ORIGINAL ARTICLE

Efficacy of Anthropometric Indicators as Risk Predictors of Metabolic Syndrome among Academic Staff: A Gender-Specific, Cross-Sectional Study

Aravan Mungvongsa, DrPH[1], Siraporn Potivichayanon, PhD[1], Chavaboon Dechsukhum, MD, PhD[2], Thidarat Somdee, DrPH[3], Suttinee Paenngoen, BSc[4]

[1] Institute of Public Health, Suranaree University of Technology, Nakhon Ratchasima, Thailand; [2] Institute of Medicine, Suranaree University of Technology, Nakhon Ratchasima, Thailand; [3] Faculty of Public Health, Mahasarakham University, MahaSarakham, Thailand; [4] Suranaree University of Technology Hospital, Suranaree University of Technology, Nakhon Ratchasima, Thailand

Background: Metabolic syndrome (MetS) is a cluster of conditions that increases the risk of non-communicable diseases, posing a significant public health problem. Identifying early risk predictors is a crucial strategy for effectively reducing premature mortality in at-risk individuals.

Objective: To evaluate the ability of gender-specific anthropometric indicators to predict MetS risk among academic staff.

Materials and Methods: A cross-sectional study was conducted in Thailand between April 19 and September 26, 2024. The present study enrolled 505 participants, all of whom were academic staff members aged 18 to 59 years. The research instruments consisted of a participant characteristics questionnaire, anthropometric measurements, and biochemical parameters obtained from medical records. Participants were randomly selected using a two-stage sampling method. The researchers evaluated the area under the curve (AUC) of the receiving operating curve (ROC) to predict MetS risk according to criteria established by the International Diabetes Federation (IDF).

Results: The overall prevalence of MetS was 34.1%. Logistic regression analyses showed that waist circumference (WC), hip circumference (Hip), waist-to-height ratio (WHtR), visceral adiposity index (VAI), A Body Shape Index (ABSI), and body roundness index (BRI) were significantly associated with an increased risk of MetS in both genders ($p<0.05$). According to AUC of ROC analysis, WC showed the highest predictive ability in men, with an AUC of 0.81 (95% confidence interval [CI] 0.74 to 0.88), followed by WHtR and VAI. In women, VAI had the highest AUC of 0.88 (95% CI 0.85 to 0.92), followed by WC and WHtR.

Conclusion: WC and VAI were the most effective predictors of MetS risk in men and women, respectively. Therefore, utilizing anthropometric indicators appropriate for each gender can enhance the accuracy of predicting MetS in at-risk individuals.

Keywords: Anthropometric indicators; Predictors; Metabolic syndrome; Academic staff

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Metabolic syndrome (MetS) is a cluster of metabolic abnormalities, including central obesity, insulin resistance, hypertension, and dyslipidemia, that significantly increases the risk of atherosclerotic cardiovascular diseases and type 2 diabetes mellitus(1). A diagnosis of MetS requires the presence of at least three of the following criteria, elevated waist circumference (WC), high triglycerides (TG), low high-density lipoprotein cholesterol (HDL-C), high blood pressure (BP), and elevated fasting blood glucose (FBG)(2). According to the International Diabetes Federation (IDF), approximately 20% to 25% of the global adult population is affected by MetS(2). In Thailand, the prevalence ranges from 28% to 50% among adults, imposing substantial health, social, and economic burdens(3). Previous studies have shown that individuals with MetS have a significantly higher risk of cardiovascular disease, type 2 diabetes, coronary artery disease, hypertension, and stroke(4,5). Excess body fat, particularly abdominal obesity, plays a central role in the development of MetS and associated chronic diseases(6). Notably, visceral adipose tissue, rather than subcutaneous fat, is strongly linked to type 2 diabetes(7).

Correspondence to:

Mungvongsa A.

Institute of Public Health, Suranaree University of Technology, Muang Nakhon Ratchasima District, Nakhon Ratchasima 30000, Thailand.

