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Metabolic Syndrome and Socioeconomic Status in Association with Chronic Kidney Disease: A Cross-Sectional Study in Ningbo, China

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Background: Metabolic syndrome (MS) and low socioeconomic status (SES) may increase the risk for chronic kidney disease (CKD). This study aimed to investigate the prevalence of MS and CKD and the association between MS, SES, and CKD among adults in Ningbo, a city in Eastern China.

Methods: A cross-sectional survey of 3212 adults was conducted between July 2019 and February 2021 in Ningbo. MS was defined as the presence of three or more risk factors: elevated blood pressure, reduced high-density lipoprotein (HDL) cholesterol, elevated triglycerides, elevated plasma glucose, and abdominal obesity. CKD was defined as an estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2 or the occurrence of albuminuria. SES was stratified according to personal education and income levels. Multivariate logistic regression was used to analyze the relationships among MS, sociodemographic factors, and CKD.

Results: The age- and sex-adjusted prevalence of CKD was 9.1% (95% CI: 8.3–10.0), the prevalence of eGFR less than 60 mL/min/ per 1·73 m^2 was 2.5% (95% CI 2.0–3.0) and that of albuminuria was 7.9% (95% CI 7.0–8.7), and the adjusted prevalence of MS was 23.1% (95% CI 21.7–24.4). MS components, including elevated blood pressure, elevated fasting glucose, abdominal obesity, elevated serum triglyceride, or reduced serum HDL-C, were independent risk factors for CKD, and the adjusted prevalence of CKD proportionally increased with the number of MS-defined parameters. Participants with MS had 2.43-fold increased odds of developing CKD compared with those without MS. In addition, age, female sex, low SES including low educational level and low income were associated with increased odds of occurrence of albuminuria and CKD.

Conclusion: The prevalence of metabolic syndrome and chronic kidney disease is high among adults in Ningbo. Metabolic syndrome and low socioeconomic status are associated with the high risk of developing chronic kidney disease.

Keywords: chronic kidney disease, metabolic syndrome, socioeconomic status, prevalence, risk factors

Introduction

Chronic kidney disease (CKD) and metabolic syndrome (MS) are major health problems worldwide. CKD is recognized as a devastating medical, social, and economic problem in both developed and developing countries.[1–3] It has been reported that more than 700 million people worldwide have chronic kidney disease.[3] MS comprises a cluster of risk factors, including abdominal obesity, dyslipidemia, hypertension, and hyperglycemia,[4] and is present in approximately 23.7% of adults.[5] With rapid economic growth and sociodemographic transformation, the prevalence of MS and CKD is increasing in both developed and developing countries. CKD is considered a significant risk factor for cardiovascular disease and is independent of other conventional risk factors that are associated with an increased risk of mortality.[6]

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Especially in patients with diabetes and hypertension, CKD is a risk multiplier and is associated with increased cardiovascular mortality.[7,8]

In recent years, cross-sectional studies have identified an independent association between MS and CKD. Furthermore, geographical region and economic status have been identified as risk factors independently associated with CKD in China.[9] In economically developed urban regions of China, such as Beijing and Shanghai, the reported prevalence of CKD was 13.0%[10] and 11.8%,[11] respectively, similar to that reported in developed countries. China's economy has developed rapidly in recent years, especially in the eastern coastal regions; however, epidemiological data on metabolic syndrome and CKD are scarce, and much less attention has been paid to their relevance. Ningbo is an eastern coastal city in China with rapid socioeconomic development, a population of 9.6 million and a total geographical size of 9816 km^2.[12] During the past three years, with an average annual increase of 7%, disposable income per capita in Ningbo was $9348 in 2022, much higher than the national average of $5269.[12,13] These characteristics may make Ningbo as a prototype of fast-growing mid-sized cities in developing countries, however, the epidemiological information on MS and CKD in this city has been lacking during recent years. Thus, the present study aimed to investigate the prevalence of MS and CKD, the association between MS and CKD, and the association between socioeconomic factors and CKD in the adult population of Ningbo, Eastern China.

