Acta Scientific MEDICAL SCIENCES (ISSN: 2582-0931)

Volume 10 Issue 4 April 2026

Research Article

Association between Metabolic Syndrome and Dyslipidemia Among Adults across Geo-climatic Setups of West Bengal, India

Partha Sarathi Datta* and Rajesh K Gautam

Department of Anthropology, Dr. Harisingh Gour Vishwavidyalaya (Central University), Madhya Pradesh, India

***Corresponding Author:** Partha Sarathi Datta, Department of Anthropology, Dr. Harisingh Gour Vishwavidyalaya (Central University), Madhya Pradesh, India.

DOI: 10.31080/ASMS.2026.10.2229

Received: January 05, 2026

Published: March 26, 2026

Abstract

Background: Metabolic syndrome (MetS) is a major public health challenge due to its strong association with cardiovascular disease and type 2 diabetes mellitus. India bears a disproportionate burden of MetS, yet regional evidence linking geo-climatic context with metabolic and lipid abnormalities remains limited, particularly from eastern India.

Objectives: The present study aimed to assess the prevalence of metabolic syndrome and its associated lipid abnormalities across five distinct geo-climatic setups of West Bengal and to examine regional variations in metabolic risk.

Methods: A community-based cross-sectional study was conducted among 1,285 adults aged 21–60 years (644 males and 641 females) selected through multistage stratified random sampling from hill, plateau, plain, delta, and coastal setups. Anthropometric measurements, blood pressure, fasting blood glucose, and lipid profiles were assessed using standardized protocols. MetS was defined using NCEP-ATP III criteria with South Asian–specific cut-offs. Statistical analyses included descriptive statistics, chi-square tests, independent t-tests, effect size estimation, and correlation analysis.

Results: The overall prevalence of MetS was 22.96%, with significant regional variation. The highest prevalence was observed in the plain region (29.76%), followed by coastal (23.64%), plateau (22.85%), delta (21.96%), and hill (16.61%) regions. Dyslipidemia showed a strong association with MetS across all regions (χ^2 = 928.03, $p < 0.05$; Cramér's V = 0.85). Individuals with MetS had significantly higher levels of triglycerides, total cholesterol, LDL, and VLDL cholesterol, along with lower HDL cholesterol. Correlation and network analyses revealed strong clustering of adiposity, blood pressure, glycemic status, and lipid abnormalities, highlighting dyslipidemia as a central component of MetS.

Conclusion: Metabolic syndrome and lipid abnormalities are widely prevalent and unevenly distributed across geo-climatic setups of West Bengal. Region-specific, integrated public health interventions focusing on lifestyle modification and early detection are essential to reduce future cardiometabolic risk.

Keywords: Metabolic Syndrome; Dyslipidemia; Geo-Climatic Variation; Lipid profile; West Bengal; India

Introduction

Metabolic syndrome (MetS) is a cluster of interrelated metabolic abnormalities that substantially increases the risk of cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM). It is typically characterised by central obesity, hypertension, dyslipidemia, and impaired glucose regulation. Individually, each component poses health risks, but their co-occurrence markedly amplifies morbidity and mortality [1]. Over the last two decades, MetS has emerged as a major public health concern worldwide, particularly in low- and middle-income countries undergoing rapid socio-economic and lifestyle transitions.

Globally, the prevalence of MetS among adults' ranges from 20% to 35%, with substantial regional heterogeneity driven by differences in diet, physical activity, urbanisation, and socio-economic conditions [2]. In South Asia, and especially in India, the burden of MetS is disproportionately high. A large systematic review and meta-analysis reported that nearly one-third of Indian adults fulfil the diagnostic criteria for MetS, making it a critical non-communicable disease challenge for the country [3]. Urban populations traditionally show higher prevalence, but recent evidence suggests a rapid rise in rural and semi-urban settings as well [4].

Dyslipidemia is a core component of MetS and plays a pivotal role in the pathogenesis of atherosclerosis and cardiovascular complications. The characteristic lipid abnormalities associated with MetS include elevated triglycerides, reduced high-density lipoprotein (HDL) cholesterol, and increased low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL) particles. In Indian populations, these abnormalities often manifest at lower body mass indices compared to Western populations, reflecting heightened metabolic susceptibility among South Asians [5]. Understanding lipid derangements in relation to MetS is therefore essential for early risk stratification and prevention.

