Molecular Mechanism Research (2025) Volume 3 Issue 2
doi: 10.59429/mmr.v3i2.11824
ISSN: 3029-2212 (O)

RESEARCH ARTICLE

Health Biomarker Analysis and Its Association with Metabolic Syndrome in Middle-Aged Individuals: A Cross-Sectional Study

Adiatuj Jahan Rimu[1], Mst.Umme Habiba[2], Md. Rashidul Islam[3], Md. Farhad Hossain Jony[4], Md. Al-Amin Hossen[5*]

[1] *Adiatuj Jahan Rimu, Department of Public Health & Life Sciences, University of South Asia, Dhaka, Bangladesh*

[2] *Mst.Umme Habiba, Department of Environmental and Life Sciences, Independent University, Dhaka, Bangladesh*

[3] *Md. Rashidul Islam, Department of Biochemistry and Cell Biology , Bangladesh University of Health Sciences, Bangladesh*

[4] *Md. Farhad Hossain Jony, Department of Biochemistry & Molecular Biology, Primeasia University, Dhaka, bangladesh*

[5] *Md. Al-Amin Hossen, Department of Pathology, United Hospital Limited, Dhaka, Bangladesh*

***Corresponding author:** Md. Al-Amin Hossen, alaminhossainrocky@gmail.com

ABSTRACT

Background: Metabolic Syndrome (MS) is a multifactorial disorder characterized by a cluster of interrelated cardiometabolic risk factors such as central obesity, dyslipidemia, hypertension, and impaired glucose metabolism. It significantly increases the risk of type 2 diabetes mellitus and cardiovascular diseases, representing a growing public health concern in Bangladesh.

Objective: To evaluate the association between anthropometric, biochemical, and cardiovascular biomarkers and the presence of Metabolic Syndrome among middle-aged adults.

Methods: This hospital-based cross-sectional study was conducted at the Department of Biochemistry, Ahad General Hospital, Savar, Dhaka, from July 2023 to June 2024, enrolling 595 participants aged 35–60 years. Anthropometric parameters (waist circumference, BMI), biochemical markers (random blood sugar, lipid profile), and blood pressure were measured using standardized protocols. Metabolic Syndrome was defined according to the International Diabetes Federation (IDF) criteria. Data were analyzed using SPSS version 26.0, applying chi-square tests, t-tests, Pearson's correlation, and multivariate logistic regression.

Results: The overall prevalence of MS was 23.7%. Prevalence increased with age and was significantly higher in females (29.6%) than in males (17.6%) ($p < 0.001$). Participants with MS showed significantly higher waist circumference (101.9 ± 12.7 cm vs. 85.8 ± 11.6 cm), BMI (29.5 ± 4.6 vs. 24.2 ± 4.5 kg/m²), triglycerides (3.33 ± 1.87 vs. 1.51 ± 0.96 mmol/L), and systolic blood pressure (129.9 ± 16.5 vs. 115.8 ± 12.8 mmHg), with lower HDL cholesterol (1.02 ± 0.29 vs. 1.38 ± 0.45 mmol/L) (all $p < 0.001$). Multivariate logistic regression identified waist circumference (OR = 1.10, $p < 0.001$), triglycerides (OR = 2.85, $p < 0.001$), low HDL (OR = 0.16, $p < 0.001$), and systolic blood pressure (OR = 1.04, $p < 0.001$) as independent predictors of MS

ARTICLE INFO
Received: 13 November 2025 | Accepted: 30 November 2025|Available online: 10 December 2025

CITATION
A. J. Rimu, M. U. Habiba, M. R. Islam, M. F. Hossain Jony, M. A. Health Biomarker Analysis and Its Association with Metabolic Syndrome in Middle-Aged Individuals: A Cross-Sectional Study. *Molecular Mechanism Research* 2025; 3(2):11824.doi: 10.59429/mmr.v3i2.11824

Conclusion: Metabolic Syndrome was common among middle-aged adults, especially females. Central obesity, high triglycerides, low HDL, and elevated systolic pressure were key predictors. Routine screening of these markers can aid early detection and prevention of cardiometabolic risks.

Keywords: Metabolic syndrome; central obesity; dyslipidemia; cardiovascular risk; bangladesh

1. Introduction

Metabolic Syndrome (MS) is a multifactorial clinical condition characterized by a cluster of interrelated cardiometabolic risk factors, including central obesity, dyslipidemia, hypertension, and impaired glucose regulation[1]. This constellation of abnormalities significantly heightens the risk for developing type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), and premature mortality, thereby posing a major public health concern worldwide[2,3]. Diagnostic frameworks such as those proposed by the International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) have standardized the identification of MS, enabling early detection of individuals at high metabolic risk who could benefit from timely preventive strategies[4].

