Rev Bras Cineantropom Desempenho Hum

Original article

https://doi.org/10.1590/1980-0037.2026v28e110521

Metabolic syndrome and its relationship with anthropometric measures in individuals with diabetes registered in the family health strategy in Rio Branco, Acre

Síndrome metabólica e sua relação com medidas antropométricas em pessoas com diabetes cadastradas na Estratégia Saúde da Família em Rio Branco, Acre

Alessandra dos Santos de Santana[1]
https ://orcid.org/0000-0001-7207-7291
Sabrina da Silva Santos[2]
https ://orcid.org/0000-0001-8327-3546
Gina Torres Rego Monteiro[2]
https ://orcid.org/0000-0002-9900-1825
Cledir de Araújo Amaral[3]
https ://orcid.org/0000-0002-7221-5364
Maurício Teixeira Leite de Vasconcellos[4]
https ://orcid.org/0000-0003-1658-2589
Maura Bianca Barbary de Deus[1]
https ://orcid.org/0000-0003-4058-1105
Thatiana Lameira Maciel Amaral[1]
https ://orcid.org/0000-0002-9197-5633

Abstract - The aim of this study was to analyze the relationship between metabolic syndrome (MS) and anthropometric measurements (AM) in people with type 2 diabetes mellitus (DM2) registered with the Family Health Strategy Units of Rio Branco, state of Acre, in 2019. Cross-sectional study with individuals with DM2. MS was the dependent variable, and anthropometric variables were obtained through physical and laboratory examinations. A Student's t-test or a Wald's chi-square test was used to compare groups. We tested correlations between AM and MS and used logistic regression to verify whether these indices were independently associated with the presence of MS. We evaluated the predictive power of the anthropometric indices using the ROC curve. A significance level of $p < 0.05$ was adopted. Of the 2,492 individuals with DM2 82.6% had MS, characterized by a high prevalence of elevated waist circumference (85%) and triglyceride levels ≥ 150 mg/dL (55%). Individuals with MS exhibited significantly higher blood pressure, triglyceride, TyG, and AM values, particularly among men. The correlation between anthropometric indicators and MS components varied by sex. The body roundness index CUN-BAE indices showed the best overall performance. The ROC analysis revealed that the BAI, CUN-BAE, and TMI indices exhibited greater discriminatory power among men, whereas the CI, WHR, and TyG indices demonstrated greater sensitivity among women. The study revealed a high prevalence of MS in the analyzed population, particularly regarding abdominal obesity and dyslipidemia. These findings reinforce the need to incorporate more specific anthropometric indicators to identify MS and prevent complications in diabetics.

Key words: Anthropometry; Diabetes *mellitus*; Metabolic syndrome.

Resumo - *O objetivo deste estudo foi analisar a relação entre síndrome metabólica (SM) e medidas antropométricas (MA) em pessoas com diabetes mellitus tipo 2 (DM2) cadastradas nas Unidades de Estratégia de Saúde da Família de Rio Branco, Acre, em 2019. Trata-se de um estudo transversal com indivíduos com DM2. A variável dependente foi a SM, e as variáveis antropométricas foram obtidas por exames físicos e laboratoriais. A comparação entre grupos utilizou os testes t de Student ou qui-quadrado de Wald. Foram testadas correlações entre as MA e a SM; e regressão logística para verificar se esses índices se associavam de forma independente à presença de SM. A capacidade preditiva dos índices antropométricos foi avaliada por meio da curva ROC. Adotou-se nível de significância de $p < 0,05$. Entre 2.492 indivíduos com DM2, 82,6% apresentaram SM, com alta frequência de circunferência da cintura elevada (85%) e triglicerídeos ≥150 mg/dL (55%). Indivíduos com SM exibiram valores significativamente maiores de pressão arterial, triglicerídeos, TyG e MA, especialmente entre os homens. A correlação entre indicadores antropométricos e componentes da SM variou conforme o sexo, com destaque para o IRC e o CUN-BAE, que mostraram melhor desempenho geral. Na análise ROC, os índices IAC, CUN-BAE e IMT apresentaram maior poder discriminatório entre homens, enquanto IC, RCQ e TyG foram mais sensíveis entre mulheres. O estudo evidenciou alta distribuição da SM na população analisada, com destaque para obesidade abdominal e dislipidemia. Esses achados reforçam a necessidade de incorporar indicadores antropométricos específicos e mais precisos para identificar a SM e prevenir complicações em diabéticos.*