Phone: +66-96-9455058

Email: aravan@sut.ac.th

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Early detection of MetS is vital for preventing chronic diseases and reducing public health costs. Traditional diagnostic approaches include invasive and expensive laboratory tests that assess plasma lipid profiles and glycemic levels. In contrast, anthropometric indicators such as WC, waist-to-height ratio (WHtR), body mass index (BMI), and neck circumference (NC) offer non-invasive and cost-effective alternatives for risk prediction and large-scale screening[8,9]. However, due to variations in body composition and fat distribution among different populations, establishing population-specific cut-off values is essential for enhancing the accuracy of MetS risk prediction[10].

Gender significantly influences the development of MetS. For example, factors such as older age, lower education level, and low income are associated with increased risk, particularly among women[11]. Studies seeking to identify the best anthropometric predictors for both genders have yielded inconsistent results. For instance, research on Thai adults identified the body roundness index (BRI) as a robust MetS screening tool in both genders[12], while a study of adults in Jordan found that BRI and WHtR had the highest MetS prediction sensitivity in both men and women. Notably, these metrics generally exhibited higher sensitivity in women, although WHtR had a higher early detection cut point in men[13]. Moreover, a Brazilian study revealed that NC is a strong predictor of MetS in women[14]. Overall, these findings emphasize the need for gender-specific anthropometric indicators of MetS risk.

Nevertheless, gender-related differences limit the applicability of universal anthropometric cutoff values, particularly in the context of diverse populations. Specifically, genetic and physiological variability influence fat distribution and metabolic responses, potentially reducing the predictive accuracy of these indicators for MetS[15]. For example, a study of obese adults in Tabriz by Fahami et al.[16] reported that BRI was a poor predictor of MetS risk. Additionally, research on middle-aged and elderly individuals in China revealed that the A Body Shape Index (ABSI) had limited MetS predictive power[17]. These and other conflicting findings have highlighted the challenges of identifying the most reliable anthropometric indicator for MetS risk prediction[18].

Taken together, effective gender-specific anthropometric indicators of MetS risk are needed. However, previous research in this area had primarily been focused on the general population. Therefore, herein, the researchers evaluated the efficacy of such metrics in a specific population (Thai adults who work in an academic setting). However, the findings from the present study may have limited generalizability, as this unique sample may not fully represent the broader population[13]. Nevertheless, the present study findings contribute knowledge regarding the use of gender-specific anthropometric metrics for MetS risk prediction.

Materials and Methods

Study population

The present study was a cross-sectional study enrolled academic staff at Suranaree University of Technology (SUT) in Nakhon Ratchasima, Thailand, a health education and research institution[19]. The study was approved by the SUT Human Research Ethics Committee (EC-66-0127). Data was collected between April 19 and September 26, 2024. Data included: 1) participant characteristic information obtained through a self-administered questionnaire, 2) biochemical data retrieved from the hospital's electronic medical records system, and 3) anthropometric measurements, including height, weight, WC, hip circumference (Hip), NC, WHtR, visceral adiposity index (VAI), ABSI, BRI, and conicity index.

Academic staff aged 28 to 59 years who had no disabilities; could read, write, and speak Thai, and consented to participate in the present study were enrolled. Individuals with serious health conditions that prevented participation, as well as pregnant individuals, were excluded.

The sample size was determined using methods described by Peat et al.[20] and considered the prevalence of MetS in Thailand to be 47.28% as reported in a previous study[21]. The following parameters were applied in the sample size calculation: Z=1.96, corresponding to a 95% confidence interval (CI); d=0.025, representing a precision of 2.5%; and p=0.47, denoting the estimated prevalence of MetS. Based on these parameters, the required sample size was calculated to be 505 participants. Participants were diagnosed with MetS according to criteria established by the IDF, with the expected sensitivity and specificity of the diagnostic measures estimated to be as high as 0.90.

