Original Research Article

METABOLIC SYNDROME AND COGNITIVE IMPAIRMENT IN ADULTS: A CROSS-SECTIONAL STUDY FROM A TERTIARY CARE HOSPITAL

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ABSTRACT

Background: Metabolic syndrome is a cluster of cardiometabolic abnormalities including central obesity, hypertension, dyslipidaemia, and impaired glucose metabolism that significantly increase the risk of cardiovascular diseases. Emerging evidence suggests that metabolic syndrome may also adversely affect cognitive function. However, data regarding this association in the Indian population remain limited. This study aimed to assess the association between metabolic syndrome and cognitive function among adults attending a tertiary care center.

Materials and Methods: A cross-sectional study was conducted among 356 adults attending a tertiary care hospital. Sociodemographic, clinical, and metabolic parameters were recorded using a structured proforma. Metabolic syndrome was diagnosed according to the criteria of the International Diabetes Federation. Cognitive function was assessed using the Mini-Mental State Examination (MMSE). Statistical analysis was performed using appropriate descriptive and inferential statistics to evaluate associations between metabolic parameters and cognitive performance.

Results: The prevalence of metabolic syndrome was 34.8%. Participants with metabolic syndrome had significantly lower MMSE scores compared to those without metabolic syndrome (24.6 ± 3.1 vs 26.9 ± 2.4, $p < 0.001$). Cognitive impairment was observed in 25.8% of individuals with metabolic syndrome compared with 9.5% among those without metabolic syndrome. Components of metabolic syndrome, including central obesity, elevated triglycerides, reduced HDL cholesterol, hypertension, and elevated fasting glucose, showed significant associations with cognitive impairment. Negative correlations were observed between MMSE scores and waist circumference, fasting glucose, triglycerides, and systolic blood pressure, while HDL cholesterol showed a positive correlation with cognitive performance.

Conclusion: Metabolic syndrome is significantly associated with reduced cognitive function. Early identification and management of metabolic risk factors may help in preventing or delaying cognitive decline.

Keywords: Metabolic syndrome; Cognitive function; Mini-Mental State Examination; Cardiometabolic risk factors; Cognitive impairment.

INTRODUCTION

Metabolic syndrome (MetS) is a cluster of metabolic abnormalities that includes central obesity, hypertension, dyslipidaemia (elevated triglycerides and reduced high-density lipoprotein cholesterol), and impaired glucose metabolism.[1] These interrelated factors collectively increase the risk of cardiovascular disease, type 2 diabetes mellitus, and overall mortality.[1] Diagnostic criteria proposed by organizations such as the International Diabetes Federation and the National Cholesterol Education Program Adult Treatment Panel III are widely used to identify individuals with metabolic syndrome, typically when three or more of these components are present.[2] Globally, metabolic syndrome has emerged as a major public health concern, with an estimated prevalence of approximately 20–25% among adults.[3]

The burden of metabolic syndrome is particularly high in developing countries undergoing rapid lifestyle and nutritional transitions.[3] In India, increasing urbanization, sedentary behavior, and dietary changes have contributed to a substantial rise in obesity, diabetes, and associated metabolic abnormalities.[4,5] Epidemiological studies in Indian populations have reported the prevalence of metabolic syndrome ranging from 20% to 40%, with higher rates observed in urban populations and individuals seeking tertiary healthcare services.[4,5] This growing prevalence has raised concerns regarding the broader systemic effects of metabolic syndrome beyond its well-recognized cardiovascular consequences.[5]

In recent years, there has been increasing interest in the potential association between metabolic syndrome and cognitive function.[6] Cognitive function refers to mental processes such as memory, attention, executive functioning, language, and visuospatial abilities, which are essential for daily activities and overall quality of life.[6] Cognitive impairment ranges from mild deficits in specific domains to severe conditions such as dementia.[6] Globally, dementia affects more than 55 million individuals and represents a significant public health challenge, particularly in aging populations.[7]

Several biological mechanisms may explain the relationship between metabolic syndrome and cognitive decline.[8] Insulin resistance, a key feature of metabolic syndrome, may impair neuronal metabolism and synaptic plasticity.[9] In addition, chronic low-grade inflammation and oxidative stress associated with obesity and dyslipidaemia may contribute to neurodegeneration.[9] Hypertension and atherosclerosis can also lead to cerebral microvascular damage, reduced cerebral perfusion, and structural brain changes that adversely affect cognitive performance.[10]