Palavras-chave: *Antropometria; Diabetes mellitus; Síndrome metabólica.*

1. Universidade Federal do Acre – UFAC. Rio Branco, AC. Brasil.
2. Fundação Oswaldo Cruz. Escola Nacional de Saúde Pública. Rio de Janeiro, RJ. Brasil.
3. Instituto Federal de Educação, Ciência e Tecnologia do Acre. Rio Branco, AC. Brasil.
4. Fundação Instituto Brasileiro de Geografia e Estatística – IBGE. Escola Nacional de Ciências Estatísticas - ENCE. Sociedade para o Desenvolvimento da Pesquisa Científica – Science. Rio de Janeiro. RJ, Brasil.

Received: January 19, 2026
Accepted: April 08, 2026

How to cite this article
Santana AS, Santos SS, Monteiro GTR, Amaral CA, Vasconcellos MTL, Deus MBB, Amaral TLM. Metabolic syndrome and its relationship with anthropometric measures in individuals with diabetes registered in the family health strategy in Rio Branco, Acre. Rev Bras Cineantropom Desempenho Hum 2026, 28:e1100521. DOI: https://doi.org/10.1590/1980-0037.2026v28e110521

Corresponding author
Alessandra dos Santos de Santana.
Universidade Federal do Acre - UFAC
Rod. BR 364, Km 04, 69920-900, Bairro Distrito Industrial, Rio Branco (AC), Brasil.
E-mail: sandraciic@hotmail.com

Scientific Editor:
Diego Augusto Santos Silva

INTRODUCTION

Non-communicable chronic diseases (NCDs) pose a significant global challenge, resulting in high rates of premature mortality, disability, and diminished quality of life. These diseases hinder the achievement of the Sustainable Development Goals (SDGs) of the 2030 Agenda due to their social and economic impacts[1]. The increase in these diseases is related to demographic and epidemiological transitions occurring worldwide. In Brazil, data from the 2019 National Health Survey indicate prevalence rates of 23.9% for hypertension, 7.7% for diabetes mellitus, and 14.6% for hypercholesterolemia among adults, diagnostic criteria for metabolic syndrome that impose a significant burden on health systems[2].

Metabolic syndrome (MS) is notable for its impact on cardiovascular morbidity and mortality. Early detection and appropriate management of its risk factors are fundamental to reducing this impact. Although there is no single consensus on its definition, the 2009 harmonized version is widely used, as it favors comparability between populations[3].

Central obesity plays a key role in identifying MS and can be assessed using simple AM such as weight, height, and waist circumference[4]. While the latter is widely used, recent studies indicate that other measurements can also be effective in assessing MS[5]. Among these, the body mass index (BMI), waist-to-hip ratio (WHR), conicity index (CI), and lesser-known measures such as the body adiposity estimator (CUN-BAE), triponderal mass index (TMI), body adiposity index (BAI), and body roundness index (BRI) stand out[6].

Considering that people with DM2 are more prone to metabolic syndrome and its complications, determining the most effective anthropometric measurements for identification becomes relevant. Thus, this study aimed to determine the prevalence of MS and its relationship with anthropometric measurements in people with DM2 registered with Family Health Strategy Units of Rio Branco, state of Acre, in 2019.

METHOD

This was a cross-sectional study conducted with individuals aged 18 years or older who were diagnosed with type 2 diabetes mellitus (DM2) and registered with Family Health Strategy (FHS) units in the urban area of Rio Branco, state of Acre. Individuals with limitations that prevented communication or understanding of the questions, pregnant women, and people with type 1 diabetes were excluded from the sample.

The sample was defined based on the FHS registries, which were updated in partnership with community health agents. The sampling plan was carried out in two stages: initially, the FHS teams were selected proportionally based on the number of registered patients. Then, individuals were randomly selected from within each team. The sample size calculation considered an estimated proportion of 50%, a sampling error of 3.5%, and a design effect of 1.5. This resulted in a minimum sample size of 308 people with DM2. To compensate for potential losses and refusals, an additional 20% was added to this number, resulting in a total of 324 participants. In the expanded sample, this represents 2,492 participants. This work is part of the project, "Study of chronic diseases from the perspective of health quality: Methodological Aspects," the additional details of which are described in Amaral et al.[7].

