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ORIGINAL RESEARCH

Elevated Waist-to-Height Ratio Increases the Risk of Cardiovascular and Cerebrovascular Disease Mortality in Elderly Type 2 Diabetes Mellitus Populations

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Objective: To investigate the association between anthropometric indicators and cardiovascular and cerebrovascular disease (CCVD) mortality risk in elderly patients with type 2 diabetes mellitus (T2DM).

Methods: This retrospective cohort study included 897 elderly T2DM patients who received long-term follow-up from January 2017 to January 2020. Baseline data included demographics, medical history, and anthropometric indicators such as body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). The primary outcome was CCVD-related mortality. A Cox proportional hazards model was used to analyze associations between physical measurements and CCVD mortality risk.

Results: During a mean follow-up of 7.13 ± 2.45 years, 45 CCVD-related deaths occurred, with a mortality rate of 70.37 per 10,000 person-years. Cox regression analysis showed that higher WHtR was significantly associated with increased CCVD mortality risk in the overall population. Subgroup analyses revealed that elevated WHR predicted higher mortality risk in males, while increased BMI and WHtR were associated with greater CCVD mortality risk in females. Among patients without dyslipidemia or hyperuricemia, elevated WHtR also indicated increased mortality risk.

Conclusion: Elevated WHtR is an independent predictor of CCVD mortality in elderly T2DM patients. WHR in males and BMI in females are also important risk factors. Monitoring and managing abdominal obesity may help reduce CCVD-related deaths in this population.

Keywords: anthropometric measurements, abdominal obesity, waist-to-height ratio, cardiovascular mortality, type 2 diabetes mellitus, risk assessment, survival analysis

Introduction

Type 2 diabetes mellitus (T2DM) is a metabolic disease characterized by chronic hyperglycemia, involving complex mechanisms such as insulin resistance and insufficient insulin secretion.[1] In recent years, with the acceleration of global population aging, the prevalence of T2DM has been increasing among the elderly,[2] and the management of elderly T2DM patients has become a growing concern. Due to the chronic hyperglycemic state in T2DM patients, they are not only prone to multiple complications but also face a significantly increased risk of fatal diseases like cardiovascular and cerebrovascular diseases (CCVD).[3] Studies[4] have indicated that CCVD is one of the major causes of death in T2DM patients, with CCVD mortality rates in T2DM patients significantly higher than in non-diabetic populations. However, effectively identifying high-risk elderly T2DM patients and implementing targeted preventive measures remains a major challenge in clinical management.

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Physical measurement indicators such as body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) are commonly used to assess individual fat distribution and metabolic risk. Multiple studies[5–7] have confirmed that these physical measurement indicators are significantly associated with the risk of obesity, metabolic syndrome, and cardiovascular disease. Indicators like WHtR and WHR, which reflect abdominal fat distribution, have been increasingly recognized as potential predictors of CCVD risk in T2DM populations.[8,9] However, existing studies predominantly focus on middle-aged cohorts, neglecting the unique body composition changes and comorbidities (eg, sarcopenic obesity) in the elderly.[10] Comparative analyses of waist-to-height ratio (WHtR) versus traditional indices (BMI, WHR) for predicting cardiovascular and cerebrovascular disease (CCVD) mortality in type 2 diabetes mellitus (T2DM) patients are limited and inconsistent.[11] Additionally, sex- and comorbidity-specific variations (eg, dyslipidemia, hyperuricemia) in these associations have been underexplored, despite their known impacts on adiposity-metabolism interplay.[12]

To address these gaps, this study conducted a retrospective analysis of the clinical data of 897 elderly T2DM patients at Huaian Fifth People's Hospital Affiliated to Yangzhou University to investigate the relationship between physical measurement indicators (BMI, WC, HC, WHR, and WHtR) and CCVD mortality risk. Furthermore, this study examined the role of these indicators across different subgroups, classified by gender, dyslipidemia status, and uric acid levels, in order to provide a more comprehensive understanding of their predictive value for CCVD risk in elderly T2DM patients.

Subjects and Methods

Study Subjects

A retrospective analysis was conducted on the clinical data of 897 T2DM patients admitted to Huaian Fifth People's Hospital Affiliated to Yangzhou University between January 2017 and January 2020 and who underwent dynamic follow-up. Inclusion criteria: ① All patients were clinically confirmed with T2DM through relevant testing;[13] ② Age > 65 years, no gender restriction; ③ Adequate cognitive and communication abilities, with high compliance in study follow-up; ④ Complete and authentic clinical data available for analysis. Exclusion criteria: ① Non-T2DM cases; ② Missing significant baseline data or outcome variables; ③ Poor compliance or dropped out during follow-up. This study was approved by the Medical Ethics Committee of Huaian Fifth People's Hospital Affiliated to Yangzhou University (Approval No.: DM-2024-FZ-012), ensuring strict adherence to ethical guidelines, protecting the privacy and rights of patients throughout the study. The study was conducted in accordance with the principles of the Helsinki Declaration, ensuring that all participants' rights and welfare were protected.

