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The Association Between Relative Fat Mass and Estimated Glomerular Filtration Rate in a Community-Dwelling Hypertensive Population

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Abstract

Background: Obese individuals are at elevated risk of chronic kidney disease (CKD), particularly in the presence of comorbid hypertension, but whether relative fat mass (RFM) can serve as an indicator of early renal dysfunction in hypertensive populations remains unclear. Among community-dwelling adults with hypertension in Jiangsu Province, China, we evaluated the relationship between RFM and estimated glomerular filtration rate (eGFR). Methods: We recruited 4439 adults with hypertension and defined reduced eGFR as <60 mL/min/1.73 m^2. Multivariable logistic regression, subgroup analyses, restricted cubic spline (RCS) modeling, and receiver operating characteristic (ROC) curve analysis were used. Results: In total, 1474 participants (33%) had reduced eGFR. Each unit increase in RFM was marginally associated with higher odds of reduced eGFR after multivariable adjustment; adjusted odds increased across RFM quartiles and reached significance in Q3 and Q4. RCS analysis indicated an approximately linear association, and RFM yielded an area under the curve (AUC) of 0.630 for identifying reduced eGFR. Conclusions: Elevated RFM is independently associated with reduced eGFR in community-dwelling hypertensive adults, supporting its potential utility as a low-cost and readily accessible anthropometric marker for early screening of renal impairment in primary care.

Keywords: hypertension; relative fat mass; estimated glomerular filtration rate; chronic kidney disease; obesity; community-based study; anthropometric index

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1. Introduction

Hypertension is a common chronic disease, with a prevalence rate of approximately 28% in China as of 2018 [1]. The prevalence of hypertension is high, and hypertension can cause damage to target organs such as the heart, brain, kidneys, and peripheral blood vessels [2]. Early-stage hypertensive kidney injury has no specific clinical symptoms and a high rate of missed diagnosis. The number of patients with end-stage renal disease attributable to primary hypertension has increased year by year [3]. Globally, the burden of chronic kidney disease (CKD) is substantial: it exceeded 16% in northern/southwestern Chinese adults, approximately 20% among US hypertensive adults, and about 12% among Tanzanian hypertensive adults [4–6]. Early identification of high-risk populations for

hypertensive kidney injury to reduce the incidence of hypertensive kidney injury has become a major clinical issue.

Obesity is an established independent risk factor for hypertension and is tightly linked to CKD [7]. Relative fat mass (RFM), as a new index of obesity [8], reflects the percentage of body fat better than body mass index (BMI). Accumulating evidence suggests a close link between RFM and the risk for incident diabetes [9]. RFM showed a strong association with cardiovascular disease risk, including atrial fibrillation, heart failure, and coronary heart disease [10]. In the general population, higher RFM is significantly associated with all-cause mortality, and this association is strengthened after adjustment for total muscle mass [11]. However, the relationship between RFM and estimated glomerular filtration rate (eGFR) in hypertensive population is unclear. This study therefore assessed the association of RFM with eGFR among community-dwelling adults with hypertension in Jiangsu Province, China. The findings are expected to provide fresh perspectives on the primary management of hypertensive nephropathy.

2. Methods

2.1. Participants

This investigation adopted a cross-sectional design with a multistage strategy of random selection. Two cities in Jiangsu Province, China, namely Huai'an and Nantong, were designated as the primary sampling units. Ten community health service centers, drawn at random from each city, served as the study units. Hypertensive patients examined at these centers between January and December 2023 were enrolled and classified into normal- and reduced-eGFR groups according to the clinical eGFR cutoff (Figure 1). All hypertensive patients were older than 18 years and met the diagnostic and classification criteria of the 2020 ISH Global Hypertension Practice Guidelines [2]. Their health records have been established and included in the management of hypertension in their community health service institutions. Exclusion criteria comprised coexisting major comorbidities (malignancy, cardiac or respiratory decompensation, or other severe conditions); end-stage renal disease requiring renal replacement therapy, including kidney transplantation or dialysis (hemodialysis or peritoneal dialysis); and any recorded psychiatric diagnosis. Additional exclusion criteria were severe communication difficulties or study-assessed ineligibility, residence outside the sampled community healthcare area, and incomplete clinical data. Of the 307 participants excluded because the routine community health examination records were incomplete, the missing values concerned the variables required to derive the adiposity indices (height, weight, and waist circumference) and the lipid parameters required for VAI and DAI (TG and HDL-C).