Between April and July of 2019, a team of 16 trained professionals collected data in a private setting at the Basic Health Units. Information was obtained through structured interviews, laboratory tests, and anthropometric assessments. The team used an electronic instrument developed on the REDCap platform that had been tested in a pilot study.

Weight, height, waist, and hip circumference measurements were collected, following the protocols of the American College of Sports Medicine[8]. Body weight was measured using a G-Tech® digital scale with participants standing barefoot in light clothing. Height was measured using a Sanny® portable stadiometer. Waist circumference was obtained using an inelastic anthropometric tape, positioned at the smallest curvature of the trunk, at the end of expiration. Blood pressure was measured with a Beurer® digital device, according to the recommendations of the Ministry of Health[9], in three consecutive measurements, considering the average of the last two.

Blood samples were drawn after a 12-hour fast for analysis of triglycerides, total cholesterol, and fractions (HDL and LDL). Additional samples were used to measure glycated hemoglobin and fasting blood glucose, the latter obtained by capillary puncture with an Accu-Chek Performa® glucometer (Roche).

The dependent variable was the presence of MS, which was classified as present or absent according to the harmonized definition[10]. The diagnosis was established when three or more of the following criteria were met: triglyceride level ≥ 150 mg/dL or use of dyslipidemia medication; systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg, or use of antihypertensive medication; fasting blood glucose ≥ 100 mg/dL or use of hypoglycemic agents; HDL < 40 mg/dL in men or < 50 mg/dL in women, or use of dyslipidemia medication; and abdominal circumference ≥ 102 cm in men or ≥ 88 cm in women.

Different anthropometric indices were evaluated, including body mass index (BMI), waist-to-hip ratio (WHR), conicity index (CI), triponderal mass index (TMI), body adiposity index (BAI), CUN-BAE, body roundness index (BRI), and triglyceride-glucose index (TyG), according to the formulas in Chart 1[6].

Chart 1. Formulas for anthropometric measurements and biochemical indices.

ANTHROPOMETRIC INDICES	FORMULAS
Triglyceride glucose index– TyG	$\text{TyG} = \frac{ln\left[\text{Fasting triglycerides}\,(mg/dL) \times \text{Fasting blood glucose}\,(mg/dL)\right]}{2}$
Body mass index – BMI	$\text{BMI} = \frac{\text{Body mass}\,(kg)}{\text{Height (m)}^2}$
Conicity index – CI	$\text{CI} = \frac{\text{Waist circumference}\,(m)}{0.109\sqrt{\frac{\text{Body weight}\,(kg)}{\text{Height}\,(m)}}}$
Body adiposity index – BAI	$\text{BAI} = \frac{WC}{\text{Height} \times \sqrt{\text{Height}}} - 18$

Note. WC = waist circumference; kg= kilogram; m= meter; mg/dL= milligram per deciliter; $\pi(pi) = 3.14$.

Chart 1. Continued...

ANTHROPOMETRIC INDICES	FORMULAS
Clínica Universidad de Navarra - Body Adiposity Estimator - CUN-BAE	$CUN-BAE = -44.988 + (0.503 \times age) + (10.689 \times sex) + (3.172 \times BMI) - (0.026 \times BMI2) + (0.181 \times BMI \times sex) - (0.02 \times BMI \times age) - (0.005 \times BMI2 \times sex) + (0.00021 \times BMI2 \times age)$, where $male = 0$ and $female = 1$
Body roundness index – BRI	$BRI = 364.2 - 365.5 \times \sqrt{1 - \frac{\left(\frac{WC}{2\pi}\right)^2}{(0.5 \times Height)^2}}$
Triponderal mass index – TMI	$TMI = \frac{\text{Body mass}(kg)}{\text{Height}(m)^3}$
Waist-to-hip ratio – WHR	$WHR = \frac{WC(cm)}{Height(cm)}$

Note. WC = waist circumference; kg= kilogram; m= meter; mg/dL= milligram per deciliter; $\pi(pi) = 3.14$.

Continuous variables were described using means and standard deviations, while categorical variables were described using absolute and relative frequencies. Student's t-test was used for continuous variables, and Wald's chi-square test was used for categorical variables to compare groups with and without MS. The correlation between AM and MS was verified using the Pearson correlation coefficient. The predictive power of anthropometric indices to identify MS was evaluated using the ROC curve. All analyses were performed using SPSS® software, version 20.0, adopting a significance level of $p < 0.05$.