The pathophysiology of MS is intricate, with insulin resistance recognized as its central feature. This metabolic impairment is further compounded by sedentary behavior, excessive caloric intake, chronic stress, and genetic predisposition[5]. These disturbances are reflected in alterations of key health biomarkers. Anthropometric indices such as waist circumference and body mass index (BMI) serve as simple yet powerful indicators of overall and visceral adiposity, the latter being metabolically active and strongly linked to cardiometabolic risk[6]. Dyslipidemia—characterized by elevated triglycerides (TG), reduced high-density lipoprotein cholesterol (HDL-C), and the predominance of small, dense low-density lipoprotein (LDL) particles—represents another hallmark of MS, contributing to its atherogenic potential[7]. Additionally, raised blood pressure and fasting plasma glucose (FPG) reflect both cardiovascular strain and impaired metabolic homeostasis[8].

Middle adulthood is a particularly vulnerable period for the onset and progression of MS. Age-related metabolic slowdown, hormonal fluctuations, and cumulative exposure to unhealthy lifestyle behaviors converge to increase susceptibility during this stage of life[9]. Consequently, middle-aged individuals represent a critical population for metabolic screening and early intervention. Although the components of MS are well-documented, the relative contribution and interrelationship of these biomarkers, as well as potential gender-based variations, remain areas of ongoing research. Most existing evidence is derived from large, heterogeneous population-based studies; however, localized, hospital-based investigations may better capture variations influenced by lifestyle, socioeconomic, and genetic factors within specific populations[10,11].

Therefore, this cross-sectional study aims to comprehensively evaluate the association between key anthropometric, metabolic, and cardiovascular biomarkers and the presence of Metabolic Syndrome among middle-aged adults

2. Literature review

Metabolic Syndrome (MS) has emerged as one of the most significant public health challenges of the 21st century, contributing substantially to the global burden of non-communicable diseases (NCDs). It represents a constellation of metabolic abnormalities, including central obesity, dyslipidemia, elevated blood pressure, and impaired glucose tolerance. These abnormalities act synergistically to increase the risk of developing type 2 diabetes mellitus, cardiovascular diseases, and premature mortality. According to the World Health

Organization (WHO)[12], the prevalence of metabolic syndrome is rising rapidly worldwide due to urbanization, unhealthy dietary habits, and sedentary lifestyles.

Globally, estimates suggest that nearly one-quarter of the adult population may be affected by MS, with marked regional and ethnic variations. The prevalence tends to be higher in urban populations than rural ones, reflecting lifestyle transitions toward high-calorie diets and reduced physical activity. Developed countries have long recognized MS as a major health burden, but recent decades have seen an alarming increase across developing nations, particularly in Asia[13], where rapid socioeconomic development has driven lifestyle changes and rising obesity rates.

In South Asia[14], the prevalence of metabolic syndrome is notably high despite relatively lower rates of obesity compared to Western populations. This phenomenon has been attributed to a higher proportion of visceral fat, insulin resistance, and genetic susceptibility among South Asians. Studies from the region have consistently shown that South Asians develop metabolic risk factors such as dyslipidemia, hypertension, and impaired glucose tolerance at a younger age and lower body mass index compared to Western populations. Dietary patterns rich in refined carbohydrates, low physical activity, and increasing stress have further accelerated the epidemic in this region[15].

In India[16], metabolic syndrome has been recognized as a major contributor to the growing burden of diabetes and cardiovascular diseases. Several community and hospital-based studies have reported prevalence rates ranging from 20% to over 40% among adults, with a higher frequency observed in urban and middle-aged populations. Indian women, particularly post-menopausal women, have been found to be disproportionately affected, reflecting both hormonal and lifestyle influences. The coexistence of obesity, hypertension, and impaired fasting glucose in this demographic underscores the need for early screening and intervention[17].

Bangladesh, like other South Asian countries, is currently undergoing a rapid epidemiological transition from communicable to non-communicable diseases. Urbanization, dietary westernization, and declining physical activity have contributed to a growing prevalence of obesity, hypertension, and diabetes. Several studies conducted in Bangladeshi urban centers have indicated that metabolic syndrome is becoming increasingly common among middle-aged adults, particularly those with sedentary occupations and higher socioeconomic status. Rural areas, though traditionally less affected, are now also witnessing an upward trend due to changes in food consumption patterns and decreased manual labor. Gender-based disparities are evident, with Bangladeshi women showing higher rates of central obesity and metabolic syndrome than men[18,19].

In the South Asian context, one of the key challenges in addressing metabolic syndrome is the lack of awareness and early diagnosis. Many individuals remain undiagnosed until they develop overt diabetes or cardiovascular complications. Limited access to regular health check-ups, insufficient public health education, and socio-cultural barriers further exacerbate the issue. Moreover, the diagnostic cut-offs for waist circumference and BMI derived from Western populations may underestimate the actual risk in South Asians, who tend to have higher body fat percentages at lower BMI levels[20].

From a global health perspective, the WHO and other international health agencies have emphasized the importance of preventive strategies focused on diet, physical activity, and regular health monitoring. Lifestyle modification remains the cornerstone of management, but population-wide interventions—such as promoting healthy eating, controlling tobacco and alcohol consumption, and encouraging workplace wellness programs—are equally essential. In resource-limited settings like Bangladesh, the integration of metabolic screening within primary healthcare systems could provide a cost-effective approach for early identification and risk reduction.

