Prevalence of chronic kidney disease and associated metabolic risk factors in a middle-aged and elderly Taiwanese population: a cross-sectional study

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Abstract

Background: This study aimed to quantify the prevalence of chronic kidney disease (CKD) and associated metabolic risk factors in a middle-aged and elderly population in Guishan District, Taoyuan City, Taiwan.

Methods: This cross-sectional study enrolled residents aged 50-90 years living in one community. All subjects received a standardized personal interview, including a structured questionnaire, anthropometric measurements, and blood samples collected for laboratory testing. CKD was defined as the presence of kidney damage (urine albumin-creatinine ratio ≥30mg/g) or estimated glomerular filtration rate (eGFR) <60 mL/min/1.73m 2 . Multiple logistic regression models were used to evaluate risk factors associated with CKD.

Results : A total of 400 subjects were enrolled. The overall prevalence of CKD was 20.3% (95% CI: 16.36–24.24%). The age-specific prevalence of CKD in subjects aged 50-64 years, 65-74 years, and 75 years and over was 17.7%, 18.8%, and 33.9%, respectively, (p value for Cochran-Armitage trend test = 0.022). Multiple logistic regression model revealed that elevated blood pressure (OR = 2.55, 95% CI: 1.30–5.01), hyperglycemia (OR = 2.78, 95% CI: 1.59–4.88), hyperuricemia (OR = 1.36, 95% CI: 1.12–1.65) and metabolic syndrome (OR = 2.48, 95% CI: 1.40–4.40) were statistically and significantly associated with CKD.

Conclusions: The prevalence of CKD in our study population is high. Hypertension, hyperglycemia, hyperuricemia and metabolic syndrome are significantly associated with CKD in a middle-aged and elderly population in Taiwan.

Background

Taiwan had the highest prevalence of end-stage renal disease (ESRD) in the world for more than a decade [1]. The prevalence of chronic kidney disease (CKD) is higher in older adults and reached 37.2% in elderly patients (age ≥ 65 years), while the prevalence of CKD is 11.93% in adults of all ages (age ≥ 20 years) in Taiwan [2]. Treatments for CKD have the greatest effects on slowing the rate of disease progression when started early. CKD can be divided into five stages based on the appearance of kidney damage or estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2. Unfortunately, most patients are unaware of their disorder until they are in the later stages [2].

Metabolic syndrome is another global health concern with rising prevalence. It is defined as a cluster of disorders and risk factors for cardiovascular disease (CVD), including abdominal obesity, hyperglycemia (including impaired glucose tolerance and diagnosed diabetes), dyslipidemia, and elevated blood pressure. Prospective observational studies demonstrate a strong association between the metabolic syndrome and risk for subsequent development of type 2 diabetes [3–6], CVD [7–10], hyperuricemia, gout [11, 12], and CKD [13]. These factors interact as both cause and effect, and the multiple mechanisms involved in the development of CKD in patients with metabolic syndrome have not been well established.

The purpose of the present study is to quantify the prevalence of CKD and associated risk factors, especially metabolic syndrome, in a middle-aged and elderly population in Taiwan. Understanding prevalence of CKD and important risk factors may lead to early detection of CKD and prevention of end-stage renal disease (ESRD), CVD, and reduce associated mortality.

Methods

Study design and subjects

This community based, cross-sectional study enrolled 400 volunteer residents aged 50 and over who lived in Guishan District, Taoyuan City, Taiwan, between January 2014 and October 2014. We recruited these volunteer subjects to join our study at gathering places in town such as temples and community centers. Each participant received a standardized personal interview, including structured questionnaire, anthropometric measurements, and collection of blood samples, on a single day.

Data collection

Data were collected from participants by structured questionnaire, including smoking habits, physical exercise habits, medical history, and current medications. Height and weight were measured to the nearest 0.1 kg and 0.1 cm using an automatic scale. BMI was calculated as the ratio between weight and height in meters squared (kg/m^2). Waist circumference was measured at the mid-point between the lower border of the rib cage and the upper iliac crest on the mid-axillary line. Blood pressure was determined using an automatic sphygmomanometer on the right upper arm after at least 15 minutes of rest. Venous blood samples were collected after overnight fasting for at least 12 hours. All blood samples were stored in a refrigerator at 4 °C and then analyzed at the clinical laboratory of Linkou Chang Gung Memorial Hospital, which was certified by the College of American Pathologists. Urine specimens were obtained in the morning, and scheduled to avoid menstrual periods. The study protocol was approved by the institutional review board (IRB) of the study hospital and signed informed consent was provided by all participants before enrollment.