The chronic disease management system was used for data collection, including general information on social demographic characteristics such as name, age, gender, alcohol consumption, smoking status, medical history information such as comorbidities, hypertension classification, physical examination data such as waist circumference (WC), height, weight, BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), laboratory examination information such as low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), total cholesterol (TC), serum creatinine, and proteinuria.

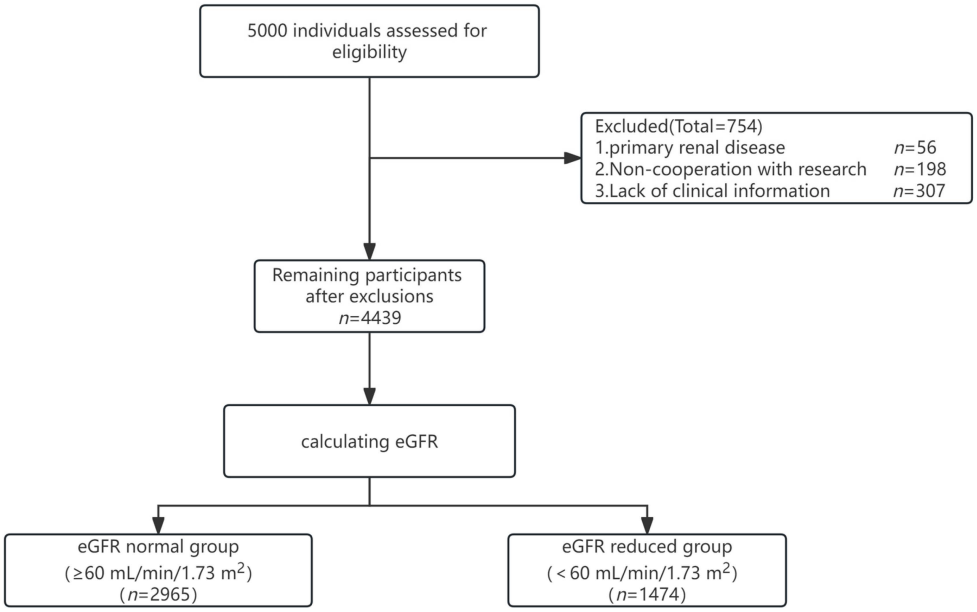


Figure 1. Participant selection and categorization flowchart for this study.

2.2. Definition of Variables

RFM, dysfunctional adiposity index (DAI), conicity index (C-index) and visceral adiposity index (VAI) were calculated using the following gender specific equations

$$\text{RFM} = 64 - 20 \times \left(\frac{\text{height}}{\text{WC}}\right) + 12 \times \text{sex} \quad (1)$$

where height and WC are measured in metres, and sex is coded as 0 for men and 1 for women [9].

$$\text{Men VAI} = \frac{\text{WC}}{(39.68 + 1.88 \times \text{BMI})} \times \frac{\text{TG}}{1.03} \times \frac{1.31}{\text{HDL} - \text{C}} \quad (2)$$

$$\text{Women VAI} = \frac{\text{WC}}{(36.58 + 1.89 \times \text{BMI})} \times \frac{\text{TG}}{0.81} \times \frac{1.52}{\text{HDL} - \text{C}} \quad (3)$$

where WC is cm, BMI is kg/m^2, TG is mmol/L, and HDL-C is mmol/L [12].

$$\text{Men DAI} = \frac{\text{WC}}{22.79 + 2.68 \times \text{BMI}} \times \frac{\text{TG}}{1.37} \times \frac{1.19}{\text{HDL} - \text{C}} \quad (4)$$

$$\text{Women DAI} = \frac{\text{WC}}{24.02 + 2.37 \times \text{BMI}} \times \frac{\text{TG}}{1.32} \times \frac{1.43}{\text{HDL} - \text{C}} \quad (5)$$

where WC is cm, BMI is kg/m^2, TG is mmol/L, and HDL-C is mmol/L [13].

$$\text{C} - \text{index} = \frac{\text{WC}}{0.109 \times \sqrt{\frac{\text{weight}}{\text{height}}}} \quad (6)$$

where WC is in metres (m), body weight in kilograms (kg), and height in metres (m) [14,15].