Methods

Study Participants

This study was a cross-sectional investigation of the association between MS and CKD in a representative sample of the general adult population in Ningbo City from July 2019 to February 2021. Ningbo City comprises ten districts, including eight urban districts and two rural counties. To ensure adequate representation, residents who lived for at least three years and were aged 20–79 years were selected using a multistage, stratified sampling method. First, three out of eight urban districts and one out of two rural districts were randomly selected in Ningbo: Cixi, Jiangbei, Haishu, and Ninghai districts, as shown in Figure 1. Five communities were randomly selected from each of the four districts, and 20 communities were chosen as the population base for the study. Finally, we randomly selected 150–200 adult individuals (random numbers generated by the SPSS software) from each selected community as representative samples. A total of 3720 individuals were included in the survey and physical examination. Of these, 3212 completed the entire questionnaire and underwent checkups. This study was approved by the Ethics Committee of the First Affiliated Hospital of Ningbo University (approval no: 2021RS010). Written informed consent was obtained from all participants before the commencement of the study.

Screening Protocol and Assessment Criteria

All participants attended the designated health checkup center and completed a comprehensive screening procedure, including a series of standardized questionnaires, physical examinations, and laboratory tests. Postgraduate medical students and physicians conducted the entire screening process and a systemic training course was offered to guarantee the quality of the study. Specifically, the questionnaire collected information regarding the participants' sociodemographics, education levels, economic status, and medical history. The physical examination included height, weight, blood pressure, and waist circumference. For laboratory tests, a venous blood sample was collected after an overnight fast of at least 10 hours to measure fasting blood glucose, serum creatinine, serum lipid, and uric acid levels. Meanwhile, a clean-catch, midstream, morning urine specimen was collected for the evaluation of urinalysis and urine albumin to creatinine ratio (UACR). All blood and urine samples were tested in three central clinical laboratories of The First Affiliated Hospital of Ningbo University with the same standardization and quality control checks. Serum total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglyceride (TGs), blood glucose, serum creatinine (SCr), and uric acid levels were measured using a Beckman Coulter AU5800 chemistry analyzer.

Figure 1 The geography of Ningbo and the four randomly selected districts in the study. Ningbo is an eastern coastal city in China, with a population of 9.6 million. The city comprises ten subsections, including six urban districts: Haishu District, Jiangbei District, Zhenhai District, Beilun District, Yinzhou District, and Fenghua District; two satellite urban county-level cities: Cixi City and Yuyao City; and two rural counties: Ninghai County and Xiangshan County. A-D represent four randomly selected districts in this study.

Chronic Kidney Disease

Chronic kidney disease was defined by the presence of reduced renal function as estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2 and/or the occurrence of albuminuria. eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation (CKD-EPI).[14] Urinary creatinine was measured using Jaffe's kinetic method and urinary albumin was measured using the immuno-turbidimetric method on a morning spot urine sample. Albuminuria was defined as an UACR value higher than 30 mg/g.

Metabolic Syndrome

The metabolic syndrome was defined by the presence of three or more of the following five risk factors, according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) guidelines:[4,15] (1) waist circumference measurement > 80 cm for women or > 90 cm for men (for Asian population), (2) serum triglycerides level ≥1.70 mmol/L (≥150 mg/dL), (3) serum high-density lipoprotein (HDL) cholesterol < 1.30 mmol/L (< 50 mg/dL) for women or < 1.04 mmol/L (< 40 mg/dL) for men, (4) blood pressure ≥130/85 mmHg and/or use of anti-hypertensive medications, and (5) fasting blood glucose ≥5.6 mmol/L (≥100 mg/dL) and/or use of insulin or hypoglycemic medication. Based on the presented number of risk factor components of MS, the study population was divided into 5 groups: participants with 0, 1, 2, 3, 4 or 5 MS components, respectively. Participants presented with ≥3 MS components are defined as having metabolic syndrome.