The study followed the ethical principles established by Resolution No. 466/2012 of the National Health Council and was approved by the Research Ethics Committee of the Federal University of Acre, under opinion number 2753401. All participants signed the Informed Consent Form.

RESULTS

Among the 2,492 people with DM2 included in the study, 40% had high blood pressure, 55% had triglycerides ≥ 150 mg/dL, 45% had low HDL, and 85% had an elevated WC. 2,059 people with diabetes presented with at least 2 other components of MS, resulting in a prevalence of 82.6% of MS in this population, according to the harmonized definition (Figure 1).

Individuals with MS presented significantly higher values for weight, blood pressure (SBP and DBP), triglycerides, TyG, and the main metabolic AM (WC, BMI, TMI, BRI, CUN-BAE, and WHR) compared to those without MS ($p < 0.05$). These differences were more pronounced among men, especially for weight, blood pressure, and triglycerides, though there was no difference for BAI. Women stood out for their older age, shorter stature, and elevated SBP, DBP, triglycerides, TyG, and body adiposity measures, except for BMI, CI, and WHR. Among the variables, blood glucose and HDL did not differ significantly in this population composed of people with DM2 (Table 1).

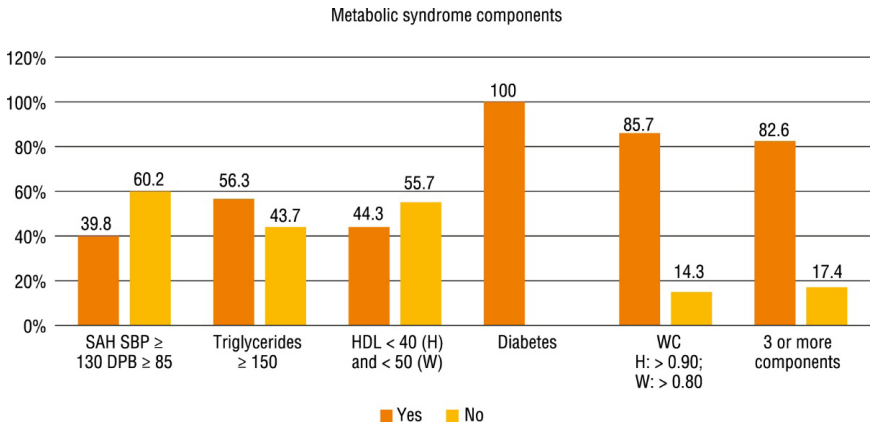

Figure 1. Distribution of metabolic syndrome components in people with diabetes registered with the Family Health Strategy (FHS) of Rio Branco, state of Acre, in 2019.

Note. SAH: Systemic arterial hypertension; HDL: High-density lipoprotein; M: Men; W: Women; WC: Waist circumference.

Correlation analysis revealed different patterns according to sex when examining the relationship between AM and MS components. In both sexes, WC showed positive correlations, although of weak to moderate magnitude, with systolic and diastolic blood pressure and a negative correlation with HDL ($p < 0.05$). In men, WC was also associated with blood glucose and triglyceride levels ($p < 0.05$). Despite being the classic indicator of central adiposity, other AM performed better with MS components. BRI and CUN-BAE were superior in both sexes, with CUN-BAE being more sensitive among men and BRI being more robust among women ($p < 0.05$). BMI and TMI exhibited intermediate performance and correlations similar to WC, while BAI, WHR, and CI showed weaker and inconsistent correlations with metabolic components (Table 2).

In the sex-stratified analysis, WC and WHR showed better discriminatory power among women, with an area under the curve (AUC) of 0.728 and 0.706, respectively. TyG also showed good performance (AUC = 0.682; $p = 0.001$) and statistical significance. Other indicators, such as BRI, CUN-BAE, TMI, WC, and BMI, had AUC values between 0.543 and 0.667, and lower discriminatory power, although some, such as BRI ($p = 0.007$), were statistically significant. Among men, the BAI, CUN-BAE, and TMI indices stood out, with AUCs of 0.824, 0.801, and 0.807 ($p < 0.001$), respectively. BRI and BMI also showed good performance with AUCs of 0.782 and 0.796, respectively ($p < 0.001$). TyG, WC, and CI presented intermediate AUCs (0.680–0.757; $p < 0.001$), while WHR (AUC = 0.654; $p = 0.121$) was not significant (Table 3).