3. Materials and methods

3.1. Study design and settings

This hospital-based cross-sectional study was conducted at the Department of Biochemistry, Ahad General Hospital, Savar, Dhaka, Bangladesh. The study was carried out over a 12-month period, extending from July 2023 to June 2024. The hospital serves a diverse population from both urban and peri-urban regions, providing an ideal setting to assess the growing burden of metabolic disorders among adults in Bangladesh.

3.2. Study population and sample size

A total of 595 participants, aged between 35 and 60 years, were enrolled in this study. All participants were individuals who attended BIHS General Hospital for routine health check-ups or diagnostic investigations and voluntarily agreed to participate. The sample size was based on the number of eligible and consenting participants available during the study period.

3.3. Inclusion and exclusion criteria

Participants were included if they were within the specified age range, apparently healthy or clinically stable, and willing to provide informed consent. Both male and female participants were considered eligible. Individuals were excluded from the study if they had any chronic or acute medical conditions that could interfere with metabolic assessment, such as diagnosed chronic liver disease, renal failure, thyroid disorders, malignancy, or any active infection or inflammation. Those who were pregnant, on corticosteroid or lipid-lowering therapy, or unwilling to provide consent were also excluded.

3.4. Data collection procedure

Data were collected using a structured, pre-tested questionnaire and verified through hospital medical records. Socio-demographic data such as age, gender, marital status, educational level, and work status were recorded. Anthropometric measurements including weight, height, and waist circumference were obtained using standardized techniques, with participants wearing light clothing and no shoes. Waist circumference was measured at the midpoint between the lower margin of the last rib and the top of the iliac crest using a flexible measuring tape. Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2), and BMI status was categorized according to WHO criteria.

Blood pressure was measured using a calibrated sphygmomanometer with participants in a seated position after at least five minutes of rest. Two readings were taken five minutes apart, and the average value was recorded for both systolic and diastolic pressures.

The parameters included in the study were: identification number (ID), age, gender, waist circumference, random blood sugar (RBS), total cholesterol, triglycerides (TG), low-density lipoprotein (LDL), high-density lipoprotein (HDL), marital status, educational level, work status, systolic blood pressure, diastolic blood pressure, BMI, BMI status, and the presence or absence of metabolic syndrome.

3.5. Sample collection and laboratory analysis

Venous blood samples, approximately 5 mL, were collected aseptically from each participant following an overnight fast of 8–10 hours. Samples were transferred into plain tubes, allowed to clot at room temperature, and centrifuged at 3000 rpm for 10 minutes to separate serum. The serum was analyzed immediately or stored at –20°C until further testing.

Biochemical analyses including random blood sugar, total cholesterol, triglycerides, LDL, and HDL were performed using an automated biochemistry analyzer (Indiko Plus, Thermo Fisher Scientific, Finland) according to manufacturer instructions. All reagents used were of analytical grade, and internal quality control was maintained daily using standard control sera to ensure analytical accuracy and precision. The laboratory followed strict quality assurance protocols to minimize analytical errors.

3.6. Definition of metabolic syndrome

The diagnosis of Metabolic Syndrome was established based on the International Diabetes Federation (IDF) criteria[21]. According to these guidelines, the presence of central obesity, defined as a waist circumference of ≥90 cm for men and ≥80 cm for women, was considered essential. In addition to central obesity, individuals were required to have any two or more of the following components: elevated triglycerides (≥150 mg/dL or 1.7 mmol/L), low HDL cholesterol (<40 mg/dL or 1.03 mmol/L in men and <50 mg/dL or 1.29 mmol/L in women), high blood pressure (systolic ≥130 mmHg or diastolic ≥85 mmHg, or current use of antihypertensive medication), and elevated blood sugar (random blood sugar ≥7.8 mmol/L or previously diagnosed diabetes mellitus). This classification allows for the uniform identification of individuals with metabolic abnormalities, which is important for assessing cardiovascular and diabetic risk.

3.7. Statistical analysis

Data were entered and analyzed using SPSS version 26.0 (IBM, USA). Continuous variables are presented as mean ± SD, and categorical variables as frequency and percentage. Associations between metabolic syndrome and biomarkers were assessed using Chi-square tests for categorical data and t-tests or ANOVA. A p-value <0.05 was considered statistically significant.

3.8. Ethical considerations

The study was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki, ensuring respect for the rights, safety, and well-being of all participants.

4. Results

Among the total 595 participants, 141 individuals (23.7%) were diagnosed with Metabolic Syndrome (MS). The distribution of demographic, anthropometric, and biochemical parameters demonstrated clear and statistically significant differences between participants with and without MS, reflecting the clustering of metabolic and cardiovascular risk factors in the affected group. The prevalence of MS increased with age. While only 26.2% of MS cases were aged 20–35 years compared to 32.7% in the non-MS group, a larger proportion of MS participants were in the 36–50 years (39.7%) and 51–65 years (31.2%) categories, indicating a progressive rise in metabolic risk with advancing age ($p = 0.003$) (Table 1).

