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ORIGINAL RESEARCH

Association Between Weight-Adjusted Waist Index and Albuminuria in Type 2 Diabetes Mellitus in the Chinese Population

Yu Qin, Jingjing Ye, Haoxiang Li, Xunan Wu, Yue Xia, Xia Deng

Department of Endocrinology, Affiliated Hospital of Jiangsu University, Zhenjiang, People's Republic of China

Correspondence: Xia Deng, Department of Endocrinology, Affiliated Hospital of Jiangsu University, Zhenjiang, 212000, People's Republic of China, Email dengxia11@outlook.com

Purpose: This study aimed to investigate the relationship between weight-adjusted waist index (WWI) and albuminuria in patients with type 2 diabetes mellitus (T2DM) in the Chinese population.

Patients and Methods: A total of 860 adult patients in the Department of Endocrinology of the Affiliated Hospital of Jiangsu University were retrospectively analyzed from June 2018 to September 2023. Correlations between WWI and albuminuria (albumin-to-creatinine ratio (UACR) ≥ 30 mg/g were defined as albuminuria) were analyzed using the Pearson and Spearman methods. The associations between albuminuria and Age, gender, body mass index (BMI), waist circumference/ hip circumference (WHR), systolic blood pressure(SBP), diastolic blood pressure (DBP), fasting plasma glucose (FPG), 2-hour postprandial plasma glucose (2h PG), fasting plasma insulin (FIns), 2-h postprandial insulin (2hINS), glycosylated hemoglobin (HbA1c), WWI, homeostasis model assessment of insulin resistance (HOMA-IR) were analyzed via binary logistic regression.

Results: Compared with the normal albumin group, serum urea nitrogen, serum creatinine, UACR, and WWI levels in the albuminuria group were significantly increased, while estimated glomerular filtration rate (eGFR) levels were significantly decreased ($P < 0.05$). Correlation analyses revealed that WWI was positively correlated with UACR but negatively correlated with urea nitrogen, serum creatinine, and eGFR ($P < 0.05$). Binary logistic regression analyses indicated that WWI was an independent risk factor for albuminuria in T2DM patients. Receiver operating characteristic curve results showed that the area under the curve for albuminuria as predicted by WWI was 0.605 [95% CI = (0.563–0.646), $P < 0.001$].

Conclusion: WWI is independently associated with albuminuria in the Chinese patients with type 2 diabetes and may serve as a simple indicator for albuminuria risk assessment.

Keywords: weight-adjusted waist index, kidney function, albuminuria, type 2 diabetes

Introduction

Diabetic kidney disease (DKD) is one of the most common microvascular complications in diabetic patients and one of the common causes of end-stage renal disease and death.[1] The main feature of DKD is an impaired glomerular filtration barrier, which is usually evaluated based on the eGFR.[2] In the early stages of DKD, clinical symptoms are typically not obvious and only manifest as glomerular hypertrophy, an increased glomerular filtration rate, slight morphological changes in the glomeruli, and microalbuminuria. However, as the disease progresses, glomerulosclerosis and tubulointerstitial fibrosis manifest, which then gradually lead to the deterioration of renal function and massive macroalbuminuria, followed by end-stage renal disease.[3,4] Therefore, UACR is often used as an evaluation indicator for early-stage DKD.[5,6] Several studies have shown that obesity can lead to renal dysfunction and the aggravated deterioration of renal function, seriously affecting patient quality of life.[7,8] Albuminuria and chronic kidney disease (CKD) progression can be significantly alleviated by drugs, surgery, alimentary control, exercise, and weight loss.[9–11]

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BMI is the traditional index used to assess obesity, but it cannot distinguish between fat-free weight and fat weight.[12] Therefore, Park et al[13] first proposed the WWI, which can be readily measured by normalizing waist circumference (WC) to body weight, as an alternative index for obesity. This index leverages the benefits of WC while weakening its correlation with BMI, allowing it to assess both fat mass and muscle mass. Previous studies have reported that WWI is closely related to the risk of hyperuricemia,[14] diabetes,[15] and cardiovascular disease.[16] However, no relevant studies have reported the relationship between WWI and albuminuria in patients with T2DM in the Chinese population. Therefore, the purpose of this study was to investigate the relationship between WWI and albuminuria in the Chinese T2DM patients.

