

# Body mass index combined with waist circumference can predict moderate chronic kidney disease

## A retrospective study

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### Abstract

Overweight and obesity may be associated with poor clinical outcome, including chronic kidney disease (CKD). However, whether body mass index (BMI), waist-to-hip ratio (WHR), and waist circumference (WC) are related to CKD is yet to be elucidated.

A total of 7593 adults were divided into 4 groups based on the estimated glomerular filtration rate (eGFR) quartile. The eGFR was calculated with the CKD Epidemiology Collaboration. Multiple linear regression analyzed the association between eGFR and WHR, BMI, and WC. Logistic regression analysis determined whether the CKD patients were associated with WHR, BMI, and WC after adjusting for other variables.

The mean age of the cohort was  $72.34 \pm 7.30$  years. Multiple linear regression analysis showed that WC ( $P = .006$ ) was associated with eGFR, although adjusted by lifestyle factor and biochemical indicators. The individuals in the underweight, overweight, and obese groups had significantly lower eGFR value than those in the healthy weight group in moderate CKD. The eGFR in the overweight group with WHR  $\leq 0.894$  was higher than in the healthy weight group with WHR  $> 0.894$  group ( $P = .036$ ). Overweight with WHR  $\leq 0.894$  group had a longer WC with a pronounced increase in the hip circumference. Logistic regression analysis showed that the WC (OR = 1.362,  $P < .001$ ) and BMI (OR = 1.227,  $P = .031$ ) were independent risk factors for moderate CKD patients. Each standard deviation (SD) of high BMI and WC level was associated with 23.0% and 17.3% higher odds of moderate CKD (OR = 1.230,  $P = .017$  and OR = 1.173,  $P = .021$ , respectively).

WC is an independent risk factor for eGFR. Combined BMI and WC are important factors that would predict moderate CKD patients.

**Abbreviations:** Alb = albumin, BMI = body mass index, CKD = chronic kidney disease, DBP = diastolic blood pressure, eGFR = estimated glomerular filtration rate, Hb = hemoglobin, HDL = high density lipoprotein, LDL = low density lipoprotein cholesterol, SBP = systolic blood pressure, SD = standard deviation, TC = total cholesterol, TG = triglyceride, WC = waist circumference, WHR = waist-to-hip ratio.

**Keywords:** body-mass index, chronic kidney disease, waist circumference, waist-to-hip ratio

## 1. Introduction

Chronic kidney disease (CKD) is increasing in prevalence and incidence and is recognized as a public health priority worldwide.<sup>[1,2]</sup> Overweight and obesity are closely related to

CKD.<sup>[1]</sup> The links between them are numerous and complex. This complexity maybe explained by inflammation, increased oxidative, insulin resistance, hypertension and dyslipidemia.<sup>[3]</sup>

Body mass index (BMI) is a critical and convenient indicator for assessing whether a subject is overweight or obese. High BMI

Editor: Hidetaka Hamasaki.

This study was supported by, Shanghai municipal commission of health and family planning scientific research project (201640100), Clinical innovation and multi discipline integrated medical construction project of south campus, Renji Hospital, school of medicine, Shanghai Jiaotong University (2014MDT02), Academic Leader Training Program of Health System in Pudong New Area, Shanghai (PwRd2018-04), and Cultivating Funds of South Campus, Renji Hospital, School of Medicine, Shanghai Jiaotong University (No. 2017PYQB05).

The authors have no conflicts of interests to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Cai H, Zhan Y, Lu J, Zhu M, Liu S, Mei J, Zhang P, Liu R, Ni Z, Zhang W, Xu G. Body mass index combined with waist circumference can predict moderate chronic kidney disease: a retrospective study. *Medicine* 2021;100:12(e25017).

Received: 28 May 2020 / Received in final form: 15 January 2021 / Accepted: 12 February 2021