Study Methods

The baseline survey included information on the patient's condition, physical examination, and laboratory testing.

(1) Patient Condition Survey: Basic patient information was collected through a detailed questionnaire, mainly covering demographic data, medical history, and medication history. This survey was conducted via face-to-face interviews by trained DM specialty nurses to ensure data accuracy and consistency. The questionnaire covered the patient's gender, age, education level, T2DM duration, smoking and alcohol history, and whether they had other metabolic diseases (eg, dyslipidemia and hyperuricemia). The diagnostic criteria for dyslipidemia were based on the literature,[14] defining it as TC > 6.22 mmol/L, HDL-C < 1.04 mmol/L, LDL-C > 4.14 mmol/L, or TG > 2.26 mmol/L. Hyperuricemia was diagnosed according to the literature,[15] defined as serum uric acid level > 420 μmol/L.

(2) Physical Examination: Measurements included height, weight, waist circumference (WC), and hip circumference (HC), with body mass index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) calculated. These metrics were measured by DM specialty nurses following a standardized process to ensure data accuracy and consistency. Height: Subjects stood barefoot, upright with eyes facing forward and arms relaxed, and height was recorded using a device accurate to 0.1 cm. Weight: The scale was placed on a stable, flat surface, and participants stood on the center of

the scale in light clothing, with weight recorded to the nearest 0.1 kg. WC: Participants stood relaxed, with the abdomen naturally relaxed. WC was measured by placing the tape horizontally around 1 cm above the navel, recorded to the nearest 0.1 cm. HC: Participants stood with hips relaxed, and the tape was horizontally placed around the widest part of the hips, recorded to the nearest 0.1 cm. Based on the measurements, the following physical metrics were calculated: $\mathrm{BMI} = \mathrm{Weight(kg)}/\mathrm{Height}\left(\mathrm{m}^2\right)$; $\mathrm{WHR} = \mathrm{WC(cm)}/\mathrm{HC(cm)}$; $\mathrm{WHtR} = \mathrm{WC(cm)}/\mathrm{Height(cm)}$.

(3) Laboratory Testing: Venous blood samples were collected from all study subjects after fasting for over 12 hours to test several biochemical indicators, specifically: HbA1c: Peripheral venous blood samples were analyzed using a Bio-Rad automatic high-performance liquid chromatography analyzer to measure HbA1c, assessing recent glycemic control. Lipid Profile: Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels in serum were measured using a Hitachi 7060 automatic biochemical analyzer. Uric Acid: Serum uric acid levels were determined using a Hitachi 7060 automatic biochemical analyzer to assess the risk of hyperuricemia in patients. Other Tests: Routine blood tests including hemoglobin (Hb) and white blood cell count (WBC) were performed to further evaluate patients' hematologic health. Additionally, a morning urine sample was collected to measure the urinary albumin-to-creatinine ratio (UACR) using a Bayer DCA 2000 analyzer, assessing renal function and diabetes-related kidney damage.

Outcome Events

The outcome event of this study was defined as death due to CCVD, including myocardial infarction, angina, cerebral hemorrhage, cerebral ischemia, and other cardiovascular-related fatal diseases. To ensure data accuracy and effective monitoring of outcome events, a systematic follow-up process was designed, with trained DM specialty nurses conducting regular follow-ups every 6 months. Follow-up methods included telephone contact, WeChat group communication, or other social platforms. Each follow-up was recorded by the nurse to document the survival status of the patient and any new CCVD events. For suspected death cases, the information was further verified to confirm the direct association between the cause of death and CCVD. After a death event, the research nurse employed multiple approaches to verify the cause of death. Firstly, the patient's past medical records, including outpatient and inpatient records, were reviewed in detail for clinical course, diagnosis confirmation, and final death diagnosis. Secondly, the nurse contacted the patient's close relatives or other informants to gather information about the patient's final symptoms and confirm the cause of death, minimizing potential recording bias. Furthermore, if necessary, the research team consulted the patient's attending physician to verify whether the cause of death met the definition criteria for CCVD.

Statistical Analysis

Data analysis and charting were performed using GraphPad Prism 8, with statistical analysis conducted using SPSS 22.0. Measurement data that met the assumptions of normal distribution and homogeneity of variance are presented as ($\overline{x} \pm s$) and compared between groups using independent sample t-tests. Categorical data were presented as n (%) and analyzed using the Chi-square (χ^2) test. Cox regression models were applied to analyze the relationship between different body measurement indicators and CCVD mortality risk. All tests were two-tailed, with a significance level of $P < 0.05$ considered statistically significant.