Definitions of measurement cutoffs and calculations

Chronic kidney disease (CKD) is defined as the presence of kidney damage (urine albumin-creatinine ratio ≥ 30 mg/g) or decreased renal function with estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2. The estimated glomerular filtration rate (eGFR) was calculated using modified equations of Modification of Diet in Renal Disease (MDRD) for Chinese CKD patients: $175 \times (\text{Creatinine})^{-1.234} \times (\text{Age})^{-0.179} \times 0.79$ (for females) [14].

Metabolic syndrome was diagnosed when subjects had at least three of the five following medical conditions, as described by The Third Report of the National Cholesterol Education Program Expert Panel on Adult Treatment Panel (NCEP ATP III) Asian diagnostic criteria: (1) elevated blood pressure (systolic BP ≥ 130 mm Hg, or diastolic BP ≥ 85 mm Hg, or drug treatment of previously diagnosed hypertension); (2) hyperglycemia (FPG ≥ 100 mg/dL, or established diagnosis of diabetes) (3) hypertriglyceridemia (TG ≥ 150 mg/dL, or drug treatment of hypertriglyceridemia); (4) low HDL level (< 40 mg/dL for males and < 50 mg/dL for females); and (5) central obesity (≥ 90 cm for males and ≥ 80 cm for females).

BMI categories were defined as follows: (1) normal weight: BMI≦23 kg/m^2; (2) overweight: 23 ≤ body mass index (BMI) < 25 kg/m^2; (3) obesity: BMI ≥ 25 kg/m^2, according to ranges established for Asian populations [15].

Statistical analysis

Data are presented as mean ± SD (standard deviation) for continuous variables and number of subjects (%) for categorical variables. Differences in the mean values of continuous variables were examined using the independent t-test and one-way ANOVA, while χ2-trend test was used for differences in proportions between categorical variables. Mantel-Haenszel χ2 test was used to analyze stratified categorical data. Multiple logistic regression models were developed to investigate the independence of risk factors associated with CKD. All statistical analyses were performed using SPSS for Windows, SPSS version 19.0 (SPSS Inc., Chicago, IL). A probability value of less than 0.05 was considered to be significant.

Results

As shown in Fig. 1, the overall prevalence of CKD in the study population (age ≥ 50 years) was 20.3% (95% CI: 16.36%-24.24%). The prevalence of CKD increased with age (p value for Cochran-Armitage trend test = 0.022), and more than one in three participants older than 75 years old (prevalence: 33.9%, 95% CI:21.50%-46.30%) were diagnosed to have CKD in this community-based study.

A total of 400 participants were categorized into 3 different age groups: 50–64 years old (n = 232), 65–74 years old (n = 112), and age 75 and ≥ 75 years (n = 56). The ratio of waist circumference to height (WC/height), diastolic blood pressure (DBP), total cholesterol, alanine aminotransferase (ALT), creatinine and eGFR were significantly different between the age subgroups (Table 1). We also compared demographic, anthropometric and clinical characteristics between CKD and non-CKD groups and found that age, waist circumference, ratio of waist circumference to height, systolic blood pressure (SBP), DBP, fasting glucose, triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), ratio of TG to HDL, and uric acid were the factors significantly associated with CKD (Table 1).

Table 1

Demographic, anthropometric and biochemical characteristics of screened subjects with and without chronic kidney disease (n = 400).