Although multiple international studies have suggested that metabolic syndrome may increase the risk of cognitive impairment and dementia, the findings remain heterogeneous due to variations in study design, populations, and cognitive assessment tools. Furthermore, evidence from the Indian population is relatively limited despite the high burden of metabolic disorders. Understanding the relationship between metabolic syndrome and cognitive function is therefore important for early identification of individuals at risk and for implementing preventive strategies. Hence, the present study was conducted to assess the association between metabolic syndrome and cognitive function among adults attending a tertiary care center. This study aims to contribute to the existing evidence by exploring the impact of metabolic abnormalities on cognitive performance in a clinical population.

MATERIALS AND METHODS

Study Design and Setting: This hospital-based cross-sectional study was conducted among adult patients attending the outpatient department of General Medicine of a tertiary care teaching hospital. The study was carried out over a period of 24 months from June 2023 to May 2025. The tertiary care centre caters to a large urban and semi-urban population and provides comprehensive diagnostic and clinical services, making it an appropriate setting to evaluate metabolic disorders and associated health outcomes. The study was designed to assess the association between metabolic syndrome and cognitive function among adults presenting to the hospital during the study period.

Study Population: The study population consisted of adults aged 30 years and above attending the outpatient department of the General Medicine at a tertiary care hospital during the study period. Participants were recruited consecutively after screening for eligibility. Individuals who were willing to participate and provided written informed consent were included in the study. Participants with a history of previously diagnosed dementia, major psychiatric illness, neurological disorders such as stroke, Parkinson’s disease or epilepsy, severe visual or hearing impairment interfering with cognitive testing, chronic alcohol dependence, or those receiving medications known to affect cognitive function were excluded from the study. Pregnant women and patients with severe systemic illness requiring immediate medical intervention were also excluded to minimize potential confounding factors affecting metabolic and cognitive parameters.

Sample Size and Sampling Technique: The required sample size was calculated based on the expected prevalence of metabolic syndrome among adults reported in a previous Indian study by Krishnamoorthy et al., which documented a pooled prevalence of approximately 30% among the adult population in India [11]. Assuming a prevalence of 30%, with a 95% confidence level and a margin of error of 5%, the minimum sample size required was estimated using the standard formula for cross-sectional studies, $n = Z^2pq/d^2$, where Z = 1.96 for 95% confidence level, p = estimated prevalence (0.30), $q = 1 - p$, and d = allowable error (0.05). Based on this calculation, the minimum required sample size was approximately 323 participants. Considering the possibility of non-response and incomplete data, 356 participants were included to ensure adequate statistical power. Eligible participants were recruited using a consecutive sampling technique until the desired sample size was achieved.

Data Collection Procedure: Data were collected using a structured and pre-tested questionnaire administered through face-to-face interviews by trained investigators. Information regarding socio-demographic characteristics such as age, sex, educational status, occupation, and lifestyle factors including physical activity, smoking, and alcohol consumption was recorded. Relevant medical history including hypertension, diabetes mellitus, and dyslipidaemia was also obtained from the participants and verified using available medical records whenever possible.

Anthropometric measurements were performed using standardized procedures. Body weight was measured using a calibrated digital weighing scale with participants wearing light clothing and no footwear, and recorded to the nearest 0.1 kg. Height was measured using a stadiometer to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m²). Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the iliac crest using a non-stretchable measuring tape. Blood pressure was measured using a calibrated sphygmomanometer after the participant had rested for at least five minutes in a seated position, and the average of two readings taken five minutes apart was recorded.

Assessment of Metabolic Syndrome: Metabolic syndrome was diagnosed using the criteria proposed by the International Diabetes Federation [12]. According to these criteria, the presence of central obesity (defined by increased waist circumference specific to South Asian populations) along with any two of the following components was considered diagnostic of metabolic syndrome: elevated triglycerides (≥150 mg/dL) or treatment for dyslipidaemia, reduced high-density lipoprotein cholesterol (<40 mg/dL in males and <50 mg/dL in females), elevated blood pressure (systolic ≥130 mmHg or diastolic ≥85 mmHg or on antihypertensive treatment), and elevated fasting plasma glucose (≥100 mg/dL) or previously diagnosed type 2 diabetes mellitus. Fasting blood samples were collected after an overnight fast of at least 8–10 hours for the estimation of fasting blood glucose and lipid profile using standard laboratory methods.

