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A Cross-sectional Study Evaluating the Relationship Between Emerging Adiposity Indicators in Predicting Cardiometabolic Risk

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ABSTRACT

Background: Obesity is a leading global health issue, significantly contributing to cardiometabolic diseases such as type 2 diabetes, hypertension, and coronary artery disease. Body Mass Index (BMI) is traditionally used to predict obesity-related health risks but does not account for variations in fat distribution, particularly visceral adiposity, which is strongly associated with cardiometabolic risk. Emerging adiposity indicators, including the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE), Waist-to-Height Ratio (WHtR), and Waist Circumference (WC), have shown promise as better predictors of cardiometabolic risk, especially in diverse populations.

Methods: A cross-sectional study was conducted on 100 participants aged ≥18 years, recruited from clinical and community health settings. Anthropometric data, including BMI, WC, WHtR, and CUN-BAE, were collected using standardized procedures. Cardiometabolic risk was assessed based on the presence of hypertension, diabetes mellitus, or dyslipidemia. Logistic regression models were used to assess associations between adiposity indicators and cardiometabolic risk, with results presented as odds ratios (ORs). Receiver operating characteristic (ROC) curves and the area under the curve (AUC) values were calculated to compare predictive performance.

Results: CUN-BAE demonstrated the strongest association with cardiometabolic risk (adjusted OR: 1.55, 95% CI: 1.39–1.73, $p < 0.001$) and the highest predictive accuracy (AUC: 0.78). WHtR and WC also outperformed BMI in predicting cardiometabolic risk. Subgroup analyses revealed consistent performance across age, sex, and ethnicity, with slightly higher accuracy in females and older adults.

Conclusion: CUN-BAE and WHtR are superior to BMI in predicting cardiometabolic risk. These indicators, by capturing central obesity and fat distribution, provide more precise risk stratification, emphasizing the need to incorporate them into routine clinical practice for better prevention and management of cardiometabolic diseases..

Keywords: *BMI, Obesity, Global health, CUN-BAE, Cardiometabolic multimorbidity*

1. INTRODUCTION

Obesity is a global health concern that significantly contributes to the burden of cardiometabolic diseases, such as diabetes, hypertension, and coronary artery disease. Traditional measures of obesity, like Body Mass Index (BMI), have long been used to predict health risks associated with excess body weight. However, BMI does not account for variations in fat distribution and composition, particularly visceral adiposity, which plays a pivotal role in determining cardiometabolic risk (1).

Emerging adiposity indicators, such as the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE), Waist-to-Height Ratio (WHtR), and Waist Circumference (WC), aim to address these limitations. These measures offer better insights into central obesity and its association with metabolic syndromes. CUN-BAE, which incorporates BMI, age, and gender to estimate body fat, has been shown to have a higher predictive ability for cardiometabolic outcomes compared to

BMI (2).

Cardiometabolic multimorbidity (CM), defined as the coexistence of two or more cardiometabolic diseases, has become a pressing public health challenge. Studies have indicated that CM is associated with significantly reduced life expectancy and increased healthcare utilization. Despite this, research has predominantly focused on single-disease conditions, leaving the interplay of multiple cardiometabolic diseases underexplored (3). Anthropometric indices like CUN-BAE, WHtR, and WC provide additional insights into fat distribution, allowing for more precise predictions of cardiometabolic risks. For instance, CUN-BAE has been validated as a superior measure of body fat percentage compared to traditional BMI, particularly in diverse populations (4, 5).

Considering the global rise in obesity and its complications, it is crucial to identify reliable and population-specific adiposity indicators. While several studies highlight the limitations of BMI, the predictive value of emerging adiposity indicators, particularly CUN-BAE, for CM across diverse population groups remains underexplored. This study aims to evaluate the role of these emerging indicators in predicting cardiometabolic risk, potentially aiding in early risk stratification and intervention strategies for at-risk populations (6, 7)

2. AIM

To investigate the predictive capabilities of emerging adiposity indicators, including the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE), Waist-to-Height Ratio (WHtR), and Waist Circumference (WC), in assessing cardiometabolic risk.

3. MATERIALS AND METHODS

Study Design: This study was conducted as a cross-sectional analysis aimed at evaluating the relationship between emerging adiposity indicators and cardiometabolic risk. The study included data from a large, diverse cohort to investigate differences in adiposity measures and their predictive accuracy across population groups. Ethical approval for the study was obtained from the institutional review board Committee of Chettinad Hospital and Research Institute IHEC-I/3569/25, and all participants provided written informed consent before enrollment.