A two-stage sampling method was used to select the study sample; a total population of 2,501 individuals met the criteria for inclusion. In the first stage, eligible individuals in all 35 university departments underwent purposive sampling to ensure the sample was representative of the population. In the second stage, proportional allocation was applied to determine the sample size for each department. Finally, simple random sampling within each department were conducted using a lottery system until a total of 505 participants were obtained.

Measurements

Participant characteristics:

Participant characteristics included gender as men or women, age in years, comorbidities such as diabetes, hypertension, stroke, cardiovascular disease, hyperlipidemia, and obesity, smoking status as never or ever smoked, alcohol consumption as never or ever drink, and physical activity as never or ever participate. These six variables were assessed using a self-reported structured questionnaire.

Anthropometric indicators:

In the present study, anthropometric indicators included WC, Hip, NC, WHtR, VAI, ABSI, BRI, and conicity index. Height and weight were measured using a stadiometer and calibrated scale, respectively. WC, Hip, and NC were assessed using measuring tape, as follows: To measure WC, the tape was drawn close to the skin (but not too tight) and positioned parallel to the floor. Hip was measured at the most salient point between the waist and the thigh. NC was measured with the upper edge of the measuring tape positioned at the base of the neck horizontally below the cricothyroid cartilage with the head upright and parallel to the wall and the eyes facing forward[22]. All measurements were obtained by trained personnel using standardized techniques and calibrated equipment. BMI was calculated by dividing the measured weight (kg) by the squared height (m²). The researchers used the Asian BMI classification system determined by the World Health Organization (WHO)[23], which includes underweight (<18.5 kg/m²), normal weight (18.5 to 22.9 kg/m²), overweight (23 to 24.9 kg/m²), and obese (≥25 kg/m²), using self-reported values.

WHtR assessment:

WHtR is a simple and effective body fat distribution metric used to assess an individual's health risk. WHtR is calculated using the following formula[24]:

$$\text{WHtR} = \frac{\text{WC}}{\text{height}}$$

VAI assessment:

VAI is calculated using WC, BMI, TG, and HDL-C. The formulas for men and women are as follows[25]:

$$\text{Men:} \quad \text{VAI} = \frac{\text{WC}}{39.68+(1.88\times\text{BMI})} \times \frac{\text{TG}}{1.03} \times \frac{1.31}{\text{HDL-C}}$$

$$\text{Women:} \quad \text{VAI} = \frac{\text{WC}}{36.58+(1.89\times\text{BMI})} \times \frac{\text{TG}}{0.81} \times \frac{1.52}{\text{HDL-C}}$$

ABSI assessment:

ABSI is calculated based on WC, weight, and height; a high ABSI indicates that WC is higher than expected for a given height and weight, and that visceral fat is more concentrated in the abdominal region. ABSI is calculated using the following formula[16]:

$$\text{ABSI} = \frac{\text{WC}}{\text{height}^{1/2}\times\text{BMI}^{2/3}}$$

BRI assessment:

BRI is a novel body shape assessment index calculated using participants' height (cm) and WC (cm)[26]. The formula is as follows[27]:

$$\text{BRI} = 364.2 - 365.5\sqrt{1 - \frac{\text{WC}\div(2\pi)^2}{(0.5\times\text{height})^2}}$$

Conicity index assessment:

The conicity index was estimated from weight, height, and WC measurements using the following equation[28]:

$$\text{Conicity index} = \frac{\text{WC(m)}}{0.019\sqrt{\frac{\text{weight(kg)}}{\text{height(m)}}}}$$

Assessment of biochemical data

Biochemical data such as BP, FBG, TG, total cholesterol (TC), and HDL-C were retrieved from the hospital's electronic medical records system. The researchers diagnosed MetS according to criteria established by the IDF[29]. Patients were diagnosed when they presented with a WC of ≥90 cm (men) or ≥80 cm (women), along with two or more of the following additional criteria: elevated BP (≥130/85 mmHg) or had been previously diagnosed with arterial hypertension; an HDL-C level of <40 mg/dL in men or <50 mg/dL in women, or the use of lipid-lowering medications; TG ≥150 mg/dL or on drug treatment; FBG level ≥100 mg/dL or had been previously diagnosed with diabetes mellitus.

