International Journal of General Medicine

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ORIGINAL RESEARCH

Prevalence of Chronic Kidney Disease and Its Association with Fat-to-Muscle Ratio in Ethnic Minority Areas of Southern China: A Cross-Sectional Study

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Purpose: The prevalence of chronic kidney disease (CKD) in ethnic minority areas of southern China is outdated. The association between fat-to-muscle ratio (FMR) and CKD in these populations remains unclear. This study aims to investigate the prevalence of CKD and the relationship between FMR and CKD and to evaluate the potential utility of FMR in CKD risk assessment.

Patients and Methods: A cross-sectional study was conducted using data from the 2020–2021 China Cardiovascular Disease and Risk Factors Surveillance in Guangxi. CKD is defined as estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m² or urine albumin-to-creatinine ratio (UACR) ≥30 mg/g. Data from questionnaires, physical exams, and laboratory tests were used to estimate CKD prevalence. Fat and muscle mass were assessed via bioelectrical impedance analysis. The association between FMR and CKD was examined using multivariable logistic regression.

Results: Among 8940 participants (median age 50; 41.9% male, 42.0% Zhuang), crude CKD prevalence was 13.8% (awareness: 1.4%), with ethnic disparity (Zhuang: 12.9% vs non-Zhuang: 14.5%, P=0.025). The overall age- and sex-adjusted CKD prevalence was 10.9%; corresponding figures were 9.6% for Zhuang and 17.1% for non-Zhuang participants after further adjustment for ethnicity. FMR was independently associated with CKD (OR=1.03 per 0.1-unit, P<0.05), even after adjusting for demographic, lifestyle, and comorbidities. Interactions were observed between FMR and ethnicity, hypertension, and diabetes (P-interaction<0.05). FMR increased progressively with CKD stage and albuminuria grade (P<0.001 for trend). A threshold effect was observed at FMR >0.84, with a higher prevalence of CKD (16.7% vs 11.1%), albuminuria (12.5% vs 7.9%), and impaired kidney function (6.0% vs 4.4%) (all P<0.001).

Conclusion: The relatively high prevalence but extremely low awareness of CKD in Guangxi highlights a critical detection and prevention gap. Incorporating FMR measurement into population-based screening may help identify individuals at high risk of CKD and guide targeted integrated prevention strategies.

Keywords: chronic kidney disease, fat-to-muscle ratio, South China, prevalence, cross-sectional study

Introduction

Chronic kidney disease (CKD) is a major global public health challenge due to its high prevalence, adverse outcomes, and considerable healthcare burden. In China, the adult CKD prevalence was 10.8% in 2012 and declined

Received: 1 July 2025
Accepted: 25 October 2025
Published: 5 November 2025

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to 8.2% by 2018–2019.[1,2] However, awareness remains extremely low, and disparities persist across regions and ethnic groups.

The Zhuang ethnic group, numbering over 16 million people, is the largest minority population in China and is predominantly concentrated in Guangxi Zhuang Autonomous Region.[3] Guangxi, located on China's southern coast, is a multi-ethnic and economically underdeveloped region characterized by unique socio-cultural and dietary practices, including higher intake of rice noodles and fermented foods, as well as a high burden of cardiometabolic risk factors.[4] Limited healthcare access and quality further compound these challenges. Such factors may contribute to a distinct profile of non-communicable diseases, including chronic kidney disease (CKD). Prior studies have suggested health disparities in this population; for example, our earlier survey in 2012 reported an elevated prevalence of CKD among the Zhuang.[5] However, up-to-date and comprehensive epidemiological evidence on CKD in this setting remains lacking, leaving a critical knowledge gap.

Obesity is a well-established risk factor for CKD, but traditional measures such as body mass index (BMI) cannot distinguish between fat and lean mass. Fat-to-muscle ratio (FMR), reflecting the proportion of adiposity relative to skeletal muscle, has emerged as a sensitive indicator of cardiometabolic risk,[6] with elevated FMR linked to type 2 diabetes,[7] hypertension,[8] and metabolic syndrome.[9] Critically, a high FMR signifies not only obesity but also a relative loss of muscle mass, which is itself a risk factor for metabolic dysregulation and adverse health outcomes. A Korean prospective cohort study demonstrated that a higher proportion of muscle relative to fat is associated with a reduced risk of CKD development.[10] In China, recent evidence suggests that elevated FMR is independently associated with hyperuricemia and estimated glomerular filtration rate (eGFR) decline.[11] However, data on the association between FMR and CKD in Chinese populations are lacking.

To address these gaps, we conducted a population-based cross-sectional study using data from the 2020–2021 China Cardiovascular Disease and Risk Factor Surveillance to estimate the prevalence of CKD in Guangxi and to explore the association between FMR and CKD.

Materials and Methods

Study Design

This study employed a cross-sectional design using data collected between July 2020 and February 2021 from the China Cardiovascular Disease and Risk Factor Surveillance, focusing on the Guangxi region.

Study Subjects and Sampling Method

Study Subjects

The study included residents aged 18 years and older from Guangxi Zhuang Autonomous Region. All participants provided informed consent, and the study was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University (Approval No. 2024-E706-01). The study was conducted in accordance with the Declaration of Helsinki.

Sampling Method

The nationwide survey employed stratified multi-stage random sampling to select 262 representative districts/counties from 31 provinces, autonomous regions, and municipalities, covering approximately 300,000 residents.[12] In Guangxi, nine counties (or urban districts) were randomly selected, followed by a random selection of two townships in each county and three village committees within each township. Individuals aged 18 and above were stratified by decade, with the corresponding number of individuals randomly selected in each stratum. The final sample size for Guangxi was 9600 residents, based on simple random sampling calculations.