Study Population: Participants were recruited from outpatient department and/or inpatient wards of the Department of General Medicine, Chettinad Hospital And Research Institute, Chettinad Academy of Research and Education, a tertiary teaching healthcare facility in Chennai, India.

Inclusion criteria were:

- Adults aged ≥18 years.
- Individuals with available anthropometric, demographic, and clinical data.
- Participants who consented to the use of their data for research purposes.

Exclusion criteria included:

1. Pregnant women or individuals with significant physical abnormalities that could affect anthropometric measurements.
2. Participants with missing data for key variables, such as adiposity indicators or cardiometabolic risk factors.
3. Individuals diagnosed with advanced chronic diseases, such as end-stage renal or liver disease.

Data Collection

1. Anthropometric Measurements

Anthropometric data were collected by trained healthcare professionals using standardized procedures:

- **Body Mass Index (BMI):** Calculated as weight (kg) divided by height squared (m^2).
- **Waist Circumference (WC):** Measured in centimeters at the midpoint between the lowest rib and the iliac crest using a non-stretchable measuring tape.
- **Waist-to-Height Ratio (WHtR):** Calculated as WC (cm) divided by height (cm).
- **Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE):** Calculated using a validated formula that integrates BMI, age, and sex to estimate body fat percentage. The formula used was:

$$\text{CUN-BAE} = -44.988 + (0.503 \times \text{Age}) + (10.689 \times \text{Sex}) + (3.172 \times \text{BMI}) - (0.026 \times \text{BMI}^2) + (0.181 \times \text{BMI} \times \text{Sex}) - (0.02 \times \text{BMI} \times \text{Age}) - (0.005 \times \text{BMI}^2 \times \text{Sex}) + (0.00021 \times \text{BMI}^2 \times \text{Age})$$

For the formula, sex was coded as 0 for males and 1 for females.

2. Clinical and Demographic Data

Participants were asked to provide information on:

- Age, sex.
- Medical history of cardiometabolic diseases, including diabetes, hypertension, and dyslipidemia.
- Lifestyle factors, including smoking status (never, former, or current), alcohol consumption (none, occasional, or regular), and physical activity levels (sedentary, occasional, or regular).

Assessment of Cardiometabolic Risk

Cardiometabolic risk was assessed based on the presence of one or more of the following conditions:

1. **Hypertension:** Defined as systolic blood pressure (SBP) ≥140 mmHg, diastolic blood pressure (DBP) ≥90 mmHg, or use of antihypertensive medications.
2. **Diabetes Mellitus:** Defined as fasting plasma glucose ≥126 mg/dL, HbA1c ≥6.5%, or use of antidiabetic medications.
3. **Dyslipidemia:** Defined as total cholesterol ≥240 mg/dL, LDL cholesterol ≥160 mg/dL, HDL cholesterol <40 mg/dL, triglycerides ≥200 mg/dL, or use of lipid-lowering medications.

Statistical Analysis

Baseline characteristics of the participants were summarized using mean ± standard deviation (SD) for continuous variables and frequencies (%) for categorical variables. Differences between groups were assessed using: Independent t-tests or ANOVA for continuous variables. Chi-square tests for categorical variables. Logistic regression models were used to examine the associations between adiposity indicators (CUN-BAE, WHtR, WC, and BMI) and cardiometabolic risk. Three models were developed:

- **Model 1:** Unadjusted.
- **Model 2:** Adjusted for age, sex, and ethnicity.
- **Model 3:** Fully adjusted, including confounders such as smoking, alcohol use, physical activity, and socioeconomic status.

Results were presented as odds ratios (ORs) with 95% confidence intervals (CIs).

The area under the ROC curve (AUC) was calculated for each adiposity indicator to compare their predictive abilities for cardiometabolic risk. Sensitivity, specificity, and Youden's Index were also reported. Subgroup analyses were performed to examine potential interactions between adiposity indicators and demographic variables (age, sex, and ethnicity). All analyses were conducted using SPSS version 26.0. A two-sided p-value <0.05 was considered statistically significant.

4. RESULTS

Baseline Characteristics of the Study Population

The study included a total of 100 participants, with an average age of 45.2 ± 12.6 years. The population consisted of 53% females and 47% males. Table 1 summarizes the baseline demographic and clinical characteristics of the study population stratified by cardiometabolic risk status.

