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Correlation Between Body Roundness Index and Normal Weight Metabolic Abnormality Phenotype in Elderly Population by Gender: A Postprint with Triglyceride-Glucose Index as a Potential Influencing Factor

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Abstract

Background Body Roundness Index (BRI) is a simple indicator for measuring central obesity and is closely associated with cardiovascular disease. The Metabolically Obese but Normal Weight (MONW) population has a higher risk of cardiovascular disease that is significantly associated with central obesity. The Triglyceride-Glucose (TyG) index is an indicator reflecting insulin resistance. Currently, research on the relationship among BRI, TyG index, and MONW phenotype in elderly populations of different genders is relatively limited.

Objective To investigate the gender differences in the association between BRI and the risk of MONW phenotype in elderly populations, and to explore the TyG index as a potential factor underlying these gender differences.

Methods Permanent residents aged $ $60 years who underwent physical examinations in 10 cities, counties, and districts of Anhui Province from July 1, 2017 to June 30, 2021 were selected as study subjects. A unified questionnaire was used to collect data on gender, age, disease history, etc., and physical and laboratory examination data were collected to calculate BRI and TyG index. Based on metabolic status and BMI levels, males and females were respectively divided into Metabolically Healthy Normal Weight (MHNW) phenotype and MONW phenotype: male MHNW phenotype (n=5,384), male MONW phenotype (n=6,251); female MHNW phenotype (n=4,498), female MONW phenotype (n=8,264). According to BRI quartiles, males and females were respectively divided into four levels, namely males: M1, M2, M3, M4, and females: F1, F2, F3, F4. Logistic regression analysis was used to explore the relationship

between BRI quartile levels and the risk of elevated TyG index as well as the risk of MONW phenotype. Z-test in R software (version 4.1.1) was used to compare differences in OR values between males and females.

Results This study included a total of 24,397 subjects, including 11,635 males (47.7%) and 12,762 females (52.3%), with a median age of 67 (64, 70) years, 9,882 cases (40.5%) of MHNW phenotype and 14,515 cases (59.5%) of MONW phenotype. In elderly populations of different genders, the MONW phenotype group had higher rates of hypertension, diabetes, dyslipidemia, systolic blood pressure, diastolic blood pressure, TyG index, BRI, fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C), and lower rates of smoking and high-density lipoprotein cholesterol (HDL-C) compared with the MHNW phenotype group ($P<0.05$). In elderly populations of different genders, those with high BRI levels had higher prevalence of MONW phenotype, hypertension, diabetes, dyslipidemia, TyG index, FPG, and TG, and lower HDL-C compared with those with low BRI levels ($P<0.05$). Univariate Logistic regression analysis showed that compared with BRI M1/F1 level, the risk of elevated TyG index increased at BRI M2/F2, M3/F3, and M4/F4 levels in elderly populations of different genders ($P<0.05$); and the risk of elevated TyG index increased with increasing BRI levels (P-trend<0.001 for males, P-trend<0.001 for females). The risk of elevated TyG index at BRI M2, M3, and M4 levels in elderly males was higher than that at BRI F2, F3, and F4 levels in elderly females ($P<0.05$). After adjusting for confounding factors, multivariate Logistic regression analysis showed that compared with BRI M1/F1 level, the risk of MONW phenotype increased at BRI M2/F2, M3/F3, and M4/F4 levels in elderly populations of different genders ($P<0.05$); and the risk of MONW phenotype increased with increasing BRI levels (P-trend<0.001 for males, P-trend<0.001 for females). The risk of MONW phenotype at BRI M2 and M4 levels in elderly males was higher than that at BRI F2 and F4 levels in elderly females ($P<0.05$).

Conclusion In elderly populations of different genders, BRI level is significantly positively correlated with the risk of MONW phenotype, with the association between high BRI level and MONW phenotype risk being stronger in elderly males. The TyG index is a potential factor contributing to this gender difference.

Full Text

Study on the Correlation between Body Roundness Index and Metabolically Obese Normal Weight Phenotype in an Elderly Population of Different Genders: Triglyceride Glucose Index as a Potential Influencing Factor

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Abstract

Background: Body roundness index (BRI) is a simple measure of central obesity that is strongly associated with cardiovascular disease. Individuals with metabolically obese normal weight (MONW) have a higher risk of cardiovascular disease that is significantly correlated with central obesity. The triglyceride glucose (TyG) index is an indicator of insulin resistance. Currently, research on the relationships among BRI, TyG index, and MONW phenotype in gender-specific elderly populations remains limited.