Hypertension and Diabetes Status

Hypertension was defined as meeting one of the following three criteria: average systolic blood pressure ≥140 mmHg or average diastolic blood pressure ≥90 mmHg, a history of hypertension, or receiving any current antihypertensive medication during the last two weeks. The procedure for measuring blood pressure was based on the Joint National Committee VIII criteria (JNC VIII).[16] Diabetes was defined as a fasting plasma glucose ≥7.0 mmol/L (126 mg/dL) and/or a 2-hour postprandial plasma glucose ≥11.1 mmol/L (200 mg/dL), or a previously established diagnosis of diabetes, or current use of hypoglycemic agents, irrespective of glucose levels.

Socioeconomic Status

The socioeconomic status was evaluated via two-dimensional parameters, including self-reported education levels and personal annual income.[17,18] Education levels were classified into three levels: low level was defined as receiving primary school education and below; medium level as having junior and high school education; high level as graduation from college and above. According to the Ningbo local statistics of personal income levels,[12] annual individual income was also categorized as: low, Income≤ $5000/yr; medium, Income<$10,000/yr, >$5000/yr; high, Income≥ $10,000/yr. The SES was stratified into three groups accordingly: High SES belonged to those who had both high educational level and high annual income, low SES belonged to low educational level and low annual income, and the others were medium SES.

Statistical Analysis

Continuous variables are presented as mean ± SD. Quantitative variables are summarized as means and 95% confidence intervals (CI). Means were compared using the Student's *t*-tests, and qualitative variables were compared using Pearson's χ^2 test. Bonferroni correction was further applied where multiple comparisons were made. Multivariate logistic regression analyses were used to estimate the odds ratios (OR) and CIs by comparing the risk factors associated with CKD. Univariate logistic regression analysis (unadjusted) and multivariate logistic regression analysis (adjusted for age and sex) were used to analyze the risk factors for CKD, the correlation between MS and its sub-items, and CKD, and the correlation between sociodemographic factors and CKD. The prevalence rate was adjusted according to the age and sex composition ratio of the 2020 seventh national population census in the Ningbo area.[12] P-values<0.05 were considered to be statistically significant. All analyses were conducted using SPSS software (version 26.0; SPSS, Inc., Chicago, IL, USA).

Results

Characteristics of Study Participants

Of the 3720 subjects enrolled in the study, 3212 completed the study and were included in the final analysis, with an effective response rate of 86.3%. The general characteristics of the participants are presented by CKD status in Table 1. Among all the participants, 48.7% were male, and the mean age was 45.58 ±14.3 years. Compared with people without CKD, those with CKD were older, had a lower percentage of high school degrees, were more likely to be female, and had lower income levels. The blood pressure, fasting blood glucose level, waist circumference, triglyceride level, and other metabolic indices of patients with CKD were significantly higher than those of patients without CKD.

Prevalence of CKD and MS

The age- and sex-adjusted CKD prevalence in the study population was 9.1% (95% CI 8.3–10.0). The adjusted prevalence of eGFR less than 60 mL/min/per 1·73 m² was 2.5% (95% CI 2.0–3.0) and that of albuminuria was 7.9% (95% CI 7.0–8.7). The age- and sex-adjusted prevalence of MS was 23.1% (95% CI 21.7–24.4). As shown in Table 2, a general trend was observed in the study population that CKD prevalence increased with age, and there was a statistical difference in CKD prevalence across various age groups after Bonferroni correction (P<0.001).

Table 1 Adjusted Characteristics of Participants with and without Chronic Kidney Disease

	Participants with the CKD (n=296)	Participants without the CKD (n=2916)	*P*-value
Age(years)	51.12±15.3	45.01±14.1	<0.001
Male	118(39.86%)	1446 (49.58%)	<0.001
Educated in primary school or below	123(41.55%)	873(29.94%)	<0.001
Income (> $5000/yr)	113(38.2%)	1832(62.8%)	<0.001
Body mass index (kg/m²)	24.80±1.1	23.31±1.2	<0.001
Waist circumference(cm)	84.19±6.8	81.94±7.0	<0.001
Systolic blood pressure (mmHg)	138.23±7.5	126.67±7.2	<0.001
Diastolic blood pressure (mmHg)	80.38±4.1	74.53±4.1	<0.001
Fasting blood glucose(mmol/L)	5.75±0.3	5.37±0.3	<0.001
Serum HDL-C (mmol/L)	1.38±0.1	1.38±0.1	0.954
Serum triglyceride (mmol/L)	4.30±1.3	1.60±0.3	<0.001
Serum uric acid (mmol/L)	368.54±45.4	331.19±46.3	<0.001
Serum creatinine (μmol/L)	99.81±12.6	71.91±7.8	<0.001
eGFR(mL/min/1.73m²)	83.95±7.4	104.99±6.8	<0.001

