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Trends in the prevalence of chronic kidney disease, other chronic diseases and health-related behaviors in an adult Korean population: data from the Korean National Health and Nutrition Examination Survey (KNHANES)

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Abstract

Background. Chronic kidney disease (CKD) is an increasing public health problem. However, there have been limited data on the trend of CKD prevalence, along with the changes of health-related behaviors and other chronic diseases in an adult Korean population.

Methods. Data from the Korean National Health and Nutrition Examination Survey in 2005 and 2007 were analyzed. The study subjects comprised 8400 participants aged ≥20 years with creatinine data. CKD was defined as estimated glomerular filtration rate (GFR) <60 mL/min/1.73m^2. GFR was estimated by the abbreviated Modification of Diet in Renal Disease equation.

Results. The CKD prevalence was significantly decreased from 2005 to 2007 (8.8 versus 7.2%; P = 0.010). The prevalence of hypertension was stable but that of diabetes was increased. The proportion of blood pressure (BP) <130/80 mmHg in the whole population, and HbA1c <7% in the diabetic participants was increased from 2005 to 2007. Participants in 2007 walked more than those in 2005. The proportion of current smoking and sodium/energy/protein excess was decreased from 2005 to 2007. In subgroup analysis, only hypertensive participants without diabetes revealed a decreasing trend of CKD.

Conclusions. The CKD prevalence was decreased from 2005 to 2007. Since increased diabetes and improved diabetic control neutralized their impact on CKD, improved BP was the fundamental reason for the decrease. Various health-related behaviors may have indirectly affected the decrease of CKD through their effect in controlling BP and diabetes.

Keywords: blood pressure control; chronic kidney disease; diabetic control; health-related behaviors; Korea

Introduction

Chronic kidney disease (CKD) has become a global public health problem. The cost of health services for patients with CKD is 1.8 times higher than that for patients without CKD [1]. In addition, CKD is a well-known predictor for hospitalization [2], cardiovascular events [2–4], cardiovascular mortality [2], noncardiac mortality [5] and all-cause mortality [2, 3]. Moreover, decreased kidney function is also a risk factor for cognitive impairment [6] or poor quality of life [7]. Furthermore, the CKD prevalence has been increased. In Australia, 16.0% of the study population in the AusDiab (Australian Diabetes, Obesity and Lifestyle Study) kidney study had one or more indicators of CKD: decreased kidney function, hematuria or proteinuria [8]. According to data from the National Health and Nutrition Examination Survey (NHANES), the CKD prevalence in the USA was increased from 10.0% on NHANES 1988–94 to 13.1% on NHANES 1999–2004 [9]. The CKD prevalence in the Asian adult population is 12.9% in Japan [10] and 13.0% in Beijing [11]. In a recent trend analysis, the overall CKD prevalence among the Japanese male population was increased from 13.8% in 1974 to 22.1% in 2002 [12].

In contrast to these other countries, however, the CKD prevalence in the adult Korean population seems to have stabilized. According to Chin *et al.* [13], the CKD prevalence in the Korean adult population was decreased from 12.4% in 2006 to 10.2% in 2008, which they attributed to the effects resulting from the World Kidney Day campaign in 2007. However, their study results were based on two tertiary hospitals and they could not explain the decreased CKD prevalence. Since lifestyle modification is a cost-effective way of controlling cardiovascular disease and diabetes, which are two important risk factors for CKD, we performed this study based on the Korean National Health and Nutrition Examination Survey (KNHANES),

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a nationwide, government-administered survey to evaluate the nationwide prevalence and trend of CKD, along with the change in health-related behaviors in the adult Korean population.