Environmental and geo-climatic factors are increasingly recognised as important determinants of metabolic health. Climate, altitude, temperature, humidity, and food ecology influence energy expenditure, dietary patterns, and physical activity levels, thereby shaping metabolic risk [6,7]. West Bengal presents a unique natural setting for such investigations, as it encompasses five distinct geo-climatic setups, hill, plateau, plain, delta, and coastal, each with characteristic environmental conditions, livelihoods, and cultural practices. These regional differences may translate into varying metabolic and lipid risk profiles, yet systematic evidence from this region remains limited.

Socio-economic and behavioural factors further interact with environmental conditions to influence MetS risk. Dietary transitions toward refined carbohydrates, declining physical activity, tobacco and alcohol use, and occupational shifts from labour-intensive to sedentary work have all been implicated in the rising burden of MetS in India [8,9]. Importantly, these factors do not operate uniformly across regions, underscoring the need for region-specific epidemiological assessments.

Against this background, the present study aims to examine the prevalence of metabolic syndrome and associated lipid abnormalities across five geo-climatic setups of West Bengal. By integrating anthropometric, biochemical, and blood pressure measurements in a large community-based sample, the study seeks to elucidate regional patterns of MetS and dyslipidemia. Such evidence is crucial for developing targeted, context-specific public health strategies to curb the growing burden of metabolic disorders in eastern India.

Materials and Methods

This community-based cross-sectional study was conducted across five distinct geo-climatic setups of West Bengal, India, namely hill, plateau, plain, delta, and coastal. These regions differ markedly in altitude, climate, dietary ecology, and lifestyle patterns, providing an appropriate setting to examine regional variations in MetS and lipid abnormalities. The study was carried out between May 2023 and January 2025.

A total of 1,285 adult participants aged between 21-60 years were included in the study, comprising 644 males and 641 females. Participants were selected using a multistage stratified random sampling method. In the first stage, districts representing each geo-climatic setup were identified. In the second stage, villages and urban wards were randomly selected, followed by household selection. One eligible adult from each household was recruited. Individuals who had been residing in the respective region for at least 15 years and who provided written informed consent were included. Pregnant women, individuals with acute illness, and those on medications known to affect lipid or glucose metabolism were excluded.

Socio-demographic information was collected through face-to-face interviews using a structured schedule. Anthropometric measurements included stature, weight, and waist circumference, measured following standard protocols recommended by the International Society for the Advancement of Kinanthropometry (ISAK) [10]. Body mass index (BMI) was calculated. Blood pressure was measured using a standardized sphygmomanometer after the participant had rested for at least five minutes. Three readings were taken at five-minute intervals, and the average was recorded. Venous blood samples were collected after an overnight fast of at least eight hours. Fasting blood glucose and lipid profile parameters, total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol, and VLDL cholesterol were analyzed using standard enzymatic methods in a certified laboratory. MetS was diagnosed according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria, with South Asian–specific waist circumference cut-offs [5,11]. Data were analyzed using SPSS version 26. Descriptive statistics, chi-square tests, independent t-tests, effect sizes (Cohen's d), and correlation analysis were performed. Statistical significance was set at $p < 0.05$.

Results

A total of 1,285 adults (644 males and 641 females) from five geo-climatic setups of West Bengal were included in the analysis. Overall, 295 individuals were identified as having MetS, yielding a prevalence of 22.96% in the study population.

Prevalence of metabolic syndrome across geo-climatic setups

Marked regional variation in MetS prevalence was observed (Table 1). The plain region showed the highest prevalence (29.76%), followed by the coastal (23.64%), plateau (22.85%), delta (21.96%), and hill (16.61%) regions. The hill region consistently exhibited the lowest proportion of affected individuals, whereas the plains showed the highest burden of MetS. Overall, nearly three-quarters of participants (77.04%) were classified as non-affected.

Dyslipidemia and MetS status

Dyslipidemia was strongly associated with MetS across all geo-climatic setups (Table 2). The proportion of dyslipidemia among individuals with MetS ranged from 16.61% in the hill region to 29.36% in the plain region. In contrast, dyslipidemia among non-MetS individuals remained consistently low across regions. The chi-square test indicated a highly significant association between MetS status and dyslipidemia ($\chi^2 = 928.03$, $p < 0.05$), with a very strong effect size (Cramér's V = 0.85), suggesting a robust clustering of lipid abnormalities among MetS-affected individuals.

Geo-climatic Setups	n	MetS Status	
		Affected (%)	Non-affected (%)
Hill	253 (19.69)	42 (16.61)	211 (83.39)
Plateau	267 (20.78)	61 (22.85)	206 (77.15)
Plain	252 (19.61)	75 (29.76)	177 (70.24)
Delta	255 (19.84)	56 (21.96)	199 (78.04)
Coastal	258 (20.08)	61 (23.64)	197 (76.36)
Total	1285 (100.00)	295 (22.96)	990 (77.04)

Table 1: MetS Status across Geo-climatic Setups.