Materials and Methods

Study Participants

This was a cross-sectional study based on a population of T2DM patients in Zhenjiang, Jiangsu, China. A total of 860 patients with T2DM, aged 52.92 ± 11.71 years old, were retrospectively selected from the Department of Endocrinology of the Affiliated Hospital of Jiangsu University from June 2018 to September 2023, comprising 505 men and 355 women.This study was divided into groups according to UACR ≥ 30 mg/g. This research complies with the principle of the Helsinki Declaration. To be eligible for inclusion, patients had to have been diagnosed as per the diagnostic criteria for diabetes established by the American Diabetes Association.[17] Hypertension was defined as SBP ≥ 140 mmHg and/or DBP≥90 mmHg.[18]

The exclusion criteria were as follows: 1) other types of diabetes; 2) acute complications of diabetes mellitus (diabetic ketoacidosis, diabetic lactic acidosis); 3) chronic viral or bacterial infections (severe infection of respiratory system, urinary system, etc); 4) other serious kidney diseases or drug-induced kidney diseases; 5) severe liver disease; 6) asthma or other autoimmune diseases; 7) tumors; or 8) mental illnesses (such as schizophrenia and depression). In addition, to reduce the influence of renal failure on outcomes, we excluded all T2DM patients with an eGFR of less than or equal to 30 mL/min/1.72m2. This study was approved by the Medical Ethics Committee of the Affiliated Hospital of Jiangsu University. All participants provided informed consent to participate.

Collection of Clinical and Biochemical Data

General clinical data were collected, including age, sex, WC (measured by circling the abdomen through the midpoint of the line connecting the twelfth rib of the mid-axillary line on both sides and the anterior superior iliac spine), hip circumference (HC; measured using a soft ruler to circle the pubic symphysis and the most convex portion of the buttocks), blood pressure (Systolic and diastolic blood pressure were measured after 15 minutes of rest), height, and weight.

After 8 hours of overnight fasting, venous blood was collected, and both fasting and 2-hour postprandial blood glucose levels were detected via the glucose oxidase method. In addition, fasting and 2-hour postprandial insulin levels were detected using a chemiluminescence method, while HbA1c levels were detected through high-performance liquid chromatography. An automatic biochemical testing instrument was used to detect liver and kidney function and to conduct lipid analyses, such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), uric acid (UA); triglyceride (TG); total cholesterol (TC); high-density lipoprotein cholesterol (HDL-c); low-density lipoprotein cholesterol (LDL-C), blood urea nitrogen (BUN); serum creatinine (Scr). Urine was collected in the middle of the morning, and the albumin and creatinine levels in these urine samples were detected with an automated biochemical detection instrument, allowing for the calculation of UACR. T2DM patients with a UACR of < 30 mg/g were defined as being in the normal albumin group (n = 584), while T2DM patients with a UACR of ≥ 30 mg/g were defined as being in the albuminuria group (n = 276).[19]

WWI was determined by dividing WC (cm) by the square root of body weight (kg).

The glomerular filtrate rate was calculated using the CKD-EPI formula:

$eGFR = a \times (Scr/b)^{c} \times (0.993)^{age,}$ eGFR < 90 is abnormal[20]

a = 141 for men and 144 for women; b = 0.9 for men and 0.7 for women; and c = −0.411 for men with Scr ≤ 0.9mg/dL, −1.209 for men with Scr > 0.9mg/dL, −0.329 for women with Scr ≤ 0.7mg/dL, and −1.209 for women with Scr > 0.7mg/dL.[21]