Note: Variables are expressed as mean ± standard deviation (SD) or proportion ±SD. Except for age, gender, education and income, other means were age and sex-adjusted. eGFR: estimated glomerular filtration rate, HDL-C: high-density lipoprotein cholesterol. CKD was defined as eGFR<60 mL/min/1.73m² or UACR≥30 mg/g. *P* <0.05 was considered statistically significant.

Table 2 Prevalence of Albuminuria, Decreased eGFR and CKD in the Study Population by Different Age Groups

Age (year)	Albuminuria		EGFR<60 mL/min/1.73 m²		CKD	
	N	Prevalence (95% CI, %)	N	Prevalence (95% CI, %)	N	Prevalence (95% CI, %)
20~29	27	6.4(4.1–8.7)	3	0.7(0.1–1.5)	27	6.4(4.1–8.7)
30~39	50	5.4(4.0–6.9)	10	1.1(0.4–1.8)	56	6.1(4.5–7.6)
40~49	44	7.3(5.2–9.4)	9	1.5(0.5–2.5)	46	7.7(5.5–9.8)
50~59	68	9.8(7.6–12.0)	13	1.9(0.9–2.9)	72	10.4(8.1–12.6)
60~69	42	12.1(8.6–15.5)	19	5.5(3.1–7.9)	52	14.9(11.2–18.7)
70~79	25	11.1(7.0–15.2)	27	12.0(7.7–16.3)	43	19.0(13.9–24.2)

Note: Data were age- and sex-adjusted prevalence (%; 95% CI). Albuminuria was defined as a urinary albumin- to-creatinine ratio (UACR) value higher than 30mg/g. CKD was defined as albuminuria and/or eGFR <60 mL/min/1.73 m2. eGFR, estimated glomerular filtration rate.

Association of CKD with MS

The age- and sex-adjusted prevalence of CKD among participants with and without one of these MS components is shown in Figure 2. The prevalence of CKD in people with elevated blood pressure, elevated fasting glucose, abdominal obesity, elevated serum triglyceride, or reduced serum HDL-C was higher than that in people without medical conditions, and the difference between the two groups was statistically significant (P<0.01). The age- and sex-adjusted prevalence of CKD increased significantly with an increase in the number of MS components (P<0.001, Figure 3). Furthermore, there was a significant dose-response relationship between the number of MS components and CKD prevalence (Table 3). Multivariate logistic regression analysis showed that participants with 1, 2, 3, 4 or 5 components of MS had 1.02-, 1.61-, 2.38-, and 3.86-fold increased odds of developing CKD compared with those without any component of MS (Table 3). Overall, people with MS had 2.43-fold increased odds of developing CKD compared with those without MS (OR=2.43, 95% CI: 1.81–3.27, P<0.001).