Statistical analysis

Data was analyzed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess data normality. Descriptive statistics were presented as frequencies and percentages, while continuous variables were expressed as medians with interquartile ranges (25th to 75th percentiles). Gender-based differences were analyzed using the chi-square test for

Table 1. The baseline characteristics of participants (n=505)

Characteristics	Without-MetS		p-value	Mets		p-value
	Men n=82	Women n=251		Men n=60	Women n=112	
Age (years); median (IQR)	45.0 (37.0 to 52.0)	41.0 (32.0 to 51.0)	<0.001*	44.0 (32.0 to 51.0)	42.0 (32.0 to 51.0)	<0.001*
Comorbidities; n (%)	15 (18.29)	53 (21.1)	<0.001*	32 (53.3)	31 (27.7)	<0.001*
Smoking; n (%)	27 (32.92)	7 (2.7)	<0.001*	24 (40.0)	1 (0.9)	<0.001*
Drinking; n (%)	74 (90.24)	180 (71.7)	0.001*	56 (93.3)	81 (72.3)	0.003*
Physical activity; n (%)	77 (93.90)	242 (96.4)	<0.001*	54 (90.0)	108 (96.4)	<0.001*
Anthropometric indicators; median (IQR)						
BMI (kg/m^2)	24.5 (22.8 to 27.1)	22.7 (20.2 to 25.8)	<0.001*	27.6 (25.6 to 32.0)	25.6 (23.5 to 27.3)	<0.001*
WC (cm)	86.0 (79.0 to 95.2)	75.0 (71.0 to 83.0)	<0.001*	97.0 (95.0 to 105.0)	87.5 (83.0 to 94.0)	<0.001*
NC (cm)	38.0 (36.0 to 40.0)	33.0 (31.0 to 35.0)	<0.001*	40.5 (39.0 to 42.0)	35.0 (33.0 to 36.0)	<0.001*
WHtR	0.50 (0.47 to 0.56)	0.48 (0.44 to 0.52)	<0.001*	0.57 (0.55 to 0.61)	0.54 (0.51 to 0.59)	<0.001*
Conicity index	6.98 (6.47 to 7.31)	6.71 (6.35 to 7.05)	<0.001*	7.48 (7.13 to 7.64)	6.81 (6.35 to 7.18)	<0.001*

IQR=interquartile range; BMI=body mass index; WC=waist circumference; NC=neck circumference; WHtR=waist to height ratio

* The significance level is p<0.05

categorical variables and the Mann-Whitney U test for continuous variables. Univariate and multivariate logistic regression assessed the associations between anthropometric indices and MetS, with results reported as adjusted odds ratios (aORs) and 95% CIs. Receiver operating characteristic (ROC) curves and area under the curve (AUC) values were used to evaluate the predictive ability of nine anthropometric indicators for MetS by gender. An AUC greater than 0.5 indicates positive predictive value, with 0.8 or greater considered good[25]. The p-values of less than 0.05 were considered statistically significant.

Results

Patient characteristics

Table 1 showed the 505 participants' baseline characteristics. Out of those, 142 (28.1%) were men and 363 (71.9%) were women. The age range of participants was 28 to 59 years, with a median age of 42 years. According to the IDF criteria, 34.1% of the participants were diagnosed with MetS and of these, 34.8% were men and 65.1% were women (p<0.001). Anthropometric measures showed significant gender-based differences. Men had significantly higher median values for BMI at 27.6 versus 25.6, WC at 97.0 versus 87.5 cm, NC at 40.5 versus 35.0 cm), WHtR at 0.57 versus 0.54, and conicity index at 7.48 versus 6.81, (p<0.001), regardless of MetS status. Additional lifestyle and health-related factors also showed significant differences. Specifically, a higher proportion of men reported smoking and alcohol consumption than women (p<0.05). Moreover, men with MetS were more likely to have a significant prior medical history at 53.3%, than women at 27.7%, (p<0.001).