Assessment of Cognitive Function: Cognitive function was assessed using the Mini-Mental State Examination (MMSE), a widely used screening tool for evaluating cognitive performance in clinical and research settings [13]. The MMSE evaluates multiple domains of cognitive function including orientation, attention, memory, language, and visuospatial skills. The maximum possible score on the MMSE is 30, with higher scores indicating better cognitive function. In general, scores of 24 or above are considered normal, while scores below this threshold may indicate varying degrees of cognitive impairment. All cognitive assessments were conducted in a quiet environment by trained investigators to ensure consistency and reliability.

Statistical Analysis: The collected data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the demographic and clinical characteristics of the study participants. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The prevalence of metabolic syndrome and cognitive impairment was calculated accordingly. The association between metabolic syndrome and cognitive function was assessed using appropriate statistical tests such as the independent t-test for comparison of continuous variables and the chi-square test for categorical variables. Pearson's Correlation analysis was performed to evaluate the relationship between metabolic parameters and cognitive scores. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee of the participating tertiary care hospital prior to the initiation of the study. Written informed consent was obtained from all participants after explaining the purpose and procedures of the study. Participants were assured that all information would remain confidential and used solely for research purposes. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

RESULTS

The study included 356 adult participants with a mean age of 48.6 ± 11.2 years. The most common age group was 40–49 years (29.2%), followed by 50–59 years (27.0%), while 23.0% were aged 30–39 years and 20.8% were aged ≥60 years. There was a male predominance (57.3%), with females accounting for 42.7% of the participants. Regarding educational status, 39.9% had completed secondary education, 38.2% were graduates or above, and 21.9% had primary education or less. In terms of occupation, 44.9% were engaged in sedentary occupations, 29.2% were manual workers, and 25.8% were unemployed or retired. Lifestyle factors showed that 24.2% of participants reported current or past smoking, while 19.1% reported alcohol consumption. Among the participants, 37.1% were known hypertensive patients and 30.3% had previously diagnosed diabetes mellitus [Table 1].

Table 1: Baseline Sociodemographic Characteristics of the Study Participants (n = 356).

Variable	Category	Frequency	%
Age Group (years)	30–39	82	23.0
	40–49	104	29.2
	50–59	96	27.0
	≥60	74	20.8
Age (years)		48.6 ± 11.2	

Gender	Male	204	57.3
	Female	152	42.7
Educational Status	Primary school or less	78	21.9
	Secondary school	142	39.9
	Graduate and above	136	38.2
Occupation	Unemployed/Retired	92	25.8
	Manual worker	104	29.2
	Sedentary occupation	160	44.9
Smoking Status	Current/Former smoker	86	24.2
	Non-smoker	270	75.8
Alcohol Consumption	Yes	68	19.1
	No	288	80.9
Known Hypertension	Yes	132	37.1
Known Diabetes Mellitus	Yes	108	30.3

The overall mean body mass index (BMI) of the participants was 26.4 ± 3.9 kg/m², indicating a predominantly overweight population. The mean waist circumference was 92.8 ± 9.6 cm. The average systolic and diastolic blood pressures were 131.6 ± 14.8 mmHg and 83.4 ± 9.7 mmHg, respectively. The mean fasting plasma glucose level was 108.5 ± 29.4 mg/dL, while the mean triglyceride level was 162.3 ± 58.1 mg/dL and HDL cholesterol was 42.1 ± 9.5 mg/dL [Table 2].

Table 2: Clinical and Metabolic Characteristics of the Study Participants (n = 356).

Variable	**Mean ± SD**
Body Mass Index (kg/m²)	26.4 ± 3.9
Waist circumference (cm)	92.8 ± 9.6
Systolic BP (mmHg)	131.6 ± 14.8
Diastolic BP (mmHg)	83.4 ± 9.7
Fasting plasma glucose (mg/dL)	108.5 ± 29.4
Triglycerides (mg/dL)	162.3 ± 58.1
HDL cholesterol (mg/dL)	42.1 ± 9.5

BP: Blood Pressure; HDL: High-Density Lipoprotein.