<http://dx.doi.org/10.1097/MD.00000000000025017>

contributed to an estimated 4 million deaths globally in 2015.<sup>[4]</sup> Several studies have shown a U-shaped association between BMI and minimum mortality in the healthy weight (20–25 kg/m<sup>2</sup>) range.<sup>[5–7]</sup> The BMI also had a J-shaped association with the overall mortality and the specific causes of death.<sup>[8]</sup> Recent studies have shown that BMI may be a predictor of kidney disease. BMI  $\geq 30$  kg/m<sup>2</sup> was associated with the rapid loss of kidney function in a patient with eGFR  $\geq 60$  ml/minutes/1.73 m<sup>2</sup>.<sup>[9]</sup> However, other studies demonstrated that waist-to-hip ratio (WHR), but not BMI, is associated with incident chronic kidney disease (CKD). The evaluation of the risk of CKD utilized WHR rather than BMI as an anthropomorphic measure of obesity<sup>[10]</sup> as it is an indirect measure of visceral fat, whereas BMI does not distinguish between visceral and non-visceral fat. An increased WHR indicates decreased gluteal muscle mass or increased visceral fat; therefore, the contribution of visceral fat and gluteal muscle to WHR was relevant. Studies in Waist circumference (WC) which also can measure visceral abdominal fat show that WC is a strong predictor of adverse events and has relationship with adverse clinical outcomes in CKD.<sup>[11]</sup> In general population and CKD patients, WC has well correlated with visceral adipose tissue. However, the majority of the patients with CKD were stage CKD1–2. The best index in predicting moderate CKD (eGFR  $< 60$  ml/minutes/1.73 m<sup>2</sup>) patients is unknown. Thus, in this study, we focus on the moderate CKD patients and measured the WC, hip circumference, BMI, and calculated the WHR to find how we can better predict the risk factors for the development of kidney disease.

## 2. Methods

### 2.1. Participants

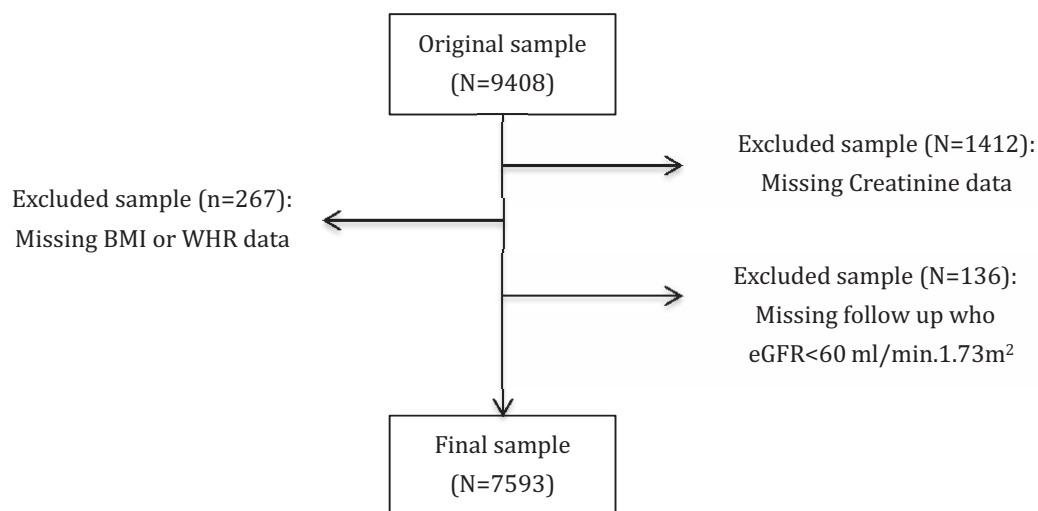
The data from individual subjects were pooled from Shanghai Pudong new area Yingbo community healthy examination from

2015 to 2018 and the study was approved by the Ethics Committee on human of Shanghai Pudong new area Yingbo community health service. All the patients provided written informed consent to participate in this study. The methods were carried out in accordance with the approved guidelines. A total of 9408 subjects, aged 12 to 93 years, were recruited in this study. Subject with a low estimated glomerular filtration rate (eGFR) ( $< 60$  ml/minutes/1.73 m<sup>2</sup>) at the first examination were followed up after 3 months. CKD was defined as eGFR  $< 60$  ml/minutes/1.73 m<sup>2</sup> for  $> 3$  months. According to CKD stage, eGFR  $< 60$  ml/minutes/1.73 m<sup>2</sup> was defined as moderate CKD. Individuals lacking data on creatinine, sex, and age were excluded from the pool (n = 1412). Also, 267 cases were excluded due to the missed BMI or WHR data. People who missed the 3-month follow-up were also excluded from the data (n = 136). Finally, a total of 7593 cases were included in the current analysis (Fig. 1).

### 2.2. Variables

WHR was calculated as WC divided by hip circumference; both were measured according to the recommendations of the World Health Organization (WHO). The subject was told to stand relaxed with arms at the sides, feet positioned close together, and weight distributed across the feet. WC was measured between the lowest rib and the superior border of the iliac crest. Hip circumference was measured at the widest portion of the buttocks. The BMI was calculated as weight in kilograms (kg) divided by squared length in meters (m<sup>2</sup>). Obese, overweight, healthy weight, and underweight were defined as BMI  $\geq 30.0$ , 25.0 to 29.9, 18.5 to 24.9, and  $< 18.5$  kg/m<sup>2</sup>, respectively.<sup>[12]</sup> Estimated GFR was calculated using the CKD Epidemiology Collaboration creatinine 2009 equation.<sup>[13]</sup>

The baseline variables included demographics (age, sex), lifestyle characteristics (smoking, alcohol use), medical history



9408 individual subjects were enrolled and excluded 1815 subjects with different reasons. A total of 7593 cases were in analysis.

