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 analysis associated 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 ± 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 ≤ 0.894 was higher than in the healthy weight group with WHR > 0.894 group (P = .036). Overweight with WHR ≤ 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.\textsuperscript{[1,2]} Overweight and obesity are closely related to CKD.\textsuperscript{[3]} The links between them are numerous and complex. This complexity may be explained by inflammation, increased oxidative, insulin resistance, hypertension and dyslipidemia.\textsuperscript{[4]}

Body mass index (BMI) is a critical and convenient indicator for assessing whether a subject is overweight or obese. High BMI
contributed to an estimated 4 million deaths globally in 2015. Several studies have shown a U-shaped association between BMI and minimum mortality in the healthy weight (20–25 kg/m²) range. The BMI also had a J-shaped association with the overall mortality and the specific causes of death. Recent studies have shown that BMI may be a predictor of kidney disease. BMI ≥30 kg/m² was associated with the rapid loss of kidney function in a patient with eGFR ≥60 ml/minute/1.73 m². 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 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 showed WC is a strong predictor of adverse events and has relationship with adverse clinical outcomes in CKD. 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/minute/1.73 m²) 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/minute/1.73 m²) at the first examination were followed up after 3 months. CKD was defined as eGFR <60 ml/minute/1.73 m² for >3 months. According to CKD stage, eGFR <60 ml/minute/1.73 m² 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 (m²). Obese, overweight, healthy weight, and underweight were defined as BMI ≥30.0, 25.0 to 29.9, 18.5 to 24.9, and <18.5 kg/m², respectively. Estimated GFR was calculated using the CKD Epidemiology Collaboration creatinine 2009 equation. 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 having a history of diagnosis, systolic blood pressure ≥140 mmHg, diastolic ≥90 mmHg, or use of antihypertensive medications.