Data Collection and Assessment Methods

Questionnaire Survey

The questionnaire collected participants' demographic information, lifestyle habits, and medical history. Physical inactivity was defined as less than 150 minutes of moderate-intensity physical activity per week in the past month.[13] Dietary intake was assessed based on a recall of the past month's diet, with classification criteria referring to the Dietary Guidelines for Chinese Residents (2022).[14]

Physical Examination and Laboratory Tests

The physical examination included measurements of height, weight, waist circumference, and blood pressure. Blood pressure was measured three times, with the average value used for analysis. Body weight, fat mass, and muscle mass were measured using bioelectrical impedance analysis (BIA) with an InBody H20B device (InBody Co., Ltd. Seoul, South Korea). The FMR was calculated as fat mass (kg) divided by muscle mass (kg). Body mass index (BMI) was determined by dividing weight (kg) by the square of height (m^2).

Fasting blood samples were used to measure glucose, glycated hemoglobin (HbA1c), lipids, creatinine, and uric acid. Morning urine was analyzed for creatinine and microalbumin. Specimens were cold-chain transported to Guangzhou Kingmed Diagnostics for testing.

Diagnostic Criteria

Chronic kidney disease (CKD) was defined as the presence of impaired kidney function (estimated glomerular filtration rate < 60 mL/min/1.73 m^2) or albuminuria (urine albumin-to-creatinine ratio ≥ 30 mg/g).[15,16] Diagnostic criteria for other comorbidities—including diabetes,[17] hypertension,[18] dyslipidemia,[19] overweight/obesity,[20] hyperuricemia,[21] and cardiovascular disease—were based on well-established Chinese and international guidelines. Detailed definitions for all conditions are provided in Supplementary Table 1.

Statistical Analysis

The age- and sex-standardized prevalence of CKD, albuminuria, and impaired kidney function were calculated using the direct standardization method, with the age and sex structure of the Guangxi population from the 2020 Seventh National Population Census as the standard population. Missing data were handled by complete case analysis. The proportion of missing values was low (<5%) for all variables included in the models. Continuous variables with non-normal distribution were presented as median (interquartile range) and analyzed using Kruskal–Wallis or Jonckheere-Terpstra tests for trend analysis. Categorical variables were expressed as frequencies (%) and compared via chi-square tests. Univariate logistic regression was used to identify factors associated with CKD, albuminuria, and impaired kidney function ($P < 0.05$ for entry). Multivariable logistic regression models were then constructed to assess the association between FMR and renal outcomes. FMR was analyzed both as a continuous variable (per 0.1-unit increment) and as quartiles (Q1–Q4) to evaluate dose–response relationships. Interactions between FMR and selected covariates were assessed in stratified models. Nonlinear associations were examined using restricted cubic splines with three knots. All analyses were performed in R version 4.4.3, and a two-sided P value <0.05 was considered statistically significant.

Results

General Information

After excluding participants with missing or invalid serum creatinine, urine albumin, or urine creatinine data, 8940 individuals were eligible for CKD prevalence estimation (Supplementary Figure 1). Of these, 8716 (97.5%) had complete bioelectrical impedance data for FMR assessments, and 8506 (95.1%) with complete covariate data were included in multivariable logistic regression analyses.

The study consisted of 3748 males (41.9%) and 5192 females (58.1%). Participants' ages ranged from 18 to 99 years, with a median age of 50 years (IQR: 36–63). Among them, 3751 were Zhuang individuals (42.0%) and 5189 were non-Zhuang individuals (58.0%), including 4952 Han and 237 individuals from other ethnic groups such as Jing, Maonan, Mulao, and Shui. The characteristics of the study participants are summarized in Table 1 (by CKD status) and Supplementary Table 2 (by ethnicity).

Prevalence of CKD

A total of 1235 CKD patients were identified, resulting in a crude prevalence rate of 13.8% (1235/8940). The prevalence was 13.6% in females (708/5192) and 14.1% in males (527/3748) ($p = 0.566$). The prevalence of albuminuria was 10.1% (906/8940), while that of impaired renal function was 5.1% (460/8940). The awareness rate of CKD was 1.4% (17/1235). Among the CKD patients, 367 were in stage 1, 408 in stage 2, 427 in stage 3, 24 in stage 4, and 9 in stage 5. There was