Materials and methods

Study population and data collection

KNHANES is a cross-sectional and nationally representative survey on the health and nutritional status of the civilian, noninstitutionalized Korean population. KNHANES, which is composed of a health questionnaire survey, health examination and nutrition survey, has been conducted four times: the first in 1998, the second in 2001, the third in 2005 and the fourth during 2007–09. The former three surveys were performed every three or four years for 10 weeks, whereas the fourth KNHANES was performed year-round, which is a similar data collection method to that used in the US NHANES [14]. With the confirmed change of the data collecting system in June 2007, the survey in the first year of the fourth KNHANES only began in July 2007, so that only half of the annual target was achieved in 2007. Although the data collection method was changed, the questionnaires and methods of health examination were not.

We used data from the third KNHANES and the first year of the fourth KNHANES in this study. The third and fourth KNHANES selected candidates based on the Korean Census of 2000 and 2005, respectively. The participants were chosen from the candidates by using proportional allocation-systematic sampling with multistage stratification (age, sex and region). The seven metropolitan cities and nine provinces were considered as urban and rural areas, respectively.

An individual who responded to the health-questionnaire survey was asked to visit the mobile examination center (MEC) for the health examination, where one was asked to undergo examinations and to provide blood and urine samples. Among the 11 843 participants who finished the health examination, 8400 (70.9 %) who were aged ≥20 years with a serum creatinine measurement were included for the analysis: 5440 (71.5%) in 2005 and 2960 (69.7%) in 2007.

Measurements

During the MEC examination, a random urine sample (early morning, if possible) was obtained by using a clean-catch technique in a sterile container. Urine protein was measured by dipstick test and results are reported in a semiquantitative scale from negative to 4 positive. Venous blood samples after an overnight fast of at least 12 h were obtained during the MEC examination. The collected urine and blood samples were refrigerated and transported to the central laboratory (Seoul Medical Science Institute) within 24 h. Routine biochemistries, including serum creatinine, were performed by ADIVIA 1650 analyzer (Siemens, Deerfield, IL). Serum creatinine was measured by Jaffe kinetic method and its coefficient of variation for quality control was <5% during the study with stable quality control.

Blood pressure (BP) was measured by using the standard protocol. The three readings were obtained by using a mercury sphygmomanometer in accordance with the recommendation of the American Heart Association Human BP Determination by sphygmomanometers [15]. Final BP for individual participants was reported by calculating the mean of the second and third reading. Height was reported by measuring the maximum distance from the floor to the highest point on the head with occiput, heels and buttocks all in contact with the wall. Weight was measured after zero-point adjustment.

Chronic kidney disease

The level of kidney function was ascertained by using an abbreviated equation developed using data from the Modification of Diet in Renal Disease (MDRD) study [16] to estimate the glomerular filtration rate (GFR) as follows: estimated glomerular filtration rate (eGFR) = 186.3 $\times$ (serum creatinine)$^{-1.154}$ $\times$ age$^{-0.203}$ $\times$ (0.742 for women). We defined CKD as eGFR <60 mL/min/1.73m^2 [17, 18].

Other chronic diseases

Hypertension was defined as the presence of either of the following two criteria: (i) systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg and (ii) following a course of antihypertensive medication at the time of interview. Diabetes was defined as participants who fulfilled at least one of the following four criteria: (i) fasting blood glucose ≥ 126 mg/dL; (ii) following a course of medication to decrease blood glucose level at the time of interview; (iii) following a course of insulin administration at the time of interview and (iv) an individual self reported as having received a physician's diagnosis of diabetes. Obesity was defined as body mass index (BMI) ≥25 kg/m^2. Weight gain was defined as a positive response to the question 'Have you gained weight compared to last year?' Appropriate BP was defined as both systolic BP <130 mmHg and diastolic BP <80 mmHg. Controlled diabetes was defined as hemoglobin A1c (HbA1c) <7.0%.

Health-related behaviors

We used the health questionnaire survey and the nutrition survey to obtain information on health-related behaviors. In the health questionnaire survey, the participants were asked to complete the questionnaires on smoking status, drinking status and physical activity. In the Nutrition survey, trained surveyors visited each household and interviewed individual participants by using 24-h recall method, which is commonly used to estimate the amount of daily food intake [19, 20]. Current smoking was defined as smoking currently five or more cigarettes throughout the lifetime. Current drinking was defined as drinking one or more alcoholic beverages in a month within the previous year. Sodium, energy and protein excesses were defined as having more than the median value of sodium (mg/day), energy (kcal/day) and protein (g/day) in the whole population and the values were calculated based on the Korean Food Composition Table [21].