Smoking was defined as smoking more than one cigarette per day for 6 consecutive or cumulative months, while alcohol consumption was defined as >6 months, with an intake of >30 g per day or >210 g per week. The recorded comorbidities were diabetes, coronary heart disease, and stroke. eGFR was estimated using the Full Age Spectrum (FAS) equation [16]. Reduced eGFR was defined as an eGFR below 60 mL/min/1.73 m^2. Participants whose current eGFR was <60 mL/min/1.73 m^2 and had declined by <25%

compared with the most recent eGFR measurement within the preceding 12 months were included [17].

2.3. Statistical Analysis

All statistical analyses were carried out using SPSS 26.0 and R 4.4.1. Cases with more than 20% missing values, as well as those lacking essential data, were removed by listwise deletion. Continuous variables following a normal distribution are expressed as mean ± standard deviation (SD); non-normally distributed variables are expressed as median with interquartile range [M (Q1, Q3)]. Categorical variables are expressed as frequencies (percentages). Normally and non-normally distributed continuous variables were compared between groups using Student's t-test and the Mann–Whitney U test, respectively, and categorical variables were analysed with the chi-squared (χ^2) test. To examine the independent association between RFM and eGFR, a multivariable logistic regression model was fitted. The model included all variables with $p < 0.05$ on univariate analysis, as well as those judged clinically important a priori. To flexibly model and visualize the dose–response relationship, a multivariable logistic regression model incorporating restricted cubic splines (RCS) was fitted. Receiver operating characteristic (ROC) curves were constructed to evaluate the ability of RFM to discriminate prevalent reduced eGFR. The resulting areas under the curves (AUCs) were compared pairwise using DeLong's test. Statistical significance was defined as a two-tailed p value below 0.05.

3. Results

3.1. Between-Group Comparison of Baseline Characteristics

In total, 5000 individuals were initially enrolled in this cross-sectional study. Following sequential exclusions of 56 individuals with pre-existing primary renal diseases, 198 who failed to complete all required study procedures, and 307 with critical missing data on core clinical variables, the final analytical cohort consisted of 4439 participants. The included population was stratified into the reduced eGFR group (n = 1474, 33%) and the normal eGFR group (n = 2965, 67%). The baseline clinical characteristics of both groups are shown in Table 1. Compared with the normal eGFR group, the reduced eGFR group demonstrated significantly lower proportions of grade 1 hypertension, male participants, smokers and drinkers, as well as significantly lower levels of DBP and HDL-C. In contrast, the reduced eGFR group had significantly higher proportions of comorbidities and grade 2 hypertension, along with significantly higher levels of age, SBP, FBG, TG, LDL-C and RFM (all $p < 0.05$). Proteinuria positivity, BMI, WC, and TC did not differ significantly between the two groups (all $p > 0.05$).

Table 1. Comparison of clinical and biochemical characteristics in two groups.

	eGFR Normal Group (n = 2965)	**eGFR Reduced Group (n = 1474)**	***p* Value**
Age (years)	70 (67, 75)	76 (71, 81)	<0.001
Male, *n* (%)	1923 (65)	622 (42)	<0.001
BMI (kg/m^2)	25.95 ± 3.22	26.05 ± 3.39	0.313
WC (cm)	89.73 ± 8.30	89.99 ± 8.56	0.332
Smoking, *n* (%)	455 (15)	158 (11)	<0.001
Drinking, *n* (%)	773 (26)	269 (18)	<0.001
SBP (mmHg)	147.18 ± 18.29	149.24 ± 20.08	0.010
DBP (mmHg)	86.03 ± 10.72	84.21 ± 11.27	<0.001
Hypertension grade, *n* (%)			
Grade 1, *n* (%)	1560 (53)	712 (48)	0.007
Grade 2, *n* (%)	1405 (47)	762 (52)	