DISCUSSION

Metabolic syndrome (MS) is highly prevalent in the studied population, with most individuals exhibiting multiple risk factors associated with abdominal obesity and elevated triglyceride levels. Individuals with MS have significantly higher blood pressure, weight, and triglycerides than those without MS. The diagnostic capacity of AM varies between men and women. WC showed weak to moderate correlations; CUN-BAE obtained better results in men, while BRI obtained better results in women.

Table 1. Mean and standard deviation of clinical and anthropometric characteristics, stratified by sex for the presence of metabolic syndrome, in people with type 2 diabetes registered with the Family Health Strategy (FHS) of Rio Branco, state of Acre, 2019.

Variables	Male			Female			Total		
	MS (Yes)	MS (No)	p-value	MS (Yes)	MS (No)	p-value	MS (Yes)	MS (No)	p-value
Age (years)	63.2±12.5	58.39±16.8	0.100	62.2±13.2	52.4±13.4	0.001	62.5±12.99	55.43±15.38	0.001
Height (cm)	164.2±0.07	164.2±0.07	0.987	151.8±0.06	156.0±0.04	0.003	156.043±8.96	160.16±7.578	0.003
Weight (kg)	83.8±20.3	63.8±11.1	0.001	71.8±16.0	69.2±15.8	0.479	75.82±18.458	66.52±13.765	0.001
SBP (mmHg)	140.6±24.6	113.3±13.9	0.001	138.0±23.4	115.1±13.6	0.001	138.98±23.830	114.20±13.691	0.001
DBP (mmHg)	82.5±14.8	68.5±8.0	0.001	76.2±10.5	67.1±10.8	0.001	78.41±12.512	67.822±9.453	0.001
Blood glucose (mg/dL)	207.0±142.1	184.1±89.1	0.483	180.1±91.0	181.0±88.3	0.970	189.59±112.597	182.59±87.652	0.695
Triglycerides (mg/dL)	225.4±136.4	119.7±67.9	0.001	195.9±107.6	137.8±90.2	0.011	206.27±119.093	129.38±80.165	0.001
Tyg (mg/dL)	5.25±0.3	4.97±0.2	0.001	5.16±0.34	5.00±0.32	0.037	5.198±0.348	4.999±0.274	0.001
HDL (mg/dL)	40.09±9.6	43.6±14.4	0.164	48.9±13.3	45.3±12.5	0.215	45.82±12.895	44.55±13.325	0.539
WC (cm)	102.0±14.2	83.9±9.3	0.001	96.6±11.7	88.4±11.0	0.002	98.474±12.877	86.163±10.395	0.001
BMI (Kg/m2)	30.8±6.4	23.6±3.6	0.001	31.0±5.9	28.4±5.9	0.057	30.95±6.108	26.00±5.463	0.001
TMI	18.7±3.9	14.4±2.3	0.001	20.4±3.8	18.2±3.8	0.013	19.87±3.948	16.30±3.688	0.001
BRI	6.03±1.9	3.6±1.07	0.001	6.39±1.9	4.79±1.5	0.001	6.272±1.911	4.200±1.461	0.001
CI	1.33±11.8	1.24±12.4	0.003	1.33±53.4	1.22±6.	0.331	133.62±44.110	123.64±9.878	0.132
CUN-BAE	33.1±6.4	23.9±6.1	0.001	44.6±5.2	40.8±6.2	0.002	40.754±7.845	31.991±10.721	0.001
BAI	32.6±23.5	24.8±2.9	0.115	38.0±6.0	34.3±5.4	0.006	36.23±14.695	29.57±6.461	0.598
WHR	1.00±0.1	0.92±0.08	0.001	0.95±0.36	0.86±0.59	0.263	0.96±0.300	89.73±0.783	0.106

Note. MS: Metabolic syndrome; SBP: Systolic blood pressure (millimeters of mercury, mmHg); DBP: Diastolic blood pressure (millimeters of mercury, mmHg); Blood glucose: Fasting blood glucose (milligrams per deciliter, mg/dL); Triglycerides: Serum triglycerides (mg/dL); TyG: Triglyceride-glucose index; HDL: High-density lipoprotein cholesterol (mg/dL); WC: Waist circumference (centimeters, cm); BMI: Body Mass Index (kilograms per square meter, kg/m²); TMI: Triponderal Mass Index; BRI: Body Roundness Index; CI: Conicity Index; CUN-BAE: Clínica Universidad de Navarra Body Adiposity Estimator; BAI: Body Adiposity Index; WHR: Waist-to-Hip Ratio.