Results

Comparison of General Information, Clinical Characteristics, and Laboratory Indicators Among Study Subjects

Among the 897 patients, there were 542 males and 355 females. Males had higher levels of education, prevalence of hyperuricemia, smoking history, drinking history, DBP, Hb, and UA compared to females. In contrast, females had higher levels of UACR, WBC, TC, TG, and HDL-C ($P<0.05$), as shown in Table 1.

Table 1 Comparison of General Information, Clinical Characteristics, and Laboratory Indicators Among Study Subjects ($\bar{x}\pm s$, n [%])

Variable	Total (n=897)	Male (n=542)	Female (n=355)	t/x^2	*P*
Age (years)	75.73±5.41	75.62±5.53	75.76±5.34	0.375	0.707
Education Level	–	–	–	21.586	<0.001
High school or below	651 (72.58)	363 (66.97)	288 (81.13)	–	–
College and above	246 (27.42)	179 (33.03)	67 (18.87)	–	–
Duration of T2DM (months)	96.85±40.39	97.37±40.28	94.96±41.12	0.869	0.385
Smoking History	–	–	–	55.607	<0.001
Yes	115 (12.82)	106 (19.56)	9 (2.54)	–	–
No	782 (87.18)	436 (80.44)	346 (97.46)	–	–
Drinking History	–	–	–	25.591	<0.001
Yes	63 (7.02)	57 (10.52)	6 (1.69)	–	–
No	834 (92.78)	485 (89.48)	349 (98.31)	–	–
SBP (mmHg)	132.16±15.27	132.77±15.43	131.34±14.85	1.377	0.168
DBP (mmHg)	74.48±9.34	75.39±9.04	73.21±9.56	3.452	<0.001
UACR (mg/g)	18.25±7.86	16.18±6.75	23.04±10.07	12.215	<0.001
Hb (g/L)	129.32±16.51	133.97±16.24	122.53±14.43	10.775	<0.001
WBC ($\times10^9$/L)	6.27±1.82	6.11±1.78	6.45±1.93	2.705	0.007
HbA1c (%)	7.62±1.85	7.54±1.82	7.65±1.95	0.860	0.389
TC (mmol/L)	4.53±1.08	4.42±1.00	4.75±1.12	4.606	<0.001
TG (mmol/L)	1.53±0.94	1.43±0.87	1.64±1.02	3.299	<0.001
HDL-C (mmol/L)	1.19±0.41	1.14±0.48	1.23±0.34	3.064	0.002
LDL-C (mmol/L)	2.73±0.85	2.68±0.85	2.79±0.87	1.877	0.060
UA (mmol/L)	334.13±35.76	345.26±40.38	318.47±43.42	9.429	<0.001
Disease History	–	–	–	–	–
Dyslipidemia	444 (49.50)	278 (51.29)	166 (46.76)	1.761	0.184
Hyperuricemia	151 (16.83)	107 (19.74)	44 (12.39)	8.271	0.004

Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric), Mann–Whitney U (non-parametric), χ^2-test (categorical).

CCVD Mortality in Different Subgroups

The mean follow-up time for the 897 patients was 7.13±2.45 years, with a cumulative follow-up of 6395.61 person-years. During the follow-up period, 45 patients died from CCVD, with a mortality density of 70.37 per 10,000 person-years. No significant difference was observed in mortality density between male and female populations (P>0.05), as shown in Table 2; likewise, no difference was found between the dyslipidemia and non-dyslipidemia groups (P>0.05), as shown in Table 3. However, the non-hyperuricemia group had a lower mortality density compared to the hyperuricemia group (P<0.05), as shown in Table 4.

Comparison of Physical Measurement Indicators Among Different Characteristic Subgroups

The total population BMI was (24.51±3.34), WHR was (0.92±0.06), WHtR was (0.54±0.07), WC was (89.12±9.56), and HC was (97.61±7.82). The WHtR in the male population was lower than in the female population; WHR, WC, and HC

Table 2 Comparison of CCVD Mortality Between Different Genders (n [%])

Group (n)	Follow-Up Time (years)	Person-Years of Follow-Up	Deaths (n)	Mortality Density (per 10,000 Person-Years)
Male (n=542)	7.11±2.47	3860.65	25	64.77
Female (n=355)	7.16±2.42	2534.97	20	78.93

Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric), Mann–Whitney U (non-parametric), χ^2-test (categorical).

Table 3 Comparison of CCVD Mortality Between Dyslipidemia and Non-Dyslipidemia Populations (n [%])

Group (n)	Follow-Up Time (Years)	Person-Years of Follow-Up	Deaths (n)	Mortality Density (per 10,000 Person-Years)
Dyslipidemia (n=444)	6.87±2.39	2763.92	25	90.48
Non-dyslipidemia (n=453)	7.36±2.48	3631.85	20	55.08

Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric), Mann–Whitney U (non-parametric), χ^2-test (categorical).