Gender differences were also notable, with females comprising 61.0% of the MS group, whereas males predominated in the non-MS group (55.3%) ($p < 0.001$). This suggests that women in this cohort may be more vulnerable to metabolic disturbances, highlighting the importance of gender-specific risk assessment and intervention strategies (Table 1).

Anthropometric parameters were significantly elevated in participants with MS. The mean waist circumference among MS individuals was 101.9 ± 12.7 cm, compared to 85.8 ± 11.6 cm in those without MS ($p < 0.001$). Similarly, BMI values were substantially higher in the MS group (29.5 ± 4.6) than in the non-MS group (24.2 ± 4.5, $p < 0.001$), reflecting the strong association between central obesity, overall adiposity, and metabolic risk. Within BMI classifications, obesity was the most prevalent in the MS group (41.8%), followed

by overweight (43.3%), whereas the non-MS group had a higher proportion of normal-weight individuals (50.7%) and underweight cases (9.0%), emphasizing the close link between excess body weight and the syndrome ($p < 0.001$) (Table 1).

Biochemical analyses further highlighted the adverse metabolic profile in MS participants. Mean random blood sugar was significantly higher in the MS group (6.00 ± 3.02 mmol/L) compared to the non-MS group (5.08 ± 2.20 mmol/L). Similarly, total cholesterol (5.08 ± 1.23 vs. 4.42 ± 1.01 mmol/L), triglycerides (3.33 ± 1.87 vs. 1.51 ± 0.96 mmol/L), and LDL cholesterol (3.27 ± 1.15 vs. 2.87 ± 1.03 mmol/L) were elevated, while HDL cholesterol was markedly lower (1.02 ± 0.29 vs. 1.38 ± 0.45 mmol/L), all with $p < 0.001$ (Table 1).

Blood pressure measurements revealed that both systolic (129.9 ± 16.5 mmHg) and diastolic (85.2 ± 11.6 mmHg) pressures were significantly higher in MS participants than in those without the syndrome (115.8 ± 12.8 and 73.6 ± 10.4 mmHg, respectively; $p < 0.001$), indicating a substantial cardiovascular burden. Collectively, these findings confirm that individuals with Metabolic Syndrome exhibit a clustering of unfavorable metabolic, anthropometric, and cardiovascular profiles, underscoring the importance of early detection and targeted preventive interventions (Table 1).

Table 1. Descriptive Statistics of Anthropometric, Biochemical, and Clinical Parameters by Metabolic Syndrome Status

Parameter	Group	No MS (N = 456)	MS (N = 141)	P-value
Age Group (years)	20–35	149 (32.7%)	37 (26.2%)	0.003
	36–50	220 (48.2%)	56 (39.7%)	
	51–65	83 (18.2%)	44 (31.2%)	
	66–80	4 (0.9%)	4 (2.8%)	
Gender	Male	252 (55.3%)	55 (39.0%)	< 0.001
	Female	204 (44.7%)	86 (61.0%)	
Waist Circumference (cm)		85.8 ± 11.6	101.9 ± 12.7	< 0.001
Random Blood Sugar (mmol/L)		5.08 ± 2.20	6.00 ± 3.02	< 0.001
Total Cholesterol (mmol/L)		4.42 ± 1.01	5.08 ± 1.23	< 0.001
Triglycerides (TG) (mmol/L)		1.51 ± 0.96	3.33 ± 1.87	< 0.001
Low-Density Lipoprotein (LDL) (mmol/L)		2.87 ± 1.03	3.27 ± 1.15	< 0.001
High-Density Lipoprotein (HDL) (mmol/L)		1.38 ± 0.45	1.02 ± 0.29	< 0.001
Systolic Blood Pressure (mmHg)		115.8 ± 12.8	129.9 ± 16.5	< 0.001
Diastolic Blood Pressure (mmHg)		73.6 ± 10.4	85.2 ± 11.6	< 0.001
Body Mass Index (BMI)		24.2 ± 4.5	29.5 ± 4.6	< 0.001
BMI Status	Underweight	41 (9.0%)	0 (0.0%)	< 0.001
	Normal weight	231 (50.7%)	21 (14.9%)	
	Overweight	125 (27.4%)	61 (43.3%)	
	Obese	59 (12.9%)	59 (41.8%)	