Among the study participants, central obesity was observed in 55.6%, elevated blood pressure in 52.2%, elevated triglycerides in 48.9%, reduced HDL cholesterol in 47.2%, and elevated fasting glucose in 42.7% of individuals. Based on these criteria, metabolic syndrome was present in 124 participants (34.8%), while 232 participants (65.2%) did not meet the diagnostic criteria for metabolic syndrome [Table 3].

Table 3: Prevalence of Metabolic Syndrome and Its Components Among the Study Participants (n = 356).

Metabolic Parameter	**Frequency**	**%**
Central obesity (increased waist circumference)	198	55.6
Elevated triglycerides	174	48.9
Reduced HDL cholesterol	168	47.2
Elevated blood pressure	186	52.2
Elevated fasting glucose	152	42.7
Metabolic Syndrome		
Present	124	34.8
Absent	232	65.2

Participants with metabolic syndrome demonstrated significantly lower cognitive scores compared with those without metabolic syndrome. The mean MMSE score in the metabolic syndrome group was 24.6 ± 3.1, whereas participants without metabolic syndrome had a significantly higher mean score of 26.9 ± 2.4 ($p < 0.001$). Cognitive impairment (MMSE <24) was observed in 25.8% of individuals with metabolic syndrome, compared to 9.5% among those without metabolic syndrome, indicating a statistically significant association between metabolic syndrome and impaired cognitive function ($p < 0.001$) [Table 4].

Table 4: Comparison of Cognitive Function Between Participants With and Without Metabolic Syndrome.

Variable	**Metabolic Syndrome (n=124)**	**No Metabolic Syndrome (n=232)**	**p-value**
	Frequency (%)/Mean ± SD		
MMSE Score (Mean ± SD)	24.6 ± 3.1	26.9 ± 2.4	<0.001
Normal cognition (MMSE ≥24)	92 (74.2%)	210 (90.5%)	<0.001
Cognitive impairment (MMSE <24)	32 (25.8%)	22 (9.5%)	<0.001

Among participants with cognitive impairment (n = 54), central obesity was present in 70.4%, elevated triglycerides in 63.0%, reduced HDL cholesterol in 59.3%, elevated blood pressure in 74.1%, and elevated fasting glucose in 66.7%. All metabolic components showed a significant association with cognitive impairment. Elevated blood pressure ($p < 0.001$) and elevated fasting glucose ($p < 0.001$) demonstrated the strongest associations, followed by central obesity ($p = 0.018$), elevated triglycerides ($p = 0.027$), and reduced HDL cholesterol ($p = 0.048$) [Table 5].

Table 5: Association Between Components of Metabolic Syndrome and Cognitive Impairment.

Variable	Cognitive Impairment (n=54)	Normal Cognition (n=302)	p-value
	Frequency (%)		
Central obesity	38 (70.4%)	160 (53.0%)	0.018
Elevated triglycerides	34 (63.0%)	140 (46.4%)	0.027
Reduced HDL	32 (59.3%)	136 (45.0%)	0.048
Elevated BP	40 (74.1%)	146 (48.3%)	<0.001
Elevated fasting glucose	36 (66.7%)	116 (38.4%)	<0.001

Correlation analysis revealed that several metabolic parameters were significantly associated with cognitive performance. The MMSE score showed a significant negative correlation with waist circumference ($r = -0.28$, $p < 0.001$), fasting plasma glucose ($r = -0.31$, $p < 0.001$), triglyceride levels ($r = -0.22$, $p = 0.001$), and systolic blood pressure ($r = -0.26$, $p < 0.001$). Conversely, HDL cholesterol demonstrated a positive correlation with MMSE score ($r = 0.19$, $p = 0.004$), suggesting that higher HDL levels were associated with better cognitive performance [Table 6].

Table 6: Correlation Between Metabolic Parameters and Cognitive Function (MMSE Score).