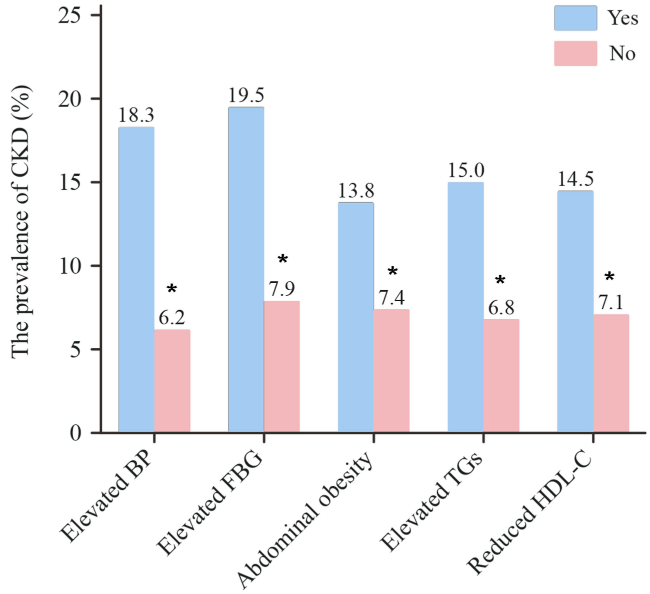

Figure 2 The adjusted prevalence of CKD in subjects with or without components of the metabolic syndrome. Data were age- and sex-adjusted prevalence (%). Yes = Subjects with the medical condition. No = Subjects without the medical condition. Elevated BP: blood pressure ≥ 130/85 mmHg; Elevated FBG: fasting blood glucose ≥5.6 mmol/L (≥100 mg/dL); Abdominal obesity: waist circumference ≥90 cm in men and ≥80 cm in women; Elevated TGs: serum triglyceride level ≥ 1.7 mmol/L (≥150 mg/dL); Reduced HDL-C: serum HDL cholesterol < 50 mg/dL (1.30 mmol/L) for women or < 40 mg/dL (1.04 mmol/L) for men. * p<0.01 compared with the subjects with the MS component.

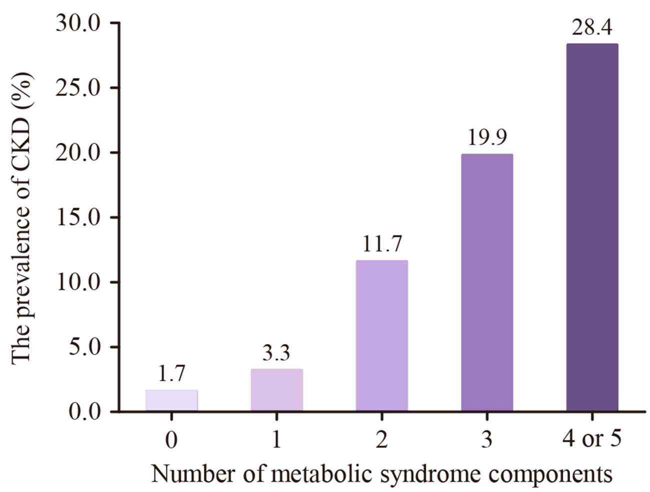

Figure 3 The adjusted prevalence of CKD by the presented number of metabolic syndrome components. Data were age- and sex-adjusted prevalence (%). The five metabolic syndrome components include elevated blood pressure, reduced high-density lipoprotein cholesterol, elevated triglycerides, elevated plasma glucose, and abdominal obesity.

Association of CKD and MS with Sociodemographic Factors

Education and income levels are two major parameters of SES, and SES were stratified into three groups accordingly. Among the participants, the proportion of high, medium, and low SES was 23.3%, 50.3%, and 26.4%. As shown in Table 4, the prevalence of CKD was higher in the participants with low education level than that with medium and high education levels, and there was a statistical difference across those three education groups after Bonferroni correction (p<0.001), whereas the difference between low and medium education groups was not significant (p=0.083). Similarly, CKD prevalence was higher in the low-income group than that in medium and high income. The Bonferroni-corrected test revealed that the difference in CKD prevalence among those three income groups was statistically significant (p<0.001), but no statistical difference between groups of high and medium income (p=0.773). In addition,

Table 3 Adjusted Odds Ratios of Chronic Kidney Disease Associated with Individual or Multiple Components of the Metabolic Syndrome