Logistic regression analyses of anthropometric indices associated with MetS

Logistic regression analysis was used to assess associations between various anthropometric indices and the risk of MetS in both genders (Table 2). Adjustments for confounding factors such as age, comorbidities, smoking, drinking, and physical activity, were performed. Most anthropometric indices were significantly associated with a higher risk of MetS in both genders (p<0.05), except for the conicity index in men and NC and BMI in women. Among men, VAI (aOR 8.67, 95% CI 2.23 to 29.36, p=0.016), ABSI (aOR 7.15, 95% CI 5.44 to 9.41, p=0.016), and WHtR (aOR 5.38, 95% CI 1.15 to 2.51, p=0.014) were significantly associated with MetS. Interestingly, BMI had the highest odds ratio (aOR 15.80, 95% CI 1.72 to 144.85, p=0.015), while BRI (aOR 4.74, 95% CI 1.91 to 11.78, p=0.001) was also significantly associated with MetS. Among women, VAI had the highest odds ratio of all indices (aOR 13.09, 95% CI 3.03 to 56.62, p=0.001), followed by WHtR (aOR 6.87, 95% CI 6.21 to 7.59, p=0.001). Furthermore, ABSI (aOR 5.97, 95% CI 2.18 to 16.39, p=0.040) and BRI (aOR 3.01, 95% CI 1.81 to 5.00, p<0.001) were significantly associated with MetS.

ROC curve analyses for predicting MetS risk

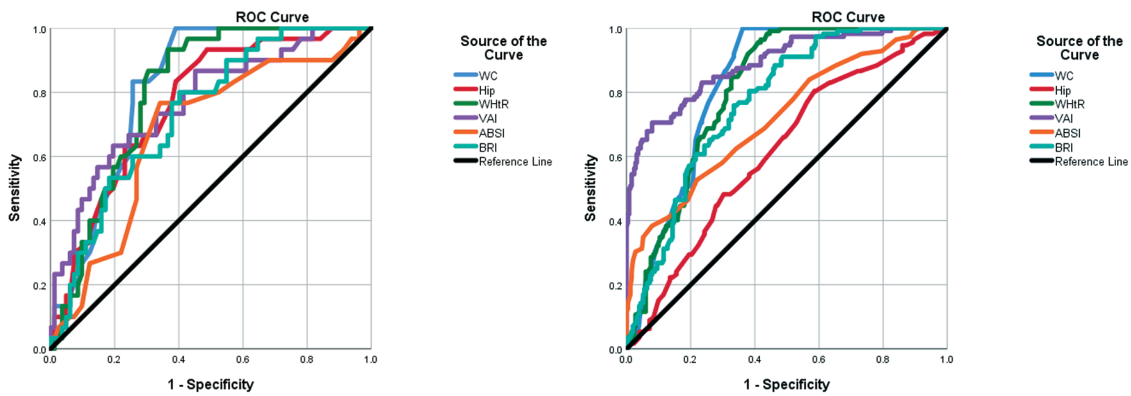
ROC curves and AUC analyses were conducted to evaluate the ability of gender-specific anthropometric indicators to predict MetS risk among academic staff. Results demonstrating the ability of WC, Hip, WHtR, VAI, ABSI, and BRI to predict MetS risk in