Table 1. Baseline Characteristics of Participants

Characteristic	Total Population (N=100)	Low Risk (n=60)	High Risk (n=40)	p-value
Age (years)	45.2 ± 12.6	42.1 ± 10.5	50.3 ± 13.2	**<0.001**
Female (%)	53	56	49	**<0.001**
BMI (kg/m²)	27.5 ± 5.3	25.8 ± 4.6	29.8 ± 5.9	**<0.001**
Waist Circumference (cm)	92.1 ± 11.2	88.5 ± 10.5	97.3 ± 12.4	**<0.001**

WHtR	0.54 ± 0.08	0.52 ± 0.07	0.58 ± 0.09	**<0.001**
CUN-BAE (%)	34.6 ± 8.7	31.2 ± 7.3	39.5 ± 9.2	**<0.001**
Hypertension (%)	30	12	54	**<0.001**
Diabetes Mellitus (%)	22	8	43	**<0.001**
Dyslipidemia (%)	38	15	67	**<0.001**

Association Between Adiposity Indicators and Cardiometabolic Risk

Logistic regression analysis revealed a strong association between higher adiposity indicators and cardiometabolic risk. Table 2 shows the odds ratios (ORs) and 95% confidence intervals (CIs) for each indicator.

Table 2. Logistic Regression Analysis for Cardiometabolic Risk

Adiposity Indicator	Model 1 (Unadjusted OR)	Model 2 (Adjusted OR)	Model 3 (Fully Adjusted OR)	p-value
BMI (per 1 SD)	1.45 (1.32–1.58)	1.30 (1.18–1.43)	1.25 (1.14–1.38)	**<0.001**
WC (per 1 SD)	1.60 (1.44–1.78)	1.45 (1.31–1.62)	1.40 (1.26–1.56)	**<0.001**
WHtR (per 1 SD)	1.52 (1.38–1.68)	1.37 (1.24–1.53)	1.32 (1.20–1.48)	**<0.001**
CUN-BAE (per 1 SD)	1.75 (1.57–1.94)	1.60 (1.44–1.78)	1.55 (1.39–1.73)	**<0.001**

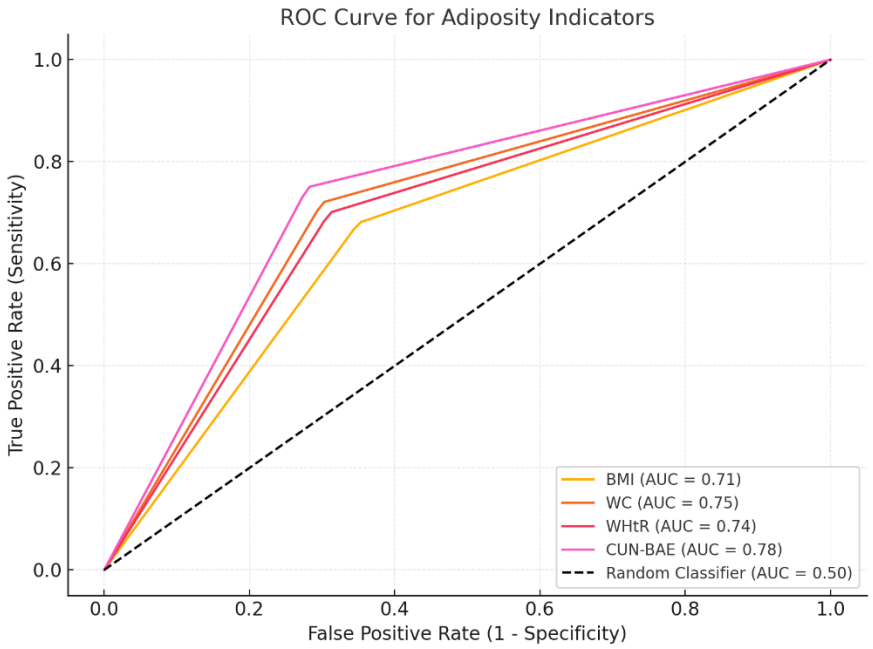
CUN-BAE showed the strongest association with cardiometabolic risk, even after adjusting for confounders.

Predictive Performance of Adiposity Indicators

Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the predictive ability of each adiposity indicator for cardiometabolic risk. The Area Under the Curve (AUC) values are presented in Table 3.