	Odds Ratio (95% CI)			
	Age- and Sex-adjusted	***P*-value**	**Multivariate Adjusted**	***P*-value**
Abdominal obesity	2.26 (1.75–2.98)	<0.001	1.16 (1.01–1.55)	0.038
Elevated BP	3.69(2.76–4.92)	<0.001	2.27 (1.68–3.08)	<0.001
Elevated FBG	2.17 (1.58–2.93)	<0.001	1.50 (1.06–1.55)	0.024
Elevated TGs	6.80(4.38–10.55)	<0.001	14.45 (10.00–20.86)	<0.001
Reduced HDL-C	2.12 (1.65–2.71)	<0.001	0.85 (0.64–1.13)	0.257
1 component[a]	1.07 (0.52–2.2)	0.857	1.02(0.50–2.1)	0.952
2 components[a]	1.61(1.15–2.27)	0.014	1.61(1.14–2.28)	0.028
3 components [a]	2.52(1.68–3.78)	0.010	2.38(1.54–3.68)	0.005
4 or 5 components [a]	4.34(2.12–8.66)	<0.001	3.86(1.90–7.82)	<0.001
Metabolic syndrome [b]	2.70(2.04–3.57)	<0.001	2.43(1.81–3.27)	<0.001

Note: The defined five MS components include elevated blood pressure, reduced high-density lipoprotein cholesterol, elevated triglycerides, elevated plasma glucose, and abdominal obesity. Participants presented with ≥3 MS components are defined as having metabolic syndrome. [a]Compared with those with 0 component; [b]Compared with those with <3 components. Categorical variables were expressed as proportions with 95% CIs; Multivariate adjusted data were adjusted for age, sex, education level and income level. *P* <0.05 was considered statistically significant.

Abbreviations: BP, blood pressure; FBG, fasting blood glucose; TG, serum triglyceride; HDL-C, High density lipid-cholesterol.

Table 4 Prevalence of Albuminuria, Decreased eGFR and CKD in the Study Population by Different Education Level, Income and SES Groups

	Albuminuria		EGFR<60 mL/min/1.73 m^2		CKD	
	N	**Prevalence (95% CI, %)**	**N**	**Prevalence (95% CI, %)**	**N**	**Prevalence (95% CI, %)**
Education level						
High, college and above	69	5.5(4.2–6.7)	15	1.2(0.6–1.8)	79	6.3(4.9–7.6)
Medium, junior and high school	79	8.3(6.5–10.1)	28	2.9 (1.9–4.0)	94	9.9(8.0–11.8)
Low, primary school and below	108	10.8(8.9–12.8)	38	3.8(2.6–5.0)	123	12.3(10.3–14.4)
Income level						
High, income≥ $10,000/yr	40	4.9(3.4–6.4)	18	2.2(1.2–3.2)	46	5.6(4.0–7.2)
Medium, income<$10,000/yr, >$5000/yr	58	5.1(3.9–6.4)	28	2.5(1.6–3.4)	67	5.9(4.6–7.3)
Low, income≤ $5000/yr	158	12.5(10.6–14.3)	35	2.8(1.9–3.7)	183	14.4(12.5–16.4)
SES						
High SES	32	4.3 (2.8–5.7)	7	0.9(0.2–1.6)	33	4.4(2.9–5.9)
Medium SES	133	8.2 (6.9–9.6)	44	2.7 (1.9–3.5)	161	10.0(8.5–11.4)
Low SES	91	10.7(8.6–12.8)	30	3.5(2.3–4.8)	102	12.0(9.8–14.2)

Note: Data were age- and sex-adjusted prevalence (%; 95% CI). High SES belonged to high educational level and high annual income, low SES belonged to low educational level and low annual income, the others were medium SES. eGFR, estimated glomerular filtration rate. SES: socioeconomic status.

participants with low SES had a higher prevalence of albuminuria, and reduced eGFR and CKD, as compared to those with medium or high SES. After the Bonferroni-correction, there were statistical differences among those three SES groups regarding the prevalence of albuminuria, reduced eGFR and CKD, respectively (p<0.001), however, there was no statistical difference in the prevalence of reduced eGFR between low and medium SES groups (p=0.259).

