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Original Article

Prevalence and correlation of metabolic syndrome with chronic kidney disease in middle-aged adults

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Abstract

Previous surveys suggest that obesity, hypertension, and diabetes mellitus may be positively related to the development of chronic kidney disease (CKD), though this association might be influenced by metabolic syndrome. CKD has become a global health problem among aging populations, yet epidemiological information on middle-aged patients with metabolic syndrome remains scarce. This hospital-based cross-sectional study aimed to identify and validate novel biomarkers that predict CKD progression in middle-aged individuals with metabolic syndrome. The study included 317 participants aged 40–59 years, all of whom underwent standardized personal interviews, structured questionnaires, anthropometric measurements, and laboratory blood tests. Metabolic syndrome was defined according to the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) criteria. The estimated glomerular filtration rate (eGFR) was calculated using the Cockcroft-Gault formula to predict CKD stages based on NKF-KDOQI guidelines. Our study revealed that metabolic syndrome was prevalent in more than half of the participants (54.2%) and increased with the worsening of CKD stages. Significant metabolic factors associated with CKD included waist circumference, fasting blood sugar, and triglycerides. Moreover, longer durations of diabetes mellitus and hypertension, particularly when combined, heightened the risk of CKD. Our findings indicate that metabolic syndrome is a major contributor to CKD, emphasizing the need for early detection and management of metabolic factors to prevent kidney damage in middle-aged populations.

Keywords: metabolic syndrome, chronic kidney disease, middle-aged patients, NCEP/ATP III, NKF-KDOQI.

Introduction

The escalating prevalence of obesity and diabetes, driven by shifts in dietary habits and lifestyle behaviors, is a significant global health concern [1–3]. An increase in metabolic syndrome has parallelled this rise, a condition that heightens the risk of mortality from chronic kidney disease (CKD), as reported by LaGuardia HA *et al.* [4]. CKD, characterized by a gradual and progressive loss of renal function over at least three months, is a primary cause of end-stage renal disease (ESRD) [5]. The global prevalence of CKD ranges from 8% to 16%, varying across different regions [6]. CKD is categorized into five stages based on the degree of kidney damage or the estimated glomerular filtration rate (eGFR) [7, 8]. Regrettably, the majority of patients remain unaware of their condition until it has advanced to a later stage [9]. Early cardiovascular disease (CVD), anemia, metabolic acidosis, and bone diseases are among the major complications associated with impaired kidney function [10]. The leading risk factors and predictors for CKD include impaired fasting plasma glucose, hypertension, and a high body mass index (BMI) [11].

There is a growing body of evidence suggesting a link between obesity, hypertension, diabetes mellitus, and the development of CKD [12, 13]. Systematic reviews and meta-analyses have indicated that metabolically unhealthy individuals are at an increased risk for CKD [14, 15]. However, it is important to note that previous studies investigating the association between

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metabolic health status phenotypes and renal disorders have primarily focused on eGFR measurements to define CKD [16].

Given the contradictory findings and the scarcity of studies examining the association between CKD and metabolic syndrome in middle-aged patients, we aim to conduct cross-sectional studies to elucidate the relationship between CKD and metabolic health status. This research will contribute to a more comprehensive understanding of these complex health issues and inform future preventative and treatment strategies.

Material and methods

Study design and participants' characteristics

This research was a cross-sectional, population-based study carried out in the medical wards of a tertiary care hospital in Erode. The participants comprised individuals who sought care at health centers in Erode. The study included individuals of all genders, aged 40–59 years, who were residents of Erode, willing to participate, and diagnosed with non-communicable diseases such as diabetes mellitus, hypertension, dyslipidemia, and obesity.

The exclusion criteria encompassed incomplete questionnaires, unwillingness to participate in the tests, and pre-existing renal diseases or other conditions that could potentially impact renal function. Ultimately, 317 eligible middle-aged individuals were included in the study. The study was conducted according to the Declaration of Helsinki and approved by the Institutional Ethics Committee of JKKN College of Pharmacy (JKKNCP/IEC-CER/0522123/38). Before the commencement of the study, all participants provided their written informed consent.