Table 2. Association between anthropometry indices and MetS risk factors

Gender	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Men				
WC	1.13 (1.08 to 1.19)	<0.001*	1.18 (1.08 to 1.29)	<0.001*
Hip	1.10 (1.06 to 1.15)	<0.001*	2.15 (1.02 to 4.52)	0.043*
NC	1.28 (1.15 to 1.44)	<0.001*	1.37 (1.12 to 1.68)	0.002*
BMI	1.24 (1.13 to 1.37)	<0.001*	15.80 (1.72 to 144.85)	0.015*
WHtR	1.65 (1.27 to 1.56)	<0.001*	5.38 (1.15 to 2.51)	0.014*
VAI	1.55 (1.27 to 1.89)	<0.001*	8.67 (2.23 to 29.36)	0.016*
ABSI	1.80 (4.45 to 7.29)	0.003*	7.15 (5.44 to 9.41)	0.016*
BRI	3.36 (1.92 to 5.87)	<0.001*	4.74 (1.91 to 11.78)	0.001*
Women				
WC	1.11 (1.08 to 1.14)	<0.001*	1.18 (1.13 to 1.23)	<0.001*
Hip	1.03 (1.01 to 1.06)	0.002*	1.15 (1.05 to 1.27)	0.003*
WHtR	6.55 (1.10 to 38.88)	<0.001*	6.87 (6.21 to 7.59)	0.001*
VAI	3.45 (2.65 to 4.49)	<0.001*	13.09 (3.03 to 56.62)	0.001*
ABSI	5.64 (1.12 to 2.84)	<0.001*	5.97 (2.18 to 16.39)	0.040*
BRI	2.83 (2.11 to 3.80)	<0.001*	3.01 (1.81 to 5.00)	<0.001*

OR=odds ratio; CI=confidence interval; WC=waist circumference; Hip=hip circumference; NC=neck circumference; BMI=body mass index; WHtR=waist to height ratio; VAI=visceral adiposity index; ABSI=a body shape index; BRI=body roundness index

* The significance level is p<0.05



(A) Men

(B) Women

Figure 1. The ROC curve of six anthropometric indices describes their quality in predicting Mets among men (A) and women (B) academic staff in Thailand.

both genders are shown in Figure 1. The findings from this analysis were gender specific. Among men, the anthropometric indicators with the highest AUCs were WC, WHtR, and VAI (AUC 0.81, 95% CI 0.74 to 0.88; 0.80, 95% CI 0.73 to 0.87; and 0.77, 95% CI 0.69 to 0.84; respectively). Among women, the metrics with the highest AUCs were VAI, WC, and WHtR (AUC 0.88, 95% CI 0.85 to 0.92; 0.82, 95% CI 0.78 to 0.86; and 0.80, 95% CI 0.76 to 0.85; respectively).

Discussion

The present study demonstrated that the overall prevalence of MetS as defined by the IDF was 34.1%. Among participants with MetS, 34.8% were men and 65.1% were women. This gender disparity is supported by studies in older Japanese adults, suggesting the potential involvement of biological or lifestyle factors[30]. The present study also showed that BMI, WC, and WHtR were the three anthropometric indicators with the highest significant median values in men. Conversely, VAI and BRI exhibited higher median values in women. The present study results suggest that men tend to accumulate more central fat, while women are more prone to visceral fat accumulation, and that these differences are driven by hormonal changes. As a result of this variability, the risk of MetS is different in men and women[11]. Thus, the present study emphasizes the importance of using gender-specific indicators for more accurate MetS risk prediction.

Multiple regression analysis was used to adjust for confounding factors. The researchers found that WC, HC, WHtR, VAI, ABSI, and BRI were associated with a higher risk of MetS in both genders ($p<0.05$). Significant associations for conicity index were also observed in men, whereas those for NC and BMI were observed in women. These findings are consistent with those of previous studies in Peruvian, Thai, and American adults, in that BRI was associated with an increased risk of MetS in both genders[12,31]. This association may be due to insulin resistance and chronic inflammation, key mechanisms underlying MetS that also correlate with BRI[32]. However, this finding contrasts with those of prior studies of Chinese adults, in which ABSI and BAI were not significantly associated with the risk of MetS in women[33].