The association between the sociodemographic factors and CKD and MS was further analyzed. As shown in Table 5, multivariate logistic regression analysis revealed that age (by decade), female sex, low education level, low income and low SES were associated with increased odds of developing albuminuria and CKD (*P*<0.001), indicating that age, female sex and low SES were independent risk factors for the development of chronic kidney disease. In addition, except for female sex, age and low SES were also associated with increased odds of developing MS (*P*<0.001).

Table 5 Adjusted Odds Ratios of Albuminuria, Chronic Kidney Disease and Metabolic Syndrome Associated with Sociodemographic Factors

	Albuminuria		Chronic Kidney Disease		Metabolic Syndrome	
	Age- and Sex-adjusted	***P*-value**	**Age- and Sex-adjusted**	***P*-value**	**Age- and Sex-adjusted**	***P*-value**
Age (per 10-yr increase)	1.02(1.02–1.03)	<0.001	1.03(1.02–1.04)	<0.001	1.04(1.03–1.04)	<0.001
Female (compared to male)	1.54(1.20–1.99)	0.001	1.68(1.31–2.16)	0.002	0.57(0.48–0.68)	<0.001
Education level						
High, college and above	1		1		1	
Medium, junior and high school	1.98(1.51–2.59)	<0.001	1.83(1.42–2.37)	<0.001	2.79(2.12–3.66)	<0.001
Low, primary school and below	2.25(1.73–2.93)	<0.001	1.98(1.54–2.55)	<0.001	2.14(1.61–2.84)	<0.001
Income level						
High, income≥ $10,000/yr	1		1		1	
Medium, income<$10,000/yr, >$5000/yr	1.49(1.15–1.94)	0.003	1.42(1.10–1.84)	0.006	1.90(1.40–2.59)	<0.001
Low, income≤ $5000/yr	1.75(1.36–2.25)	<0.001	1.58(1.24–2.02)	<0.001	1.87(1.38–2.55)	<0.001
SES						
High SES	1		1		1	
Medium SES	2.07(1.39–3.09)	<0.001	2.12 (1.44–3.13)	<0.001	5.16 (3.71–7.18)	<0.001
Low SES	2.51(1.59–3.94)	<0.001	2.53(1.64–3.91)	<0.001	3.77(2.63–5.40)	<0.001

Notes: Categorical variables were expressed as proportions with 95% CIs; Except for age and gender, other means and proportions were age- and sex-adjusted. P <0.05 was considered statistically significant.
Abbreviations: SES, socioeconomic status.

Discussion

In this study, we investigated the prevalence of CKD and its relationship with MS and SES. The study indicated that 9.1% of adults in this population had CKD, there was a significant positive association between metabolic syndrome and CKD, and an inverse relationship between SES and CKD. CKD risk increases with an increase in the number of MS components. These relationships were independent of age, sex, and other potential risk factors for CKD. Although several related studies have been conducted in major affluent Chinese cities, Ningbo is one of the typical mid-sized cities in China with rapid socioeconomic development. Moreover, it is representative of this category because its economic standing, education level, and health insurance coverage are higher than the national average, making our findings noteworthy of documentation. Given the fact that there is an increasing incidence of CKD worldwide, the identification of modifiable risk factors and their amelioration would improve the adverse outcome of the disease.

In 2017, the prevalence of CKD in the world's population was estimated to be 9.1%, with one-third of the population living in China and India,[19] which was similar to the prevalence in this study (9.1%). The prevalence of decreased renal function was approximately 2.5% in the present study, which was higher than that reported in several previous studies.[20] Several studies have shown that dietary or lifestyle interventions can improve health-related quality of life and eGFR in patients with CKD.[21,22] Public health strategies should consider screening for CKD and its associated risk factors so that intensive intervention can reduce these risk factors. Owing to the aging of the population and rapid changes in lifestyle and cardiometabolic risk factors, the prevalence of CKD and MS has rapidly increased in recent years. We also noted a strong independent association between MS and CKD in Chinese adults. The prevalence of CKD increased with an increase in the number of MS components. These associations were independent of age, sex, BMI, and other potential risk factors for CKD. The results of this study were consistent with the results of several previous studies.[23,24] Therefore, screening for CKD in high-risk individuals and populations with MS is a cost-effective way to reduce the mortality from progression to CKD and end-stage renal disease (ESRD).