			Age							Chronic kidney disease				
	Total		50–64		65–74		≧ 75			Yes		No		
	(n = 400)		(n = 232)		(n = 112)		(n = 56)			(n = 81)		(n = 319)		
Variables	mean	±SD	mean	±SD	mean	±SD	mean	±SD	p value for F-test	mean	±SD	mean	±SD	p value for t-test
Age (year)	64.47	± 8.45	58.53	± 4.01	69.31	± 2.89	79.34	± 3.42	< 0.001	66.67	± 9.71	63.91	± 8.02	0.02
BMI (kg/m^2)	24.55	± 3.57	24.54	± 3.66	24.76	± 3.26	24.16	± 3.78	0.59	25.10	± 3.93	24.41	± 3.46	0.12
WC (cm)	85.07	± 9.68	84.30	± 9.76	85.68	± 8.59	87.02	± 11.14	0.12	87.11	± 10.63	84.55	± 9.37	0.03
WC/height	0.54	± 0.06	0.53	± 0.06	0.54	± 0.05	0.55	± 0.07	0.01	0.55	± 0.06	0.53	± 0.06	0.02
SBP (mmHg)	129.5	± 16.71	128.00	± 16.65	130.80	± 15.66	133.13	± 18.47	0.07	135.38	± 16.51	128.01	± 16.46	< 0.001
DBP (mmHg)	76.93	± 11.36	78.75	± 11.33	76.80	± 10.55	69.66	± 10.26	< 0.001	79.99	± 13.42	76.15	± 10.66	0.01
FPG (mg/dL)	96.23	± 25.73	94.72	± 20.67	98.00	± 26.51	98.96	± 39.59	0.38	105.31	± 40.20	93.93	± 19.95	0.02
Triglyceride (mg/dL)	122.07	± 65.97	122.55	± 59.99	123.79	± 74.09	116.68	± 73.08	0.80	145.95	± 87.39	116.01	± 57.94	0.004
Total cholesterol (mg/dL)	197.15	± 35.71	200.98	± 36.98	194.17	± 32.93	187.20	± 33.70	0.02	190.72	± 34.94	198.78	± 35.77	0.07
HDL-C (mg/dL)	54.43	± 13.93	54.75	± 13.91	54.52	± 13.81	52.93	± 14.44	0.68	51.04	± 15.16	55.29	± 13.49	0.01
TG/HDL-C	2.55	± 1.96	2.54	± 1.81	2.57	± 2.04	2.59	± 2.42	0.97	3.37	± 2.72	2.35	± 1.66	< 0.001
Uric acid (mg/dL)	5.75	± 1.41	5.75	± 1.43	5.70	± 1.40	5.82	± 1.39	0.87	6.27	± 1.77	5.62	± 1.28	0.002
ALT (U/L)	22.63	± 12.95	24.33	± 13.26	20.61	± 13.12	19.59	± 10.04	0.01	24.11	± 14.51	22.25	± 12.52	0.25
HS-CRP (mg/dL)	2.79	± 6.00	2.94	± 5.91	2.16	± 5.15	3.41	± 7.72	0.37	4.23	± 8.99	2.42	± 4.92	0.08
Creatinine (mg/dL)	0.78	± 0.43	0.71	± 0.21	0.81	± 0.47	0.99	± 0.78	< 0.001	1.06	± 0.83	0.7	± 0.17	< 0.001
eGFR (ml/min/1.73 m^2)	112.97	± 33.43	119.05	± 29.86	110.08	± 34.99	93.52	± 36.51	< 0.001	96.25	± 46.29	117.21	± 27.82	< 0.001

Notes: Clinical characteristics are expressed as mean ± SD for continuous variables. P-value were derived from one-way analysis of variance (one-way ANOVA) and independent two-sample t-test for continuous variables.

Abbreviations: BMI, body mass index; WC, Waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; ALT, alanine aminotransferase; HS-CRP, high sensitivity C-reactive protein; eGFR, estimated glomerular filtration rate.

Table 2 shows the associations between the five components of metabolic syndrome and CKD. Elevated blood pressure, hyperglycemia, hypertriglyceridemia, and low HDL-C were statistically significantly associated with an increased age-specific prevalence of CKD, while central obesity showed a similar trend but without statistical significance.

Table 2

Associations between metabolic risk factors and chronic kidney disease in subjects by age group (n = 400).