No Metabolic Syndrome: No MS; *Metabolic Syndrome: MS*

Table 2. Association of Anthropometric Indicators with Metabolic Syndrome

Anthropometric Indicator	MS Group (Mean ± SD / %) / N	Non-MS Group (Mean ± SD / %) / N	Statistical Test & Value	P-value
Waist Circumference (cm)	101.9 ± 12.7	85.8 ± 11.6	t = -13.95	< 0.001
BMI (kg/m²)	29.5 ± 4.6	24.2 ± 4.5	t = -11.82	< 0.001
BMI Category	Underweight: 0 (0%) Normal: 21 (14.9%) Overweight: 61 (43.3%) Obese: 59 (41.8%)	Underweight: 41 (9.0%) Normal: 231 (50.7%) Overweight: 125 (27.4%) Obese: 59 (12.9%)	$\chi^2 = 142.5$, df = 3	< 0.001
Predictive Power (Waist)	–	–	OR = 1.12 [1.10–1.14]	< 0.001
Predictive Power (BMI)	–	–	OR = 1.24 [1.19–1.30]	< 0.001

This table 2 demonstrates the strong association between anthropometric measures and Metabolic Syndrome. Waist circumference and BMI were significantly higher in MS participants compared to non-MS individuals, with p-values < 0.001, indicating a strong link between adiposity and metabolic risk. BMI category analysis revealed that MS prevalence escalates progressively from normal weight to obese participants, highlighting obesity as a major risk factor. Logistic regression confirmed that both waist circumference and BMI are powerful independent predictors of MS, with every 1 cm increase in waist circumference increasing the odds by 12% and every 1 kg/m² increase in BMI increasing the odds by 24%. These findings emphasize the critical role of routine anthropometric monitoring in identifying individuals at high risk for Metabolic Syndrome (Table 2).

Table 3. Relationship between Lipid Profile and Metabolic Syndrome

Lipid Parameter	No MS (Mean ± SD)	MS (Mean ± SD)	T-test Statistic	P-value
Cholesterol	4.42 ± 1.01	5.08 ± 1.23	t(595) = -6.92	**< 0.001**
Triglycerides (TG)	1.51 ± 0.96	3.33 ± 1.87	t(595) = -14.12	**< 0.001**
LDL	2.87 ± 1.03	3.27 ± 1.15	t(595) = -4.88	**< 0.001**
HDL	1.38 ± 0.45	1.02 ± 0.29	t(595) = 11.87	**< 0.001**

Analysis of the lipid profile revealed significant differences between participants with and without Metabolic Syndrome. In univariate comparisons, individuals with MS exhibited higher total cholesterol (5.08 ± 1.23 mmol/L vs. 4.42 ± 1.01 mmol/L), triglycerides (3.33 ± 1.87 mmol/L vs. 1.51 ± 0.96 mmol/L), and LDL cholesterol (3.27 ± 1.15 mmol/L vs. 2.87 ± 1.03 mmol/L), along with significantly lower HDL cholesterol (1.02 ± 0.29 mmol/L vs. 1.38 ± 0.45 mmol/L), all with p-values < 0.001. These findings indicate that dyslipidemia is strongly associated with Metabolic Syndrome (Table 3). Multivariate logistic regression analysis, which accounted for the combined effect of all lipid parameters, showed that elevated triglycerides and low HDL remained the dominant independent predictors of MS. Specifically, each unit increase in triglycerides increased the odds of MS by approximately 2.85 times, while higher HDL was protective, reducing the odds by 84%. In contrast, LDL and total cholesterol lost statistical significance when considered together (p = 0.302 and p = 0.156, respectively) (Table 3).

Table 4. Relationship between Blood Pressure and Metabolic Syndrome

Blood Pressure Parameter	No Metabolic Syndrome (Mean ± SD)	Metabolic Syndrome (Mean ± SD)	T-test Statistic	P-value
Systolic BP (mmHg)	115.8 ± 12.8	129.9 ± 16.5	t(595) = -10.27	< 0.001
Diastolic BP (mmHg)	73.6 ± 10.4	85.2 ± 11.6	t(595) = -10.89	< 0.001
Predictive Power (Multivariate Logistic Regression)	_	_	_	_

Blood pressure analysis revealed significant elevations in both systolic and diastolic pressures among participants with Metabolic Syndrome compared to those without the syndrome. The mean systolic blood pressure in MS individuals was 129.9 ± 16.5 mmHg, substantially higher than 115.8 ± 12.8 mmHg in the non-MS group ($p < 0.001$). Similarly, diastolic blood pressure was elevated in the MS group (85.2 ± 11.6 mmHg) versus the non-MS group (73.6 ± 10.4 mmHg, $p < 0.001$), indicating that hypertension is closely associated with the syndrome (Table 4). When assessing the independent predictive power using multivariate logistic regression, systolic blood pressure remained a significant predictor of Metabolic Syndrome, with each 1 mmHg increase raising the odds by 4% (OR = 1.04, 95% CI: 1.02–1.06, $p < 0.001$). In contrast, diastolic blood pressure did not retain independent significance after adjusting for other risk factors (OR = 1.02, 95% CI: 0.99–1.05, $p = 0.121$). These findings highlight that while both components of blood pressure are elevated in MS, systolic hypertension is the more critical independent indicator for identifying individuals at risk (Table 4).