Geo-Climatic Setups	Dyslipid-emia (%) with MetS	Dyslipidemia (%) without MetS	χ^2	Cra-mér's V
Hill	16.61	11.98	928.03*	0.85
Plateau	22.85	6.74		
Plain	29.36	0		
Delta	21.57	5.49		
Coastal	22.87	4.26		
Total	22.64	5.69		

Table 2: Dyslipidemia with MetS Status across Geo-climatic Setups.

[*p < 0.05].

Lipid profile differences by MetS status

Significant differences in lipid profile parameters were observed between MetS-affected and non-affected individuals across all regions (Table 3). Individuals with MetS consistently showed higher mean levels of total cholesterol, triglycerides, LDL cholesterol, and VLDL cholesterol, along with significantly lower HDL cholesterol.

Geo-climatic Setups	MetS Status	Total Cholesterol (mg/dL)		t	Cohen's *d*	Triglycerides (mg/dL)		t	Cohen's *d*	HDL Cholesterol (mg/dL)		t	Cohen's *d*	LDL Cholesterol (mg/dL)		t	Cohen's *d*	VLDL Cholesterol (mg/dL)		t	Cohen's *d*
		Mean	SD			Mean	SD			Mean	SD			Mean	SD			Mean	SD		
Hill	Affected	186.86	26.78	1.82	0.48	152.02	20.97	10.56*	1.48	45.64	12.85	9.33*	1.53	113.26	28.82	6.14*	0.93	30.41	4.19	9.85*	1.47
	Non-affected	174.97	22.71			109.01	35.75			66.11	14.63			88.19	25.85			21.81	7.15		
Plateau	Affected	192.67	24.81	7.43*	0.96	148.95	22.16	12.08*	1.55	46.67	13.21	10.22*	1.59	116.54	31.47	7.65*	1.07	29.79	4.43	10.13*	1.49
	Non-affected	170.95	21.84			104.84	32.86			65.12	11.59			85.59	23.51			20.97	6.57		
Plain	Affected	189.51	26.02	2.47*	0.65	148.53	21.31	14.20*	1.86	47.40	13.56	11.12*	1.68	114.23	31.37	7.91*	1.10	29.71	4.26	11.16*	1.64
	Non-affected	174.79	18.32			98.11	34.06			67.11	10.09			84.24	21.91			19.62	6.81		
Delta	Affected	175.29	24.35	0.84	0.22	144.82	26.16	12.97*	1.78	48.14	15.84	8.73*	1.43	106.65	36.19	2.85*	0.64	28.96	5.23	10.38*	1.65
	Non-affected	169.78	26.39			89.18	35.11			68.35	12.32			83.04	26.05			17.84	7.02		
Coastal	Affected	186.81	21.64	3.00*	0.82	149.23	23.75	15.99*	2.13	48.20	13.19	10.61*	1.79	107.61	31.49	5.87*	0.90	29.84	4.75	11.42*	1.82
	Non-affected	169.07	22.87			86.84	34.25			70.46	11.25			81.43	26.39			17.37	6.85		

Table 3: Cross-tabulation of Lipid Profile Level with MetS Status across Geo-climatic Setups.

[*p < 0.05].

[SD: Standard Deviation, HDL: High-Density Lipoprotein, LDL: Low-Density Lipoprotein and VLDL: Very Low-Density Lipoprotein].

Triglycerides exhibited the largest effect sizes across regions, particularly in the plain and coastal setups (Cohen's d >1.8), indicating pronounced hypertriglyceridemia among MetS cases. HDL cholesterol levels were markedly reduced in MetS-affected individuals, with large effect sizes observed in all regions. Differences in LDL and VLDL cholesterol were also statistically significant, with moderate to large effect sizes, highlighting atherogenic lipid patterns associated with MetS.

Correlation and network structure of metabolic parameters

Correlation analysis revealed significant interrelationships among anthropometric, metabolic, and lipid variables (Table 4). BMI and waist circumference showed positive correlations with blood pressure and lipid parameters. Systolic and diastolic blood pressure were strongly correlated with each other and showed moderate associations with triglycerides and LDL cholesterol.

Variables	BMI	WC	SBP	DBP	BG	TC	TG	HDL	LDL
BMI	-	.080*	.055*	.052	.049	.097*	.021	-.030	.055*
WC		-	.040	.043	.087*	.037	-.064*	.018	.013
SBP			-	.779*	.090*	.045	.155*	-.153*	.090*
DBP				-	.119*	.033	.151*	-.169*	.095*
BG					-	.033	.179*	-.066*	.007
TC						-	.317*	-.301*	.742*
TG							-	-.474*	.325*
HDL								-	-.670*
LDL									-

Table 4: Correlation Matrix of Metabolic and Cardiovascular Parameters among Studied Participants.
[*p < 0.05].