**Figure 1.** Flowchart describing sample selection 9408 individual subjects were enrolled and excluded 1815 subjects with different reasons. A total of 7593 cases were in analysis.

(diabetes, hypertension), and examination findings (systolic and diastolic blood pressure), as well as laboratory variables (hemoglobin, albumin (Alb), creatinine, total cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), and triglyceride). Cigarette smoking and alcohol consumption was dichotomized as current users and non-users. Diabetes was defined as a history of previous diagnosis and use of an oral hypoglycemic agent or insulin. Hypertension was defined as have a history of diagnosis, systolic blood pressure  $\geq 140$  mmHg, diastolic  $\geq 90$  mmHg, or use of antihypertensive medications.

### 2.3. Statistical analysis

Continuous variables were described as mean  $\pm$  SD or medians with interquartile range (IQR), depending on their distributions, while categorical variables were expressed as numbers (percentages). The differences in demographic data and clinical variables across the eGFR quartiles were analyzed using the independent-samples *t*-test for continuous variables and the Chi-Squared test or Fisher exact test for categorical variables. Multiple linear regression analysis was adjusted for potential confounders to assess the association between eGFR and WHR, BMI, and WC. A binary logistic regression analysis was performed to determine the association of moderate CKD with BMI, WC, and WHT, adjusting for demographic and clinical variables. All the variables were set to binary dependent variable. To compare the effects of WHR, BMI, and WC, risks were presented also per standard deviation (SD) increase in the independent variable.  $P < .05$  was

considered statistically significant. SPSS 20.0 was used to compute the statistical analyses.

## 3. Results

### 3.1. Baseline characteristics

The mean of the cohort was  $72.34 \pm 7.30$  years. The mean BMI, WHR, and WC were  $23.91 \pm 5.04$  kg/m<sup>2</sup>,  $0.90 \pm 0.15$ , and  $85.50 \pm 10.71$  cm, respectively. The mean baseline serum creatinine was  $74.30 \pm 23.13$  mmol/L, and mean eGFR was  $81.54 \pm 17.58$  ml/minutes/1.73 m<sup>2</sup>. As anticipated, individuals with low eGFR were likely to have a high prevalence of smoking, alcohol use, and high systolic blood pressure (SBP). The low level of hemoglobin (Hb), Alb, and HDL are associated with low eGFR (Table 1).

### 3.2. Multiple linear regression analysis with eGFR and WHR, WC, BMI

All the individual subjects were enrolled to identify the association between WC, BMI, WHR with eGFR, a multiple linear regression analysis was performed (Table 2). Age ( $\beta = -1.039$ , 95% confidence interval (CI):  $-1.117$  to  $-0.962$ ,  $P < .001$ ), Hb ( $\beta = 0.112$ , 95% CI:  $0.074$ – $0.150$ ,  $P < .001$ ), HDL ( $\beta = 1.931$ , 95% CI:  $0.240$ – $5.115$ ,  $P = .025$ ), WC ( $\beta = -0.066$ , 95% CI:  $-0.113$  to  $-0.019$ ,  $P = .006$ ) were associated with the level of eGFR after adjusting for lifestyle factor and biochemical indicators (Table 2).

**Table 1**

**In whole cohort, Baseline characteristics of community-living individuals and laboratory data by quartiles of eGFR quartiles.**