Table 2. Correlation between anthropometric variables and metabolic syndrome components in people with diabetes registered with the Family Health Strategy (FHS) of Rio Branco, state of Acre, in 2019.

Variables	SBP	DBP	Blood glucose	Triglycerides	TyG	HDL	WC	BMI	TMI	BRI	CI	CUN-BAE	BAI	WHR
Female														
SBP	1													
DBP	0.528**	1												
Blood glucose	-0.085**	0.007	1											
Triglycerides	0.043	0.081**	0.478**	1										
TyG	0.064*	0.064*	0.663**	0.815**	1									
HDL	-0.065*	-0.038	-0.120**	-0.389**	-0.326**	1								
WC	0.168**	0.285**	0.057*	0.046	0.019	-0.145**	1							
BMI	0.092**	0.301**	-0.017	-0.001	-0.033	-0.074**	0.841**	1						
TMI	0.132**	0.279**	0.012	0.009	-0.006	-0.073**	0.815**	0.974**	1					
BRI	0.222**	0.230**	0.080**	0.077**	0.065*	-0.146**	0.935**	0.795**	0.849**	1				
CI	0.033	0.006	0.089**	-0.058*	-0.013	-0.067*	0.320**	0.050	0.052*	0.657**	1			
CUN-BAE	0.186**	0.306**	0.069*	-0.014	-0.066*	-0.071**	0.846**	0.946**	0.947**	0.824**	0.074**	1		
BAI	0.190**	0.154**	0.008	-0.063*	-0.058*	-0.023	0.704**	0.800**	0.877**	0.817**	0.084**	0.827**	1	
WHR	0.022	0.028	0.098**	-0.021	0.014	-0.092**	0.323**	0.059*	0.059*	0.549**	0.991**	0.078**	0.038	1
Male														
SBP	1													
DBP	0.671**	1												
Blood glucose	0.064	0.041	1											

Note. SBP: Systolic blood pressure (millimeters of mercury, mmHg); DBP: Diastolic blood pressure (millimeters of mercury, mmHg); Blood glucose: Fasting blood glucose (milligrams per deciliter, mg/dL); Triglycerides: Serum triglycerides (mg/dL); TyG: Triglyceride-glucose index; HDL: High-density lipoprotein cholesterol (mg/dL); WC: Waist circumference (centimeters, cm); BMI: Body Mass Index (kilograms per square meter, kg/m^2); TMI: Triponderal Mass Index; BRI: Body Roundness Index; CI: Conicity Index; CUN-BAE: Clínica Universidad de Navarra Body Adiposity Estimator; BAI: Body Adiposity Index; WHR: Waist-to-Hip Ratio. **. The correlation is significant at 0.01 (two-tailed). *. The correlation is significant at 0.05 (two-tailed).

Table 2. Continued...

Variables	SBP	DBP	Blood glucose	Triglycerides	TyG	HDL	WC	BMI	TMI	BRI	CI	CUN-BAE	BAI	WHR
Triglycerides	0.097**	0.274**	-0.043	1										
TyG	0.081*	0.266**	0.126**	0.832**	1									
HDL	-0.226**	-0.089**	0.021	-0.456**	-0.416**	1								
WC	0.220**	0.243**	-0.119**	0.213**	0.153**	-0.192**	1							
BMI	0.243**	0.300**	-0.066	0.195**	0.159**	-0.213**	0.807**	1						
TMI	0.238**	0.289**	-0.032	0.188**	0.162**	-0.204**	0.773**	0.982**	1					
BRI	0.247**	0.217**	-0.065	0.181**	0.141**	-0.147**	0.951**	0.804**	0.834**	1				
CI	0.032	0.021	0.015	0.052	0.069	0.011	0.697**	0.164**	0.185**	0.684**	1			
CUN-BAE	0.313**	0.316**	-0.093*	0.229**	0.181**	-0.274**	0.806**	0.952**	0.951**	0.821**	0.231**	1		
BAI	0.048	0.078*	-0.030	-0.006	-0.039	-0.073*	0.165**	0.193**	0.194**	0.163**	0.037	0.191**	1	
WHR	0.062	0.081*	-0.040	0.055	0.069	-0.049	0.686**	0.266**	0.273**	0.670**	0.862**	0.342**	0.020	1