Table 1. *Cont.*

	eGFR Normal Group (n = 2965)	eGFR Reduced Group (n = 1474)	p Value
Comorbidities, *n* (%)	880 (30)	544 (37)	<0.001
FBG (mmol/L)	6.02 (5.47, 7.11)	6.10 (5.55, 7.26)	0.026
TC (mmol/L)	4.73 ± 1.11	4.79 ± 1.19	0.108
TG (mmol/L)	1.38 (0.99, 1.98)	1.52 (1.10, 2.12)	<0.001
LDL-C (mmol/L)	3.14 ± 0.93	3.27 ± 0.98	<0.001
HDL-C (mmol/L)	1.26 (1.15, 1.52)	1.23 (1.15, 1.43)	0.010
Proteinuria, *n* (%)	509 (17)	278 (19)	0.164
RFM	29.49 (26.07, 38.34)	36.95 (28.38, 41.34)	<0.001

eGFR, estimated glomerular filtration rate; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; RFM, relative fat mass.

3.2. The Association Between RFM and Prevalent Reduced eGFR

The association of RFM with prevalent reduced eGFR was assessed via multivariable logistic regression, with reduced eGFR (0 = No, 1 = Yes) as the dependent variable. Covariates showing significant inter-group differences on univariate screening were subsequently incorporated into the multivariable models. Model 1 was unadjusted, and Model 2 was adjusted for gender and age. Model 3 was further adjusted for alcohol consumption, smoking, comorbidities, hypertension grade, DBP, SBP, TG, LDL-C, FBG, and HDL-C.

Multivariable logistic regression analyses were conducted to evaluate the independent association between RFM and reduced eGFR. In the unadjusted analysis (Model 1), RFM, treated as a continuous variable, raised the odds of reduced eGFR per unit increase (odds ratio [*OR*] 1.065). After sequential adjustment for confounding factors, the association persisted in the most complete model (Model 3), with an *OR* of 1.021 (*95% CI*: 1.000–1.042; $p < 0.05$), suggesting that higher RFM independently correlates with reduced eGFR.

According to the RFM quartile level, patients were divided into Q1 (<26.58), Q2 (26.58~ < 30.72), Q3 (30.72~ < 39.72), and Q4 (≥39.72) groups. Taking the Q1 group as the reference, the crude Model 1 showed that the odds of prevalent reduced eGFR increased progressively across higher RFM quartiles, with significantly elevated odds observed in Q3 (*OR* = 2.142, *95% CI*: 1.778–2.580) and Q4 (*OR* = 3.070, *95% CI*: 2.555–3.690). The graded odds elevation was robust to sequential adjustment for all predefined confounders (Model 3), with adjusted *OR*s of 1.448 (*95% CI*: 1.082–1.937) for Q3 and 1.461 (*95% CI*: 1.026–2.080) for Q4 (all $p < 0.05$) (Table 2).

Table 2. Association between RFM and prevalent reduced eGFR in study population.

Variable	Model 1		Model 2		Model 3	
	OR (95% CI)	p Value	*OR (95% CI)*	p Value	*OR (95% CI)*	p Value
RFM	1.065 (1.056, 1.075)	<0.001	1.019 (0.998, 1.040)	0.070	1.021 (1.000, 1.042)	0.048
RFM Quartiles						
Q1	1		1		1	
Q2	1.166 (0.958, 1.418)	0.125	1.105 (0.896, 1.363)	0.349	1.094 (0.885, 1.353)	0.406
Q3	2.142 (1.778, 2.580)	<0.001	1.386 (1.041, 1.845)	0.025	1.448 (1.082, 1.937)	0.013
Q4	3.070 (2.555, 3.690)	<0.001	1.360 (0.962, 1.922)	0.082	1.461 (1.026, 2.080)	0.035

Model 1: unadjusted; Model 2: adjusted for gender, age; Model 3: adjusted for gender, age, smoking, alcohol consumption, comorbidities, hypertension grade, SBP, DBP, FBG ,TG, LDL-C and HDL-C. RFM, relative fat mass; eGFR, estimated glomerular filtration rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

3.3. Association of RFM with Prevalent Reduced eGFR: A Stratified Subgroup Analysis

We further evaluated the robustness of the association between RFM and reduced eGFR across pre-specified subgroups. Formal interaction tests detected no statistically significant effect modification by age, gender, smoking status, alcohol consumption, or comorbidity burden (all p for interaction > 0.05). The positive association remained generally consistent across these strata (Table 3).