Table 4 Comparison of CCVD Mortality Between Hyperuricemia and Non-Hyperuricemia Populations (n [%])

Group (n)	Follow-Up Time (Years)	Person-Years of Follow-Up	Deaths (n)	Mortality Density (per 10,000 Person-Years)
Hyperuricemia (n=151)	7.09±2.47	965.74	13	134.72
Non-hyperuricemia (n=746)	7.16±2.41	5429.81	32	58.94*

Notes: *P<0.05. Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric), Mann–Whitney U (non-parametric), χ^2-test (categorical).

were higher than in the female population (P<0.05), as shown in Figure 1. The BMI, WHR, WHtR, WC, and HC levels in the group without dyslipidemia were lower than those in the dyslipidemia group (P<0.05), as shown in Figure 2. The BMI, WHtR, WC, and HC levels in the non-hyperuricemia group were lower than those in the hyperuricemia group (P<0.05), as shown in Figure 3.

Cox Proportional Hazards Regression Analysis of Physical Measurement Indicators and CCVD Mortality Risk

The results of the Cox proportional hazards regression analysis showed that, after adjusting for potential confounding factors, an increase in WHtR was associated with an elevated risk of CCVD mortality in the general population. Further subgroup analysis revealed that an elevated WHR increased the CCVD mortality risk in the male population, while both BMI and WHtR increases were associated with higher CCVD mortality risk in the female population. In the populations without dyslipidemia and without hyperuricemia, an elevated WHtR similarly increased the CCVD mortality risk, as shown in Table 5.

Discussion

This study establishes three principal findings in elderly T2DM patients: WHtR superiority: WHtR demonstrated the strongest association with CCVD mortality (HR=1.518 per SD increase), outperforming BMI and WC in the overall cohort. Sex-specific patterns: WHR emerged as the primary predictor in males (HR=1.513), whereas BMI (HR=1.708) and WHtR (HR=1.903) dominated in females. Metabolic paradox: WHtR retained predictive power even in metabolically "healthier" subgroups without dyslipidemia/hyperuricemia (HR=1.724 and 1.673). These results align with but crucially extend prior evidence by delineating context-dependent utility of anthropometric indices in geriatric diabetes care.

Previous large-scale cohort studies have shown that BMI within the normal range (18.5–24.9 kg/m²) is associated with the lowest risk of CCVD incidence, mortality, and all-cause mortality, displaying a "U" or "J" shaped curve relationship.[16] Notably, our data challenge this paradigm in elderly T2DM—BMI exhibited linear risk association in females, suggesting age- and diabetes-mediated shifts in adiposity pathophysiology. A meta-analysis integrating 10 prospective cohort studies[17] similarly confirmed that, in the 40–59 age group, the CCVD mortality risk in obese populations was significantly higher than in those with normal BMI, with an increase of up to 1.53 times. However, some studies[18] have found that among T2DM patients, overweight individuals had a lower all-cause mortality risk compared to those with normal weight, suggesting that moderate fat may have a protective effect in elderly individuals or