	50–64 yrs CKD Prevalence(95%CI)	65–74 yrs CKD Prevalence(95%CI)	≧ 75 yrs CKD Prevalence(95%CI)	Total CKD Prevalence(95%CI)	p value
Metabolic syndrome	24.7(17.63–31.77)	35.0(27.18–42.82)	46.2(38.03–54.37)	31.5(23.89–39.11)	< 0.001
Metabolic components					
Elevated blood pressure[a]	21.6(16.5–26.7)	26.9(21.5–32.3)	39.5(33.5–45.5)	26.3(20.9–31.7)	< 0.001
Central obesity[b]	19.2(14.1–24.3)	21.4(16.1–26.7)	37.1(30.9–43.3)	22.6(17.2–28.0)	0.26
Hyperglycemia[c]	32.2(23.7–40.7)	28.9(20.7–37.1)	57.9(48.9–66.9)	35.3(26.6–44.0)	< 0.001
Hypertriglyceridemia[d]	24.3(16.7–31.9)	31.0(22.8–39.2)	50.0(41.1–58.8)	29.8(21.7–37.9)	0.003
Low HDL-C[e]	24.2(16.2–32.2)	36.7(27.7–45.7)	47.1(37.7–56.5)	31.2(22.5–39.9)	0.002
Note:					
[a] SBP ≧ 130 mmHg or DBP ≧ 85 mmHg or self-reported hypertension.					
[b] Waist circumference ≥ 90 cm in men or ≥ 80 cm in women.					
[c] Fasting blood glucose ≥ 100 mg/dL or self-reported diabetes mellitus.					
[d] TG ≥ 150 mg/dL.					
[e] HDL-C < 40 mg/dL in men or < 50 mg/dL in women.					
Abbreviations: HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; CKD, chronic kidney disease; CI, confidence interval.					

The effects of independent associated risk factors on CKD were examined using multiple logistic regression models, after adjusting for age, sex, smoking, physical exercise, BMI categories, ALT, and uric acid. The metabolic syndrome (yes versus no, OR = 2.48, 95% CI: 1.40–4.40) was still significantly associated with CKD (Table 3-model A). Another model was used to examine each of the five components of metabolic syndrome. After adjusting for the above-mentioned confounding factors, elevated blood pressure (yes versus no, OR = 2.55, 95% CI: 1.30–5.01) and hyperglycemia (yes versus no, OR = 2.78, 95% CI: 1.59–4.88) were still the metabolic components significantly associated CKD (Table 3-model B).

Table 3
Multiple logistic regression of factors associated with chronic kidney disease in screened subjects (n = 400).

Variables	Odds ratio	CKD versus non-CKD 95% CI	p value
Model A			
Age			
(65–74 versus 50–64)	1.03	0.56–1.91	0.92
(≧75 versus 50–64)	2.23	1.11–4.49	0.02
Sex (men versus women)	0.90	0.50–1.64	0.74
Smoking (yes versus no)	0.65	0.26–1.64	0.36
Physical exercise (yes versus no)	0.70	0.34–1.44	0.33
BMI			
(Overweight versus normal)	0.93	0.49–1.79	0.84
(Obese versus normal)	0.88	0.44–1.78	0.73
Metabolic syndrome (yes versus no)	2.48	1.40–4.40	0.002
ALT(U/L)	1.01	0.99–1.03	0.36
Uric Acid (mg/dL)	1.36	1.12–1.65	0.002
Model B			
Age			
(65–74 versus 50–64)	0.95	0.50–1.80	0.87
(≧75 versus 50–64)	2.17	1.05–4.48	0.04
Sex (men versus women)	0.81	0.43–1.51	0.50
Smoking (yes versus no)	0.69	0.26–1.82	0.45
Physical exercise (yes versus no)	0.66	0.31–1.39	0.28
BMI			
(Overweight versus normal)	1.17	0.58–2.37	0.67
(Obese versus normal)	1.01	0.45–2.30	0.97
Elevated blood pressure (yes versus no)	2.55	1.30–5.01	0.01
Central obesity (yes versus no)	0.74	0.37–1.52	0.42
Hyperglycemia (yes versus no)	2.78	1.59–4.88	< 0.001
Hypertriglyceridemia (yes versus no)	1.27	0.70–2.31	0.44
Low HDL-C (yes versus no)	1.67	0.91–3.05	0.10
ALT(U/L)	1.01	0.99–1.03	0.44
Uric Acid (mg/dL)	1.35	1.11–1.65	0.003

Abbreviations: BMI, body mass index; ALT, alanine aminotransferase; HDL-C, high-density lipoprotein cholesterol; CKD, chronic kidney disease; CI, confidence interval.