The results of the ROC curve and AUC analyses revealed the ability of WC, Hip, WHtR, VAI, ABSI, and BRI to predict MetS risk in both men and women. WC had an AUC value of 0.81 and showed the best MetS predictive ability in men. This finding underscores the importance of central obesity in assessing MetS risk. Although VAI and Hip also displayed notable predictive power, they were slightly less robust than WC and WHtR. WC is a key clinical parameter used to indirectly measure increased visceral fat but may not distinguish between subcutaneous and visceral fat[34]. Indeed, a prospective cohort study conducted by Seyedhoseinpour et al.[35] identified WC as the best predictor of MetS, particularly because it reflects the accumulation of abdominal fat, a key driver of insulin resistance and cardiovascular risk. On the contrary, studies by Piqueras et al.[36] found that WC may be a weaker predictor than WHtR and BMI. Additionally, combining WC with other metrics can enhance its MetS risk prediction accuracy[37]. Taken together, these findings suggest that while WC is useful, it may not always be the most sensitive predictor of MetS risk.

The present study showed that VAI had the best MetS predictive ability in women, with an AUC value of 0.88. This finding is consistent with those of similar studies in Mexico in which VAI had the highest AUC, indicating its strong MetS diagnostic performance. These findings suggest that VAI is a promising metric for identifying MetS[38]. VAI is a new parameter associated with tissue insulin sensitivity and visceral adipose tissue as it pertains to metabolic disorders[39]. In contrast, a study by Ferreira et al. of workers in rural Brazil showed that VAI had the lowest AUC but remained a useful predictor[40]. Thus, while WC and WHtR are still effective predictors, the stronger performance of VAI suggests it may be a better gender-specific predictor of MetS risk. However, VAI should be used in conjunction with other metrics when assessing health risk[41]. Thus, VAI may have clinical value for the early detection of MetS risk, especially in women.

Strengths of the present study include the diverse age range of the study sample, ensuring broad applicability. Additionally, the participants' cultural and lifestyle homogeneity enhances reliability. In summary, identifying gender-specific differences in anthropometric indicators of MetS risk provides valuable insights into personalized health assessments and targeted interventions.

Limitation and recommendation

The limitations of the present study include its cross-sectional design. The researchers were unable to draw any conclusions about how the anthropometric indicators change over time. Additionally, as the study sample was limited to academic staff from a single institution, the study results may not be generalized to academic staff from different regions[42]. Furthermore, despite adjusting for confounding factors, residual confounding, such as age and physical activity-related factors, may explain why some anthropometric indicators were not significantly associated with MetS. More heterogeneous populations from a wide range of institutions should be included in future studies to improve the applicability of the present findings.

Conclusion

In conclusion, WC and VAI were found to be the most robust predictors of MetS risk in men and women, respectively. These findings advocate for the use of gender-specific anthropometric screening indicators to improve MetS risk prediction and prevention. Future research should focus on validating these results in diverse populations.

What is already known about this topic?

A summary of key findings in this field of study shows various anthropometric indicators have been used to predict MetS risk, and that the utility of each metric varies based on the gender of the individual. Therefore, using gender-specific anthropometric indicators improves the accuracy of identifying individuals at risk of MetS.

What does this study add?

This study evaluates the ability of nine anthropometric indicators to accurately predict MetS risk in association with gender. It focuses on academic staff, a group prone to specific issues due to their sedentary lifestyles and high stress levels. This study findings help prioritize the use of health screening indicators, showing that WC and VAI are more effective than traditional metrics for predicting MetS. Thus, this study findings support the use of these indicators during annual health examinations and help guide strategies to prevent MetS in the university setting.

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Conflicts of interest

The authors declare no conflicts of interest.

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