Table 5. Combined Impact of All Biomarkers on Metabolic Syndrome Diagnosis

Predictor	Odds Ratio (OR)	95% Confidence Interval	P-value
Waist Circumference	1.10	[1.07, 1.12]	**< 0.001**
Triglycerides (TG)	2.85	[2.25, 3.62]	**< 0.001**
HDL	0.16	[0.08, 0.30]	**< 0.001**
Systolic BP	1.04	[1.02, 1.06]	**< 0.001**
Diastolic BP	1.02	[0.99, 1.05]	0.121
LDL	1.12	[0.90, 1.40]	0.302
Cholesterol	1.25	[0.92, 1.70]	0.156
BMI	1.01	[0.95, 1.08]	0.705

The multivariate logistic regression analysis, which simultaneously considered all key anthropometric, biochemical, and clinical biomarkers, provides a comprehensive assessment of their independent contributions to Metabolic Syndrome (MS) risk. Among the variables included, waist circumference, triglycerides (TG), HDL cholesterol, and systolic blood pressure emerged as significant independent predictors. Specifically, each 1 cm increase in waist circumference was associated with a 10% higher likelihood of MS, reflecting the central role of abdominal adiposity in metabolic risk. Elevated triglycerides demonstrated a particularly strong effect, with individuals exhibiting high TG levels being nearly three times more likely to have MS, while higher HDL cholesterol acted as a protective factor, substantially reducing the odds of MS (Table 5). Systolic blood pressure also retained its predictive significance, with each 1 mmHg increment increasing the odds of MS by 4%, underscoring the importance of elevated systolic pressure in metabolic dysregulation. In contrast, diastolic blood pressure, LDL cholesterol, total cholesterol, and BMI did not demonstrate independent predictive

significance in the presence of other biomarkers, indicating that their individual contribution is less pronounced when multiple risk factors are considered together (Table 5).

Table 6. Gender-Based Analysis of Metabolic Syndrome

Analysis	Result	Statistical Test & P-value
Prevalence of MS in Males	54 / 307 (17.6%)	χ^2 Test, $p < 0.001$
Prevalence of MS in Females	86 / 290 (29.6%)	–
Mean Waist Circumference (Male)	87.8 cm	T-test, $p = 0.001$
Mean Waist Circumference (Female)	89.2 cm	–
Gender Interaction in Multivariate Model	Not Significant	$p = 0.18$

The gender-based analysis revealed that Metabolic Syndrome is significantly more prevalent among females (29.6%) than males (17.6%) in this cohort, indicating that women are at higher metabolic risk. Interestingly, although males exhibited a slightly larger mean waist circumference (87.8 cm) compared to females (89.2 cm), this did not translate into a higher prevalence of MS, suggesting that other metabolic or hormonal factors may contribute to the increased susceptibility in women (Table 6).

4. Discussion

Age-related patterns in our cohort demonstrated a clear trend of increasing MS prevalence with advancing age. Participants aged 36–50 and 51–65 years exhibited higher proportions of MS compared to younger individuals, suggesting that metabolic disturbances accumulate over time. This age-dependent increase aligns with physiological changes such as reduced insulin sensitivity, altered lipid metabolism, and the progressive accumulation of visceral fat, which together contribute to heightened metabolic risk in older adults.

Gender differences were notable in this study. Females comprised 61.0% of the MS group, while males predominated in the non-MS group. Despite slightly higher waist circumferences in males, the prevalence of MS was significantly higher in females. This suggests that women may experience a greater susceptibility to metabolic derangements independent of central adiposity. Potential explanations include hormonal influences, differences in fat distribution, and other metabolic factors that predispose women to dyslipidemia, insulin resistance, and elevated blood pressure. Notably, the multivariate analysis indicated that the relationship between biomarkers and MS risk was similar for both genders, suggesting that the higher female prevalence is not due to amplified effects of individual risk factors but may reflect intrinsic biological vulnerability or lifestyle differences[22,23].

Anthropometric indicators, including waist circumference and BMI, were significantly elevated in MS participants. The mean waist circumference in the MS group exceeded 100 cm, underscoring the pivotal role of central obesity in metabolic risk. Logistic regression analysis revealed that each 1 cm increase in waist circumference was associated with a 10% higher odds of MS, while each 1 kg/m^2 increase in BMI increased the odds by 24%. The stratified BMI analysis further confirmed that obesity was strongly linked to MS, with 41.8% of MS participants classified as obese. These findings highlight that excess adiposity, particularly central obesity, is a primary driver of metabolic disturbances and reinforces the importance of routine anthropometric monitoring for early risk detection[24].

Lipid profile abnormalities were prominent among MS participants. Elevated triglycerides and reduced HDL cholesterol emerged as the strongest independent predictors of MS. Individuals with higher triglyceride levels were nearly three times more likely to have MS, while higher HDL exerted a protective effect. Although

total cholesterol and LDL cholesterol were higher in the MS group, their independent predictive significance was attenuated when analyzed alongside other biomarkers. These results suggest that dyslipidemia in MS is characterized primarily by high triglycerides and low HDL, consistent with the pathophysiological profile of insulin resistance and impaired lipid metabolism[25,26].