Table 1 The Characteristics of Participants by CKD Status

Characteristic	Total (n = 8940)	Non-CKD Group (n=7705)	CKD Group (n=1235)	*p* value
Sex, Male	3748 (41.9)	3221 (41.8)	527 (42.7)	0.566
Age, y				<0.001
18-24	762 (8.5)	731 (9.5)	31 (2.5)	
25-34	1239 (13.9)	1182 (15.3)	57 (4.6)	
35-44	1511 (16.9)	1417 (18.4)	94 (7.6)	
45-54	1803 (20.2)	1616 (21.0)	187 (15.1)	
55-64	1562 (17.5)	1326 (17.2)	236 (19.1)	
65-74	1240 (13.9)	968 (12.6)	272 (22.0)	
≥75	823 (9.2)	465 (6.0)	358 (29.0)	
Ethnicity, Zhuang	3751 (42.0)	3269 (42.4)	482 (39.0)	0.025
Educational Level				<0.001
No schooling	776 (8.7)	585 (7.6)	191 (15.5)	
Primary school	2443 (27.3)	1976 (25.7)	467 (37.8)	
Secondary school	4054 (45.3)	3576 (46.4)	478 (38.7)	
College/University	1667 (18.6)	1568 (20.4)	99 (8.0)	
Urban-Rural, Rural	2961 (33.1)	2530 (32.8)	431 (34.9)	0.153
Per capita income (last year, 10,000 CNY)				<0.001
<2	2316 (25.9)	1925 (25.0)	391 (31.7)	
2-<3	2045 (22.9)	1747 (22.7)	298 (24.1)	
3-<5	2286 (25.6)	1984 (25.8)	302 (24.5)	
≥5	2293 (25.6)	2049 (26.6)	244 (19.8)	
Smoking	1632 (18.4)	1419 (18.6)	213 (17.4)	0.323
Drinking	1779 (20.0)	1559 (20.4)	220 (17.9)	0.048
Vegetable intake <300 g/d	5574 (62.8)	4827 (63.1)	747 (60.9)	0.143
Fruit intake <200 g/d	6258 (70.5)	5362 (70.1)	896 (73.1)	0.033
Red meat intake ≥200 g/d	3364 (37.9)	2879 (37.6)	485 (39.6)	0.198
Aquatic product intake <40 g/d	5268 (59.4)	4487 (58.7)	781 (63.7)	<0.001
Physical inactivity	2006 (22.7)	1710 (22.5)	296 (24.3)	0.158
BMI, kg/m^2				<0.001
18.5-<24	521 (6.0)	3693 (49.4)	530 (44.3)	
<18.5	4223 (48.6)	458 (6.1)	63 (5.3)	
24-<28	2882 (33.2)	2453 (32.8)	429 (35.8)	
≥28	1055 (12.2)	880 (11.8)	175 (14.6)	

(*Continued*)

Table 1 (Continued).

Characteristic	Total (n = 8940)	Non-CKD Group (n=7705)	CKD Group (n=1235)	*p* value
FMR (median [IQR])	0.83 (0.61, 1.05)	0.82 (0.60, 1.04)	0.91 (0.70, 1.14)	<0.001
Hypertension				<0.001
No hypertension	5386 (60.6)	5005 (65.4)	381 (31.0)	
Newly diagnosed	2169 (24.4)	1778 (23.2)	391 (31.8)	
Previously diagnosed	1334 (15.0)	875 (11.4)	459 (37.3)	
Diabetes				<0.001
No diabetes	4774 (53.4)	4373 (56.8)	401 (32.5)	
Prediabetes	3089 (34.6)	2576 (33.4)	513 (41.5)	
Newly diagnosed	775 (8.7)	568 (7.4)	207 (16.8)	
Previously diagnosed	302 (3.4)	188 (2.4)	114 (9.2)	
Dyslipidemia	2935 (32.9)	2405 (31.3)	530 (43.2)	<0.001
Hyperuricemia	2078 (23.3)	1626 (21.2)	452 (36.8)	<0.001
CVD	141 (1.6)	100 (1.3)	41 (3.4)	<0.001

Notes: Values are presented as number (% of column total), except for FMR, which is expressed as median (interquartile range). Categorical variables were compared using the χ^2-test, and FMR was analyzed using the Mann–Whitney *U*-test (Z statistic reported). Denominators reflect complete cases. Missing data for all covariates were <3%.
Abbreviations: CKD, chronic kidney disease; BMI, body mass index; CVD, cardiovascular disease; FMR, fat-to-muscle ratio.

a significant difference in CKD prevalence between the Zhuang and non-Zhuang populations, with rates of 12.9% (482/3751) and 14.5% (753/5189) respectively (χ^2 = 5.05, p = 0.025). The prevalence of CKD, albuminuria, and impaired renal function significantly increased with age (P for trend < 0.001 for all; Supplementary Figure 2). After adjusting for sex and age based on the 2020 Seventh National Population Census data, the prevalence rates were 10.9% for CKD, 8.2% for albuminuria, and 3.7% for impaired renal function. Adjusting for ethnic distribution, the prevalence of CKD was 9.6% in the Zhuang population and 17.1% in the non-Zhuang population.

Among CKD patients, 513 were pre-diabetic, 321 had diabetes (114 previously diagnosed), and 850 had hypertension (459 previously diagnosed).

Analysis of Factors Influencing CKD

In multivariable models incorporating FMR and traditional risk factors (Table 2), significant associations with CKD included: age (45–54 years, OR 1.77, 95% CI 1.16–2.80, P=0.011; 55–64 years, OR 2.1, 1.37–3.33, P=0.001; 65–74 years, OR 2.8, 1.81–4.46, P<0.001; 75 years and above, OR 7.61, 4.92–12.2, P<0.001), non-Zhuang ethnicity (OR 1.15, 1.00–1.33, P=0.049), aquatic products intake less than 40 g/day (OR 1.23, 1.06–1.43, P=0.007), hypertension (newly diagnosed OR 1.76, 1.48–2.09, P<0.001; previously diagnosed OR 3.13, 2.60–3.77, P<0.001), diabetes (prediabetes OR 1.18, 1.00–1.38, P=0.049; newly diagnosed OR 2.02, 1.62–2.51, P<0.001; previously diagnosed OR 2.54, 1.89–3.39, P<0.001), dyslipidemia (OR 1.22, 1.06–1.41, P=0.007), and hyperuricemia (OR 1.95, 1.68–2.27, P<0.001). Notably, FMR showed an independent association (OR=1.03 per 0.1-unit, 95% CI 1.01–1.06, P=0.016), whereas traditional adiposity measures like BMI demonstrated no significant effect in either FMR-integrated or BMI-only models (all P >0.05, see Supplementary Table 3).