	All (n = 7593)	eGFR quartiles (ml/min 1.73 m <sup>2</sup> )			
		I $\leq 70.76$ (n = 1899)	70.76 < II $\leq 83.25$ (n = 1898)	83.25 < III $\leq 92.68$ (n = 1898)	IV > 92.68 (n = 1898)
<b>Demographics</b>					
Male, n (%)	3427 (45.1)	822 (43.3)	879 (46.3)	633 (33.4)**	1093 (57.6)**
Age, yr	72.34 $\pm$ 7.30	76.34 $\pm$ 7.80	73.13 $\pm$ 6.90**	71.49 $\pm$ 6.06**	68.39 $\pm$ 5.95**
Smoker, n (%)	1460 (19.2)	511 (26.9)	374 (19.7)**	275 (14.5)**	300 (15.8)**
Hypertension, n (%)	2504 (33.0)	637 (33.5)	584 (30.3)*	620 (32.7)	663 (34.9)
Alcohol Use, n (%)	2224 (29.3)	651 (34.3)	640 (33.7)	538 (28.3)**	395 (20.8)**
Diabetes, n (%)	672 (8.85)	162 (8.53)	175 (9.23)	168 (8.85)	167 (8.80)
<b>Physical Findings</b>					
SBP, mm Hg	141.43 $\pm$ 21.18	143.39 $\pm$ 21.67	141.73 $\pm$ 20.22*	140.91 $\pm$ 20.72**	139.62 $\pm$ 21.90**
DBP, mm Hg	79.42 $\pm$ 14.80	78.28 $\pm$ 11.96	79.18 $\pm$ 11.81	79.70 $\pm$ 15.06**	80.58 $\pm$ 19.24**
BMI, kg/m <sup>2</sup>	23.91 $\pm$ 5.04	23.97 $\pm$ 0.91	23.82 $\pm$ 0.90	23.97 $\pm$ 0.89	23.88 $\pm$ 0.90
WHR	0.89 $\pm$ 0.15	0.91 $\pm$ 0.16	0.90 $\pm$ 0.11	0.89 $\pm$ 0.08**	0.90 $\pm$ 0.21*
WHR (Male)	0.91 $\pm$ 0.10	0.92 $\pm$ 0.07	0.91 $\pm$ 0.14*	0.91 $\pm$ 0.08*	0.91 $\pm$ 0.08**
WHR (Female)	0.89 $\pm$ 0.18	0.90 $\pm$ 0.21	0.88 $\pm$ 0.77*	0.88 $\pm$ 0.08**	0.89 $\pm$ 0.08*
WC (cm)	85.50 $\pm$ 10.71	86.49 $\pm$ 9.88	85.49 $\pm$ 12.29**	84.71 $\pm$ 10.42**	85.28 $\pm$ 10.00**
WC (cm) (Male)	87.49 $\pm$ 11.10	88.89 $\pm$ 9.48	87.79 $\pm$ 14.84*	87.17 $\pm$ 9.15**	86.38 $\pm$ 9.5**
WC (cm) (Female)	83.88 $\pm$ 10.10	84.66 $\pm$ 9.80	83.52 $\pm$ 9.13*	83.58 $\pm$ 10.80*	83.79 $\pm$ 10.47*
<b>Baseline Laboratory Results</b>					
Scr, mmol/l	74.30 $\pm$ 23.13	96.44 $\pm$ 31.99	75.98 $\pm$ 10.46**	64.73 $\pm$ 10.31**	60.02 $\pm$ 10.56**
eGFR, ml/min 1.73 m <sup>2</sup>	81.54 $\pm$ 17.58	58.92 $\pm$ 10.33	77.30 $\pm$ 3.63**	88.20 $\pm$ 2.75**	101.74 $\pm$ 11.26**
Hb, g/l	136.18 $\pm$ 15.00	132.55 $\pm$ 17.27	136.63 $\pm$ 14.70**	136.42 $\pm$ 13.41**	138.96 $\pm$ 13.91**
Alb, g/l	46.25 $\pm$ 3.30	45.97 $\pm$ 3.46	46.27 $\pm$ 3.26	46.26 $\pm$ 3.12	46.51 $\pm$ 3.34**
TC, mmol/l	4.71 $\pm$ 2.00	4.69 $\pm$ 1.58	4.68 $\pm$ 1.09	4.82 $\pm$ 2.02	4.62 $\pm$ 2.22
TG, mmol/l	1.73 $\pm$ 1.64	1.77 $\pm$ 1.23	1.71 $\pm$ 1.21	1.81 $\pm$ 1.57	1.63 $\pm$ 1.14
LDL, mmol/l	2.52 $\pm$ 0.86	2.52 $\pm$ 0.88	2.54 $\pm$ 0.84	2.55 $\pm$ 0.87	2.47 $\pm$ 0.85
HDL, mmol/l	1.35 $\pm$ 0.34	1.32 $\pm$ 0.33	1.36 $\pm$ 0.35**	1.38 $\pm$ 0.34**	1.36 $\pm$ 0.33*

\* Compared with group I  $P < .05$ ; \*\* Compared with group I  $P < .001$

SBP = systolic blood pressure, DBP = diastolic blood pressure, BMI = body mass index, WHR = waist hip ratio, WC = Waist Circumference, Hb = haemoglobin, Alb = albumin, Scr = serum creatinine, eGFR = estimated glomerular filtration rate, TC = total cholesterol, TG = triglyceride, LDL = low density lipoprotein cholesterol, HDL = high density lipoprotein.