Discussion

In our study, hypertension, hyperglycemia, hyperuricemia and metabolic syndrome are significantly associated with CKD in a middle-aged and elderly population in Taiwan. In several studies among different countries and races, the metabolic syndrome has been disclosed as a risk factor for developing CKD [16–20]. In Japan, Tozawa et al followed 6,371 subjects without CKD or diabetes mellitus for a 5-year period and found that the relative risk of developing CKD was 1.86 (95% CI: 1.43–2.41, $p < 0.0001$) in subjects with metabolic syndrome after adjusting for age, sex, current cigarette smoking and alcohol drinking habits [21]. In the United States, Kurella et al enrolled 10,096 nondiabetic participants with 9 years follow-up, also revealing that metabolic syndrome was independently associated with an increased risk for incident CKD in nondiabetic adults; the OR of incident CKD among participants with the metabolic syndrome was 1.24 (95% CI, 1.01 to 1.51) after adjusting for the subsequent development of diabetes and hypertension [22]. In the present study, metabolic syndrome also serves as an independent risk factor for the development of CKD (yes versus no, OR = 2.48, 95% CI: 1.40–4.40) in a middle-aged and elderly population in Taiwan after adjusting for age, sex, smoking, physical exercise, BMI categories, ALT, and uric acid.

Each component of metabolic syndrome can cause renal damage; however, the components may not contribute equally to the risk of developing CKD [17, 23, 24]. Many studies have further reported the gradient associations between CKD risk and the number of components of metabolic syndrome [21, 22, 24–26]. The multiple mechanisms of renal damage caused by each metabolic syndrome component and their interactions with each other are not yet thoroughly understood. In the present study, elevated blood pressure and hyperglycemia served as independent risk factors for CKD, while other components did not reach statistical significance after adjusting for confounding factors.

High-normal BP is significantly associated with microalbuminuria when compared with optimal BP, and the increase in urinary protein causes injury to tubular cells, leading to interstitial inflammation and fibrosis [27, 28]. Previous studies have also revealed that elevated blood pressure, as a component of metabolic syndrome, is an independent risk factor for the development of CKD. Cao et al. [29] enrolled 11274 subjects and found CKD risk was significantly greater (OR, 1.30; 95% CI: 1.03–1.63) in males with high-normal blood pressure than in those with optimal blood pressure. Song et al. [24] followed 75,468 urban workers for a 2-year period and found that the OR of metabolic syndrome related to reduced eGFR was 1.43 (95% CI, 1.13 to 1.83) [24]. In addition, lower blood pressure targets (i.e., 130/80 mmHg) are strongly associated with better renal outcomes [30]. Thus, aggressive blood pressure control is suggested in the management of patients with metabolic syndrome and mild renal function decline to promote a better prognosis.

Hyperglycemia, including previously diagnosed diabetes and impaired fasting glucose, is another component of metabolic syndrome that is significantly associated with CKD in the present study. Increased GFR, also called hyperfiltration, is a proposed mechanism for renal injury in diabetes, which has been hypothesized to cause intra-glomerular hypertension leading to albuminuria and then reduced GFR. Hyperfiltration also occurred in patients with impaired fasting glucose, and can be used as a predictor of diabetic nephropathy [31–34].

Hypertriglyceridemia, low HDL-C levels, and central obesity were not significantly associated with CKD in the present study. Several other studies also had similar results. Although metabolic syndrome itself is an independent risk factor associated with CKD, dyslipidemia (including both hypertriglyceridemia and low HDL-C level) is not significantly associated with the development of CKD [18, 21, 22, 25, 26, 35]. Some studies have shown that hypertriglyceridemia or low HDL-C level is only significantly associated with the development of CKD in patients with metabolic syndrome [24, 36]. However, the role of central obesity in developing CKD has not reached consensus [25, 27, 36–38]. Differences in race, large disparities in subjects' ages, definition of CKD, and adjusted confounding factors in these studies might be other reasons for discrepancies between studies.