Supplementary Tables 4 and 5 present multivariable-adjusted associations for albuminuria and impaired kidney function, respectively. Key factors associated with albuminuria included age ≥75 years, Non-Zhuang ethnicity, higher FMR, hypertension, diabetes status (prediabetes, newly and previously diagnosed), dyslipidemia, and hyperuricemia (all

Table 2 Multivariable Logistic Regression Analysis of Factors Associated with CKD

Characteristic	OR (95% CI)	*p* value
Age, y		
18-24	1.00 (Reference)	
25-34	1.11 (0.69–1.83)	0.7
35-44	1.38 (0.89–2.21)	0.2
45-54	1.77 (1.16–2.80)	0.011
55-64	2.10 (1.37–3.33)	0.001
65-74	2.80 (1.81–4.46)	<0.001
≥75	7.61 (4.92–12.20)	<0.001
Ethnicity		
Zhuang	1.00 (Reference)	
Non-Zhuang	1.15 (1.00–1.33)	0.049
Educational Level		
No schooling	1.00 (Reference)	
Primary school	1.00 (0.81–1.25)	>0.9
Secondary school	1.01 (0.80–1.26)	>0.9
College/University	0.76 (0.55–1.06)	0.11
Per capita income (last year, 10,000 CNY)		
<2	1.00 (Reference)	
2-<3	0.94 (0.78–1.13)	0.5
3-<5	1.07 (0.88–1.30)	0.5
≥5	0.88 (0.71–1.08)	0.2
Drinking		
No	1.00 (Reference)	
Yes	0.91 (0.75–1.09)	0.3
Fruit intake <200 g/d		
No	1.00 (Reference)	
Yes	1.05 (0.90–1.23)	0.5
Aquatic product intake <40 g/d		
No	1.00 (Reference)	
Yes	1.23 (1.06–1.43)	0.007
FMR per 0.1-unit	1.03 (1.01–1.06)	0.016
BMI, kg/m²		
18.5- <24	1.00 (Reference)	

(*Continued*)

Table 2 (Continued).

Characteristic	OR (95% CI)	*p* value
<18.5	1.32 (0.95–1.81)	0.093
24-<28	0.87 (0.74–1.02)	0.088
≥28	0.82 (0.65–1.04)	0.1
Hypertension		
No hypertension	1.00 (Reference)	
Newly diagnosed	1.76 (1.48–2.09)	<0.001
Previously diagnosed	3.13 (2.60–3.77)	<0.001
Diabetes		
No diabetes	1.00 (Reference)	
Prediabetes	1.18 (1.00–1.38)	0.049
Newly diagnosed	2.02 (1.62–2.51)	<0.001
Previously diagnosed	2.54 (1.89–3.39)	<0.001
Dyslipidemia		
No	1.00 (Reference)	
Yes	1.22 (1.06–1.41)	0.007
Hyperuricemia		
No	1.00 (Reference)	
Yes	1.95 (1.68–2.27)	<0.001
CVD		
No	1.00 (Reference)	
Yes	1.11 (0.73–1.67)	0.6

Notes: FMR was analyzed as a continuous variable per 0.1-unit increment (ie, original value ×10).
Abbreviations: ORs, odds ratios; CI, confidence interval; BMI, body mass index; FMR, fat-to-muscle ratio; CVD, cardiovascular disease.

P<0.05). For impaired kidney function, significant associations were observed with male sex, age ≥45 years, low aquatic product intake (<40 g/d), and previously diagnosed hypertension, dyslipidemia, and hyperuricemia. (all P<0.05).

All VIFs were <2, suggesting no evidence of problematic multicollinearity, including between BMI and FMR.

The Association Between FMR and CKD

Primary Associations

Table 3 presents the association between FMR (per 0.1-unit increase) and kidney outcomes across sequentially adjusted models. In unadjusted models (Model 1), higher FMR was significantly associated with CKD, albuminuria, and impaired kidney function (all P<0.001). In fully adjusted models (Model 5), which included demographic factors, lifestyle factors, BMI (for CKD and albuminuria), and cardiometabolic comorbidities, FMR remained significantly associated with CKD (OR 1.03, 95% CI 1.00–1.06, P<0.05) and albuminuria (OR 1.04, 95% CI 1.02–1.07, P<0.01), but not with impaired kidney function (OR 1.01, 95% CI 0.97–1.05, P>0.05).

Table 3 FMR and Kidney Outcomes Across Sequential Models (per 0.1-Unit Increase)

Outcome	Model 1	Model 2	Model 3	Model 4	Model 5
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
CKD	1.10 (1.08–1.12)***	1.05 (1.03–1.07)***	1.06 (1.03–1.08)***	1.04 (1.02–1.07)***	1.03 (1.01–1.06)*
Albuminuria	1.09 (1.07–1.12)***	1.06 (1.03–1.08)***	1.06 (1.03–1.08)***	1.05 (1.02–1.08)***	1.04 (1.02–1.07)**
Impaired Kidney Function	1.09 (1.06–1.12)***	1.07 (1.03–1.11)***	1.07 (1.03–1.11)***	—	1.01 (0.97–1.05)

Notes: Covariates were selected based on significance in univariate analysis for each outcome. Model 1: Unadjusted; Model 2: Adjusted for significant demographic factors (eg, age, sex, ethnicity, education, income, urban/rural); Model 3: Model 2 + lifestyle factors (eg, fruit, red meat, aquatic products, physical inactivity, drinking); Model 4: Model 3 + BMI (not included for impaired kidney function due to non-significance in univariate analysis); Model 5: Model 4 + cardiometabolic comorbidities (hypertension, diabetes, dyslipidemia, cardiovascular disease, hyperuricemia). *P < 0.05; **P < 0.01, ***P < 0.001.
Abbreviations: FMR, fat-to-muscle ratio; ORs, odds ratios; CI, confidence interval; CKD, chronic kidney disease; BMI, body mass index.