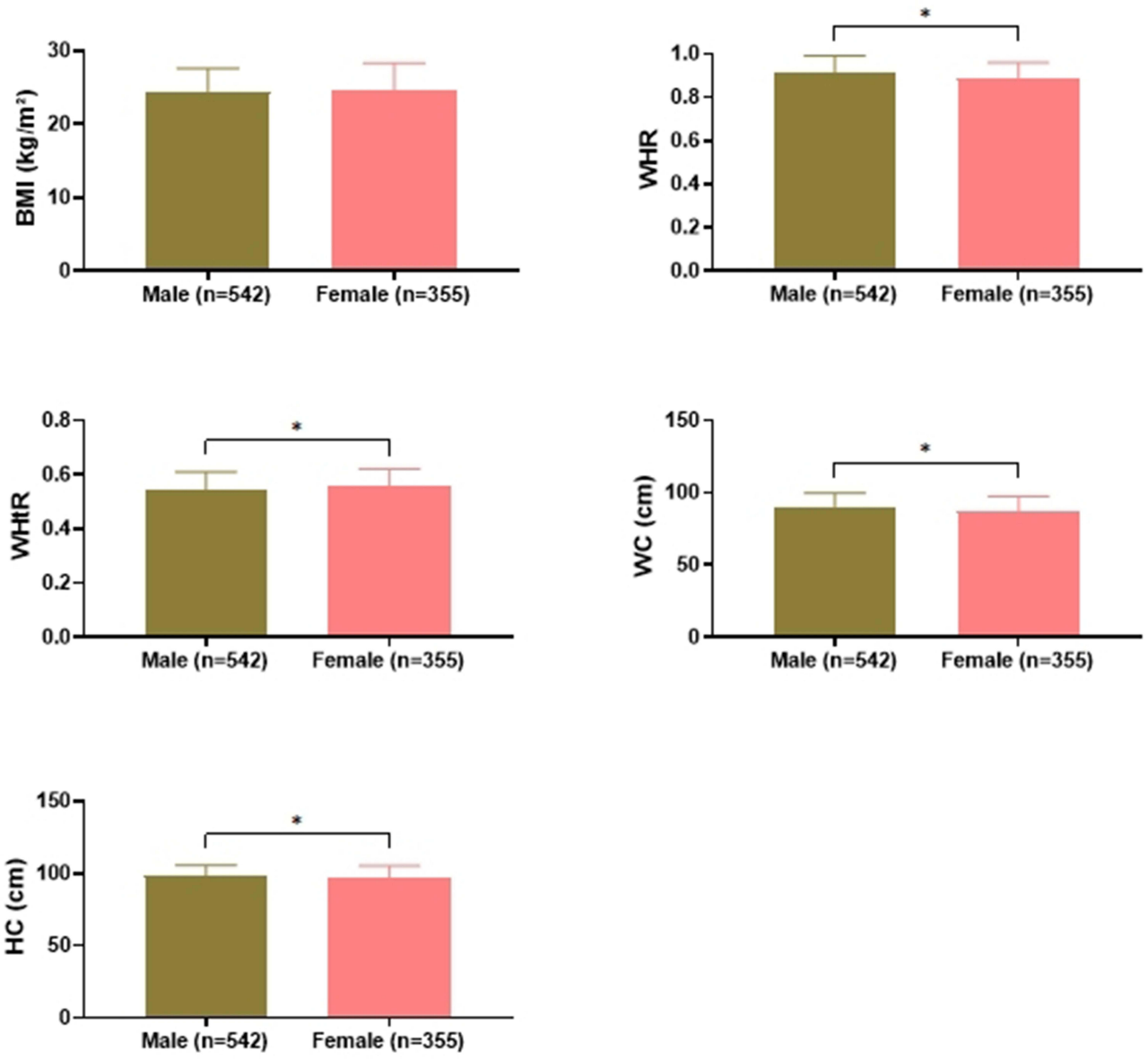

Figure 1 Comparison of Physical Measurement Indicators Between Different Genders ($\bar{x} \pm s$).
Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric). *P < 0.05.

individuals with specific pathological conditions. Additionally, a large-scale cohort study based in the UK, involving 3.6 million people and a follow-up period of up to 12.7 years,[19] found that the association between BMI and CCVD mortality risk weakens in populations over 70 years old. This phenomenon may be related to significant changes in body composition among the elderly, where the ratio of muscle mass to fat mass impacts BMI more than in younger populations. Our observation of BMI's female-specific predictive value likely reflects accelerated sarcopenic obesity progression in elderly diabetic women, exacerbating visceral adiposity despite stable BMI.[20] Although these studies have confirmed a direct association between BMI and CCVD morbidity and mortality events, BMI's inability to effectively differentiate between fat and lean mass, and its failure to reflect fat distribution within the body, limit its utility as an independent predictive indicator. Therefore, even for patients with abdominal fat accumulation, a BMI within the normal range may still be associated with a higher CCVD risk.[21] Particularly in T2DM patients, central obesity (eg, abdominal fat accumulation) is more important than overall BMI[22] and is often closely related to the occurrence of CCVD events. In this study, we found that the association between BMI and CCVD mortality risk was mainly observed among elderly