The research took into account a variety of characteristics of the participants, including their age, gender, place of residence, level of physical activity, dietary habits, and medical history. The participants' ages were divided into four categories: 40–44, 45–49, 50–54, and 55–59 years. The International Physical Activity Questionnaire (IPAQ) was used to classify physical activity levels as high, moderate, or low [17]. Dietary habits were categorized as healthy, moderate, or unhealthy based on the Healthy Eating Index (HEI) score [18, 19]. The duration of conditions such as diabetes and hypertension was determined through direct patient interviews. Information on current smoking habits and alcohol consumption was also collected.

Metabolic syndrome assessment

Risk factors for renal failure, including hypertension, dyslipidemia, waist circumference, smoking, blood pressure, fasting blood glucose, lipid analysis, BUN/creatinine, and BMI were analyzed. Metabolic syndrome was diagnosed based on the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) [20]. Participants were diagnosed with metabolic syndrome if they met three or more of the following five criteria: waist circumference ≥90 cm (men) or ≥85 cm (women), fasting blood sugar ≥100 mg/dL, triglycerides >150 mg, HDL –C level <40 mg/dL (men) or <50 mg/dL (women), and blood pressure ≥130/85 mmHg. The data from participants diagnosed with metabolic syndrome were then analyzed.

Biochemical analysis

Blood samples were primarily drawn from the median cubital and cephalic veins after a minimum of 8 hours of fasting. The samples were refrigerated and sent to a diagnostic medical laboratory for analysis within 24 hours. The levels of triglycerides, HDL-C, and fasting blood glucose were measured using enzymatic methods on Lipid Biosensor (Tamil Nadu, India) [21].

Chronic kidney disease assessment

The assessment of chronic kidney disease (CKD) was conducted using the estimated Glomerular Filtration Rate (eGFR), calculated with the Cockcroft-Gault formula [22]. This formula takes into account the patient's creatinine levels, age, gender, and ethnicity: CrCl=72×serum creatinine in mg/dL (140–age in years) weight in kg (for females, the result is multiplied by a factor of 0.85).

Following the National Kidney Foundation-Kidney Disease Outcomes Quality Initiative (NKF-KDOQI), CKD was categorized into five stages: normal (stage 1), mildly decreased (stage 2), mildly to moderately decreased (stage 3a), moderately to severely decreased (stage 3b), and severely decreased (stage 4) (stage 1, eGFR ≥90 mL/min/1.73 m^2; stage 2, 89 to 60 mL/min/1.73 m^2; stage 3a, 59 to 45 mL/min/1.73 m^2; stage 3b, 44 to 30 mL/min/1.73 m^2; and stage 4, <30 mL/min/1.73 m^2, respectively) [23].

Our research aimed to understand the effects of metabolic syndrome on the progression of renal function deterioration. To achieve this, we categorized participants into five distinct groups based on their renal function: normal, mildly decreased, mildly to moderately decreased, moderately to severely decreased, and

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severely decreased. We then analyzed various factors that could potentially influence the deterioration of renal function.

Statistical analysis

Data were collated in an Excel spreadsheet and analyzed using SPSS version 27.0.1.0. The mean ± standard deviation (SD) for continuous variables was calculated, and the number of participants was expressed as a percentage for categorical variables. Hypothesis testing for continuous variables was performed using an independent t-test and One-way ANOVA to examine differences in the mean values between groups. For categorical variables, the Chi-squared test and X2-trend test were used to identify differences in proportions. Multiple logistic regression models were developed to investigate the association between the metabolic components of metabolic syndrome and chronic kidney disease (CKD). A p-value of less than 0.05 was considered statistically significant.