To further elucidate the association, participants were categorized into quartiles based on their FMR values (Q1: lowest, Q4: highest). In the fully adjusted model, compared to the lowest quartile (Q1), participants in the highest quartile (Q4) had a significantly higher risk of CKD (OR: 1.61, 95% CI: 1.27–2.04) and albuminuria (OR: 1.90, 95% CI: 1.48–2.45). A significant dose-response relationship was observed for both outcomes (P for trend <0.001). The association with impaired kidney function remained non-significant across all quartiles (Table 4).

To address potential confounding by antihypertensive treatment status, we re-categorized hypertension as no hypertension, untreated hypertension, and treated hypertension. In these models, the association between FMR and

Table 4 Association Between FMR Quartiles and Kidney Outcomes in Fully Adjusted Models

Outcome	FMR Quartiles	OR (95% CI)	*p* value	*p* for trend
CKD	Q1	1.00 (Reference)		<0.001
	Q2	1.42 (1.14–1.77)	0.002	
	Q3	1.33 (1.06–1.67)	0.013	
	Q4	1.61 (1.27–2.04)	<0.001	
Albuminuria	Q1	1.00 (Reference)		<0.001
	Q2	1.52 (1.19–1.95)	<0.001	
	Q3	1.48 (1.15–1.90)	0.002	
	Q4	1.90 (1.48–2.45)	<0.001	
Impaired Kidney Function	Q1	1.00 (Reference)		0.986
	Q2	1.02 (0.72–1.44)	>0.9	
	Q3	0.95 (0.67–1.36)	0.8	
	Q4	1.02 (0.70–1.49)	>0.9	

Notes: Participants were categorized into quartiles (Q) based on FMR values, with cutpoints: Q1 (<0.61), Q2 (0.61–<0.83), Q3 (0.83–<1.05), Q4 (≥1.05). Q1 was the reference group. Models were adjusted for demographic factors (age, sex, ethnicity, education, income, urban/rural), lifestyle factors (fruit, red meat, aquatic products, physical inactivity, drinking), BMI (for CKD and albuminuria), and cardiometabolic comorbidities (hypertension, diabetes, dyslipidemia, cardiovascular disease, hyperuricemia).
Abbreviations: BMI, body mass index; CI, confidence interval; CKD, chronic kidney disease; FMR, fat-to-muscle ratio; OR, odds ratio; Q, quartile.

CKD remained robust (per 0.1-unit increase: OR 1.03, 95% CI 1.01–1.06; P=0.016). Detailed results are provided in Supplementary Table 6.

Subgroup Analyses

In the subgroup analyses, a per 0.1-unit increase in fat-to-muscle ratio (FMR) was significantly associated with higher odds of CKD in males (OR=1.09, 95% CI:1.03–1.15, P=0.003), the Zhuang population (OR=1.05, 95% CI:1.00–1.09, P=0.043), individuals with overweight (OR=1.05, 95% CI:1.01–1.10, P=0.024) or obesity (OR=1.08, 95% CI:1.01–1.14, P=0.017), and those with newly diagnosed hypertension (OR=1.08, 95% CI:1.04–1.13, P<0.001), or prediabetes (OR=1.06, 95% CI:1.02–1.11, P=0.002). Significant interactions were observed for hypertension status (P-interaction=0.004), ethnicity (P-interaction=0.046), and diabetes status (P-interaction=0.034) (details in Figure 1).

For albuminuria, associations paralleled CKD findings in males, the Zhuang population, individuals with overweight or obesity, those with newly diagnosed hypertension, or those with prediabetes. An inverse association was observed in participants with previously diagnosed diabetes (OR=0.89, 95% CI: 0.80–1.00, P=0.043). Significant interactions emerged for hypertension (P-interaction=0.028) and diabetes (P-interaction=0.015) (details in Supplementary Figure 3).

Nonlinear Association and Threshold Validation

Restricted cubic spline analysis showed a significant linear association between FMR and the odds of CKD (P for overall association = 0.013; P for nonlinearity = 0.603) and identified a threshold at FMR = 0.84 (Figure 2). Above this threshold, CKD prevalence increased from 11.1% to 16.7%, albuminuria from 7.9% to 12.5%, and impaired kidney function from 4.4% to 6.0% (all P < 0.001) (Supplementary Table 7).

Fat-to-Muscle Ratio Across CKD Stages and Albuminuria Categories

Among 8716 participants with valid FMR measurements, significant positive trends were observed across advancing CKD stages (Z=9.76, P<0.001) and albuminuria grades (Z=8.63, P<0.001), indicating progressively higher adiposity relative to muscle mass with disease severity (Supplementary Table 8).