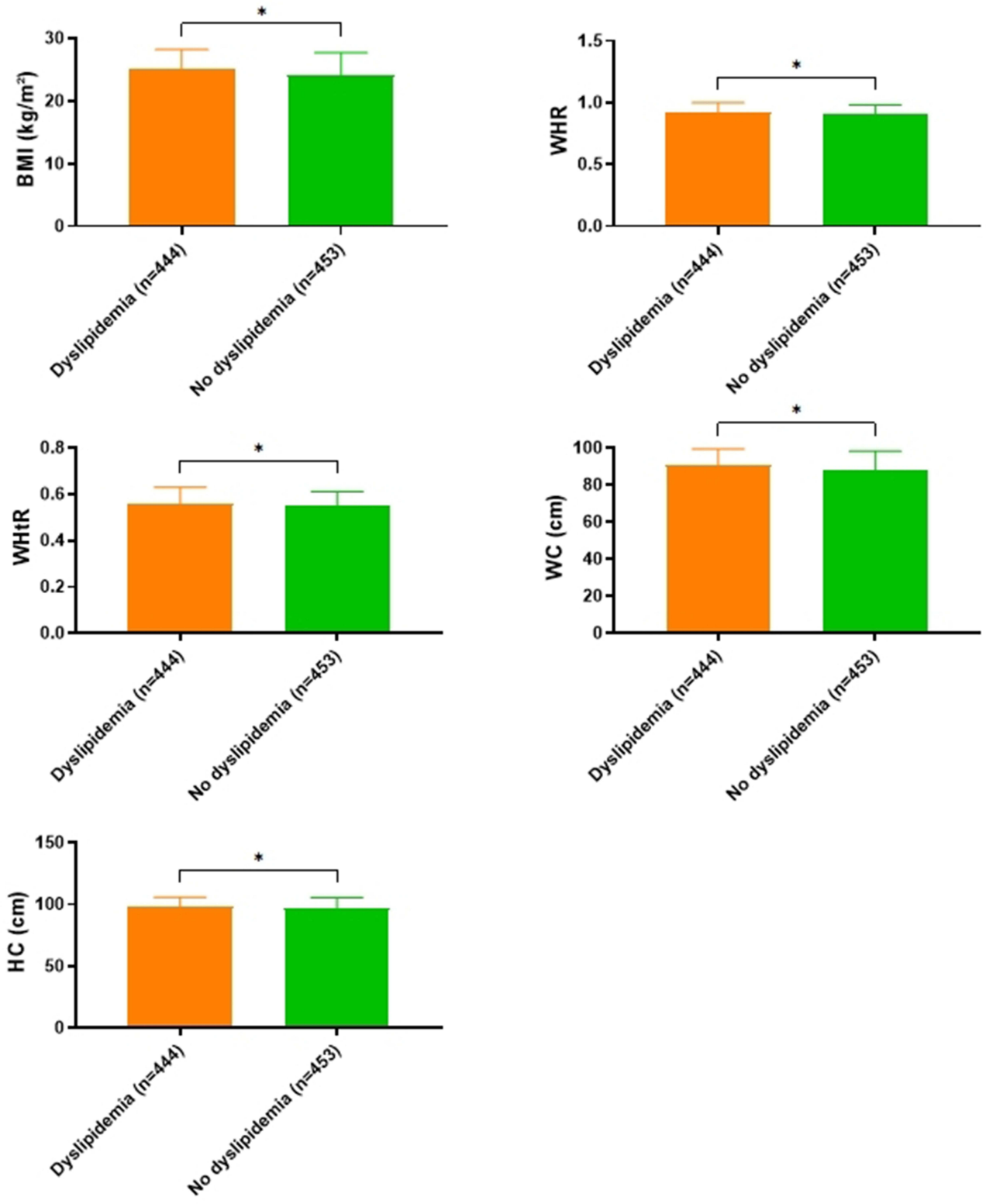

Figure 2 Comparison of Physical Measurement Indicators Between Groups With and Without Dyslipidemia ($\bar{x} \pm s$).
Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric). *P < 0.05.

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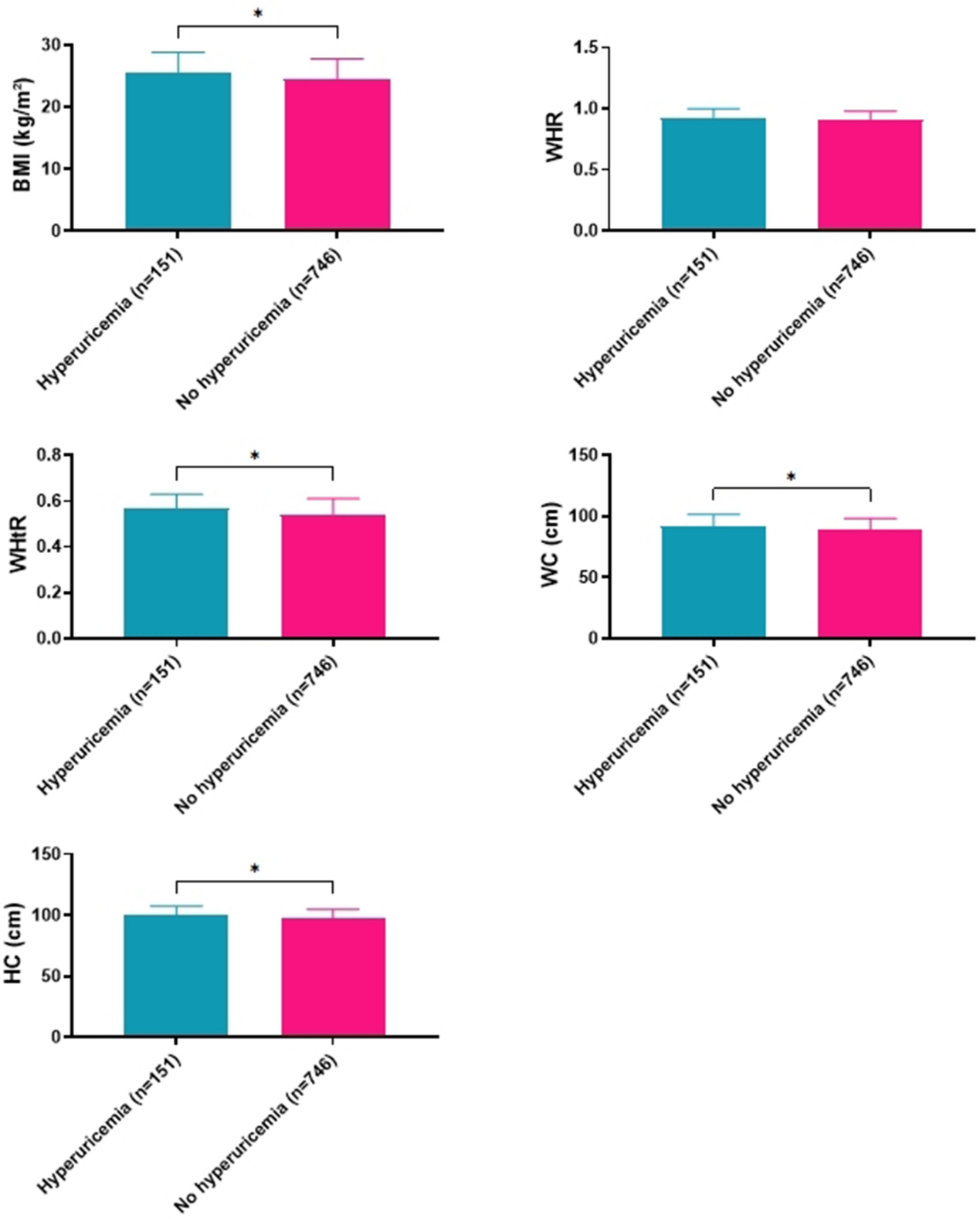