Table 3. Subgroup analysis of the association between RFM and prevalent reduced eGFR in study population.

	Number	*OR* (*95% CI*)	*p* Value	*p* for Interaction
Gender				
Male (%)	2545 (57)	1.041 (1.010, 1.073)	0.009	0.117
Female (%)	1894 (43)	1.001 (0.973, 1.030)	0.947	
Age				
<80 years (%)	3699 (83)	1.032 (1.010, 1.056)	0.005	0.099
≥80 years (%)	740 (17)	1.041 (1.022, 1.061)	<0.001	
Smoking				
Yes (%)	613 (14)	1.074 (1.006, 1.146)	0.033	0.181
No (%)	3826 (86)	1.016 (0.994, 1.039)	0.154	
Alcohol consumption				
Yes (%)	1042 (23)	1.032 (0.984, 1.081)	0.193	0.862
No (%)	3397 (77)	1.019 (0.996, 1.043)	0.113	
Comorbidities				
Yes (%)	1424 (32)	0.993 (0.958, 1.030)	0.718	0.562
No (%)	3015 (68)	1.036 (1.010, 1.063)	0.007	

RFM, relative fat mass; eGFR, estimated glomerular filtration rate.

In the multivariable-adjusted models, the *OR*s per 1-unit increment in RFM ranged from 1.032 to 1.074 across subgroups where the association reached statistical significance. Subgroup analyses revealed statistically significant associations in male participants, both age groups (<80 and ≥80 years), smokers, and individuals without comorbidities, whereas no significant associations were observed among female participants, non-smokers, or those with comorbidities, or by alcohol consumption status (Table 3).

3.4. Restricted Cubic Spline Analysis of RFM in Relation to Prevalent Reduced eGFR

Using multivariable-adjusted logistic regression and RCS analysis, we evaluated the association of RFM with prevalent reduced eGFR. After adjusting for all predefined confounders, the test for nonlinearity was not statistically significant (p = 0.091), suggesting a linear dose–response relationship across the observed exposure range. Accordingly, in the fully adjusted model, higher RFM levels were independently linked to significantly greater odds of prevalent low eGFR (Figure 2).

3.5. ROC Analysis of RFM for Prevalent Reduced eGFR

To evaluate whether the four novel obesity-related indicators (RFM, VAI, DAI, and C-index) could identify prevalent reduced eGFR, we performed ROC analysis. Reduced eGFR status (0 = normal, 1 = reduced) was used as the state variable. Optimal cut-off values were determined by maximizing the Youden index, and the corresponding ROC curves are shown in Figure 3. Among the four indicators, RFM achieved the highest AUC of 0.630 (*95% CI*: 0.613–0.648). At an optimal cut-off of 34.60, its sensitivity and specificity were 56% and 66%, respectively. Pairwise comparisons using DeLong's test revealed that the AUC of RFM was statistically significantly greater than that of VAI (AUC 0.584, *95%*

CI: 0.567–0.602), DAI (AUC 0.574, *95% CI*: 0.557–0.592), and C-index (AUC 0.542, *95% CI*: 0.524–0.560) (all $p < 0.001$, Table 4).