Blood pressure analysis revealed that both systolic and diastolic pressures were significantly elevated in MS participants. Multivariate regression identified systolic blood pressure as an independent predictor, with a 4% increase in MS odds per mmHg increment. In contrast, diastolic pressure, while elevated, did not independently predict MS. This underscores the importance of systolic hypertension as a critical component of metabolic dysregulation and a key target for intervention in individuals at risk of cardiovascular events.

5. Conclusion

In this study, Metabolic Syndrome (MS) was observed with higher prevalence in females and older age groups. Central obesity, elevated triglycerides, low HDL cholesterol, and increased systolic blood pressure emerged as the strongest independent predictors of MS, highlighting the clustering of metabolic and cardiovascular risk factors. Despite slightly higher waist circumference in males, females demonstrated a significantly greater susceptibility to MS, suggesting the influence of additional metabolic or hormonal factors. These findings emphasize the importance of routine anthropometric, biochemical, and clinical monitoring, particularly in women and older adults, to enable early identification and intervention. Targeted strategies addressing obesity, dyslipidemia, and hypertension are essential for reducing the risk of Metabolic Syndrome and its associated cardiovascular complications.

6. Limitations of the study

This study was conducted at a single center, which may limit the representativeness of the findings for the general population. Being cross-sectional in nature, it could not establish causal relationships between metabolic risk factors and the development of Metabolic Syndrome. The sample size, although adequate for statistical analysis, may not fully capture regional or socioeconomic variations. Additionally, important lifestyle determinants such as dietary habits, physical activity levels, smoking status, alcohol consumption, and genetic predispositions were not comprehensively evaluated. Future multicenter, longitudinal studies incorporating lifestyle and genetic factors are recommended to better understand the dynamics and causal pathways of Metabolic Syndrome in the Bangladeshi population.

Conflict of interest

The authors declare no conflict of interest

References

1. Dallmeier D, Larson MG, Vasan RS, Keaney Jr JF, Fontes JD, Meigs JB, Fox CS, Benjamin EJ. Metabolic syndrome and inflammatory biomarkers: a community-based cross-sectional study at the Framingham Heart Study. Diabetology & metabolic syndrome. 2012 Jun 20;4(1):28.

2. Fu S, Ping P, Luo L, Ye P. Deep analyses of the associations of a series of biomarkers with insulin resistance, metabolic syndrome, and diabetes risk in nondiabetic middle-aged and elderly individuals: results from a Chinese community-based study. Clinical Interventions in Aging. 2016 Oct 27:1531-8.
3. Moreira MA, da Câmara SM, Fernandes SG, Azevedo IG, Cavalcanti Maciel ÁC. Metabolic syndrome in middle-aged and older women: A cross-sectional study. Women's Health. 2022 Jan;18:17455065211070673.
4. Kaikkonen JE, Würtz P, Suomela E, Lehtovirta M, Kangas AJ, Jula A, Mikkilä V, Viikari JS, Juonala M, Rönnemaa T, Hutri-Kähönen N. Metabolic profiling of fatty liver in young and middle-aged adults: Cross-sectional and prospective analyses of the Young Finns Study. Hepatology. 2017 Feb;65(2):491-500.
5. Abdi HI, Mohamed MN, Rahman MA. Impact of Urbanization and Dietary Transitions on Metabolic Syndrome and Insulin Resistance in Bangladesh: A Cross-Sectional Study. Viral Infections and Cancer Research. 2024;1(1):8141.
6. Li Y, Gui J, Liu H, Guo LL, Li J, Lei Y, Li X, Sun L, Yang L, Yuan T, Wang C. Predicting metabolic syndrome by obesity-and lipid-related indices in mid-aged and elderly Chinese: a population-based cross-sectional study. Frontiers in endocrinology. 2023 Jul 28;14:1201132.
7. Andaku DK, D'Almeida V, Carneiro G, Hix S, Tufik S, Togeiro SM. Sleepiness, inflammation and oxidative stress markers in middle-aged males with obstructive sleep apnea without metabolic syndrome: a cross-sectional study. Respiratory research. 2015 Jan 14;16(1):3.
8. Shamrin T, Mohamed MN, Siddik AB, Islam S, Sarker N, Halder S, Akter T, Rahman MA. Research Article Serum Gamma-Glutamyl Transferase as a Predictive Biomarker for Metabolic Syndrome and Insulin Resistance: Implications for Early Risk Assessment and Preventive Healthcare.
9. Benguigui C, Bongard V, Ruidavets JB, Chamontin B, Sixou M, Ferrières J, Amar J. Metabolic syndrome, insulin resistance, and periodontitis: a cross-sectional study in a middle-aged French population. Journal of clinical periodontology. 2010 Jul;37(7):601-8.
10. Chowdhury MZ, Anik AM, Farhana Z, Bristi PD, Abu Al Mamun BM, Uddin MJ, Fatema J, Akter T, Tani TA, Rahman M, Turin TC. Prevalence of metabolic syndrome in Bangladesh: a systematic review and meta-analysis of the studies. BMC public health. 2018 Mar 2;18(1):308.
11. Rahman MM, Kibria MG, Begum H, Haque M, Sultana N, Akhter M, Rowshon AH, Ahmed F, Hasan M. Prevalence, risk factors and metabolic profile of the non-obese and obese non-alcoholic fatty liver disease in a rural community of South Asia. BMJ open gastroenterology. 2020 Dec 1;7(1).
12. Ali N, Mahmood S, Manirujjaman M, Perveen R, Al Nahid A, Ahmed S, Khanum FA, Rahman M. Hypertension prevalence and influence of basal metabolic rate on blood pressure among adult students in Bangladesh. BMC Public Health. 2017 Jul 25;18(1):58.
13. Sultana M, Hasan MM, Hasan T. Gender difference in metabolic syndrome and quality of life among elderly people in Noakhali, Bangladesh. Heliyon. 2025 Jan 15;11(1).
14. Mohamud AA, Mohamed MN, Rahman MA. Serum Gamma-Glutamyl Transferase as a Biomarker for Insulin Resistance and Metabolic Syndrome in Dhaka, Bangladesh: A Cross-Sectional Study. Molecular Mechanism Research. 2024;2(1):7097.
15. Mangat C, Goel NK, Walia DK, Agarwal N, Sharma MK, Kaur J, Singh R, Singh G. Metabolic syndrome: a challenging health issue in highly urbanized Union Territory of north India. Diabetology & metabolic syndrome. 2010 Mar 23;2(1):19.
16. Misra A, Vikram NK. Insulin resistance syndrome (metabolic syndrome) and Asian Indians. Current Science. 2002 Dec 25:1483-96.

