.856 [1.372-2.510]	<0.001
Over 90th percentile	3.346 [2.308-4.851]	<0.001	2.441 [1.642-3.629]	<0.001
Diabetes mellitus, no	1.000	–	1.000	–
Diabetes mellitus, yes	3.549 [2.617-4.814]	<0.001	2.532 [1.823-3.517]	<0.001
Fasting Glucose (mg/dL)				
Less than 110	1.000	–	1.000	–
110-125	2.031 [1.280-3.222]	0.003	1.460 [0.892-2.390]	0.132
126 or more	4.012 [2.785-5.781]	<0.001	2.169 [1.161-4.050]	0.015
Hypertension, no	1.000	–	1.000	–
Hypertension, yes	2.685 [2.112-3.413]	<0.001	1.850 [1.420-2.410]	<0.001
SBP (mmHg)				
Less than 110	1.308 [0.792-2.158]	0.294	1.355 [0.806-2.277]	0.252
110-119	1.000	–	1.000	–
120-129	1.489 [0.957-2.316]	0.077	1.213 [0.766-1.918]	0.410
130-139	2.405 [1.570-3.685]	<0.001	1.818 [1.157-2.857]	0.010
140 or more	3.786 [2.546-5.629]	<0.001	1.874 [1.111-3.161]	0.019
DBP (mmHg)				
Less than 70	1.000	–	1.000	–
70-79	1.363 [0.907-2.049]	0.137	1.300 [0.841-2.010]	0.238
80-89	1.667 [1.130-2.458]	0.010	1.373 [0.894-2.107]	0.148
90 or more	3.205 [2.142-4.794]	<0.001	2.308 [1.366-3.900]	0.002
Cholesterol (mg/dL)				
Less than 200	1.000	–	1.000	–
200 or more	1.496 [1.173-1.907]	0.001	1.270 [0.979-1.649]	0.072
LDL-cholesterol (mg/dL)				
Less than 100	1.000	–	1.000	–
100-119	1.016 [0.658-1.361]	0.918	0.991 [0.725-1.354]	0.954
120 or more	1.461 [1.109-1.926]	0.007	1.308 [0.973-1.758]	0.075

*History of CVD: cerebrovascular disease such as coronary arterial disease and cerebrovascular accident reported by participants; BMI: less than the 10th percentile (BMI <20.7 kg/m^2), 10th to 50th percentile (BMI 20.7 to 24 kg/m^2), 50th to 90th percentile (BMI 24.1 to 28.0 kg/m^2), and greater than the 90th percentile (BMI >28.0 kg/m^2); [†]Adjusted with age, gender, BMI, hypertension, and diabetes mellitus.
CKD, chronic kidney disease; OR, odds ratio; CVD, cerebrovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

accurate equation to estimate GFR, especially in Asian patients. Hence, we need to re-analyze this data in the near future according to the new method of estimating GFR. The prevalence of CKD in subjects with routine health check-up from a Korean tertiary hospital was 16.1% (25) higher than that of this study because the criteria of albuminuria in that study was defined by the result of urine dipstick test, the hematuria was also regarded as the sign of renal damage, and the study population was not matched to the general population but included from the visitors to health promotion center of a tertiary hospital.

Advanced age is a well known risk factor for CKD, and our study supported this finding (3, 4, 19). Individuals without diabetes mellitus or hypertension, which are also independent risk factors for CKD that increase with aging, were more likely to have CKD and decreased renal function in old age (19). The prevalence of decreased renal function (eGFR less than 60 mL/min/1.73 m^2) was low in younger participants (0.3% in age group 35 to 44 yr, 1.1% in age group 45 to 54 yr) without diabetes or hypertension, but it was quite high (21.1%) among subjects older than 65 yr of age without diabetes or hypertension, similar to the NHANES III report (19).