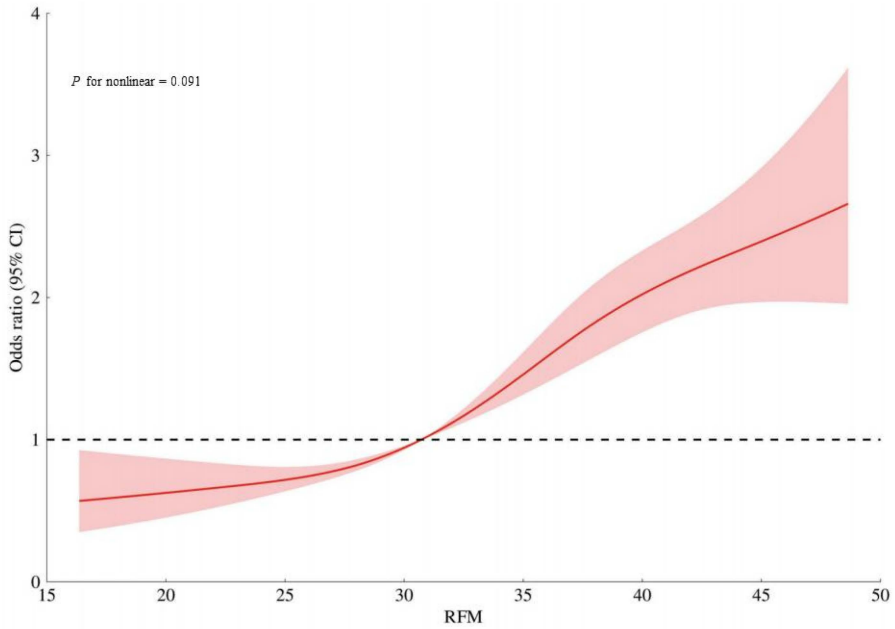


Figure 2. Restricted cubic spline plots visualizing the dose–response association between RFM and prevalent reduced eGFR in the study population. RFM, relative fat mass; eGFR, estimated glomerular filtration rate. Overall spline curve (red solid line) with 95% confidence limits (red area).

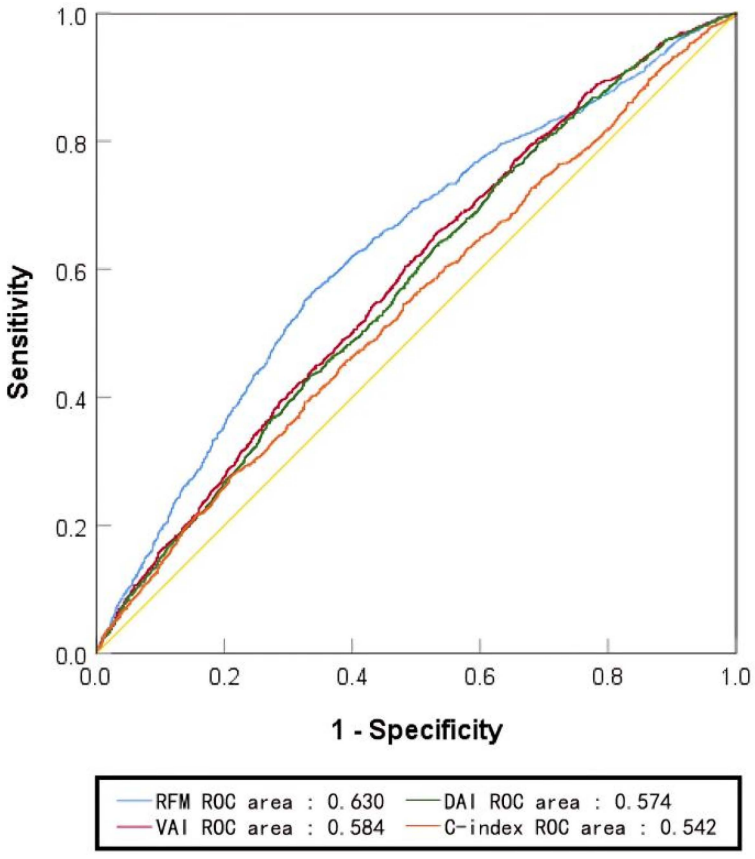


Figure 3. ROC curve illustrating the diagnostic performance of different anthropometric indicators for prevalent reduced eGFR in the study population. ROC, receiver operating characteristic; eGFR, estimated glomerular filtration rate; RFM, relative fat mass; DAI, dysfunctional adiposity index; VAI, visceral adiposity index, C-index, conicity index.

Table 4. The diagnostic performance of RFM for prevalent reduced eGFR in the study population.

Variable	Optimal Cut-Off Value	Sensitivity (%)	Specificity (%)	AUC (*95% CI*)	P_1	P_2
RFM	34.601	56%	66%	0.630 (0.613,0.648)	<0.001	-
VAI	1.525	66%	47%	0.584 (0.567,0.602)	<0.001	<0.001
DAI	0.805	74%	36%	0.574 (0.557,0.592)	<0.001	<0.001
C-index	1.144	97%	5%	0.542 (0.524,0.560)	<0.001	<0.001

RFM, relative fat mass; VAI, visceral adiposity index; DAI, dysfunctional adiposity index; C-index, conicity index; P_1 represents the test result of the area under the curve compared to 0.5; P_2 shows the comparison of the RFM with other obesity indices based on the area under the curve.