Figure 3 Comparison of Physical Measurement Indicators Between Groups With and Without Hyperuricemia ($\bar{x} \pm s$).
Notes: Data: Mean ± SD or n (%) (categorical variables). Statistical tests: Independent *t*-test (parametric). *P < 0.05.

Table 5 Cox Proportional Hazards Regression Analysis of Physical Measurement Indicators and CCVD Mortality Risk

Population (n)	HR (95% CI)				
	BMI	WHR	WHtR	WC	HC
General population (n=897)	1.195 (0.879~1.625)	1.229 (0.903~1.668)	1.518 (1.104~2.079)	1.286 (0.923~1.778)	1.037 (0.762~1.411)
Male (n=453)	0.947 (0.602~1.483)	1.513 (1.015~2.274)	1.376 (0.872~2.151)	1.223 (0.789~1.916)	0.813 (0.522~1.263)
Female (n=355)	1.708 (1.076~2.674)	0.893 (0.524~1.539)	1.903 (1.176~3.058)	1.482 (0.875~2.487)	1.478 (0.924~2.368)
Dyslipidemia (n=444)	1.123 (0.754~1.683)	1.462 (0.941~2.278)	1.408 (0.927~2.116)	1.253 (0.792~1.985)	0.841 (0.542~1.296)
Without dyslipidemia (n=453)	1.271 (0.796~2.043)	0.987 (0.596~1.619)	1.724 (1.012~2.915)	1.362 (0.821~2.234)	1.365 (0.879~2.113)
Hyperuricemia (n=151)	1.502 (0.905~2.481)	1.223 (0.596~2.527)	1.568 (0.849~2.867)	1.305 (0.667~2.539)	1.125 (0.623~2.047)
Without hyperuricemia (n=746)	1.105 (0.751~1.598)	1.273 (0.891~1.829)	1.673 (1.142~2.439)	1.471 (0.986~2.193)	1.112 (0.764~1.625)

female T2DM patients, where each standard deviation increase in BMI was associated with an increase in CCVD mortality risk. This gender difference may be related to various physiological factors, specifically: ① Female patients often experience body fat distribution changes related to hormonal fluctuations, with fat accumulation usually concentrated in the abdominal area,[23] which increases cardiovascular risk; ② Differences in muscle mass and fat distribution between males and females may also affect BMI's predictive accuracy, as females are more likely to accumulate visceral fat with increased BMI, directly associated with a higher risk of cardiovascular events.