Results

Proportion of participants with chronic kidney disease

According to Table 1, more than half of the participants (54.2%) had metabolic syndrome, while the rest (45.8%) did not. Among those with metabolic syndrome, the distribution of chronic kidney disease (CKD) stages was as follows: Stage 2, n=64 (95% CI: 38.3–55); Stage 3a, n=41 (95% CI: 44.7–67.5); Stage 3b, n=20 (95% CI: 57.5–90.6); Stage 4, n=9 (95% CI: 59–104.6). The data indicate that the prevalence of metabolic syndrome increases with the worsening of CKD, especially in Stages 3b, 4, and 5. This implies a potential causal link between the severity of CKD and the occurrence of metabolic syndrome. The p-value confirms the statistical significance of the association between metabolic syndrome status and different glomerular filtration rate (GFR) levels. This highlights the need for regular screening and management of metabolic syndrome in CKD patients to prevent further deterioration of kidney function.

Patient demographics

A total of 317 participants were categorized into four different age groups: 40–44 (n=25), 45–49 (n=78), 50–54 (n=90) and 55–59 (n=124). Gender, BMI, waist circumference, physical activity level, alcohol consumption status, previous history of dyslipidemia, metabolic syndrome presence, and CKD stages were significantly correlated between different age groups (Table 2).

Association between metabolic syndrome and chronic kidney disease

The logistic regression analysis highlights significant associations between certain metabolic factors and CKD (stages 3a to 5). It shows that for every unit increase in Waist Circumference (WC), there is a 3% decrease in the odds of having CKD, significant at a p-value of 0.007. On the other hand, each unit increase in Fasting Blood Sugar (FBS) and Triglycerides (TG) is associated with a 1% increase in the odds of having CKD, significant at p-values of 0.011 and 0.001, respectively. Moreover, individuals with metabolic syndrome have approximately 101% higher odds of having CKD (stages 3a to 5) compared to those without metabolic syndrome, as indicated by an Odds Ratio of 2.01. This association is statistically significant at the 5% significance level with a p-value of 0.004, providing strong evidence of a notable relationship between metabolic syndrome status and CKD (Table 3).

Table 1: Proportion of participants with chronic kidney disease.

CKD stage	Metabolic syndrome presence			Metabolic syndrome absence			P-value
	n	Prevalence	95% CI	n	Prevalence	95% CI	
Stage 1	32	50.79	38.5–63.1	31	49.21	36.8–61.5	0.0011
Stage 2	64	46.7	38.3–55	73	53.2	44.9–61.6	
Stage 3a	41	56.1	44.7–67.5	32	43.8	32.4–55.2	
Stage 3b	20	74	57.5–90.6	7	25.9	9.4–42.4	
Stage 4	9	81.8	59–104.6	2	18.18	4.61–40.97	
Stage 5	6	100	100–100	0	0	0	

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Table 2: Demographics and biochemical characteristics.