4. Discussion

In Canada, intervention programs based on multidisciplinary primary healthcare have been implemented and significantly improve lifestyle and increase the speed of achieving blood pressure targets within one year [18]. Primary community medical service centers were the principal settings for the prevention and management of hypertension in China. Therefore, general practitioners need to strengthen the capacity building of community hypertension prevention and standardized management. The 2012–2015 national survey showed that the prevalence of hypertension in Chinese adults was approximately 46% according to the 2017 ACC/AHA guideline [19], similar to the reported prevalence of approximately 50% in the United States from 2017 to 2018 [20].

Many indicators have been shown to be related to kidney function in evaluating obesity, such as BMI [21]. BMI, calculated from weight and height, is the most widely used clinical measure for identifying obesity [22]. Although BMI is valuable as a tool for assessing weight and identifying potential health risks in high BMI populations, it has serious limitations in assessing heterogeneity among individuals who may be overweight, and it does not describe the distribution of body fat or distinguish between muscle mass and adipose tissue mass [23–25]. To overcome the limitations of BMI, WC has been proposed to evaluate abdominal obesity and is an important indicator of obesity-related risk such as end-stage renal disease [26]. However, the measurement of WC is not standardized in clinical practice and is difficult to measure in subjects with BMI greater than 35 kg/m^2. In addition, abdominal circumference is influenced by multiple factors, including gender, age, and race, and cannot distinguish between visceral and subcutaneous fat [27].

Therefore, new obesity assessment indices have been developed, such as VAI and BRI [28,29]. RFM can accurately estimate body fat percentage [8], and it is positively correlated with both SBP and DBP [30]. Although RFM is a new indicator for estimating whole-body fat distribution, it is unclear whether RFM is associated with renal dysfunction in hypertensive patients.

In this community-based hypertensive population in Jiangsu Province, China, RFM exhibited a linear association with prevalent reduced eGFR. After accounting for demographic characteristics (age and sex), lifestyle habits (smoking and alcohol consumption), clinical features (comorbidities and hypertension grade), and cardiometabolic indices—SBP, DBP, FBG, TG, LDL-C, and HDL-C—the association remained statistically significant in multivariable models. Furthermore, subgroup analyses demonstrated generally consistent effect estimates across all predefined strata, with formal interaction tests revealing no significant effect modification by gender, age, alcohol consumption, smoking status, or comorbidity burden. Consistent with our results, a study on type 2 diabetes patients showed that RFM was negatively correlated with renal function [31].

Notwithstanding the modest magnitude of the independent association, the observed correlation carries meaningful research value and promising clinical implications. Although

every unit increment in RFM corresponded to only a 2% relative rise in the odds of reduced eGFR in the fully adjusted model, RFM spanned a wide distribution across the included hypertensive cohort, with its interquartile range fully covering the predefined quartile strata from 26.58 at the 25th percentile to 39.72 at the 75th percentile. For individuals in the highest RFM quartile ($\geq$39.72), this small per-unit risk increment would accumulate into a substantial elevation in the odds of early renal impairment. Clinically, RFM may not function as a highly accurate standalone marker for renal dysfunction, but it can serve as a low-cost, easily measurable auxiliary anthropometric obesity marker that complements existing metabolic risk indicators, to optimize the early identification of individuals at high risk of kidney impairment in community-based hypertensive populations.

Although the mechanisms underlying the RFM–reduced eGFR relationship remain poorly understood, RFM reliably reflects obesity, and the contribution of obesity to kidney disease may explain this link. Obesity is an independent risk factor for CKD, which is associated with decreased eGFR and the development of proteinuria [32]. Obesity will increase the risk of diabetes, hypertension and dyslipidemia, which are often the main risk factors for CKD [33]. After adjustment for metabolic abnormalities, including blood glucose, blood pressure, and blood lipid levels, obesity was not associated with an increased risk of CKD [34]· However, some studies reported that metabolically healthy overweight and obese individuals had a higher risk of incident CKD than those with normal BMI [35]. In obese individuals, the over-activation of the renin-angiotensin system and the sympathetic nervous system can cause hemodynamic disorders and glomerular hyperfiltration, leading to podocyte injury and renal fibrosis [36]. Lipotoxicity caused by excessive lipid accumulation can promote apoptosis, inflammation, and fibrosis, leading to glomerular injury [37]. Moreover, obesity causes an imbalance in the secretion of adipokines and inflammatory mediators, leading to renal inflammation, oxidative stress and fibrosis [38,39]. In parallel, fat deposition and local tissue hypoxia induce hypoxia-inducible factor-α (HIF-α). HIF-α then promotes the production of pro-inflammatory cytokines, including tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) [40,41]. These mediators impair renal endothelial function and reduce the glomerular filtration rate. Deeper investigation of these mechanisms could reveal candidate therapeutic targets for obesity-related CKD.