This study further explored the relationship between sociodemographic factors and the risk of CKD. Multivariate logistic regression analysis showed that age (by decade), female sex, low income, low education level and low SES were associated with an increased risk of CKD. A few epidemiological studies have also found that being female is a risk factor for CKD,[19,20] but there are also reports with different opinions. It has also been found that female sex is a risk factor for proteinuria but not for decreased renal function,[25] which is consistent with the conclusions of this study. Katherine et al[26] found that the prevalence of CKD was similar in young people of different sexes, whereas the prevalence of CKD was significantly higher in women than in men in the middle and old age groups. Therefore, further stratified studies of different age and sex groups and related studies with larger sample sizes are needed to confirm the relationship between sex and CKD. Recent studies have also shown a tight association between socioeconomic status and CKD; low income and poor education are negatively correlated with the incidence, progression, and severity of CKD.[27,28] A cross-sectional study in the United States also found that the prevalence of CKD was higher among people with lower levels of education and income, and the gap in the prevalence of CKD by socioeconomic status was largely persistent over 28 years.[29] Another study found that compared to Caucasians, low-income blacks may have a stronger association with albuminuria, suggesting that albuminuria can be used as the preferred screening indicator for early CKD in low-income populations.[30] In this study, after considering the confounding factors of sex and age, we also found that the prevalence of CKD and MS in people with low income or low education level was higher than that in those with high income or high education level, and socioeconomic status was negatively associated with the prevalence of both CKD and MS. The underlying causes may be related to differences in diet, lifestyle, and ideology among people with different incomes, readily available healthcare access and quality. Moreover, the disparity in health information regarding disease awareness, prevention, and lack of health education may also contribute immensely to a further increase in the prevalence of CKD and MS. In this regard, more focused attention needs to be paid on the vulnerable populations with low SES. Improving their social welfare and health education levels will be effective strategies for the prevention and management of these major public health problems.

This study has certain limitations. First, the cross-sectional study design makes it difficult to draw inferences regarding the causal relationship between metabolic syndrome, SES and CKD. Second, the CKD indicator measurements were not tested repeatedly, which may have resulted in the uncertainty of the persistent occurrence of albuminuria, thus leading to a potential overestimation of the prevalence of CKD, as defined in the KDIGO guidelines.[31] Third, this study focused on education and income levels as two critical indicators of SES, other SES variables, eg occupation, were not included in the SES assessment. Also, the stratification of SES was based on a questionnaire, we could not avoid information bias. In addition, although an increase in diabetes-related CKD has been observed in China,[32] glomerulonephritis remains an important cause of ESRD, and hematuria should also be included as a type of kidney damage. However, taking many other causes of transient hematuria into consideration and being consistent with the previous nationwide study, subjects with hematuria were not included in the estimated prevalence of CKD,[9,33] which may lead to an underestimation of the prevalence of CKD.

In conclusion, there is a strong independent association between metabolic syndrome, socioeconomic status and chronic kidney disease in the adult population of Ningbo, China. Metabolic syndromes including elevated blood pressure, elevated blood glucose, dyslipidemia, and abdominal obesity are independent risk factors for chronic kidney disease. In addition, low socioeconomic status including low education and low income levels were identified as independent risk factors for developing CKD and MS. Prevention and treatment strategies for MS are essential to reduce the occurrence of chronic kidney disease, and socioeconomic factors also need to be considered when developing comprehensive strategies for CKD and MS prevention, in order to reduce the incidence and burden of these major chronic diseases.

Institutional Review Board Statement

The study was approved by the Ethics Committee of The First Affiliated Hospital of Ningbo University (Ethics Approval No: 2021RS010), and was performed in accordance with the Declaration of Helsinki treaty.

Data Sharing Statement

The Data presented in this study are available upon request from the corresponding author.

Informed Consent Statement

Written informed consent was obtained from all participants before commencement of the study.

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Disclosure

The authors declare no conflict of interest associated with the paper.

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