**Table 2**  
Multiple linear regression analysis of risk factors for serum estimated GFR.

	Univariate analysis		Multi variate analysis	
	$\beta$	P	$\beta$	P
Age	-0.957 (-1.007, -0.907)	<.001	-1.039 (-1.117, -0.962)	<.001
SBP	-0.05 (-0.07, -0.031)	<.001		
DBP	0.07 (0.042, 0.099)	<.001		
Hb	0.234 (0.204, 0.265)	<.001	0.112 (0.074, 0.150)	<.001
Alb	0.380 (0.214, 0.545)	<.001		
TC	0.144 (-0.071, 0.359)	.088		
TG	-0.229 (-0.491, 0.034)	.088		
HDL	1.776 (0.504, 3.048)	0.006	1.931 (0.240, 5.115)	.025
LDL	-0.162 (-0.663, 0.339)	.527		
BMI	0.002 (-0.078, 0.082)	.964		
WHR	-3.436 (-6.147, -0.726)	.013		
WC	-0.083 (-0.121, -0.045)	<.001	-0.066 (-0.113, -0.019)	.006

Statistical model used multiple linear regression analysis for measure the risk of serum estimated GFR adjusting for demographic data and clinical data.

SBP = systolec blood pressure, DBP = diastolec blood pressure, Hb = haemoglobin, Alb = albumin, TC = total cholesterol, TG = triglyceride, LDL = low density lipoprotein cholesterol, HDL = high density lipoprotein, BMI = body mass index, WHR = waist-to-hip Ratio, WC = Waist Circumference.

### 3.3. Association of moderate CKD with BMI, WC and WHR

Univariate analysis showed that moderate CKD patients were correlated with WC, WHR, and BMI. Logistic regression analysis showed that WC level (hazard ratio (HR)=1.362,  $P=.001$ ), BMI level (HR=1.227,  $P=.031$ ), smoker (HR=1.551,  $P=.002$ ), male gender (HR=1.416,  $P=.015$ ), and the level of Hb (HR=0.437,  $P<.001$ ) and Alb (HR=0.798,  $P=.044$ ) were independent risk factors for the moderate CKD patients after adjusting for demographics and biochemical indexes (Table 3).

### 3.4. Correlation between different levels of BMI, WHR, and the value of eGFR in moderate CKD

Incidence of moderate CKD and lower eGFR value were higher in both underweight and overweight/obese people than in healthy

weight people. The healthy weight with WHR  $\leq 0.894$  group had the highest value of eGFR as compared to the other groups. The value of eGFR in the overweight with WHR  $\leq 0.894$  group was higher than in the healthy weight with WHR  $> 0.894$  group ( $P=.036$ ). Although the obese with WHR  $\leq 0.894$  group ( $n=23$ ) had a higher value of eGFR, it was not statistically significant as compared to the healthy weight with WHR  $> 0.894$  group. In addition, compared to the healthy weight with WHR  $> 0.894$ , overweight with WHR  $\leq 0.894$  group had a longer WC with a pronounced increase in the hip circumference (Table 4).

Each SD of high BMI and WC level was associated with 23.0% and 17.3% higher odds of moderate CKD in a model adjusted for lifestyle factors and biochemical indicators (odds ratio (OR)=1.230,  $P=.017$  and OR=1.173,  $P=.021$ , respectively) (Table 5).

**Table 3**  
Analysis of risk factor for moderate CKD.

	Unadjusted			Adjusted 1			Adjusted 2		
	OR	95% CI	P value	OR	95% CI	P	OR	95% CI	P value
WC	1.270	1.084-1.489	.003	0.894	0.652-1.213	.091	1.362	1.215-1.526	<.001
WHR	1.244	1.161-1.334	<.001	1.466	1.193-1.801	<.001	1.212	0.825-1.691	.661
BMI	1.246	1.118-1.390	<.001	1.254	1.083-1.452	.002	1.227	1.129-1.628	.031
Smoker				1.724	1.082-1.991	.005	1.551	1.199-2.591	.002
Alcohol				1.141	0.617-4.812	.493	1.112	0.401-3.989	.626
Male				1.225	0.694-3.811	.628	1.416	1.071-1.873	.015
Diabetes				1.228	0.724-5.221	.361	1.374	0.628-4.259	.249
Age							1.488	0.523-6.968	.321
SBP							1.201	0.824-1.879	.320
DBP							0.662	0.364-1.098	.221
Hb							0.437	0.335-0.571	<.001
Alb							0.798	0.532-0.922	.044
TC							0.724	0.445-1.187	.375
TG							1.233	0.784-1.663	.275
LDL							1.103	0.751-1.557	.555
HDL							0.839	0.647-1.429	.093