The present study has several limitations. First, this was a cross-sectional study, thus, the causal relationship between CKD and associated risk factors cannot be evaluated and determined. Second, the number of participants in this study was relatively small and all were recruited from only a single community. Third, volunteer bias may exist due to subjects participating on a volunteer basis. Volunteer bias is defined as the bias that comes from the fact that a particular sample contains only those participants who are actually willing to participate in the study. Those who participate and find the topic particularly interesting are more likely to volunteer, and the same is true of those who are expected to be evaluated on a positive level [39]. In addition, we recruited these volunteer subjects to join our study at gathering places in town such as temples and community centers. This means that people who require considerable assistance or frequent medical care had a lower possibility to be recruited. Volunteer bias would potentially influence the prevalence of CKD and the associated risk factors, and the association between CKD and associated risk factors in those who require substantial assistance or care might not be observed in the present study.

Conclusions

CKD is significantly associated with older age, elevated uric acid level, and metabolic syndrome after adjusting for sex, smoking, physical exercise, ALT, and BMI categories in a middle-aged and elderly population in Taiwan. Among the components of metabolic syndrome, elevated blood pressure and hyperglycemia are independently associated with the risk of CKD. For patients with metabolic syndrome, clinical intervention such as life style modification, weight reduction, the use of medications to correct elevated blood pressure, hyperglycemia, dyslipidemia, and hyperuricemia should be provided to prevent or delay the progression of CKD.

Abbreviations

CKD, chronic kidney disease; CVD, cardiovascular disease; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; ALT, alanine aminotransferase; HS-CRP, high sensitivity C-reactive protein; eGFR, estimated glomerular filtration rate; CI, confidence interval.

Declarations

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding authors upon reasonable request.

Authors' Contributions

MCL was involved in writing of the manuscript. IJC, WCY, HHC, YCT and WCL conceived and supervised the study. IST provided statistical advice. JYC and THT contributed conceived and designed the experiments, analyzed the data, revising it critically for important intellectual content and final approval of the version to be submitted.

Ethics approval and consent to participate

The study was approved by Chang-Gung Medical Foundation Institutional Review Board (102-2304B), and written informed consent was given by all the participants before enrollment.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

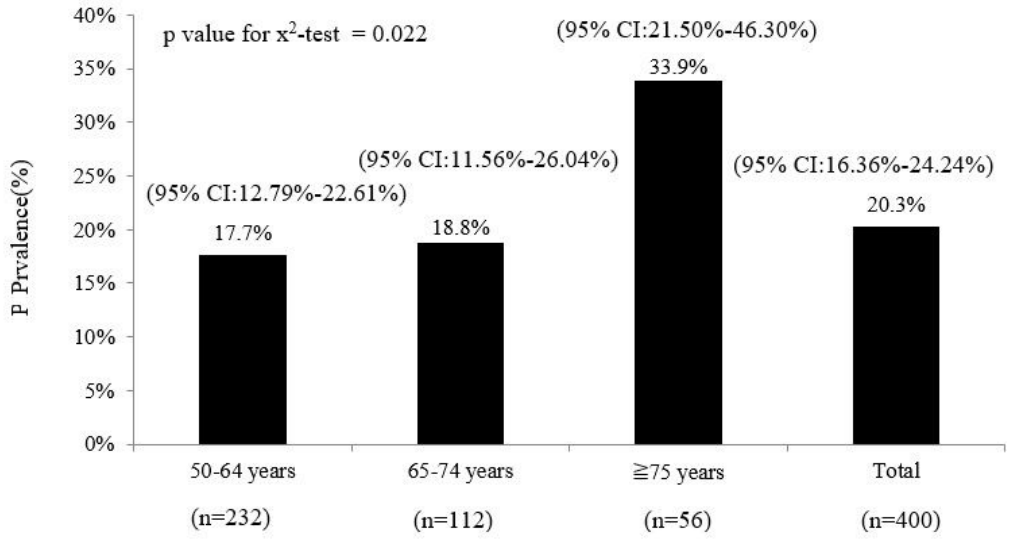

Figure 1

Age-specific prevalence of chronic kidney disease in screened subjects in Guishan District, Taoyuan City, Taiwan (n=400).