Male gender is known as a risk factor for ESRD (26). In women, the cumulative incidence of ESRD remains lower than that of men during the reproductive years, but then increases after menopause (26). However, in many cross-sectional studies, the prevalence of CKD is greater in women than it is in men. The NHANES data showed a higher prevalence of CKD in women (19, 27). The AusDiab study also reported a significant gender difference (9.3% in males and 13.0% in females) (2). In the present study, there were no differences in the CKD prevalences between the genders. However, male participants younger than 50 yr of age showed a higher prevalence of CKD than females of the same age did, and female participants 50 yr of age or more had a higher prevalence of CKD than male participants did. One of the possible explanations of the gender difference in CKD prevalence according to age was that the increase rates of the prevalence of hypertension, diabetes, and higher BMI with aging in females were higher than in males from the ages of 40-50 yr (Fig. 2).

In our study, high BMI was also an independent predictor of CKD, as in other studies (4, 28). High BMI was an independent risk factor of decreased renal function (29) and was also associated with an increased incidence of ESRD in Japanese individuals living on Okinawa (26). In the present study, the risk of CKD increased in participants with BMI greater than 24 kg/m^2, which means that the modest increase in BMI could be a risk factor for renal injury in Asian populations (28, 30). This is consistent with the findings that Asians develop cardiovascular complications at lower BMIs compared to white individuals and that the upper limit of normal BMI for Asians is closer to 23 kg/m^2 than it is to 25 kg/m^2 (31).

It is already known that factors such as hypertension (4, 19, 32), diabetes (19, 32), and blood pressure (27, 33) contribute to CKD, which is also evident in this study. We confirmed that systolic blood pressures of 130 mmHg or more, diastolic blood pressures of 90 mmHg or more, and fasting blood glucose levels of 126 mg/dL or more were independently related to the prevalence of CKD.

The present study has some limitations. First, study participants were not randomly selected across the whole nation, and they were mainly urbanites. This indicates a selection bias. However, the selected participants were representative of urban residents because they were selected in proportion to the age and sex of the general populations in the 7 cities, which contain approximately 50% of the Korean population. Second, the present study was a cross-sectional design. Therefore, we could not confirm definite causality between CKD and its risk factors. Third, for laboratory studies, estimation was based on one measurement and might have false positive or false negative errors. CKD patients in this study may or may not have had acute renal insufficiency. Although the method used to measure serum creatinine in participating hospitals was the Jaffe method, the auto-analyzer models differed. We did not standardize the serum creatinine result among hospitals. These factors could have led to overestimation or underestimation of the prevalence of CKD. And, as stated above, the MDRD equation for Koreans has not been validated and is under investigation. For this reason, the CG/BSA equation was also used for estimating GFR on supplementary analysis.

Despite the above limitations, the present study is the first epidemiologic study designed to survey the prevalence of CKD in Korea. The prevalence of CKD in Korea was 13.7%, which is similar to that seen in Chinese patients in Beijing. The factors associated with CKD were age, BMI, diabetes mellitus, hypertension, blood pressure, and fasting glucose. Korea, in which the prevalence of CKD including ESRD is increasing, should prepare a policy of early detection and appropriate treatment for CKD patients. The present data will be helpful in taking this action.

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APPENDIX

Institutions that participated in the study (Investigators).

Chonnam National University Medical School (Nam Ho Kim), Chungnam National University College of Medicine (Ki-Ryang Na, Kang Wook Lee), Ewha Womans University College of Medicine (Seung-Jung Kim, Kyu Bok Choi), Gachon University of Medicine and Science (Woo Kyung Chung), Hallym University College of Medicine (Ji Eun Oh, Tae Jin Park), Korea University College of Medicine (Won Yong Cho), Kyungpook National University School of Medicine (Chan-Duck Kim, Yong-Lim Kim), Pusan National University College of Medicine (Dong Won Lee), Seoul National University College of Medicine (Kwon Wook Joo, Kook Hwan Oh), University of Ulsan College of Medicine (Jong Soo Lee), ordered by alphabet.

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