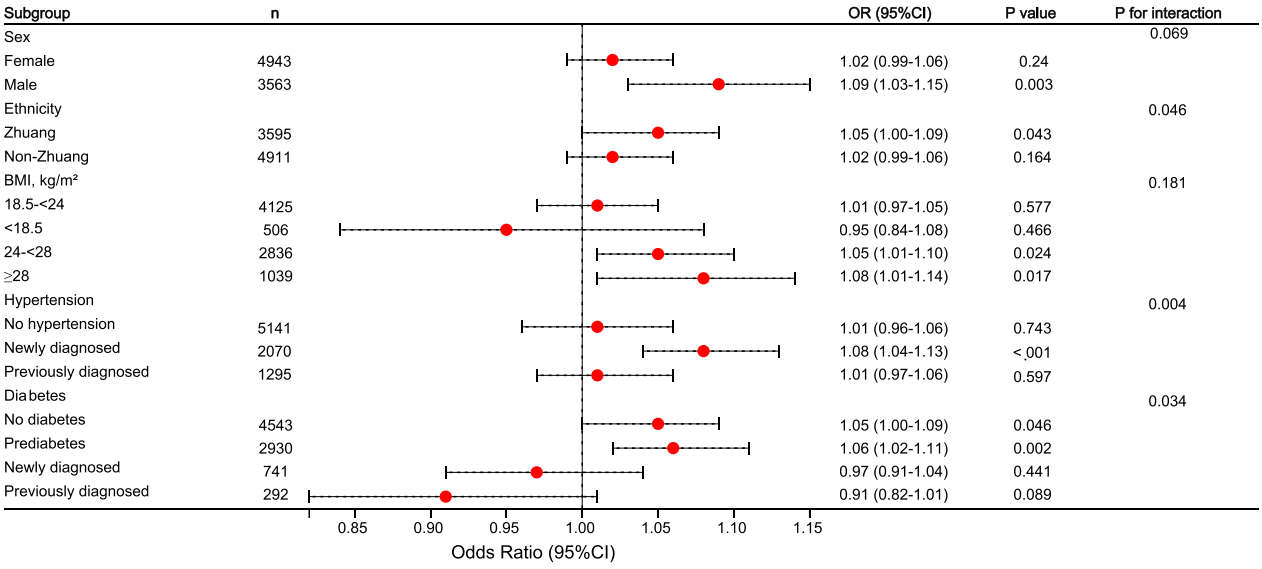

Figure 1 Association Between FMR (per 0.1-Unit Increase) and CKD Across Subgroups.
Abbreviations: FMR, fat-to-muscle ratio; CKD, chronic kidney disease; BMI, body mass index; OR, odds ratio; CI, confidence interval.

https://doi.org/10.2147/IJGM.S550519

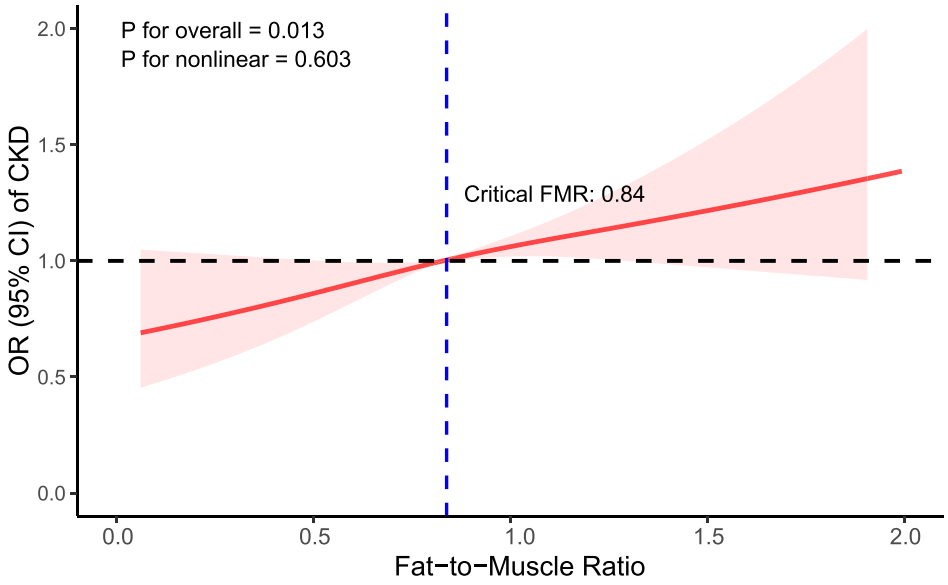

Figure 2 FMR and the odds ratio of CKD: Restricted cubic splines analysis.
Notes: RCS model with 3 knots, selected based on minimal BIC, was used to assess the association between FMR and CKD risk. Model was adjusted for age, ethnicity, BMI, aquatic product consumption, hypertension, diabetes, dyslipidemia and hyperuricemia. Odds ratios correspond to 1-unit FMR increases. Shaded area represents 95% confidence interval. The blue dashed line indicates the critical FMR threshold (0.84) where OR=1.0 (black reference line).
Abbreviations: FMR, fat-to-muscle ratio; CKD, chronic kidney disease; OR, odds ratio; CI, confidence interval; BMI, body mass index.

Discussion

This cross-sectional study utilized data from the 2020 China Cardiovascular Disease and Risk Factors Surveillance to investigate CKD epidemiology among adults in the Guangxi Zhuang Autonomous Region, a minority area in southern China. Among 8940 participants (93.1% completion rate), the age- and sex-adjusted prevalence of CKD, albuminuria, and impaired kidney function was 10.9%, 8.2%, and 3.7%, respectively. Notably, our study found that the FMR was independently associated with CKD, with each 0.1-unit increase linked to 3% higher odds (adjusted OR = 1.03, 95% CI 1.01–1.06) after controlling for traditional metabolic risk factors. A dose-response relationship was evident, with FMR increasing progressively across CKD stages and albuminuria grades (P-trend < 0.001). A critical risk threshold was identified at FMR > 0.84.