Multiple studies[24,25] have confirmed that abdominal fat accumulation is a critical risk factor in promoting the occurrence and progression of CCVD. Our findings refine this consensus by demonstrating that WHtR—integrating both central adiposity (WC) and stature—provides superior risk stratification in elderly T2DM compared to isolated WC or BMI measurements. Typically, as BMI and WC levels increase, the likelihood of developing CCVD-related risk factors, such as diabetes and hyperlipidemia, also significantly rises.[26] However, compared to BMI, WC has greater independence and accuracy in predicting chronic diseases, particularly cardiovascular diseases and metabolic syndrome. Moreover, this trend is particularly evident in studies of specific populations. For instance, a cohort study[27] observed that, among originally lean women, an increase in WC significantly raised the risk of cardiovascular disease and all-cause mortality. Similarly, in men with weight loss, increased WC was significantly associated with higher cardiovascular disease and all-cause mortality risk.[28] Furthermore, a meta-analysis of 31 prospective studies[29] indicated that individuals with increased WHR, even within the normal BMI range, had significantly higher mortality risk compared to those with normal fat distribution. This suggests that the distribution pattern of abdominal fat may be more crucial than overall body weight. Additionally, a body fat percentage prediction model developed by Henry et al,[30] specifically for Asian Chinese populations, based on WC and height (rather than WHtR) showed high accuracy, suggesting a close relationship between WC and height with body fat, potentially providing a basis for more precise risk prediction. A study by Munckhof et al[31] also demonstrated that in male populations, WHtR had a stronger association with arterial stiffness index femoral pulse wave velocity than BMI, WC, and WHtR, suggesting that WHR may have greater value in cardiovascular health assessment. Although a meta-analysis[32] concluded that WHR's predictive advantage is not significantly superior to WC and BMI, WHR's measurement convenience and interpretability regarding abdominal fat distribution grant it high clinical value. In this study, although no direct association was found between increased WC and CCVD mortality risk, the data indicated that an increase in WHR was significantly related to CCVD mortality, particularly evident among females with higher WHtR and individuals without dyslipidemia and hyperuricemia. This finding suggests that monitoring and intervening in individuals with increased WHR may effectively reduce CCVD-related health risks. Practical Implication: We propose WHtR $\geq$0.54 (mean +0.5 SD in our cohort) as a threshold for intensified CCVD monitoring in elderly T2DM clinics. Overall, abdominal indicators such as WHR, WC, and WHtR play a vital role in CCVD risk prediction and should be a key focus in future health management and prevention strategies.

Notably, our cohort exhibited significant gender disparities in education levels (33.03% of males vs 18.87% of females with college education, $P < 0.001$). Higher education is associated with improved health literacy, better glycemic control, and adherence to preventive measures in T2DM populations.[33] While we adjusted for education in sensitivity analyses, residual confounding may persist due to unmeasured socioeconomic factors (eg, income, healthcare access) that

correlate with both education and health behaviors.[34] For instance, educated males may adopt healthier lifestyles (eg, smoking cessation, balanced diets), potentially attenuating CCVD risks independent of anthropometric indices. Future studies should incorporate granular socioeconomic data to disentangle these effects.

Although this study provides valuable insights, it has several limitations: ① Limited sample representativeness: The sample for this study was drawn from a specific population, so the findings may not be fully generalizable to broader populations. ② Residual confounding: Despite adjusting for education level and comorbidities, unmeasured socioeconomic factors (eg, income, healthcare access) may influence both anthropometric indices and CCVD outcomes. ③ Potential information bias in the data: Since some data were collected through telephone follow-ups or relied on previous medical records, the completeness and accuracy of information may be limited, possibly introducing bias into the results. ④ Lack of in-depth examination of potential confounding factors: Although some confounding variables were adjusted for in this study, other factors, such as dietary habits, exercise levels, and socioeconomic factors, might not have been fully controlled, potentially affecting the robustness of the study conclusions. ⑤ Insufficient sample size for subgroup analysis: This study conducted subgroup analyses by gender, dyslipidemia, and hyperuricemia status, but the sample size for certain subgroups was relatively small, limiting the statistical power of the findings. ⑥ Temporal dynamics: Single-timepoint anthropometric measurements may not capture longitudinal body composition changes influencing CCVD risk. In summary, there remains room for improvement in sample representativeness, study design, and data collection in this research. Future studies should address these areas to provide a more scientific basis for the prediction and prevention of CCVD risk.

Conclusion

This study examined the association between body measurement indicators and CCVD mortality risk, showing that different indicators have significant predictive value in specific populations. Multivariate Cox proportional hazards regression analysis demonstrated a significant association between increased WHtR and CCVD mortality risk, particularly in females and individuals without dyslipidemia or hyperuricemia. Additionally, subgroup analysis suggested that increased WHR in males is also closely associated with a heightened risk of CCVD mortality. Compared to traditional indicators such as BMI, abdominal fat-related measures like WHtR and WHR more effectively reflect the impact of body fat distribution on CCVD risk. This finding underscores the importance of focusing on abdominal fat when assessing cardiovascular health, especially in diabetic populations. In the future, further studies are recommended to validate the predictive efficacy of these indicators across diverse populations and to incorporate longer follow-up studies to deepen the understanding of the relationship between body fat distribution and CCVD risk, thereby providing more precise guidance for the prevention and management of cardiovascular disease.

Data Sharing Statement

All data generated or analysed during this study are included in this published article. This study was approved by the ethics committee of Huaian Fifth People's Hospital Affiliated to Yangzhou University. Informed consent was obtained from all study participants. All the methods were carried out in accordance with the Declaration of Helsinki.

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Disclosure

The authors declare that they have no competing interests in this work.

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