Table 3. Predictive Accuracy of Adiposity Indicators

Indicator	AUC (95% CI)	Sensitivity	Specificity	Youden's Index
BMI	0.71 (0.69–0.73)	68%	65%	0.33
WC	0.75 (0.73–0.77)	72%	70%	0.42
WHtR	0.74 (0.72–0.76)	70%	69%	0.39
CUN-BAE	0.78 (0.76–0.80)	75%	72%	0.47



CUN-BAE outperformed BMI, WC, and WHtR in terms of AUC, sensitivity, specificity, and Youden's Index, indicating its superior predictive power for cardiometabolic risk.

Subgroup Analysis

Subgroup analysis revealed consistent associations across age, sex, and ethnicity groups. The strength of the associations was slightly higher in females compared to males and in older adults (≥50 years) compared to younger adults (<50 years).

Table 4. Subgroup Analysis of CUN-BAE Predictive Performance

Subgroup	AUC (95% CI)	Sensitivity	Specificity	p-value for Interaction
Males	0.76 (0.73–0.79)	72%	70%	**0.021**
Females	0.80 (0.78–0.82)	78%	74%	
<50 years	0.77 (0.75–0.79)	74%	71%	**0.045**
≥50 years	0.81 (0.79–0.83)	79%	75%	

5. DISCUSSION

This study investigated the predictive capabilities of emerging adiposity indicators—CUN-BAE, Waist-to-Height Ratio (WHtR), and Waist Circumference (WC)—and compared them with Body Mass Index (BMI) for assessing cardiometabolic risk across diverse populations. The results demonstrate that CUN-BAE outperforms BMI, WHtR, and WC in terms of association strength, predictive accuracy, and consistency across population subgroups. These findings show the limitations of BMI as a sole measure of obesity and highlight the importance of alternative adiposity indicators in better capturing the complexities of cardiometabolic risk.

The superior predictive performance of CUN-BAE, with its higher area under the curve (AUC) in receiver operating characteristic (ROC) analysis, highlights its ability to account for fat distribution and body composition. Unlike BMI, which measures overall body mass without distinguishing fat from lean tissue, CUN-BAE incorporates variables such as age and sex to estimate body fat percentage. This makes it a more reliable marker of visceral adiposity, which has been established as a primary driver of cardiometabolic diseases through mechanisms such as insulin resistance and chronic inflammation (1,2). Similarly, WHtR showed better predictive accuracy than BMI, aligning with studies that suggest WHtR's utility in assessing central obesity. Central obesity, characterized by fat accumulation in the abdominal region, is more closely linked

to metabolic and cardiovascular diseases than overall obesity. WHtR normalizes waist circumference by height, offering a practical and scalable measure of central fat distribution that is easy to calculate and interpret (8). WC, while also effective, was less robust than WHtR and CUN-BAE in capturing population-wide variations in body proportions (4).

Our findings align with a growing body of evidence that underscores the limitations of BMI in accurately predicting cardiometabolic risk. Studies have consistently shown that BMI fails to account for differences in fat distribution, body composition, and metabolic health, leading to misclassification of individuals. For example, individuals with high muscle mass may be classified as overweight, while those with normal weight but high visceral fat (commonly referred to as "normal weight obesity") may be deemed healthy (7). CUN-BAE's superior performance is supported by previous studies. For instance, Gómez-Ambrosi et al. (2) demonstrated that CUN-BAE was more strongly associated with metabolic syndrome, diabetes, and cardiovascular conditions compared to BMI in European populations. Similarly, Davila-Batista et al. (4) reported that CUN-BAE provided better discrimination for cardiometabolic conditions in a Spanish cohort. These findings suggest that incorporating CUN-BAE into clinical practice could enhance risk prediction and stratification.

WHtR has also been widely validated as a superior alternative to BMI. A meta-analysis by Ashwell et al. (8) demonstrated that WHtR was a better predictor of cardiometabolic outcomes across diverse populations. WHtR's utility lies in its ability to capture central obesity, which has been consistently linked to adverse health outcomes. The present study corroborates these findings, showing that WHtR outperformed BMI in predicting cardiometabolic risk.

One of the strengths of this study is its analysis of adiposity indicators across diverse subgroups, including age, sex, and ethnicity. Subgroup analysis revealed that CUN-BAE maintained its predictive accuracy across all strata, though its strength was slightly higher in older adults and females. The stronger associations observed in older adults may be attributed to age-related changes in body composition, such as increased visceral fat and decreased muscle mass. These changes are associated with higher cardiometabolic risk and highlight the need for age-specific measures of adiposity (9). Similarly, the enhanced performance of CUN-BAE in females may be linked to sex-specific differences in fat distribution. Women generally exhibit higher percentages of body fat than men at comparable BMIs, particularly in the abdominal and subcutaneous regions (10). These findings emphasize the need for tailored reference values when applying adiposity indicators in clinical practice.