Demographic and clinical data		Age range (in years)				P-value
		40–44	45–49	50–54	55–59	
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	
Age (in years)		42.12±1.07	46.8±1.19	52.3±1.22	56.9±1.26	<0.001
Male		18 (5.67)	34 (10.7)	55 (17.3)	59 (18.6)	0.039
Female		8 (2.5)	43 (13.5)	36 (11.3)	64 (20.1)	
Height		159.9±7.93	155.4±11.22	158.9±10.35	156.4±8.7	0.072
Weight		62.6±9.26	62.6±9.16	60.7±9.3	61.6±10	0.580
Body Mass Index		24.7±3.4	26.18±4.6	24.17±3.9	25.3±4.2	0.019
Waist circumference		102.6±8.09	97.18±9.45	100.2±10.6	99.3±8.19	0.039
Systolic BP (mmHg)		133.69±21.15	137.7±23.7	141.3±27.7	141.6±28.6	0.436
Diastolic BP (mmHg)		84±11.52	86.8±11.37	89.3±15.9	88.16±14.3	0.334
Fasting blood sugar		161.9±48.25	152.9±60.9	154.4±54	154.4±61.9	0.926
High-density lipoprotein cholesterol		40.9±10.34	44.8±8.5	44.241±8.7	43.1±9.3	0.230
Post prandial blood sugar		187±61.7	174±63.5	183±60.2	177.2±71.4	0.750
Low-density lipoprotein cholesterol		93.1±20.1	97.9±20.6	97±18.7	101±17.5	0.179
Very low-density lipoprotein cholesterol		28.9±7.6	25.9±9.8	26.8±8.16	26.3±7.6	0.448
Blood urea		41.5±38.1	36.7±28.8	34±7.3	34.7±18.4	0.482
Serum creatinine		1.42±1.54	1.18±0.79	1.2±0.9	1.23±0.8	0.694
eGFR		77.9±29.9	75.1±27	69.8±26.9	65.2±32.45	0.061
Residence, n (%)	Rural	14 (53.8)	41 (53.2)	48 (52.7)	65 (52.8)	0.996
	Urban	12 (46.15)	36 (46.7)	43 (47.2)	58 (47.15)	
Physical activity, n (%)	High	4 (15.38)	23 (29.8)	21 (23)	17 (13.8)	0.030
	Moderate	22 (84.6)	54 (70.1)	66 (72.5)	98 (79.67)	
	Low	0	0	4 (4.4)	8 (6.5)	
Diet Intake, n (%)	Healthy	10 (38.4)	29 (37.6)	19 (20.8)	36 (29.2)	0.263
	Moderate	14 (53.8)	40 (51.9)	58 (63.7)	68 (55.2)	
	Unhealthy	2 (7.6)	8 (10.39)	14 (15.3)	19 (15.4)	
Smoking, n (%)	Yes	13 (50)	23 (29.8)	40 (43.9)	43 (34.9)	0.132
	No	13 (50)	54 (70.1)	51 (56)	80 (65)	
Alcohol, n (%)	Yes	15 (57.6)	25 (32.4)	41 (45)	42 (34.1)	0.049
	No	11 (42.3)	52 (67.5)	50 (54.9)	81 (65.8)	
Diabetes mellitus, n (%)	Yes	19 (73)	50 (64.9)	71 (78)	89 (72.3)	0.311
	No	7 (26.9)	27 (35)	20 (21.9)	34 (27.6)	
Hypertension, n (%)	Yes	13 (50)	56 (72.7)	60 (65.9)	82 (66.6)	0.209
	No	13 (50)	21 (27.2)	31 (34)	41 (33.3)	
Dyslipidemia, n (%)	Yes	0	1 (1.3)	0	7 (5.6)	0.036
	No	26 (100)	76 (98.7)	91 (100)	116 (94.3)	
Metabolic syndrome, n (%)	Presence	16 (61.5)	31 (40.2)	54 (59.3)	71 (57.7)	0.042
	Absence	10 (38.5)	46 (59.7)	37 (40.6)	52 (42.2)	

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Table 2: Continued.

Demographic and clinical data		Age range (in years) 40–44 Mean±SD	45–49 Mean±SD	50–54 Mean±SD	55–59 Mean±SD	P-value
CKD stages, n (%)	Stage 1	10 (38.4)	22 (28.5)	18 (19.7)	13 (10.5)	0.053
	Stage 2	8 (30.7)	33 (42.8)	43 (47.2)	53 (43)	
	Stage 3a	6 (23)	15 (19.4)	18 (19.7)	34 (27.6)	
	Stage 3b	0	4 (5.1)	7 (7.6)	16 (13)	
	Stage 4	1 (3.8)	1 (1.3)	4 (4.4)	5 (4)	
	Stage 5	1 (3.8)	2 (2.6)	1 (1.1)	2 (1.6)	

Table 3: Association between metabolic syndrome and chronic kidney disease.