The global prevalence of CKD exceeds 10%, with substantial underdiagnosis worldwide.[22] In Guangxi, the age-adjusted CKD prevalence (10.9%) significantly surpassed national estimates (8.2%),[2] while awareness remained alarmingly low (1.4% vs 10% nationally). Importantly, 37.2% of CKD patients had Stage 3–5 disease, consistent with the elevated burden observed in southern China where nearly half of CKD cases progress to advanced stages.[2] This disparity likely reflects heightened regional cardiometabolic burdens: hypertension (39.7% vs 27.6%) and hyperuricemia (23.3% vs 14.1%) prevalence markedly exceeded national averages, while diabetes prevalence aligned (12.0% vs 12.4%).[2] Notably, 34.6% of participants had prediabetes, indicating a reservoir for future CKD progression given the 5–15-year latency of diabetic nephropathy.[23] Similarly, among CKD patients, hypertension (69.0% vs 60.5% nationally) and hyperuricemia (36.8% vs 21.5%) were disproportionately prevalent. These findings align with global trends where cardiometabolic comorbidities drive CKD progression.[22] Collectively, these data reveal critical gaps in early CKD detection and underscore the imperative for integrated management of metabolic risks in Guangxi.

We found CKD prevalence rose sharply after age 45, mirroring global aging trends.[24] This inflection likely reflects cumulative nephron loss compounded by sarcopenia, which can artifactually elevate creatinine-based eGFR and mask early decline.[25] Concurrently, diminished renal reserve in older adults further predisposes to overt disease. Together, these findings underscore the critical role of body composition, and not age alone, in CKD risk.

Similar to racial disparities observed in the United States,[25] ethnic disparities in CKD prevalence persisted in our study even after multivariable adjustment, with non-Zhuang individuals exhibiting 15% higher odds of CKD than Zhuang counterparts (aOR=1.15). This may be linked to the Zhuang's lower hypertension rates and ethnic genetic factors. Compared with a survey conducted a decade ago among 7588 rural Zhuang adults in Guangxi,[5] our findings indicate a substantial epidemiological shift. In that study, the age- and sex-adjusted prevalence of CKD was 4.9% (excluding hematuria), and only 3.6% of patients were aware of their condition. Hypertension and advancing age were the primary risk factors, while diabetes and dyslipidemia were uncommon and not associated with CKD. In contrast, our study revealed a markedly higher CKD prevalence in the Zhuang population (9.6%) and an even lower awareness rate (1.4%). The burden of cardiometabolic comorbidities has risen sharply, with hypertension, diabetes, hyperuricemia, dyslipidemia, and obesity increasing from 14.7%, 3.4%, 13.4%, 15.9%, and 3.3% to 37.5%, 12.8%, 23.4%, 32.6%, and 12.5%, respectively. These conditions now represent major independent drivers of CKD. Moreover, novel risk factors, such as low seafood intake and unfavorable FMR emerged, underscoring the influence of shifting dietary and lifestyle patterns.

The accumulating evidence underscores that the relationship between body composition and CKD extends beyond mere adiposity, hinging critically on the balance between fat and muscle mass. Our study reinforces this paradigm by demonstrating a strong, independent association between a higher FMR and the prevalence of CKD and albuminuria in a multi-ethnic population from Southern China. This finding consolidates observations from diverse populations, including a large Korean cohort where a higher muscle-to-fat ratio (the inverse of FMR) was protective against CKD incidence,[10] and a recent Chinese study linking elevated FMR to reduced eGFR exclusively in middle-aged men.[11] The mechanistic underpinnings of this association are multifactorial and synergistic. Our findings, along with existing literature, underscore that the pathological link between high FMR and CKD likely transcends simple obesity metrics and is rooted in a dual pathology of ectopic lipid deposition and loss of metabolically active muscle mass.[26] This body composition imbalance creates a pro-inflammatory and pro-fibrotic milieu. On one hand, visceral and ectopic fat (eg, perirenal fat) secretes adipokines that drive systemic inflammation, oxidative stress, and RAAS activation, directly promoting glomerular hypertension and renal injury.[27] The detrimental role of ectopic fat is further highlighted in advanced CKD, where the accumulation of intermuscular adipose tissue has been independently linked to heightened inflammation and functional decline.[28] On the other hand, concurrent muscle wasting, or sarcopenia, diminishes the secretion of protective myokines and exacerbates insulin resistance, further impairing renal microvascular health.[29,30] This synergistic "double hit" from both excess fat and deficient muscle may explain why FMR is a more potent risk indicator than BMI alone.