Statistical analysis

All analyses and calculations were performed using SPSS software (SPSS version 17.0, Chicago, IL). Data are presented as the mean ± SD for continuous variables and as a percentage for categorical variables. Differences were analyzed using the chi-square test for categorical variables and the Student's *t*-test for the continuous variables. The odds ratio (OR) and 95 % confidence interval (95 % CI) of associated factors for the CKD were calculated by using logistic regression analysis. P-value <0.05 was considered statistically significant.

Results

The CKD prevalence in the adult Korean population was decreased during the study period from 8.8% in 2005 to 7.2% in 2007 (P = 0.010, Table 1). The change in the CKD prevalence was mainly derived from the change of prevalence in subjects with eGFR 45–59 mL/min/1.73m^2 since no change was noted in the prevalence of subjects with eGFR <45 mL/min/1.73m^2 (Table 2). During the period, the mean age was increased from 47.17 ± 15.27 years in 2005 to 49.97 ± 16.34 years in 2007 (P < 0.001). No significant changes were noted in the proportion of females and urban areas.

The prevalence of diabetes was increased from 2005 to 2007 (8.9% versus 10.5%; P = 0.023), but the proportion of controlled diabetes in the diabetic participants was also increased from 45.4% in 2005 to 58.4% in 2007 (P = 0.001). On the other hand, the prevalence of hypertension did not change over the study period: 25.7% in 2005 and 26.1% in 2007 (P = 0.659). The proportion of appropriate BP increased from 53.6% in 2005 to 58.5% in 2007 (P < 0.001). The proportion of antihypertensive drug use increased from 13.4% in 2005 to 15.8% in 2007 (P = 0.002). The prevalence of obesity and mean BMI did not change. However, the proportion of weight gain was decreased from 2005 to 2007 (28.5 versus 17.0%; P < 0.001). The proportion of proteinuria 1+ or more by urine dipstick test was increased from 2005 to 2007 (2.2 versus 3.2%; P = 0.007, Table 1).

In the analysis of health-related behaviors, the proportion of daily walking over an hour was increased from 46.3%

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Table 1. Trend in demographic and clinical characteristics over the survey period in adult Korean population

	KNHANES 2005, (n = 5440)	KNHANES 2007, (n = 2960)	P-value
Age (years)	47.17 ± 15.27	49.97 ± 16.34	<0.001
Age group (years)			
20–39 (%)	34.9	32.3	0.015
40–59 (%)	41.3	36.6	<0.001
60–74 (%)	19.6	24.3	<0.001
75+ (%)	4.2	6.8	<0.001
Female sex (%)	57.4	58.0	0.598
Region (urban area %)	43.9	42.2	0.150
Hypertension (%)	25.7	26.1	0.659
Antihypertensive drug use (yes %)	13.4	15.8	0.002
Appropriate BP (%)	53.6	58.5	<0.001
Systolic BP (mmHg)	119.27 ± 17.86	117.71 ± 17.42	<0.001
Diastolic BP (mmHg)	77.34 ± 10.79	75.72 ± 10.01	<0.001
Diabetes (%)	8.9	10.5	0.023
Controlled diabetes (%)	45.4	58.4	0.001
Obesity (%)	32.6	32.3	0.750
BMI (kg/m^2)	23.72 ± 3.27	23.70 ± 3.27	0.732
Weight gain (%)	28.5	17.0	<0.001
CKD (%)	8.8	7.2	0.010
Serum creatinine (mg/dL)	0.99 ± 0.20	0.96 ± 0.25	<0.001
eGFR (mL/min/1.73m^2)	75.98 ± 12.28	77.71 ± 13.02	<0.001
Proteinuria group			0.026
<1+ (%)	97.8	96.8	0.007
1+ (%)	1.3	1.9	0.049
≥2+ (%)	0.9	1.3	0.069