Objective: To explore gender-specific differences in the association between BRI and MONW phenotype risk among elderly populations, and to investigate the TyG index as a potential factor underlying these gender differences.

Methods: Permanent residents aged $ $60 years who underwent physical examinations in 10 cities and counties in Anhui Province from July 1, 2017, to June 30, 2021, were selected as study subjects. A standardized questionnaire was used to collect data on gender, age, disease history, and other information. Physical examination and laboratory test data were collected, and BRI and TyG index were calculated. Based on metabolic status and BMI levels, both men and women were classified into metabolically healthy normal weight (MHNW) and MONW phenotypes: male MHNW phenotype (n=5,384), male MONW phenotype (n=6,251); female MHNW phenotype (n=4,498), female MONW phenotype (n=8,264). According to BRI quartiles, men and women were each divided into four levels: males–M1, M2, M3, M4; females–F1, F2, F3, F4. Logistic regression analysis was used to examine the associations between BRI quartile levels and the risk of elevated TyG index and MONW phenotype. The Z-test in R software (version 4.1.1) was used to compare differences in OR values between men and women.

Results: A total of 24,397 subjects were included in this study, comprising 11,635 men (47.7%) and 12,762 women (52.3%), with a median age of 67 (64, 70) years. There were 9,882 MHNW phenotype cases (40.5%) and 14,515 MONW phenotype cases (59.5%). In both genders, elderly individuals with MONW phenotype had significantly higher rates of hypertension, diabetes, dyslipidemia, systolic blood pressure, diastolic blood pressure, TyG index, BRI, fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C) compared to MHNW phenotype, while smoking rates and high-density lipoprotein cholesterol (HDL-C) were lower ($P<0.05$). In both genders, elderly individuals with high BRI levels had higher

prevalence of MONW phenotype, hypertension, diabetes, dyslipidemia, TyG index, FPG, and TG, and lower HDL-C compared to those with low BRI levels ($P<0.05$). Univariate logistic regression analysis showed that compared with BRI M1/F1 levels, BRI M2/F2, M3/F3, and M4/F4 levels were associated with increased risk of elevated TyG index in both genders ($P<0.05$), with the risk increasing as BRI levels increased (P-trend<0.001 for men; P-trend<0.001 for women). The risk of elevated TyG index at BRI M2, M3, and M4 levels in elderly men was higher than at BRI F2, F3, and F4 levels in elderly women ($P<0.05$). After adjusting for confounding factors, multivariate logistic regression analysis showed that compared with BRI M1/F1 levels, BRI M2/F2, M3/F3, and M4/F4 levels were associated with increased risk of MONW phenotype in both genders ($P<0.05$), with the risk increasing as BRI levels increased (P-trend<0.001 for men; P-trend<0.001 for women). The risk of MONW phenotype at BRI M2 and M4 levels in elderly men was higher than at BRI F2 and F4 levels in elderly women ($P<0.05$).

Conclusion: BRI levels are significantly and positively associated with MONW phenotype risk in elderly populations of different genders, with high BRI levels showing a stronger association with MONW phenotype risk in elderly men. The TyG index is a potential factor contributing to this gender difference.

Keywords: Body roundness index; Metabolically obese normal weight phenotype; Triglyceride glucose index; Gender; Aged; Central obesity; Correlation studies

Introduction

Obesity is a major risk factor for metabolic diseases. However, research has revealed that some individuals with normal BMI still exhibit adverse cardiometabolic characteristics. These individuals are referred to as metabolically obese normal weight (MONW) populations. The characteristics of this population include hypertriglyceridemia, hyperglycemia, elevated blood pressure, and reduced high-density lipoprotein cholesterol. Studies show that the global prevalence of MONW phenotype is 30%, with an Italian study reporting 35% and Chinese research showing 34.1%. Because this population lacks obvious signs of obesity, they are easily overlooked in health examinations.