17. Tsou MT, Pai TP, Chiang TM, Huang WH, Lin HM, Lee SC. Burnout and metabolic syndrome among different departments of medical center nurses in Taiwan-Cross-sectional study and biomarker research. journal of Occupational Health. 2021 Jan;63(1):e12188.
18. Lai W, Wang L, Chen X, Du S, Wu Y, Wu L, Qin H, Li X, Wu L, Zhou B. Association between metabolic score for insulin resistance and hypertension in middle-aged and older adults: a nationwide cross-sectional and longitudinal study. Aging Clinical and Experimental Research. 2025 Jun 13;37(1):187.
19. Prabhakaran D, Chaturvedi V, Shah P, Manhapra A, Jeemon P, Shah B, Srinath Reddy K. Differences in the prevalence of metabolic syndrome in urban and rural India: a problem of urbanization. Chronic Illness. 2007 Mar;3(1):8-19.
20. Chanda M, Biswas T, Amiruzzaman M, Begum H, Tabassum F, Munmun ST, Rahman A, Akram A. Association of serum uric acid and liver enzymes in adults at Tertiary Level Hospital in Bangladesh. Bangladesh Medical Journal. 2022;51(3):18-27.
21. Chowdhury SR. Metabolic health in Bangladesh: trends and challenges. The Egyptian Journal of Internal Medicine. 2022 Dec;34(1):76.
22. Kuiper LM, Smit AP, Bizzarri D, van den Akker EB, Reinders MJ, Ghanbari M, van Rooij JG, Voortman T, Rivadeneira F, Dollé ME, Herber GC. Lifestyle factors and metabolomic aging biomarkers: meta-analysis of cross-sectional and longitudinal associations in three prospective cohorts. Mechanisms of Ageing and Development. 2024 Aug 1;220:111958.
23. Syauqy A, Hsu CY, Rau HH, Chao JC. Association of dietary patterns, anthropometric measurements, and metabolic parameters with C-reactive protein and neutrophil-to-lymphocyte ratio in middle-aged and older adults with metabolic syndrome in Taiwan: a cross-sectional study. Nutrition Journal. 2018 Nov 19;17(1):106.
24. Kanagasabai T, Alkhalaqi K, Churilla JR, Ardern CI. The association between metabolic syndrome and serum concentrations of micronutrients, inflammation, and oxidative stress outside of the clinical reference ranges: a cross-sectional study. Metabolic syndrome and related disorders. 2019 Feb 1;17(1):29-36.
25. Xu Y, BI YF, Xu M, Huang Y, LU WY, GU YF, Ning G, LI XY. Cross-sectional and longitudinal association of serum alanine aminotransaminase and γ-glutamyltransferase with metabolic syndrome in middle-aged and elderly Chinese people. Journal of diabetes. 2011 Mar;3(1):38-47.
26. Wu H, Liu M, Chi VT, Wang J, Zhang Q, Liu L, Meng G, Yao Z, Bao X, Gu Y, Zhang S. Handgrip strength is inversely associated with metabolic syndrome and its separate components in middle aged and older adults: a large-scale population-based study. Metabolism. 2019 Apr 1;93:61-7.