HOMA − IR = fasting plasma glucose(FPG) (mmol⁄L) × fasting plasma insulin(FIns),(U⁄mL)⁄22.5,HOMA-IR>2.7 is abnormal[22]

WHR=WC/HC;

BMI = Weight (kg)/[Height (m)]^2

Statistical Analysis

Statistical analyses were performed using SPSS version 22.0. For normally distributed data, continuous variables were expressed as mean ± SD; for skewed data, continuous variables were expressed as median [quartile (IQR)]; and for categorical variables, the data were expressed as frequencies (n) and percentages (%). One-way ANOVA was used to compare data between groups. Spearman/Pearson correlations were used to analyze the correlations between WWI and clinical parameters. The factors influencing renal function and albuminuria were analyzed through binary logistic regression analyses. $P < 0.05$ was considered statistically significant. To evaluate the predictive performance of WWI for the risk of albuminuria in T2DM, receiver operating characteristic (ROC) curves were generated. Optimal cut-off values were derived from the Youden index (maximum [sensitivity + specificity − 1]). All significance tests were two-tailed, with $P < 0.05$ as the threshold for statistical significance.

Results

Characteristics of the Study Population According to Albuminuria Status

All participants (860) were divided into a normal albumin group and an albuminuria group. The prevalence of increased albuminuria among participants was (n=276) 32.1%. Compared with the normal albumin group, the albuminuria group exhibited a higher prevalence of hypertension, a longer course of disease, and significantly increased BUN, Scr, UACR, WWI, blood pressure, BMI, WHR, FIns, 2hIns, UA, TG, and HOMA-IR levels, whereas eGFR and HDL-c levels were significantly decreased ($P < 0.05$) (Table 1).

Table 1 Baseline Clinical Characteristics of All Patients

	T2DM with Normal Albumin Levels (n = 584)	T2DM with Albuminuria (n = 276)	$Z/\chi^2/t$	*P* value
Age(y)	52.78±11.38	53.48±12.42	−0.890 [a]	0.374
Sex (male/female)	333/251	172/104	2.171[b]	0.141
Smoking[n(%)]	196(33.6%)	99(35.9%)	0.443 [b]	0.506
Hypertension[n(%)]	206(35.3%)	144(52.2%)	22.180 [b]	<0.001
Duration of T2DM (m)	26.50(0.00–102.75)	55.00(0.25–121.00)	−2.731	0.006
DBP(mmHg)	75(68.00–82.00)	77(70.00–86.75)	−3.292	0.001
SBP(mmHg)	124.00(114.00–136.00)	133.00(117.00–146.00)	−5.769	<0.001
BMI	23.85(22.10–26.30)	24.95(23.03–27.10)	−3.837	<0.001
WHR	0.92(0.88–0.96)	0.94(0.90–0.98)	−5.276	<0.001
FPG (mmol/L)	10.27(8.04–12.99)	10.56(8.24–13.40)	−1.157	0.247
2hPG (mmol/L)	19.34±5.27	19.46±5.65	−0.237[a]	0.812
FIns (μIU/mL)	5.67(3.51–9.47)	7.47(4.48–12.15)	−4.659	<0.001
2hIns (μIU/mL)	21.53(13.16–36.87)	25.67(14.01–41.62)	−2.083	0.037
HbA1c (%)	9.75(8.00–11.30)	10.00(8.70–11.38)	−1.551	0.121

(*Continued*)

Table 1 (Continued).