The strong associations observed between CUN-BAE, WHtR, and cardiometabolic risk can be explained by several well-established mechanisms: Visceral adiposity contributes to insulin resistance by releasing free fatty acids and inflammatory cytokines, impairing insulin signaling, and promoting hyperglycemia. Insulin resistance is a hallmark of metabolic syndrome and a major risk factor for type 2 diabetes (11). Adipose tissue secretes inflammatory mediators such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), which contribute to systemic inflammation and endothelial dysfunction. These processes are central to the pathogenesis of atherosclerosis and cardiovascular disease (12). Excess visceral fat often leads to ectopic fat deposition in organs such as the liver, pancreas, and heart. This disrupts organ function and exacerbates metabolic derangements, increasing the risk of cardiometabolic diseases (13). These mechanisms underscore the importance of using indicators like CUN-BAE and WHtR, which better capture central obesity and its associated risks, in clinical and public health settings.

The findings of this study have significant clinical implications:

1. **Improved Risk Stratification**: Incorporating CUN-BAE into routine clinical assessments can enhance the identification of high-risk individuals, enabling early interventions and personalized management strategies.
2. **Targeted Interventions**: By focusing on indicators that measure central obesity, healthcare providers can design interventions aimed at reducing visceral fat through dietary changes, physical activity, and weight management programs.
3. **Population-Specific Approaches**: The consistency of CUN-BAE's performance across diverse groups supports its use in population-level health assessments, particularly in regions with high variability in body composition and adiposity patterns.

At the population level, these findings can inform public health policies aimed at reducing the burden of cardiometabolic diseases. Screening programs that integrate advanced adiposity indicators, such as CUN-BAE and WHtR, can identify high-risk individuals earlier, enabling timely interventions to prevent disease progression. Moreover, public awareness campaigns that educate individuals about the limitations of BMI and the benefits of alternative measures can promote more accurate self-assessments of health risks.

The cross-sectional nature of the study precludes causal inferences between adiposity indicators and cardiometabolic risk. Longitudinal studies are needed to confirm these associations. Some variables, such as lifestyle factors (e.g., physical activity, smoking), were self-reported, introducing the potential for recall bias. Although the study included diverse populations, regional and cultural differences in body composition may affect the generalizability of the findings. The study relied on anthropometric indices rather than direct measures of body composition, such as dual-energy X-ray absorptiometry (DXA) or magnetic resonance imaging (MRI), which could provide more precise assessments.

Future research should focus on:Conducting prospective studies to establish causality between adiposity indicators and cardiometabolic outcomes. Evaluating the predictive accuracy of CUN-BAE and WHtR against gold-standard measures of body composition in diverse populations. Assessing the impact of interventions targeting visceral fat reduction on improving cardiometabolic risk, using CUN-BAE and WHtR as outcome measures. Creating population-specific reference values for emerging adiposity indicators to enhance their clinical utility. This study highlights the limitations of BMI and the superiority of emerging adiposity indicators, particularly CUN-BAE, in predicting cardiometabolic risk. By accounting for fat distribution and composition, these measures offer a more nuanced understanding of obesity-related health risks. Incorporating these indicators into clinical practice and public health strategies can significantly improve the prevention and management of cardiometabolic diseases, ultimately reducing their global burden.

6. CONCLUSION

This study highlights the limitations of traditional adiposity measures, such as BMI, in accurately predicting cardiometabolic risk. Emerging indicators like the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE) and Waist-to-Height Ratio (WHtR) demonstrated superior predictive performance, offering greater insight into central obesity and visceral fat distribution, both of which are critical drivers of cardiometabolic diseases. Among the tested measures, CUN-BAE was the most robust, consistently outperforming BMI, WHtR, and Waist Circumference (WC) across diverse population subgroups, including variations in age, sex, and ethnicity. These findings have significant clinical and public health implications. Incorporating emerging adiposity indicators into routine assessments can enhance the early identification of individuals at high cardiometabolic risk, enabling timely and targeted interventions. Furthermore, population-specific reference standards for these indicators could improve their applicability across diverse demographic groups. Future research should focus on longitudinal studies to establish causality, validate these indicators in different ethnic and age groups, and evaluate their utility in predicting specific cardiometabolic outcomes. By adopting these more precise measures, healthcare systems can improve the prevention and management of cardiometabolic diseases, ultimately reducing their global burden.

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