Table 2. Distribution of eGFR group by survey period, demographics and clinical characteristics in adult Korean population[a]

	No. of participants	eGFR group (mL/min/1.73m^2)			
		<45	45–59	60–89	90+
KNHANES					
2005	5440	0.8	8.0	79.0	12.2
2007	2960	1.0	6.2*	79.1	13.7*
Age group (years)					
20–39	2853	0.0	0.4	73.1	26.5
40–59	3330	0.3††	2.2†	90.3†	7.2†
60–74	1786	1.7†	20.9†	73.7†	3.7†
75+	431	6.7†	37.8†	54.1†	1.4††
Female sex					
No	3557	0.7	3.6	78.5	17.2
Yes	4843	1.0	10.2‡	79.5	9.4‡
Hypertension					
No	6158	0.3	4.4	80.4	14.9
Yes	2144	2.5‡	16.2‡	75.6‡	5.7‡
Diabetes					
No	7511	0.6	6.4	79.8	13.2
Yes	785	3.7‡	16.7‡	73.9‡	5.7‡
Daily walking ≥ 1 h					
No	3949	0.9	8.7	78.0	12.3
Yes	3717	0.8‡‡	6.2‡	80.5‡‡	12.5‡

[a]Values are proportions of an individual eGFR group in each condition, expressed as percentage (%).
*P-value <0.05 when compared with KNHANES 2005 in each column of eGFR group, †P-value < 0.001, ††P-value < 0.05 when compared the two adjacent age groups in each column of eGFR group, ‡P-value < 0.001 and ‡‡P-value = 0.01 when compared yes with no in each column of eGFR group.

in 2005 to 53.3% in 2007 (P < 0.001). The proportion of current smoking was decreased from 2005 to 2007 (22.4 versus 20.1%; P = 0.014). Mean sodium intake was decreased from 5676.60 ± 3287.68 mg/day in 2005 to 4392.14 ± 2645.79 mg/day in 2007 (P < 0.001). Total daily energy intake was also decreased from 1995.90 ± 834.90 kcal/day in 2005 to 1741.55 ± 746.24 kcal/day in 2007 (P < 0.001). Participants in 2005 had a larger amount of daily protein (76.74 ± 41.32 g/day) than those in 2007 (versus 62.09 ± 34.72 g/day; P < 0.001). During the period, the proportion of current drinking was stationary (49.1% in 2005 versus 50.3% in 2007; P = 0.283, Table 3).

In comparison with eGFR groups, older age, female gender, hypertension and diabetes were associated with lower eGFR, but daily walking over an hour was associated with higher eGFR (Table 2). In multivariate analysis, older age, female gender, hypertension, diabetes and higher proteinuria were independent risk factors for the CKD, but daily walking over an hour had a protective effect on the CKD with an OR of 0.80 (95% CI 0.65–0.98; P = 0.032, Table 4).

Since hypertension and diabetes are important risk factors for CKD, we analyzed the trend of CKD according to the status of hypertension and diabetes. Among the hypertensive participants without diabetes (n = 1,708), the CKD prevalence was decreased from 17.9% in 2005 to 14.1% in 2007 (P = 0.046). On the other hand, the CKD prevalences in 2005 among the participants without hypertension and diabetes (n = 5775), diabetic participants without hypertension (n = 357) and participants with hypertension and diabetes (n = 418) were not different from those in 2007 (Figure 1).