Metabolic syndrome factors	Odds ratio	95% Confidence Interval	P-value
Waist circumference	0.97	0.94–0.99	0.007
Systolic blood pressure	1.01	1.0–1.01	0.211
Diastolic blood pressure	1.01	0.99–1.02	0.431
Fasting blood sugar	1.01	1.0–1.01	0.011
Triglycerides	1.01	1.01–1.02	0.001
High-density Lipoprotein-C	0.98	0.95–1.0	0.101
Metabolic syndrome (presence *vs.* absence)	2.01	1.25-3.21	0.004

Interplay of DM and hypertension duration in predictors of CKD

Research into Chronic Kidney Disease (CKD) predictors highlights the significant impact of Diabetes Mellitus (DM) and Hypertension (HT) durations. Specifically, durations of 5–10 years and over 10 years for both DM and HT show high significance (OR>1) with increased risks for CKD. For instance, 5–10 years of DM and HT exhibit an Odds Ratio (OR) of 11.08, and over 10 years show an OR of 15.28, indicating substantially heightened risks for CKD. However, the duration of 5–10 years and over 10 years for HT alone display low significance (OR<1) with reduced likelihoods of CKD (OR: 0.035 and 0.103, respectively). These findings emphasize the critical role of DM and longer durations of both DM and HT in the onset and progression of CKD. Vigilant monitoring and effective management

Table 4: Interplay of DM and hypertension duration in predictors of CKD.

Duration		Duration of Hypertension OR (95% CI) <5 years	5–10 years	>10 years	Nil
Duration of diabetes mellitus OR (95% CI)	<5 years	4.75 (1.92–11.73)	3.09 (0.98–9.77)	4.51 (0.57–35.67)	0.761 (0.315–1.841)
	5–10 years	5.22 (2.03–13.40)	11.08 (4.65–26.40)	2.20 (0.67–7.24)	-
	>10 years	Zero counts	6.73 (0.86–52.755)	15.28 (4.81–48.5)	2.19 (0.81–5.95)
	Nil	7.85 (3.05–20.21)	0.035 (0.012–0.098)	0.103 (0.027–0.393)	6.26 (1.74–22.51)

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strategies are crucial for at-risk populations to mitigate these potential risks (Table 4).

Discussion

This study's primary findings indicate that metabolic syndrome independently contributes to developing chronic kidney disease (CKD). The results affirm the efficacy of the modified ATP III guideline in diagnosing metabolic syndrome and predicting CKD incidence.

In this cross-sectional study, we observed a significant positive correlation between the prevalence of CKD and Metabolic Syndrome. Furthermore, a decrease in the Glomerular Filtration Rate (GFR) was associated with Metabolic Syndrome. Our study adds to the growing body of evidence suggesting that individuals with Metabolic Syndrome are at an elevated risk of developing CKD.

While previous studies have reported a 65% prevalence of metabolic syndrome among CKD patients, this association could be significantly influenced by hypertension [24]. Prior research has proposed that the link between metabolic syndrome and CKD may be weakened by diabetes mellitus and obesity [25]. Conversely, our study aligns with the view that Metabolic Syndrome is a crucial risk factor for secondary chronic kidney damage, including mild renal dysfunction, with diabetes and increased Body Mass Index (BMI) being the most significant risk factors [26].

The literature presents inconsistent results regarding the association between metabolic syndrome and CKD. Contrary to our study, a cross-sectional study on middle-aged men and women reported that metabolic syndrome increases the risk of CKD.

Interpreting this study's results requires considering several limitations. Due to its cross-sectional nature, we cannot establish a causal relationship between CKD indicators and associated factors.

Conclusion

Our study demonstrated a strong positive correlation between the prevalence of Metabolic Syndrome and CKD. Moreover, we found that increased waist circumference, fasting blood glucose, and triglyceride levels were risk factors for CKD in the middle-aged population. Our results also showed that the duration of diabetes mellitus (DM) and hypertension (HT) for 5–10 years and more than 10 years were significantly associated with higher odds ratios (OR>1) for CKD. These findings suggest that middle age is a critical stage for the development and progression of metabolic syndrome and CKD and that early detection and intervention are essential to prevent further complications.

Conflict of interest

The authors declare no conflict of interest.

Ethics approval

The approval for this study was obtained from the Ethics Committee of JKKN College of Pharmacy (approval ID: JKKNCP/IEC-CER/0522123/38).

Consent for publication

Written informed consent was obtained from all the participants.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author, Dr. Satheesh S., Associate Professor at JKKN College of Pharmacy, on reasonable request. However, the data are not publicly available because they contain information that could compromise the privacy of research participants.

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