In our study, a higher FMR was independently associated with increased odds of both CKD (adjusted OR=1.03 per 0.1-unit, 95% CI 1.01–1.06) and albuminuria (OR=1.04, 95% CI 1.02–1.07). Participants in the highest FMR quartile had 1.61-fold and 1.90-fold higher odds of CKD and albuminuria, respectively, compared to those in the lowest quartile. However, we found no significant association between FMR and impaired kidney function (eGFR <60 mL/min/1.73 m²). By contrast, He et al reported that higher FMR predicted reduced eGFR (<90 mL/min/1.73 m²) in a large Chinese adult cohort.[11] Two key factors may underlie these discrepant results: first, differing eGFR thresholds—our threshold (eGFR <60) excludes mild dysfunction cases (60–89), which He et al included, potentially capturing early FMR-related decline; second, disease stage and population characteristics—at advanced impairment (eGFR <60), other pathophysiological drivers (eg, long-standing hypertension or diabetes) may predominate, attenuating FMR's effect. These methodological and clinical distinctions likely explain the divergent associations with reduced kidney function. Furthermore, the attenuation of FMR's effect in Model 5 may reflect statistical overadjustment, since hypertension, dyslipidemia, and hyperuricemia could plausibly lie on the pathway linking FMR with CKD rather than acting as independent confounders. Notably, BMI showed no independent association with CKD regardless of FMR inclusion, suggesting FMR's greater sensitivity to pathological fat-muscle imbalances than conventional adiposity metrics, as supported by recent evidence.[31]

Subgroup analyses showed significant interactions between FMR and ethnicity, hypertension status, and glucose metabolism (all P-interaction <0.05). Each 0.1-unit increase in FMR was associated with higher odds of CKD in Zhuang individuals (OR 1.05 vs non-Zhuang 1.02), newly diagnosed hypertensives (OR 1.08), and those with prediabetes (OR 1.06), but not in diabetes or established hypertension. Similar patterns emerged for albuminuria (OR 1.10 in new

hypertensives; OR 1.07 in prediabetes). These results imply that FMR exerts its greatest renal harm during the incipient phases of cardiometabolic dysregulation.[32] In new-onset hypertension, excess visceral fat may amplify hemodynamic stress via sympathetic overactivity and renin-angiotensin-aldosterone system (RAAS) activation.[33] In prediabetes, the dual pathology of muscle loss and adiposity likely exacerbates insulin resistance and low-grade inflammation, directly impairing renal function.[34] Conversely, in diabetes and established hypertension, advanced vascular injury may overshadow the influence of body composition, and lifestyle or pharmacologic interventions may further attenuate FMR's effect on CKD odds.[35,36] Nevertheless, the association between FMR and CKD remained robust in sensitivity analyses that further adjusted for antihypertensive treatment status, reinforcing that this link is independent of disease management practices. An unexpected inverse trend of FMR with albuminuria in the small subgroup of previously diagnosed diabetics warrants cautious interpretation—it could reflect residual confounding (eg, renoprotective medications) or limited power. Although the interaction between FMR and BMI was not statistically significant, the stratified analysis suggested a stronger association between FMR and CKD in overweight and obese individuals, indicating a potential trend worthy of further investigation.[27]

Although the FMR–CKD association appeared stronger in males, no significant interaction was detected (P=0.069), suggesting similar utility across sexes. Therefore, we identified an FMR threshold of 0.84 in the overall population, beyond which CKD risk increased significantly. This may represent a biological tipping point where adiposity surpasses renal compensatory capacity,[37] independent of BMI-defined obesity. The identified FMR threshold (0.84), derived from routine bioimpedance analysis, offers a low-cost and practical tool for early CKD risk stratification in high-risk subpopulations. These findings challenge the traditional reliance on BMI and highlight FMR as a novel anthropometric marker with dose-dependent risk and a clinically actionable cut-off.

Finally, besides body composition, low consumption of aquatic products was also significantly associated with CKD. Participants consuming less than 40 g of aquatic products daily had 23% higher odds of CKD (OR 1.23; 95% CI 1.06–1.43), possibly due to reduced intake of anti-inflammatory n-3 PUFAs found in these products.[38]

This study has several limitations. First, as a cross-sectional analysis, causality between FMR and CKD cannot be established. Second, CKD was defined based on a single measurement of eGFR and UACR, whereas guidelines recommend persistent abnormalities for at least 3 months; this may lead to misclassification and biased prevalence estimates. Third, although BIA provides a convenient and noninvasive assessment of fat and muscle mass, it cannot differentiate visceral from subcutaneous fat, and our FMR reflects overall rather than regional adiposity. Fourth, our sample had a higher proportion of female participants. Although we adjusted for sex in multivariate analyses and standardized prevalence estimates to the Guangxi population structure, this imbalance may still limit the generalizability of our absolute prevalence estimates. Fifth, the interpretation of hypertension-related subgroups is complicated by potential confounding by indication. We observed a higher adjusted odds ratio for CKD in participants taking antihypertensive medication compared to those with untreated hypertension. This likely does not indicate a harmful effect of treatment, but rather that treatment status acts as a marker for more severe or longer-standing disease, which is itself a strong risk factor for CKD. Our cross-sectional design and lack of data on specific medication classes, treatment duration, and adherence preclude further causal interpretation of this finding. Future longitudinal studies with repeated measurements and imaging-based body composition assessments are needed to confirm these findings and further clarify underlying mechanisms.

Conclusion

This cross-sectional study updates the CKD epidemiological profile in southern China's ethnic minority populations, revealing a persistently high disease burden with low awareness. Our findings suggest that FMR may serve as a novel, dose-dependent predictor of CKD risk (threshold: FMR >0.84), potentially offering advantages over BMI in capturing adiposity-muscle imbalance. FMR shows potential as a practical anthropometric index for early risk stratification in community settings. Future studies should validate its prognostic value and explore targeted interventions.

Funding

This work was supported by the National Natural Science Foundation of China (Grant No. 82360092), Guangxi Key Research and Development Program (Grant No. 2023AB3004), Guangxi Medical and Health Appropriate Technology Development and Application Project (Grant No. S2024026), and Guangxi Traditional Chinese Medicine Appropriate Technology Development and Promotion Project (Grant No. GZSY2024057).

Disclosure

The authors report no conflicts of interest in this work.

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