[BMI: Body Mass Index, WC: Waist Circumference, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, BG: Blood Glucose, TC: Total Cholesterol, TG: Triglycerides, HDL: High-Density Lipoprotein, and LDL: Low-Density Lipoprotein].

Triglycerides displayed strong negative correlations with HDL cholesterol and positive correlations with LDL cholesterol. Total cholesterol was strongly correlated with LDL cholesterol, indicating shared metabolic pathways. The network visualization graph (Figure 1) based on these correlations demonstrated clear clustering of adiposity measures, blood pressure, glycemic status, and dyslipidemia, emphasizing the interconnected nature of MetS components. This network structure highlights dyslipidemia, particularly triglycerides and HDL cholesterol, as central nodes linking metabolic and cardiovascular risk factors. Overall, the results underscore pronounced regional disparities in MetS prevalence and reveal strong associations between MetS and adverse lipid profiles across geo-climatic setups of West Bengal.

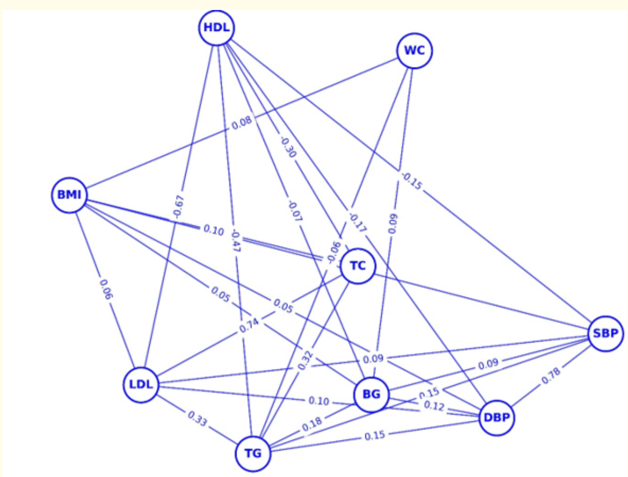

Figure 1: Network Visualization of Correlation Matrix of Metabolic and Cardiovascular Parameters among Studied Participants.

Discussion

The present study documents a 22.96% prevalence of MetS among adults from five geo-climatic regions of West Bengal, with marked regional variation. The plain region showed the highest burden, while the hill region exhibited the lowest prevalence. This pattern reflects the combined influence of environment, lifestyle, and dietary practices on metabolic health.

The observed prevalence is broadly comparable with national estimates from India. A large systematic review and meta-analysis reported a pooled MetS prevalence of approximately **30%** among Indian adults, with wide inter-regional variation [3]. The slightly lower prevalence in the present study may be attributed to the inclusion of mixed rural-semi-urban populations and ecologically diverse settings. Similar regional heterogeneity has been reported in community-based studies from different parts of India [9].

A key finding of this study is the strong clustering of dyslipidemia with MetS**,** supported by a very high chi-square value and large effect size. Individuals with MetS consistently showed elevated triglycerides, LDL, and VLDL cholesterol, along with reduced HDL cholesterol across all geo-climatic setups. This lipid pattern is characteristic of the South Asian metabolic phenotype and has been widely documented in Indian populations [1,5]. The particularly high triglyceride levels observed in the plain and coastal regions may reflect high carbohydrate intake and reduced physical activity, both of which are common in these areas.

From a global perspective, the findings align with reports from the World Health Organization (WHO) and the Global Burden of Disease (GBD) study. The GBD 2019 and subsequent updates identify raised LDL cholesterol, high fasting plasma glucose, and high systolic blood pressure among the leading contributors to cardiovascular disease and premature mortality worldwide, with India contributing substantially to this burden. Although MetS as a composite entity is not directly estimated by GBD, its individual components account for a major share of disability-adjusted life years (DALYs) [12,13].

National data from ICMR–INDIAB studies further support the present findings. These surveys indicate a high and rising prevalence of dyslipidemia, diabetes, and hypertension across Indian states, including eastern India, even among individuals with relatively low BMI. This supports the concept of widespread 'metabolic vulnerability' in Indian populations [14].