Discussion

In the Kidney Disease Outcomes Quality Initiative guideline, CKD is usually defined as the presence of either decreased kidney function (GFR < 60 mL/min/1.73m^2) or kidney damage for >3 months [16]. However, we defined CKD only using decreased kidney function since proteinuria was measured by dipstick test in this study. Although proteinuria by dipstick test was associated with end-stage renal disease [22, 23] and mortality [24, 25], and it has been used to define CKD along with eGFR [12, 13, 26], it might be inappropriate for the trend analysis due to the poor sensitivity and specificity of the dipstick test [27], and the absence of any unified threshold for the presence of proteinuria by dipstick test [22, 24, 28].

In the present study, identical equipment and central laboratory facility were employed to measure serum creatinine. Based on eGFR by MDRD equation, the CKD prevalence in the adult Korean population was decreased from 2005 to 2007. Although the observational interval was too short to deduce any trend concerning the stabilization of CKD in Korean adults, this pattern certainly does differ from that in other countries [9, 12]. Since hypertension, diabetes and obesity are important risk factors for CKD, we compared the trend of these chronic diseases and the control rate in order to ascertain the fundamental reasons for the change in the CKD prevalence.

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Table 3. Trend of health-related behaviors over the survey periods

	KNHANES 2005, (n = 5440)	KNHANES 2007, (n = 2960)	P-value
Daily walking ≥ 1 h (%)	46.3	53.3	<0.001
Current smoking (%)	22.4	20.1	0.014
Current drinking (%)	49.1	50.3	0.283
Sodium intake (mg/day)	5676.60 ± 3287.68	4392.14 ± 2646.79	<0.001
Sodium excess[a] (%)	55.9	39.1	<0.001
Energy intake (kcal/day)	1995.90 ± 834.90	1741.55 ± 746.24	<0.001
Energy excess[a] (%)	54.7	41.4	<0.001
Protein intake (g/day)	76.74 ± 41.32	62.09 ± 34.72	<0.001
Protein excess[a] (%)	55.5	39.9	<0.001

[a]Sodium excess, energy excess and protein excess are defined as having nutrients more than their median value in whole population (n = 8400); median (interquartile range) values of sodium, energy and protein were 4567.56 (3065.53–6671.46) mg/day, 1777.73 (1370.48–2298.24) kcal/day and 63.00 (44.34–88.99) g/day, respectively.

Table 4. Logistic regression[a] of factors for the association with CKD

	B	Wald	OR	95% CI	P-value
Age group (versus 20–39 years)		447.05			<0.001
40–59 years	1.65	23.21	5.19	2.66–10.15	<0.001
60–74 years	3.94	141.48	51.39	26.85–98.35	<0.001
75+ years	4.85	191.01	127.80	64.24–254.24	<0.001
Sex (female versus male)	1.15	68.10	3.16	2.41–4.16	<0.001
Hypertension (yes versus no)	0.33	9.20	1.39	1.13–1.73	0.002
Diabetes (yes versus no)	0.48	12.51	1.61	1.24–2.09	<0.001
Proteinuria group (versus <1+)		15.65			<0.001
1+	0.76	5.18	2.14	1.11–4.13	0.023
≥2+	1.17	10.94	3.21	1.61–6.40	0.001
Daily walking ≥ 1 h (yes versus no)	−0.22	4.58	0.80	0.65–0.98	0.032

[a]Adjusted variables are age group, sex, hypertension, diabetes, proteinuria group, daily walking ≥1 h, obesity, region, current smoking, current drinking, sodium excess, protein excess and energy excess.

In the present study, the prevalence of hypertension was not changed, but the prevalence of diabetes was increased from 2005 to 2007. As for the disease control, the proportions of appropriate BP (<130/80 mmHg) and of controlled diabetes (HbA1c < 7%) were both increased from 2005 to 2007. The prevalence of obesity was not changed. Since increased diabetes and improved diabetic control rate could neutralize their impact on CKD, we attributed the decrease of CKD from 2005 to 2007 mainly to the improved control of BP. The subgroup analysis based on the status of hypertension and diabetes supported our assumption since the decrease of CKD prevalence from 2005 to 2007 was only evident among hypertensive participants without diabetes.