Previous studies have demonstrated that the triglyceride glucose (TyG) index, as an effective indicator of insulin resistance, has high sensitivity and specificity in screening high-risk MONW individuals and serves as an effective tool for identifying high-risk MONW phenotype. The body roundness index (BRI), which combines height and waist circumference, is an effective indicator for identifying central obesity and is associated with insulin resistance. Wu et al. showed a positive and non-linear relationship between BRI and type 2 diabetes mellitus (T2DM) incidence, suggesting that BRI could serve as a predictor for early detection and prognosis of T2DM. Research has also indicated that BRI is a po-

tential risk factor for coronary artery disease and carotid atherosclerosis, with elevated BRI associated with increased cardiovascular disease risk. However, current research on the relationships among BRI, TyG index, and MONW phenotype remains limited. Therefore, this study aims to analyze the relationship between BRI and MONW phenotype in elderly populations of different genders, explore whether gender differences exist in the association between BRI and MONW phenotype, and evaluate the correlation of these differences with the TyG index.

Methods

Study Population

This study was based on the Cardiovascular Disease High-Risk Population Early Screening and Comprehensive Intervention Project. Using multi-stage cluster sampling, 58,962 permanent residents aged $ 60 years from 10 cities and counties in Anhui Province were selected f (1) having lived in the area for more than 6 months in the year before the survey; (2) age between 60 and 75 years; (3) BM and 24.0 kg/m^2; and (4) voluntary participation with signed informed consent. Exclusion criteria were: (1) missing general information; and (2) having malignant tumors, severe cardiac, hepatic, renal, cerebral, or hematological diseases. A total of 24,397 subjects were ultimately included. This study was approved by the Ethics Committee of Suzhou Municipal Hospital (A2022033).

Data Collection

A standardized questionnaire was used to collect information on gender, age, education level, smoking, alcohol consumption, and history of hypertension, diabetes, and dyslipidemia. Physical examinations were conducted by professional physicians who measured height, body weight, waist circumference, and blood pressure, and calculated BMI. Laboratory tests included fasting venous blood samples to measure fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C), which were determined using a Beckman automatic biochemical analyzer.

Definitions

BMI: 18.5 kg/m^2 $\leq$ BMI $<$ 24.0 kg/m^2 was defined as normal weight; BMI $\geq$ 24.0 kg/m^2 was defined as overweight/obese.

Metabolic Abnormality: Defined as meeting two or more of the following criteria: (1) systolic blood pressure (SBP) $\geq$ 130 mmHg (1 mmHg = 0.133 kPa) or diastolic blood pressure (DBP) $\geq$ 85 mmHg or history of hypertension or receiving antihypertensive treatment; (2) TG $\geq$ 1.7 mmol/L; (3) HDL-C $<$ 1.04 mmol/L for men or HDL-C $<$ 1.29 mmol/L for women; (4) FPG $\geq$ 5.6 mmol/L or history of diabetes or receiving hypoglycemic treatment.

Smoking: Defined as having smoking behavior at the time of survey. **Alcohol Consumption:** Defined as drinking alcohol ≥ 1 time per week at the time of survey.

Disease History: Hypertension was defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg, or previously diagnosed hypertension, or using antihypertensive medication within the past 2 weeks. Diabetes was defined as previously diagnosed diabetes or using hypoglycemic medication within the past 2 weeks. Dyslipidemia was defined as meeting any of the following criteria or previously diagnosed dyslipidemia or using lipid-lowering medication within the past 2 weeks: (1) TC ≥ 6.2 mmol/L; (2) TG ≥ 2.3 mmol/L; (3) LDL-C ≥ 4.1 mmol/L; (4) HDL-C < 1.0 mmol/L.

Index Calculation

BRI was calculated as:

$$BRI = 364.2 - 365.5 \times \left\{ 1 - \left[\frac{waist\ circumference\ (cm)}{2\pi} \right]^2 / \left[0.5 \times height\ (cm) \right]^2 \right\}^{0.5}$$

TyG index was calculated as:

$$TyG\ index = \ln \left[\frac{TG\ (mmol/L) \times FPG\ (mmol/L)}{2} \right]$$

Grouping

Based on metabolic status and BMI levels, both men and women were classified into metabolically healthy normal weight (MHNW) and MONW phenotypes: male MHNW phenotype (n=5,384), male MONW phenotype (n=6,251); female MHNW phenotype (n=4,498), female MONW phenotype (n=8,264). According to BRI quartiles, men and women were each divided into four levels: males–M1 (BRI ≤ 2.6372), M2 (2.6373 ≤ BRI ≤ 3.0918), M3 (3.0919 ≤ BRI ≤ 3.5848), M4 (BRI ≥ 3.5849); females–F1 (BRI ≤ 3.0096), F2 (3.0097 ≤ BRI ≤ 3.5273), F3 (3.5270 ≤ BRI ≤ 4.0708), F4 (BRI ≥ 4.0709).