Note. SBP: Systolic blood pressure (millimeters of mercury, mmHg); DBP: Diastolic blood pressure (millimeters of mercury, mmHg); Blood glucose: Fasting blood glucose (milligrams per deciliter, mg/dL); Triglycerides: Serum triglycerides (mg/dL); TyG: Triglyceride-glucose index; HDL: High-density lipoprotein cholesterol (mg/dL); WC: Waist circumference (centimeters, cm); BMI: Body Mass Index (kilograms per square meter, kg/m^2); TMI: Triponderal Mass Index; BRI: Body Roundness Index; CI: Conicity Index; CUN-BAE: Clínica Universidad de Navarra Body Adiposity Estimator; BAI: Body Adiposity Index; WHR: Waist-to-Hip Ratio. **. The correlation is significant at 0.01 (two-tailed). *. The correlation is significant at 0.05 (two-tailed).

Table 3. Performance of anthropometric indices in discriminating metabolic syndrome according to sex, based on ROC curve analysis, in people with type 2 diabetes registered with the Family Health Strategy (FHS) of Rio Branco, state of Acre, in 2019.

Indices	AUC (95% CI)	p-value	Cutting point	Sensitivity (%)	Specificity (%)	Youden index
Female						
BMI	0.543 (0.405-0.681)	0.539	29.0592	58.9	58.8	0.177
WHR	0.706 (0.599-0.813)	0.001	0.8888	71.0	62.5	0.338
CI	0.728 (0.621-0.835)	0.001	1.2457	71.3	62.5	0.338
CUNBAE	0.622 (0.481-0.762	0.091	42.6749	64.0	64.7	0.287
TMI	0.590 (0.459-0.721)	0.178	19.0061	61.1	64.7	0.258
BRI	0.667 (0.547-0.787)	0.007	5.3801	66.7	62.5	0.292
BAI	0.564 (0.438-0.690)	0.319	35.6635	59.8	62.5	0.223
WC	0.594 (0.460-0.728)	0.170	93.85	54.2	56.2	0.105
TyG	0.682 (0.573-0.790)	0.001	4.9453	72.9	64.7	0.376
Male						
BMI	0.796 (0.679-0.913)	0.001	26.6120	67.3	72.7	0.401
WHR	0.654 (0.459-0.848)	0.121	0.9665	64.6	70.0	0.346
CI	0.680 (0.483-0.877)	0.073	1.2902	76.0	70.0	0.460
CUNBAE	0.801 (0.677-0.926)	0.001	26.1349	86.7	73.6	0.504
TMI	0.807 (0.681-0.933)	0.001	15.4368	78.6	72.7	0.513
BRI	0.782 (0.659-0.904)	0.001	4.1215	82.7	70.0	0.527
BAI	0.824 (0.697-0.952)	0.001	25.8502	80.6	80.0	0.606
WC	0.757 (0.636-0.879)	0.001	93.38	66.3	60.0	0.263
TyG	0.732 (0.639-0.826)	0.001	4.9904	75.5	62.5	0.380

Note. AUC: Area Under the Curve; TyG: Triglyceride-glucose index; WC: Waist circumference (centimeters, cm); BMI: Body Mass Index (kilograms per square meter, kg/m^2); TMI: Triponderal Mass Index; BRI: Body Roundness Index; CI: Conicity Index; CUN-BAE: Clínica Universidad de Navarra Body Adiposity Estimator; BAI: Body Adiposity Index; WHR: Waist-to-Hip Ratio.

These findings reinforce the idea that everyone with diabetes is at risk for metabolic complications and requires intervention, either through lifestyle changes or medication. Hyperglycemia, characterized by elevated glucose levels, is one of the five criteria for diagnosing MS, according to the main international consensus guidelines[9]. It is important to note that the lack of a standardized definition of MS makes evaluation difficult and increases the risk of complications[11]. Most individuals with DM2 meet the criteria for MS[12], resulting in a high prevalence in this study.

Studies conducted in different geographical contexts corroborate the high values found in this study. In Pakistan, MS was identified in 65.6% of diabetics according to the IDF criteria[13]; in Ghana, the prevalence reached 58% according to NCEP ATP III; and in Malaysia, the proportions were 95.8% (WHO), 96.1% (NCEP ATP III), 84.8% (IDF), and 97.7% (harmonized definition)[14] In Brazil, a study in the Northeast region identified a prevalence of 74.3% using IDF criteria, 70.8% according to NCEP ATP III, and 76.1% according to the harmonized definition[15] In Piauí, 50.7% of people with diabetes mellitus presented with MS, according to the NCEP ATP III criteria[16] These data demonstrate that the prevalence of MS among people with diabetes is alarming, both in different countries and in different regions of Brazil. In the local context of Rio Branco, state of Acre, our findings indicate a similarly concerning situation, reinforcing the necessity of systematic primary healthcare interventions aimed at preventing, detecting early, and managing multiple metabolic risk factors.