Statistical model used logistic regression analysis for measure the risk of moderate CKD patients adjusting for demographic data and clinical data. (Set WC  $\leq 85.5$  cm = 0, WC  $> 85.5$  cm = 1; WHR  $\leq 0.894$  = 0, WHR  $> 0.894$  = 1, BMI  $\leq 24.9$  = 0, BMI  $> 24.9$  = 1; Smoker = 1, no smoker = 0; Alcohol = 1, no Alcohol = 0; Male = 1, Female = 0, Diabetes = 1 non-Diabetes = 0, Age  $\leq 72.34$  (y) = 0, Age  $> 72.34$  (y) = 1, SBP  $\leq 141.43$  mm Hg = 0, SBP  $> 141.43$  mm Hg = 1, DBP  $\leq 79.42$  mm Hg = 0, DBP  $> 79.42$  mm Hg = 1, Hb  $\leq 136.18$  (g/l) = 0, Hb  $> 136.18$  (g/l) = 1, Alb  $\leq 46.25$  g/l = 0, Alb  $> 46.25$  g/l = 1, TC  $\leq 4.71$  mmol/l = 0, TC  $> 4.71$  mmol/l = 1, TG  $\leq 1.73$  mmol/l = 0, TG  $> 1.73$  mmol/l = 1, LDL  $\leq 2.52$  mmol/l = 0, LDL  $> 2.52$  mmol/l = 1, HDL  $\leq 1.35$  mmol/l = 0, HDL  $> 1.35$  mmol/l = 1)

WHR = Waist-to-hip Ratio, BMI = body mass index, SBP = systolec blood pressure, DBP = diastolec blood pressure, Hb = haemoglobin, Alb = albumin, TC = total cholesterol, TG = triglyceride = LDL = low density lipoprotein cholesterol, HDL = high density lipoprotein.

**Table 4**  
The relationship between eGFR and BMI, Waist circumference, Hip circumference in people with moderate CKD.

		Underweight ( $<18.5 \text{ kg/m}^2$ )	Healthy weight ( $18.5\text{--}24.9 \text{ kg/m}^2$ )	Overweight ( $25.0\text{--}29.9 \text{ kg/m}^2$ )	Obese ( $\geq 30.0 \text{ kg/m}^2$ )
Moderate CKD (n, %)	774 (10.2)	45 (12.1) <sup>§</sup>	373 (8.6)	288 (11.5) <sup>§&amp;</sup>	68 (17.2) <sup>§&amp;</sup>
eGFR (ml/min $1.73 \text{ m}^2$ )	All	$48.92 \pm 10.38$	$51.28 \pm 9.43$	$49.82 \pm 9.87$	$47.66 \pm 9.37$
	WHR $\leq 0.894$	$53.63 \pm 9.62$	$52.73 \pm 7.84^{\#}$	$51.22 \pm 9.86^{\#}$	$49.76 \pm 9.39$
	WHR $> 0.894$	$47.10 \pm 12.04$	$48.85 \pm 9.76^*$	$48.16 \pm 9.81^*$	$44.63 \pm 13.75$
Waist Circumference (cm)	All	$72.34 \pm 13.62^{\&}$	$81.59 \pm 6.97$	$93.09 \pm 7.89^{\&}$	$98.42 \pm 10.23^{\&}$
	WHR $\leq 0.894$	$67.81 \pm 6.38^{* \# \#}$	$78.53 \pm 6.57^{\# \#}$	$86.33 \pm 7.76^{* \# \#}$	$77.50 \pm 10.61$
	WHR $> 0.894$	$78.14 \pm 19.70$	$82.58 \pm 6.81^{**}$	$93.72 \pm 7.65^{* \# \#}$	$99.09 \pm 9.57^{* \# \#}$
Hip Circumference (cm)	All	$81.83 \pm 20.95^{\&}$	$91.79 \pm 6.11$	$99.53 \pm 6.30^{\&}$	$103.92 \pm 7.85^{\&}$
	WHR $\leq 0.894$	$84.63 \pm 4.36^{* \# \#}$	$93.20 \pm 5.43^{\#}$	$100.13 \pm 6.55^{* \# \#}$	$90.00 \pm 7.07$
	WHR $> 0.894$	$87.93 \pm 17.80^*$	$91.33 \pm 6.25^*$	$99.48 \pm 6.29^{* \# \#}$	$104.36 \pm 7.51^{* \# \#}$