2.3. Statistical analysis
Continuous variables were described as mean ± 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. All the variables were set to binary dependent variables. 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 ± 7.30 years. The mean BMI, WHR, and WC were 23.91 ± 0.90 kg/m², 0.90 ± 0.15, and 85.50 ± 10.71 cm, respectively. The mean baseline serum creatinine was 74.30 ± 2.13 mmol/L, and mean eGFR was 81.54 ± 17.58 ml/minute/1.73 m². 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 were 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, eGFR, with a multiple linear regression analysis was performed (Table 2). Age (β = −1.039, 95% confidence interval (CI): −1.117 to −0.962, P < .001), Hb (β = 0.112, 95% CI: 0.074–0.150, P < .001), HDL (β = 1.931, 95% CI: 0.240–5.115, P = .023), WC (β = −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 | I: 70.76 (n = 1899) | II: 70.76–83.25 (n = 1898) | III: 83.25–92.68 (n = 1898) | IV: 92.68 (n = 1898) |
|---|---|---|---|---|
| **Demographics** | | | | |
| Male, n (%) | 3427 (45.1) | 822 (44.3) | 879 (46.3) | 633 (33.4)** 1093 (57.6)** |
| Age, yr | 72.34 ± 7.30 | 76.34 ± 7.80 | 73.13 ± 6.90** 71.49 ± 6.00 | 74.30 ± 9.59** 68.39 ± 9.59** |
| 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) 396 (20.8)** |
| Diabetes, n (%) | 672 (8.65) | 162 (8.53) | 175 (9.23) | 169 (8.95) 167 (8.60) |
| **Physical Findings** | | | | |
| SBP, mm Hg | 141.43 ± 21.18 | 143.39 ± 21.67 | 141.73 ± 20.22** 140.91 ± 20.72** | 139.62 ± 21.90** |
| DBP, mm Hg | 79.42 ± 14.80 | 78.28 ± 11.96 | 79.18 ± 11.81 | 79.70 ± 10.66** 80.58 ± 10.24** |
| BMI, kg/m² | 23.91 ± 5.04 | 23.97 ± 9.91 | 23.82 ± 9.00 | 23.97 ± 8.09 23.88 ± 9.00 |
| WHR | 0.89 ± 0.15 | 0.91 ± 0.16 | 0.90 ± 0.11 | 0.89 ± 0.08** 0.90 ± 0.21** |
| WC (cm) | 85.50 ± 10.71 | 86.49 ± 9.88 | 85.49 ± 12.29** 84.71 ± 10.42** | 85.28 ± 10.00** |
| WC (cm) (Male) | 87.49 ± 11.10 | 88.89 ± 9.48 | 87.79 ± 14.84** 87.17 ± 9.15** | 86.38 ± 9.5** |
| WC (cm) (Female) | 83.88 ± 10.70 | 84.66 ± 9.80 | 83.52 ± 9.13 | 83.58 ± 10.80** 83.79 ± 10.47** |
| **Baseline Laboratory Results** | | | | |
| Scr, mmol/l | 74.30 ± 23.13 | 96.44 ± 31.99 | 75.98 ± 10.46*** 64.73 ± 10.31*** | 60.02 ± 10.58** |
| eGFR, ml/min 1.73m² | 81.54 ± 15.78 | 59.82 ± 10.33 | 77.30 ± 8.63** 88.20 ± 7.05** | 101.74 ± 11.26** |
| Hb, g/l | 136.18 ± 15.00 | 132.55 ± 17.27 | 136.63 ± 14.70** 136.42 ± 13.41** | 138.96 ± 13.91** |
| Alb, g/l | 46.25 ± 3.30 | 45.97 ± 3.46 | 46.27 ± 3.26 46.26 ± 3.12 | 46.51 ± 3.24** |
| TC, mmol/l | 4.71 ± 2.00 | 4.69 ± 1.58 | 4.68 ± 1.09 | 4.82 ± 2.02 4.62 ± 2.22 |
| TG, mmol/l | 1.73 ± 1.64 | 1.77 ± 1.23 | 1.71 ± 1.21 | 1.81 ± 1.57 1.63 ± 1.14 |
| LDL, mmol/l | 2.52 ± 0.86 | 2.52 ± 0.88 | 2.54 ± 0.84 | 2.55 ± 0.87 2.47 ± 0.85 |
| HDL, mmol/l | 1.35 ± 0.34 | 1.32 ± 0.33 | 1.36 ± 0.35** 1.38 ± 0.34** | 1.36 ± 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 |          |          |
|------------------|---------------------|----------|----------|------------------------|----------|----------|
|                  | β                   | P        | β        | P                      | β        | P        |
| Age              | −0.957 (~1.007, −0.907) | <.001    | −1.039 (~1.117, −0.962) | <.001    |
| SBP              | −0.05 (~−0.07, −0.03)  | <.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)  | 0.088    |          |                        |          |
| TG               | −0.229 (~0.491, 0.034) |          | 0.088    |                        |          |
| HDL              | 1.776 (0.504, 3.048)   | 0.006    | 1.931 (0.240, 5.115)    | .025     |
| LDL              | −0.162 (~0.663, 0.339) | 0.527    |          |                        |          |
| BMI              | 0.002 (~0.078, 0.082)  | 1.964    |          |                        |          |
| WHR              | −3.436 (~6.147, −2.726) | .013     |          |                        |          |
| WC               | −0.083 (~0.121, −0.045) |          | −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.