	T2DM with Normal Album Levels (n = 584)	T2DM with Albuminuria (n = 276)	$Z/\chi^2/t$	*P* value
ALT (U/L)	19.35(13.40–32.18)	20.40(13.00–33.78)	−0.632	0.527
AST (U/L)	16.00(12.63–22.98)	16.60(13.00–23.10)	−0.717	0.473
UA (μmol/L)	270.00(212.00–323.00)	296.50(240.50–357.00)	−4.526	<0.001
TG (mmol/L)	1.67(1.22–2.55)	2.00(1.36–3.08)	−3.807	<0.001
TC (mmol/L)	4.84(4.23–5.62)	4.87(4.24–5.74)	−0.819	0.413
HDL-c (mmol/L)	1.15(0.95–1.41)	1.07(0.84–1.29)	−3.970	<0.001
LDL-c (mmol/L)	2.85(2.34–3.53)	2.79(2.23–3.53)	−0.397	0.692
HOMR-IR	2.55 (1.54–4.26)	3.28(2.20–5.31)	−4.982	<0.001
BUN (mmol/L)	5.20(4.33–6.10)	5.44(4.49–6.45)	−2.307	0.021
Scr (μmol/L)	56.15(48.63–65.90)	60.00(47.00–71.08)	−2.391	0.017
eGFR (mL/[min 1.73m^2])	106.25(99.66–116.56)	104.48(95.13–115.71)	−2.500	0.012
UACR (mg/g)	7.68(3.80–13.03)	89.07(48.24–242.00)	−23.698	<0.001
WWI	10.71(10.30–11.01)	10.95(10.46–11.48)	−4.958	<0.001

Notes: a is the *t* value, b is the χ^2 value, and the rest is the *Z* value.

Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure; BMI, body mass index; WHR, waist-to-hip ratio; FPG, fasting plasma glucose; 2hPG, 2-hour postprandial plasma glucose; FIns, fasting plasma insulin; 2hIns, 2-hour postprandial plasma insulin; HbA1c, glycosylated hemoglobin c; ALT, alanine aminotransferase; AST, aspartate aminotransferase; UA, uric acid; TG, triglyceride; TC, total cholesterol; HDL-c, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HOMR-IR, homeostasis model assessment-insulin resistance index; BUN, blood urea nitrogen; Scr, serum creatinine; eGFR, Estimated glomerular filtration rate. a Median (interquartile range); UACR, urinary albumin-to-creatinine ratio; WWI, weight-adjusted waist circumference index.

Correlations Between WWI and Other Parameters

In all participants, WWI was positively correlated with age, SBP, WHR, BMI, FIns, 2hIns, TC, LDL-c, HOMR-IR, and UACR levels, whereas it was negatively correlated with BUN, Scr, and eGFR levels ($P < 0.05$) (Table 2).

Binary Logistic Regression Analysis of UACR in T2DM Patients

To assess the effects of WWI on the risk of albuminuria in T2DM, we used a binary logistic regression model. The dependent variable was whether patients had albuminuria (normal UACR = 0; abnormal UACR = 1). Age, gender, BMI, WHR, SBP, DBP, FPG, 2h PG, FIns, 2h Ins, HbA1c, WWI, and HOMA-IR were independent variables, and a binary logistic regression analysis was performed. The results showed that WWI, SBP, Scr, UA, and HDL-c were independent risk factors for an abnormal UACR in T2DM patients (Table 3).

Table 2 Correlation of WWI with Clinical Parameters

	r	P
Age	0.377	<0.001
DBP	−0.013	0.710
SBP	0.154	<0.001
BMI	0.244	<0.001
WHR	0.514	<0.001
FPG	−0.030	0.376
2hPG	0.036	0.298
FIns	0.220	<0.001
2hIns	0.248	<0.001
HbA1c	−0.013	0.704
ALT	0.019	0.576

(*Continued*)

Table 2 (Continued).

	r	P
AST	0.064	0.063
UA	0.015	0.660
TG	0.104	0.002
TC	0.125	<0.001
HDL-c	0.011	0.743
LDL-c	0.093	<0.001
HOMR-IR	0.208	<0.001
BUN	−0.075	0.028
Scr	−0.217	<0.001
eGFR	−0.277	<0.001
UACR	0.152	<0.001

Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure; BMI, body mass index; WHR, waist-to-hip ratio; FPG, fasting plasma glucose; 2hPG, 2-hour postprandial plasma glucose; FIns, fasting plasma insulin; 2hIns, 2-hour postprandial plasma insulin; HbA1c, glycosylated hemoglobin c; ALT, alanine aminotransferase; AST, aspartate aminotransferase; UA, uric acid; TG, triglyceride; TC, total cholesterol; HDL-c, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HOMR-IR, homeostasis model assessment-insulin resistance index; BUN, blood urea nitrogen; Scr, serum creatinine; eGFR, Estimated glomerular filtration rate. a Median (interquartile range); UACR, urinary albumin-to-creatinine ratio; WWI, weight-adjusted waist circumference index.