\* compared with group of Healthy weight and WHR  $\leq 0.894$ ,  $P < .05$ , \*\* compared with group of Healthy weight and WHR  $\leq 0.894$ ,  $P < .01$ ;  
<sup>#</sup> compared with group of Healthy weight and WHR  $> 0.894$ ,  $P < .05$ , <sup>##</sup> compared with group of Healthy weight and WHR  $> 0.894$ ,  $P < .01$   
<sup>&</sup> compared with group of Healthy weight (All),  $P < .05$ , <sup>&&</sup> compared with group of Healthy weight (All),  $P < .01$ ;

**4. Discussion**

Due to the rising prevalence of CKD, the prevention, treatment, and detection of the disease in the early stage is under the focus of the doctor. Overweight and obesity are closely related to CKD according to the epidemiological studies. Overweight, obesity, diabetes, cardiovascular disease, and some tumors have been listed as the focus of global public health. In the present study, irrespective of the gender and in the general population, the WHR of patients with eGFR  $< 70 \text{ ml/minutes}/1.73 \text{ m}^2$  was significantly higher than that of patients with higher eGFR. Compared to BMI, WHR exhibited a correlation with the progress in renal function. In creatinine-based models, WHR increased the risk of CKD by 22%, albeit no significant correlation was established between BMI and CKD. Therefore, the researchers suggested using WHR instead of BMI as a predictor of CKD.<sup>[10]</sup>

This phenomenon might be attributed to the inability of BMI to distinguish among peripheral fat, visceral fat, and muscle tissue.<sup>[14,15]</sup> The WHR can indirectly reflect visceral obesity, which is an independent risk factor for cardiovascular events in non-dialysis patients. Visceral obesity is also an independent risk factor for cardiovascular disease in the normal population. However, multivariate linear regression analysis found that WC, not WHR, was an independent risk factor for eGFR after correcting the general conditions and biochemical indicators. Although WHR can indirectly respond to visceral obesity, it cannot distinguish whether the increase in WHR is due to

decreased gluteal muscle mass or increased visceral fat. In the general population, the most widely used measure of central fat distribution is waist circumference, which is easier to determine than WHR and provides equivalent prognostic information.<sup>[16]</sup> Interestingly, unlike WHR, WC is an established criterion for the diagnosis of metabolic syndrome. One study suggested that WC and visceral obesity are closely related in CKD patients, with a correlation coefficient of 0.75 for men and 0.81 for women.<sup>[17]</sup> In a study consisting of 4222 participants, the increase in BMI and WHR was closely related to the incidence of CKD, after adjusting for smoking, drinking, age, and sex. However, the majority of the patients with CKD in this study were stage CKD1-2, while only a small number of patients had eGFR  $< 60 \text{ ml/minutes}/1.73 \text{ m}^2$ .<sup>[18]</sup> In this study, we focus on the moderate CKD patients and the moderate CKD patients with WC and BMI as independent risk factors for predicting the occurrence of CKD; even if the general situation and biochemical indicators were corrected, the OR values were 1.362 and 1.227, respectively. Therefore, WHR may not be an optimal indicator for moderate CKD patients.

BMI is recommended by the WHO to assess whether a patient is overweight or obese. BMI (at  $> 25$  and  $< 30 \text{ kg/m}^2$ , and  $> 30 \text{ kg/m}^2$  was defined as overweight and obesity, respectively.<sup>[14]</sup> The correlation between BMI and the all-cause mortality in healthy population showed an anti-J shape. Compared to normal BMI ( $> 18.5$ ,  $< 25 \text{ kg/m}^2$ ), BMI  $< 18.5 \text{ kg/m}^2$  and  $> 30 \text{ kg/m}^2$  significantly increased the risk of all-cause mortality.<sup>[12]</sup> However, high BMI might also affect the progress of the renal function. Xie et al

**Table 5**  
Association between moderate CKD and WHR, BMI, WC.

Model	WHR per SD (0.147) greater		BMI per SD (5.07 kg/m <sup>2</sup> ) greater		WC per SD (10.763) greater	
	OR	P	OR	P	OR	P
Unadjusted	1.056 (1.002, 1.113)	.043	1.061 (0.983, 1.146)	.129	1.200 (1.107, 1.301)	$< .001$
Life Adjusted <sup>*</sup>	1.080 (0.998, 1.170)	.058	1.115 (1.007, 1.234)	.036	1.138 (1.043, 1.242)	.004
Full Adjusted <sup>**</sup>	1.011 (0.923, 1.107)	.841	1.230 (1.037, 1.458)	.017	1.173 (1.024, 1.344)	.021

\* Adjusted for age, sex, smoking, Alcohol Use,

\*\* Adjusted for lifestyle model plus BMI, Hb, Alb, TC, TG, HDL, LDL, SBP, DBP.