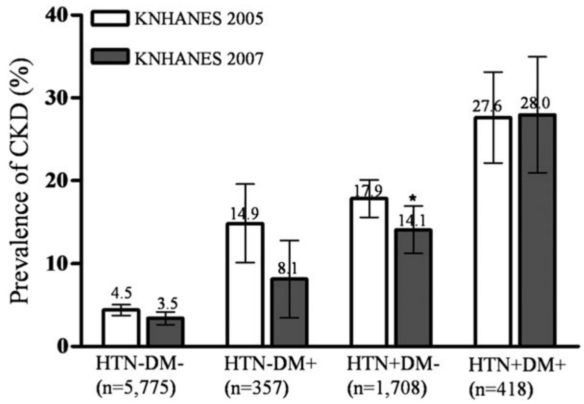

Fig. 1. Trends in the prevalence of CKD from KNHANES 2005 to 2007 based on hypertension (HTN) and diabetes (DM). Each number of participants in four subgroups was presented below group name. Error bars indicate 95% CI, and *designated P-value <0.05 when compared with KNHANES 2005.

In the analysis of various health-related behaviors, the rates of weight gain compared to the previous year, current smoking, sodium intake, energy intake and protein intake were decreased, whereas current drinking was not changed, and daily walking over an hour was increased from 2005 to 2007. These changes of health-related behaviors from 2005 to 2007 were paralleled by improvements of BP and diabetic control in step with the decrease of CKD prevalence in the same period. In general, lifestyle modification, such as losing weight, reducing sodium intake, increased physical activity, limited alcohol consumption and smoking cessation, is an effective way to lessen BP [29–31] and to control serum glucose level [32, 33]. Low-protein diet might prevent CKD progression [34]. Although various health-related behaviors were not directly associated with CKD prevalence in multivariate analysis, except for daily walking over an hour, we could assume that lifestyle modification exerted an indirect effect on the decrease of CKD prevalence through its effect in controlling BP and diabetic control.

The decrease of CKD prevalence was mainly derived from the decreased proportion of eGFR 45–59 mL/min/1.73m^2. Due to the controversy regarding the threshold of eGFR for CKD [35–37], lower eGFR values of 45 or 50 mL/min/1.73m^2 have been proposed as better cut-off criteria for CKD [36, 38]. Therefore, we could not confirm whether the decrease of CKD was a real phenomenon. However, irrespective of whether the eGFR 45–59 group is a 'disease' or not, we could suggest that people with eGFR 45–59 mL/min/1.73m^2 would be advised to modify their health-related behaviors since any deterioration of their kidney function to the level of eGFR <45 mL/min/1.73m^2 would impede any improvement gained by lifestyle modification.

The study suffered several limitations. First, as this study was cross-sectional, a causal relationship could not be confirmed. To confirm the association among health-related behaviors, BP, diabetic control and CKD prevalence, long-term randomized controlled prospective studies are needed. Second, repeated measurements of creatinine are not always possible in studies with large samples [8,11–13, 18] such as

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the present study. A single measurement might lead to overestimation. In addition, we could not calibrate the serum creatinine measurement by using the values from the Cleveland Clinic. No coefficient of the MDRD study equation has yet been published for Koreans. These limitations rendered our CKD prevalence results imprecise. Nevertheless, we considered that these problems did not strongly affect our conclusion since the extent of the misclassification of eGFR levels is likely to have been similar across the surveys. Finally, 70% of the total participants were aged ≥20 years without missing creatinine measurement. In comparison with a Korean Census (data not shown), more elderly women than young men were included in this study. The study participation rate was higher in rural areas than in urban areas. This imbalance may also have resulted in overestimation of the CKD prevalence. However, the deviated selection of the study population was similar across the surveys and we did not consider it to have strongly affected our findings.

In conclusion, the CKD prevalence among the adult Korean population was decreased from 2005 to 2007. We attributed this decrease of CKD prevalence primarily to improved control of BP and secondarily to improved health-related behaviors.

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Conflict of interest statement. None declared.

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