Table 3 Results of Binary Logistic Regression Analysis for UACR in T2DM Patients

	β	SE	Wald χ^2	P	OR	95% CI
WWI	0.356	0.149	5.684	0.017	1.428	1.065–1.913
SBP	0.027	0.006	18.607	<0.001	1.027	1.015–1.040
Scr	0.017	0.006	8.076	0.004	1.018	1.005–1.030
UA	0.002	0.001	4.244	0.039	1.002	1.000–1.004
HDL-c	−0.863	0.316	7.444	0.006	0.422	0.227–0.784
Constant	−11.046	1.683	43.069	<0.001	0.000	

Abbreviations: WWI, weight-adjusted waist circumference index; SBP, systolic blood pressure; Scr, serum creatinine; Scr, serum creatinine; HDL-c, high-density lipoprotein cholesterol.

Assessment of the Predictive Value of WWI for Albuminuria in T2DM

Finally, we analyzed the value of WWI for the diagnosis of albuminuria in T2DM. ROC curves yielded an AUC of 0.605 [95% CI = (0.563–0.646), $P < 0.001$], indicating that WWI offered diagnostic value for albuminuria in T2DM patients. The optimal cut-off for WWI was 11, with sensitivity and specificity values of 48.2% and 74.3%, respectively (Figure 1).

Discussion

In this study, the relationship between WWI and albuminuria in T2DM patients was investigated for the first time in a Chinese population. The results showed that WWI values in T2DM patients with albuminuria were significantly higher

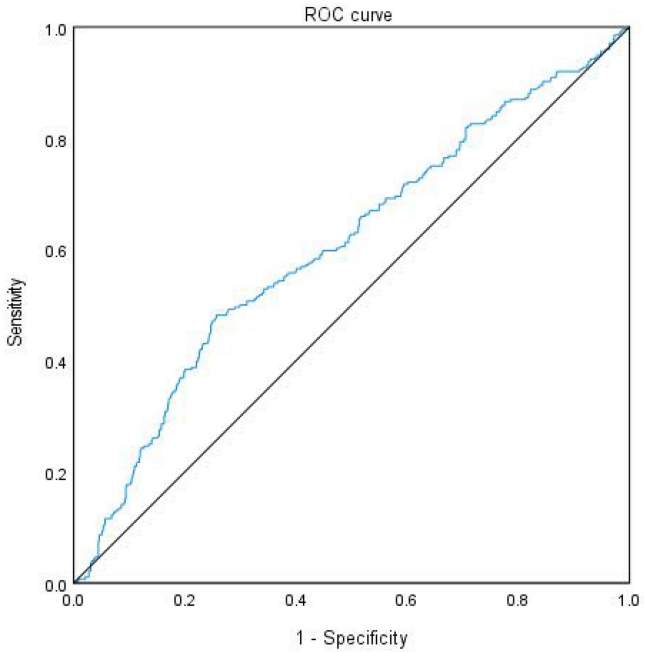

Figure 1 ROC curves of WWI indices in predicting albuminuria risk in T2DM patients.

than those in T2DM patients in the normal albumin group. Correlation analyses indicated that WWI was positively correlated with UACR and negatively correlated with eGFR. Regression analyses showed that WWI was independently associated with albuminuria, even after adjusting for multiple confounders. These results indicate that WWI, a simple indicator, can be used for the early prediction and evaluation of albuminuria.