The correlation and network analysis in this study highlight the interconnected nature of adiposity, blood pressure, glucose, and lipid parameters. Strong positive associations between triglycerides, LDL cholesterol, waist circumference, and blood pressure, along with inverse associations between triglycerides and HDL cholesterol, reflect shared pathophysiological pathways involving insulin resistance and chronic inflammation. Similar clustering patterns have been reported in both Indian and international studies [15]. The lower MetS prevalence observed in the hill region is noteworthy and may be linked to higher physical activity, traditional diets, and climatic factors that promote greater energy expenditure. Environmental influences on metabolic health are increasingly recognized, and geo-climatic context should be considered in public health planning [6]. Overall, the study underscores that MetS and dyslipidemia are significant and unevenly distributed public health challenges in West Bengal. Region-specific prevention strategies focusing on dietary quality, physical activity, and early screening are essential to reduce future cardiovascular disease risk.

Conclusion

This study demonstrates that MetS and lipid abnormalities constitute a significant public health concern across the diverse geo-climatic setups of West Bengal. Nearly one-quarter of the adult population was affected by MetS, with clear regional disparities. The plain and coastal regions exhibited the highest burden, while the hill region showed a comparatively lower prevalence.

Dyslipidemia emerged as a central component of metabolic syndrome in all geo-climatic setups. Elevated triglycerides, increased atherogenic lipoproteins, and reduced HDL cholesterol were consistently observed among affected individuals. These findings highlight the strong clustering of lipid abnormalities with other metabolic risk factors such as central obesity, hypertension, and impaired glucose regulation.

The observed regional variation underscores the influence of environmental context, dietary practices, and lifestyle patterns on metabolic health. Geo-climatic factors, when combined with socio-economic and behavioral determinants, appear to shape the distribution of metabolic risk in the population. The network-based associations further confirm the interconnected nature of metabolic syndrome components.

Overall, the findings emphasize the need for region-specific public health strategies focusing on early screening, dietary modification, and promotion of physical activity. Addressing metabolic syndrome through an integrated, context-sensitive approach is essential to reduce the future burden of cardiovascular disease and related non-communicable disorders in eastern India.

Bibliography

1. Madan K., *et al*. "Metabolic syndrome: The constellation of co-morbidities, a global threat". *Endocrine, Metabolic and Immune Disorders - Drug Targets* 23.12 (2023): 1491-1504.
2. Krupp K., *et al*. "Prevalence and correlates of metabolic syndrome among rural women in Mysore, India". *Indian Heart Journal* 72.6 (2020): 582-588.
3. Krishnamoorthy Y., *et al*. "Prevalence of metabolic syndrome among adult population in India: A systematic review and meta-analysis". *PLOS ONE* 15.10 (2021): e0240971.
4. Krishnamoorthy Y., *et al*. "Association between behavioural risk factors and metabolic syndrome among adult population in India: A systematic review and meta-analysis of observational studies". *Nutrition, Metabolism and Cardiovascular Diseases* 32.1 (2022): 40-52.
5. Pandit K., *et al*. "Metabolic syndrome in South Asians". *Indian Journal of Endocrinology and Metabolism* 16.1 (2012): 44-55.
6. Bhatnagar A. "Environmental determinants of cardiovascular disease". *Circulation Research* 121.2 (2017): 162-180.
7. Zhang T., *et al*. "Research on the relationship between metabolic syndrome and meteorological factors in a subtropical humid city of China". *BMC Public Health* 23.1 (2023): 2363.
8. Bhalwar R. "Metabolic syndrome: The Indian public health perspective". *Medical Journal, Armed Forces India* 76.1 (2020): 8-16.
9. Selvaraj P and Muthunarayanan L. "Prevalence of metabolic syndrome and associated risk factors among men in a rural health centre area in Tamil Nadu". *Journal of Lifestyle Medicine* 9.1 (2019): 44-51.
10. International Society for the Advancement of Kinanthropometry. "International standards for anthropometric assessment (2nd ed.)". ISAK (2019).
11. National Cholesterol Education Program (NCEP). "Third report of the National Cholesterol Education Program (NCEP) Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III)". *Circulation* 106.25 (2002): 3143-3421.
12. World Health Organization. "Global report on hypertension: The race against a silent killer". WHO (2023).

13. GBD 2019 Risk Factors Collaborators. "Global burden of 87 risk factors in 204 countries and territories, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019". *The Lancet* 396.10258 (2020): 1223-1249.

14. Anjana RM., *et al*. "Prevalence of diabetes and prediabetes in 15 states of India: Results from the ICMR-INDIAB population-based cross-sectional study". *The Lancet Diabetes and Endocrinology* 5.8 (2017): 585-596.

15. Shen W., *et al*. "Waist circumference correlates with metabolic syndrome indicators better than percentage fat". *Obesity* 14.4 (2006): 727-736.