Multivariate logistic regression analysis of moderate CKD patients. After adjusting lifestyle and clinical data, each SD of high BMI and WC level but not WHR was higher risk of moderate CKD.

showed that the risk of renal function progress increased by 82% in hypertensive patients with BMI >28.0 kg/m<sup>2</sup> with normal renal function. Increased BMI was an independent risk factor for renal function progression.<sup>[19]</sup> Intriguingly, the effect of BMI on renal function may also be related to age. The higher the BMI, the more severe the loss of renal function and the higher the mortality in patients >40-years-old. BMI and renal function did not seem to correlate in younger patients (<40-years-old). However, in the current study, BMI was not significantly correlated with eGFR, but BMI was found to be an independent risk factor for moderate CKD. For every SD add to BMI, the risk of CKD increased by 23.0%. This correlation persisted even if habits and biochemical indicators were corrected. In a recent study of 3,376,187 subjects, BMI (>30 kg/m<sup>2</sup>) was found to be closely related to the rapid loss of renal function in patients with eGFR (>60 ml/minutes/1.73 m<sup>2</sup>).<sup>[20]</sup> In the current study, eGFR of people with moderate CKD showed an inverted “J” pattern. BMI in the 18.5 to 24.9 kg/m<sup>2</sup> group exhibited the maximal eGFR level. With the gradual increase and decrease of BMI, the level of eGFR was gradually decreased.

Since WC and BMI are related indicators of metabolic syndrome and obesity, this study evaluated the correlation between obesity and CKD. Although there are reports that WHR is associated with the occurrence of CKD, in this study, WC is an independent risk factor affecting eGFR and predicting CKD after correcting the general condition and biochemical indicators of the patients. WC is strongly correlated with visceral fat and an independent risk factor for cardiovascular events in CKD patients.<sup>[14]</sup> High WHR cannot differentiate between lower gluteal muscle due to malnutrition or visceral obesity. In the present study, the level of eGFR of overweight and WHR <0.894 groups was significantly higher than that of healthy weight and WHR >0.894 groups. Although the WC in the former group was slightly larger than that in the latter group, and the hip circumference of the former was significantly larger than that of the latter group. This phenomenon indicated that the overweight in the overweight and WHR <0.894 groups was caused by the increase in hip circumference, and not by the increase in WC. The WHR cannot distinguish the correlation between visceral obesity and gluteal muscles, and hence, WC has more predictive value. Multiple linear regression analysis also supported that WC is an independent risk factor for predicting the eGFR level.

In the current study, high BMI is an independent risk factor for predicting CKD, which is caused by the increase in renal sinus fat,<sup>[21]</sup> glomerulomegaly,<sup>[22]</sup> and glomerular hypertension.<sup>[23]</sup> Overweight and obese patients increase the risk of hypertension and diabetes mellitus, which leads the kidney to have high perfusion and filtration. Hyperfiltration in patients with high BMI often occurs at an early age in the case of prehypertension and prediabetes.<sup>[24]</sup> The structural and physiological changes in nephrons result from obesity, which might occur after prolonged exposure, followed by irreversible pathological change.<sup>[25]</sup> Therefore, long-time and continuous control of ideal BMI is an effective means to protect the kidney.

Nevertheless, the present study has several limitations. First, the definition of CKD in the study was limited to patients with eGFR <60 ml/minutes/1.73 m<sup>2</sup>. Due to the lack of data on urine protein, the prevalence of CKD might be underestimated. Second, this study mainly focused on patients with eGFR <60 ml/minutes/1.73 m<sup>2</sup>. The lack of data on patients with eGFR >60 ml/minutes/1.73 m<sup>2</sup> might not reflect the characteristics of CKD patients. Third, there was no long-term follow-up in this study. Whether BMI and WC predicted the prognosis of CKD patients and CVD

complications is yet unknown. Finally, the subjects in this study were urban residents, which could not represent the characteristics of the vast rural population. Thus, we need to continue to follow up patients to observe if BMI and WC can predict the occurrence of cardiovascular events and the progression of kidney disease.

In conclusion, the association between BMI and eGFR in this cohort of patients with CKD is anti-J shaped. WC is an independent risk factor for eGFR. BMI and WC are important factors that would predict moderate CKD patients. Thus, randomized controlled trials are essential to deduce the optimal BMI and WC in the case of eGFR loss interventions and the optimal duration for which such interventions should be maintained to achieve satisfactory clinical outcomes.

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