Obesity is a condition caused by excessive accumulation of body fat.[23] Traditional measures of obesity such as BMI, WC, and WHR are associated with DKD risk, but the results are still controversial. For example, one study reported that patients who were overweight or obese rather than exhibiting abdominal obesity were more likely to develop DKD.[24] However, in another study, abdominal obesity was more closely associated with DKD than general obesity.[25] In addition, diabetic patients with a higher BMI have been shown to exhibit a lower risk of DKD and decreased kidney function.[26] As a new obesity-related indicator, WWI leverages the advantages of WC while weakening its correlation with BMI.[13] WWI is positively correlated with total fat mass and abdominal fat mass and negatively correlated with skeletal muscle mass.[27] In addition, WWI levels are reportedly significantly higher in metabolically unhealthy individuals relative to healthy subjects, even with similar levels of obesity.[28] Thus, WWI can reflect "true obesity" that is metabolically unhealthy. The results of this study revealed that the WWI levels in the albuminuria group were significantly higher than those in the normal albumin group. Correlation analyses indicated that WWI was positively correlated with UACR and negatively correlated with eGFR levels. ROC curve results further showed that the risk of albuminuria increased significantly after WWI was greater than 11. Studies of American adults have also found that WWI is closely related to albuminuria, and the correlation is stronger than that between BMI and WC.[29] Li et al found that WWI was positively correlated with CKD and albuminuria, and the correlation was better than that for other obesity indicators (BMI, WC, height, or weight), such that WWI was considered to be the best obesity indicator for predicting CKD and albuminuria.[19,29] The cut-off of WWI was 11.3446, and its prediction value for albuminuria was 0.5889 in Li'study.The cut-off of WWI was 11, and its prediction value for albuminuria was 0.605 in ours.Our study was based on a Chinese population. These two studies were based on an American population. Thus, WWI was a better predictor of urinary albumin in the Chinese population. Previous studies have also shown that visceral obesity, as assessed by visceral adiposity index(VAI) is significantly correlated with the increase in UACR levels in Chinese pre-diabetic subjects, indicating that abdominal obesity may be closely related to albuminuria.[30]

The results of this study also found that WWI was positively correlated with FIns, 2hIns, TG, TC, LDL-c, and HOMR-IR levels, among other indicators. An elevated WWI reflects a state of excessive body fat accumulation and increased muscle mass loss.[27] Muscle-fat imbalance leads to dysregulation of adipocytokine release, inflammation, dysregulated lipid metabolism, and insulin resistance.[31] Previous studies have shown that dyslipidemia, insulin resistance, and chronic inflammation play a crucial role in the development of DKD. When the reserve capacity of the adipose tissue is lower than the production of lipids, lipids will be deposited in the kidneys and other tissues and organs, leading to insulin resistance. Moreover, large amounts of lipid accumulation can promote lipopolysaccharide-induced inflammation through the 5' -adenylate activated protein kinase or peroxisome proliferator-activated receptor-α mediated signaling pathways, resulting in the extensive proliferation of glomerular basement membrane cells and aggravated glomerular sclerosis and tubulointerstitial damage.[32]

This study has some limitations. First, due to the cross-sectional nature of this study, we were unable to draw a causal relationship between WWI and albuminuria. Second, we adjusted for some potential covariates, but we could not completely exclude the influence of other possible confounding factors. Nevertheless, our results still show that WWI is closely related to the occurrence and development of albuminuria. For people with high WWI levels, early assessment of target organ damage and timely intervention may reduce the risk of DKD and improve prognosis. Moreover, WWI is simple to calculate, economical, and generally applicable to different populations. It may be a superior indicator for assessing obesity. Further longitudinal follow-up studies are needed to verify whether WWI can be used as an early screening tool to prevent early kidney disease in patients.

Conclusion

WWI is independently associated with albuminuria in the Chinese patients with type 2 diabetes and may serve as a simple indicator for albuminuria risk assessment.

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Disclosure

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