Among the components of MS, the absence of significant differences in blood glucose and HDL levels between the groups with and without MS deserves highlighting, especially among individuals with DM2. This is plausible since

glycemic control tends to be more consistent due to diabetes-specific drug treatment and dietary interventions. Therefore, the focus of metabolic risk shifts to other components of MS, such as obesity, blood pressure, and triglycerides. In this study, these factors proved to be the most frequently altered. These results corroborate previous research pointing to these alterations as determinants of increased cardiovascular and metabolic risk in people with DM2[7-19].

Correlation analysis of the AM and MS components revealed distinct patterns depending on sex. BRI and CUN-BAE performed better in both sexes. In a study of European adults, CUN-BAE also performed well in both men and women when BMI was added for men, and the weight-for-height ratio was added for women[20]. A possible explanation for this performance is that its formula includes age, BMI, and sex, which takes into account each individual's particularities, setting it apart from other measurements that do not consider these particularities[21] BRI is also supported by Chinese research that showed the relevance of this measurement in predicting MS[22].

The CI and WHR were more correlated with blood glucose, which is a similar relationship found in elderly diabetics[23]. Despite being an indicator of central adiposity, WHR did not reach statistical significance in diabetic individuals. However, in studies of healthy populations, it has shown relevance[24-26].

Thus, the data revealed that although WC is still more commonly used to predict MS, other measures have higher correlations in the diabetic population. In summary, the AM evaluated in this study showed higher correlations than WC in predicting MS. These findings are consistent with those of other studies on the subject[27-30].

It is also worth noting that this study involved a representative population of people with DM2 registered in primary care. This allowed for the assessment of MS based on objective health data and the use of different AM in a specific clinical and population context. Using multiple anthropometric indices, including alternatives to WC, and conducting stratified analyses by sex adds methodological robustness. This allows us to identify which measures are more discriminatory in men and women with significant health condition differences in a specific population. However, there are limitations to consider. The cross-sectional design prevents inferring causal relationships between AM and MS. In addition, some behavioral and clinical variables were obtained through self-report. Finally, although the study included multiple anthropometric indices, it did not evaluate other biomarkers or more advanced body composition and position measures, such as bioimpedance, which could complement metabolic risk analysis.

In conclusion, incorporating more precise and contextualized metabolic indices can optimize the early detection of MS, guide lifestyle interventions and drug treatment, and reduce the risk of cardiovascular and metabolic complications in individuals with diabetes. Further longitudinal and multicenter research is necessary to validate these indices in different populations and develop evidence-based clinical recommendations.

CONCLUSION

In summary, our findings indicate a high prevalence of metabolic syndrome (MS) in the analyzed population, with abdominal obesity and dyslipidemia emerging as the primary altered components. The observed differences between the sexes reinforce the influence of biological and behavioral factors on the manifestation of

MS. Alternative anthropometric indices, such as CUN-BAE and BRI, exhibited stronger correlations with MS components and greater discriminatory power than WC alone. The identification of male sex, non-smoking, and the use of oral medication as protective factors emphasizes the importance of integrated therapeutic strategies focusing on metabolic control and lifestyle modification. These results highlight the need to incorporate more precise, individualized anthropometric indicators into clinical practice to improve the screening and prevention of MS and its complications in diabetic populations.

Compliance with ethical standards

Funding

This study was supported by the Acre State Research Support Foundation (FAPAC) – PPSUS Call 004/2017, through the Research Program for the SUS: shared health management (FAPAC-SESACRE-Decit/SCTIE/MS-CNPq), Process No. 6068-18-0000299, Grant Agreement No. 032/2018.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee of the Federal University of Acre (UFAC), and the protocol (CAAE: 84541517.0.0000.5009; approval report no. 2.753.401) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: Santana AS, Santos SS, Monteiro GTR, Amaral CA, Vasconcellos MTL, Deus MBB, Amaral TLM. Contributed reagents/materials/analysis tools: ASS, TLMA. Wrote the paper: Santana AS, Santos SS, Monteiro GTR, Amaral TLM.

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