The obesity indicators currently used in clinical practice include BMI, WC and waist-to-height ratio, while some novel obesity-related metrics derived from anthropometric and lipid parameters have been developed in recent years, including VAI, DAI, and C-index. A previous study of 8295 adults in the Netherlands reported that RFM showed the strongest association with incident heart failure among all included obesity indicators [42]. A large prospective cohort study of 167,729 adults also demonstrated that RFM has the highest correlation with the development of diabetes [43]. Consistent with these prior findings, our cross-sectional analysis indicates that RFM exhibits superior diagnostic performance for prevalent reduced eGFR in community-dwelling hypertensive populations, compared with VAI, DAI, and C-index. Nevertheless, larger prospective cohort studies are still warranted to confirm whether RFM is longitudinally associated with renal function decline.

5. Limitations

Several limitations of this study merit acknowledgment when interpreting the results. First, the cross-sectional design, together with the use of self-administered questionnaires to obtain data on medical history and comorbid conditions, may have introduced response or selection bias, with potential consequences for the accuracy of our findings. Second, because participants were not followed longitudinally, the RFM–eGFR decline association cannot be interpreted as causal. Future longitudinal cohort studies are therefore needed to

clarify the temporal relationship between these variables and to identify the underlying causal mechanisms. Third, although we adjusted for a wide range of confounders, residual confounding remains a possibility. Notably, due to limitations in the available physical examination items, we did not collect data on urinary albumin-to-creatinine ratio, use of antihypertensive drugs, duration of diabetes, serum uric acid, etc., all of which are known to impact renal function. Antihypertensive drug classes may also have influenced eGFR. Renin–angiotensin system inhibitors (angiotensin-converting enzyme inhibitors and angiotensin receptor blockers) regulate blood pressure and kidney function through both direct and indirect mechanisms [36], reduce intraglomerular pressure, and commonly cause an acute fall in eGFR that subsequently stabilises, whereas sodium–glucose cotransporter 2 inhibitors lower eGFR acutely through tubuloglomerular feedback before slowing the long-term decline [44]. As these agents are preferentially prescribed to patients with diabetes, albuminuria or reduced kidney function, they may have confounded or modified the association observed here; future studies with detailed medication data are needed to address this. Finally, recruitment was confined to Jiangsu Province, which may restrict how far our findings can be extrapolated to populations in other regions or ethnic groups. Multi-center studies recruiting larger and more diverse cohorts are therefore needed to verify these results.

6. Conclusions

In summary, elevated RFM is independently associated with prevalent reduced eGFR in community-dwelling hypertensive populations. RFM exhibited modest yet statistically significant diagnostic performance for prevalent reduced eGFR in hypertensive patients, suggesting its practical value in flagging individuals at high risk of renal dysfunction.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Review Committee of the Affiliated Huai'an No.1 People's Hospital of Nanjing Medical University (approval no. KY-2023-049-02; amendment approved on 13 March 2025).

Informed Consent Statement: Informed consent was waived by ethics committee since this is a retrospective, non-interventional cross-sectional study based on routinely collected clinical and laboratory records. No study-specific procedures were introduced, and routine diagnosis and care were not affected. The study therefore imposed no additional burden or risk and did not affect patients' medical rights. Patient identifiers were replaced with study codes. Only the research team could access the data; the sponsor, ethics committee, and regulators could access it only within their authorized roles. Results are reported only as aggregated data and contain no identifiable patient information.

Data Availability Statement: Due to privacy and ethical restrictions, the data supporting this study are not publicly available. Anonymized data may be requested from the corresponding author with institutional ethics approval.

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