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 <0.894 group had the highest value of eGFR as compared to the other groups. The value of eGFR in the overweight with WHR <0.894 group was higher than in the healthy weight with WHR >0.894 group (P = .036). Although the obese with WHR <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 <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 value  | 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                | 1.023−1.431 | .001     |
| 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                | 0.164−2.988 | .221    |
| Hb               | 0.437                | 0.335−5.71 | <.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                | 0.731−1.557 | .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 ≤65.5 cm = 0, WC >65.5 cm = 1; WHR ≤0.894 = 0, WHR >0.894 = 1, BMI <24.90 = 0, BMI ≥24.90 = 1; Smoker = 1, no smoker = 0; Alcohol = 1, no Alcohol = 0; Male = 1, Female = 0; Diabetes = 1, no-Diabetes = 0; Age <72.34 (g) = 0, Age ≥72.34(g) = 1; SBP ≤141.43 mm Hg = 0, SBP >141.43 mm Hg = 1; DBP ≤79.42 mm Hg = 0, DBP >79.42 mm Hg = 1, Hb ≤136.18 g/l = 0, Hb >136.18 g/l = 1, Alb ≤46.25 g/l = 0, Alb >46.25 g/l = 1, TC ≤7.91 mmol/l = 0, TC >7.91 mmol/l = 1, TG ≤1.73 mmol/l = 0, TG >1.73 mmol/l = 1, LDL ≤2.52 mmol/l = 0, LDL >2.52 mmol/l = 1, HDL ≥1.35 mmol/l = 1, HDL <1.35 mmol/l = 1; WHR = Waist-to-hip Ratio, BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic 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 kg/m²) | Healthy weight (18.5–24.9 kg/m²) | Overweight (25.0–29.9 kg/m²) | Obese (≥30.0 kg/m²) |
|----------------------|---------------------------|----------------------------------|-----------------------------|---------------------|
| Moderate CKD (n, %)  | 774 (10.2)                | 45 (12.1)a                        | 373 (8.6)                   | 288 (11.5)          |
|                      |                           | 288                              | 49.82 ± 9.87                | 47.66 ± 9.37        |
|                      |                           | 45                               | 51.28 ± 9.43                | 49.07 ± 9.39        |
|                      |                           | 373                              | 52.73 ± 7.84a               | 51.22 ± 9.86a       |
|                      |                           | 288                              | 48.85 ± 9.76                | 48.16 ± 9.81a       |
|                      |                           | 68                               | 81.59 ± 6.97                | 93.09 ± 7.89a       |
|                      |                           |                                  | 78.53 ± 6.57**              | 86.33 ± 7.76**      |
|                      |                           |                                  | 78.14 ± 10.70               | 93.72 ± 7.65**      |
|                      |                           |                                  | 82.58 ± 6.81                | 99.09 ± 9.57**      |
|                      |                           |                                  | 91.79 ± 6.11                | 103.92 ± 7.65a      |
|                      |                           |                                  | 93.20 ± 5.43*               | 100.13 ± 6.55**     |
|                      |                           |                                  | 91.33 ± 6.25                | 94.48 ± 6.29**      |
|                      |                           |                                  | 87.93 ± 17.80               | 104.36 ± 7.51**     |

* Compared with group of Healthy weight and WHR < 0.894, P < .05. ** Compared with group of Healthy weight and WHR ≥ 0.894, P < .01.
* Compared with group of Healthy weight and WHR > 0.894, P < .05. ### Compared with group of Healthy weight and WHR > 0.894, 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 ml/minutes/1.73 m² was significantly higher than that of patients with higher eGFR. Compared to BMI, WHR exhibited a correlation with the all-cause mortality in healthy individuals. Overweight, obesity, and WHR might also affect the progression of the renal function. Xie et al suggested using WHR instead of BMI as a correlation was established between BMI and CKD. Therefore, 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 <30 ml/minutes/1.73 m². Therefore, WHR was not an optimal indicator for moderate CKD. Compared to BMI, 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 <30 ml/minutes/1.73 m². Therefore, WHR was not an optimal indicator for moderate CKD.

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

|                      | WHR per SD (0.147) greater | BMI per SD (5.07 kg/m²) greater | WC per SD (10.763) greater |
|----------------------|---------------------------|--------------------------------|--------------------------|
| Model                | OR                         | P                             | OR                      | P                      | OR                  | P                      |
| Unadjusted           | 1.056                      | .043                          | 1.061                    | .129                   | 1.200               | <.001                  |
|                      | (1.002, 1.113)             |                               | (0.983, 1.146)           |                         | (1.107, 1.301)      |                         |
| Life Adjusted†       | 1.060                      | .058                          | 1.115                    | .036                   | 1.138               | .004                   |
|                      | (0.998, 1.170)             |                               | (1.007, 1.234)           |                         | (1.043, 1.242)      |                         |
| Full Adjusted†**     | 1.011                      | .041                          | 1.230                    | .017                   | 1.173               | .021                   |
|                      | (0.923, 1.107)             |                               | (1.037, 1.458)           |                         | (1.024, 1.344)      |                         |

* 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 progression increased by 82\% in hypertensive patients with BMI >28.0 kg/m² with normal renal function. Increased BMI was an independent risk factor for renal function progression. 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/m²) was found to be closely related to the rapid loss of renal function in patients with eGFR (>60 ml/minutes/1.73 m²). In the current study, eGFR of people with moderate CKD showed an inverted “J” pattern. BMI in the 15.8 to 24.9 kg/m² 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. 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, glomerulomegaly, and glomerular hypertension. 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. The structural and physiological changes in nephrons result from obesity, which might occur after prolonged exposure, followed by irreversible pathological change. 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 m². 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 m². The lack of data on patients with eGFR >60 ml/minutes/1.73 m² 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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