Statistical Analysis

SPSS 25.0 and R (version 4.1.1) software were used for data analysis. Non-normally distributed continuous variables were expressed as median (P25, P75), and comparisons between two groups were performed using the rank-sum test. Comparisons among BRI quartile levels were performed using the Kruskal-Wallis H trend test. Categorical variables were expressed as frequency and percentage, with comparisons between two groups using the ^{2} test and comparisons among BRI quartile levels using the ^{2} trend test. Logistic regression analysis was used to examine the associations between BRI quartile levels and the risk of elevated TyG index and MONW phenotype. The Z-test in R software

(version 4.1.1) was used to compare differences in OR values between men and women. P<0.05 was considered statistically significant.

Results

Comparison of Characteristics Between MONW and MHNW Phenotypes by Gender

This study included 24,397 subjects, with 11,635 men (47.7%) and 12,762 women (52.3%), and a median age of 67 (64, 70) years. There were 9,882 MHNW phenotype cases (40.5%) and 14,515 MONW phenotype cases (59.5%). In elderly men, significant differences were observed between MONW and MHNW phenotypes in age, smoking, alcohol consumption, education level, hypertension, diabetes, dyslipidemia, SBP, DBP, TyG index, BRI, FPG, TC, TG, HDL-C, and LDL-C (P<0.05). Specifically, elderly men with MONW phenotype had lower rates of smoking and education level, but higher BRI, FPG, TC, TG, and LDL-C compared to MHNW phenotype. In elderly women, MONW phenotype was associated with higher age, hypertension, diabetes, dyslipidemia, SBP, DBP, TyG index, BRI, FPG, TC, TG, and LDL-C, and lower smoking and HDL-C compared to MHNW phenotype (P<0.05). No significant differences were found between MONW and MHNW phenotypes in elderly women regarding alcohol consumption and education level (P>0.05) .

Comparison of Characteristics Across BRI Quartile Levels by Gender

In both genders, elderly individuals in higher BRI quartiles showed increasing prevalence of MONW phenotype, hypertension, diabetes, dyslipidemia, TyG index, FPG, and TG, while HDL-C decreased (P<0.05) [TABLE:3, TABLE:4]. Among men, those in the M4 group had significantly higher rates of MONW phenotype, hypertension, diabetes, and dyslipidemia compared to the M1 group, along with higher TyG index, FPG, and TG, and lower HDL-C (P<0.001 for all trend tests). Similar patterns were observed in women across F1 through F4 groups, with significant trends for all metabolic indicators (P<0.001).

Univariate Logistic Regression Analysis of BRI and TyG Index by Gender

Using elevated TyG index (assignment: no=0, yes=1) as the dependent variable and BRI quartile levels [assignment (male/female): M1/F1=1, M2/F2=2, M3/F3=3, M4/F4=4] as the independent variable, univariate logistic regression analysis showed that compared with BRI M1/F1 levels, BRI M2/F2, M3/F3, and M4/F4 levels were associated with increased risk of elevated TyG index in both genders (P<0.05). The risk of elevated TyG index increased with higher BRI levels (P-trend<0.001 for men; P-trend<0.001 for women). The risk of elevated TyG index at BRI M2, M3, and M4 levels in elderly men was significantly

higher than at BRI F2, F3, and F4 levels in elderly women (P<0.05) .

Multivariate Logistic Regression Analysis of BRI and MONW Phenotype by Gender

Using MONW phenotype risk (assignment: no=0, yes=1) as the dependent variable and BRI quartile levels [assignment (male/female): M1/F1=1, M2/F2=2, M3/F3=3, M4/F4=4] as the independent variable, multivariate logistic regression analysis adjusted for age (assignment: actual value), education level (assignment: primary school or below=1, junior high and high school=2, college or above=3), smoking (assignment: no=0, yes=1), and alcohol consumption (assignment: no=0, yes=1) showed that compared with BRI M1/F1 levels, BRI M2/F2, M3/F3, and M4/F4 levels were associated with increased risk of MONW phenotype in both genders (P<0.05). The risk of MONW phenotype increased with higher BRI levels (P-trend<0.001 for men; P-trend<0.001 for women). The risk of MONW phenotype at BRI M2 and M4 levels in elderly men was significantly higher than at BRI F2 and F4 levels in elderly women (P<0.05) .

Discussion

MONW represents a subgroup of obesity involving multiple diseases, including insulin resistance, hypertension, and dyslipidemia. The prevalence of MONW phenotype varies from 14.7% to 59% across different global populations. Our study found that the prevalence of MONW phenotype among elderly individuals aged 60 and above in Anhui Province was 59.4%, which is higher than the 34.1% reported in Zhejiang Province among individuals aged 20 and above. This discrepancy suggests regional and age-related differences in MONW phenotype prevalence. Our results also showed that regardless of gender, the prevalence of hypertension, diabetes, and dyslipidemia was significantly higher in MONW populations compared to MHNW populations, consistent with the findings of Wildman et al.

BMI may not be the optimal indicator for assessing obesity because it cannot reflect visceral fat or distinguish between muscle and adipose tissue. Asians tend to have more visceral fat at similar BMI levels compared to other ethnic groups, making them more susceptible to abdominal obesity. BRI is a novel assessment indicator that can predict body fat percentage and visceral adipose tissue percentage. Studies have shown that BRI has important value in predicting the risk of metabolic diseases. Our results demonstrated that in both men and women, the prevalence of hypertension, diabetes, and dyslipidemia increased with higher BRI levels, consistent with the findings of Hwang et al. Therefore, reducing BRI may help control the development of metabolic diseases such as hypertension, diabetes, and dyslipidemia.

BRI has certain advantages in assessing metabolic disease risk across different genders, with better gender discriminatory power than BMI and waist circumfer-

ence. Our study, focusing on elderly populations, found that MONW phenotype prevalence increased with higher BRI levels in both men and women. Logistic regression analysis after adjusting for confounding factors showed that compared with low BRI levels, high BRI levels were associated with increased MONW phenotype risk in both men and women, with the risk increasing as BRI levels rose. The risk increase was more pronounced in elderly men, with the M4 group showing a 123.3% higher risk compared to the M1 group, while the F4 group showed an 82.0% higher risk compared to the F1 group, suggesting a stronger association between BRI and MONW phenotype risk in elderly men.

Previous studies have shown that the TyG index is a marker of insulin resistance and has predictive value for new-onset type 2 diabetes and cardiovascular disease. Obese men with high TyG index levels are more likely to develop high cardiovascular disease risk. Our study found that TyG index was higher in MONW phenotype than in MHNW phenotype across both genders, indicating greater insulin resistance in MONW populations. Li et al. demonstrated that BRI is associated with metabolic syndrome, insulin resistance, and inflammatory factors, showing optimal ability to identify insulin resistance in obese and overweight populations. Although MONW individuals have normal BMI, their abdominal fat content may be excessive, leading to elevated BRI and insulin resistance. Our results showed that BRI is associated with insulin resistance, with the risk of insulin resistance increasing as BRI increases. Compared with low BRI levels, high BRI levels in both men and women were associated with increased risk of elevated TyG index, with the risk gradually increasing as BRI levels rose. The risk of elevated TyG index was higher in elderly men than in elderly women. Therefore, the TyG index may be a potential factor contributing to gender differences in the relationship between BRI and MONW phenotype.

Men have lower insulin sensitivity than women, resulting in less capacity to increase subcutaneous fat storage compared to women. Research by Xu et al. showed that visceral fat accumulation differs between genders, with men having higher visceral fat content than women. Consequently, as fat increases, excess fat is more likely to be stored outside the subcutaneous layer, increasing cardiovascular disease risk. Additionally, estrogen secretion significantly improves insulin sensitivity, and the development of metabolic disorders is also influenced by estrogen. Therefore, reduced estrogen levels in elderly women leading to insulin resistance is an important factor increasing their risk of metabolic disorders.

This study has several strengths, including a large sample size and strong specificity, with separate analyses for different genders exploring MONW phenotype risk and influencing factors, providing a robust theoretical basis for translating BRI into a more precise screening indicator. The study also examined the TyG index as a potential factor underlying gender differences in the relationship between BRI and MONW phenotype, providing more detailed evidence for this association.

Limitations: As a cross-sectional study, we cannot establish causal relation-

ships between BRI and MONW phenotype. Additionally, the study was limited to elderly populations in Anhui Province, so results should be cautiously applied to different regions and age groups.

In conclusion, BRI levels are significantly and positively associated with MONW phenotype risk in elderly populations of different genders, with high BRI levels showing a stronger association with MONW phenotype risk in elderly men. The TyG index is a potential factor contributing to this gender difference. Therefore, reducing BRI levels and decreasing TyG index may have greater significance for preventing MONW phenotype in elderly men.

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