Variable	Pearson Correlation Coefficient (r)	p-value
Waist circumference	−0.28	<0.001
Fasting glucose	−0.31	<0.001
Triglycerides	−0.22	0.001
HDL cholesterol	0.19	0.004
Systolic blood pressure	−0.26	<0.001

DISCUSSION

The present cross-sectional study evaluated the association between metabolic syndrome and cognitive function among adults attending a tertiary care center and demonstrated a significant relationship between metabolic abnormalities and impaired cognitive performance. In this study, the overall prevalence of metabolic syndrome was 34.8%, which is consistent with the increasing burden of metabolic disorders reported in India in studies by Selvaraj et al., and Sundarakumar et al.[14,15] Several epidemiological studies from India by Basu et al., and Ashwin Raj et al., have reported metabolic syndrome prevalence ranging from 25% to 40% among adults, particularly in urban and hospital-based populations.[16,17] For instance, Krishnamoorthy et al., reported a pooled prevalence of approximately 30% among Indian adults, highlighting the growing public health impact of metabolic syndrome in the country.[11] Similarly, studies conducted in tertiary care settings by Selvaraj et al., Sundarakumar et al., Basu et al., and Ashwin Raj et al., have documented prevalence estimates between 32% and 38%, reflecting clustering of cardiometabolic risk factors in clinical populations.[14-17]

The demographic characteristics of the present study showed that the majority of participants were middle-aged, with a mean age of 48.6 ± 11.2 years, and a modest male predominance (57.3%). This pattern aligns with previous Indian studies by Mohan et al., and Latha et al., that report higher metabolic risk among middle-aged individuals due to progressive accumulation of lifestyle-related risk factors such as sedentary behavior, unhealthy diet, and central obesity.[18,19] The observed high proportion of participants engaged in sedentary occupations (44.9%) further supports the influence of lifestyle factors on the development of metabolic abnormalities in urbanizing populations.[20]

With regard to metabolic parameters, the study population demonstrated a high burden of cardiometabolic risk factors, including central obesity (55.6%), elevated blood pressure (52.2%), elevated triglycerides (48.9%), and reduced HDL cholesterol (47.2%). These findings are consistent with earlier Indian studies by Pandit et al., and Mahajan et al., reports indicating that abdominal obesity and hypertension are among the most prevalent components of metabolic syndrome in South Asian populations.[21,22] South Asians are known to exhibit a greater propensity for visceral adiposity even at lower body mass indices, a phenomenon often referred to as the “Asian Indian phenotype,” which contributes to insulin resistance, dyslipidaemia, and increased cardiometabolic risk.[21,22]

A key finding of the present study was the significantly lower cognitive performance observed among participants with metabolic syndrome compared with those without metabolic syndrome. The mean MMSE score in individuals with metabolic syndrome (24.6 ± 3.1) was significantly lower than that in individuals without metabolic syndrome (26.9 ± 2.4; $p < 0.001$). Furthermore, cognitive impairment was nearly three times more common among participants with metabolic syndrome (25.8%) compared with those without metabolic syndrome (9.5%). These findings are consistent with several international studies by Koutsonida et al., and

Bahchevanov et al., that have demonstrated an association between metabolic syndrome and cognitive decline.[23,24] A large population-based study by Yaffe et al., reported that individuals with metabolic syndrome had a significantly increased risk of developing cognitive impairment during follow-up.[25] Similarly, a review by Panza et al., concluded that metabolic syndrome and its individual components are associated with an increased risk of mild cognitive impairment and dementia.[26]

The association between metabolic syndrome and cognitive impairment can be explained by several biological mechanisms.[8] Insulin resistance, which is central to the pathophysiology of metabolic syndrome, has been shown to impair neuronal glucose metabolism and synaptic plasticity in the brain.[9] Impaired insulin signaling may disrupt neurotransmitter regulation and contribute to neurodegenerative processes.[9] Additionally, chronic low-grade inflammation associated with metabolic syndrome leads to increased production of pro-inflammatory cytokines and oxidative stress, which can damage neuronal structures and accelerate cognitive decline.[8,9]

Another important observation in the present study was the significant association between individual components of metabolic syndrome and cognitive impairment. Among participants with cognitive impairment, elevated blood pressure (74.1%) and elevated fasting glucose (66.7%) showed the strongest associations with impaired cognition ($p < 0.001$ for both). These findings are supported by previous studies by Jamalnia et al., and Wu et al., that highlight the adverse effects of hypertension and hyperglycemia on brain health.[27,28] Chronic hypertension can cause structural and functional changes in cerebral blood vessels, leading to reduced cerebral perfusion, microvascular damage, and white matter lesions.[27] These vascular changes are strongly associated with cognitive decline and vascular dementia.[27] Similarly, chronic hyperglycemia contributes to advanced glycation end products, oxidative stress, and endothelial dysfunction, which may impair neuronal function and accelerate neurodegenerative processes.[28]

The correlation analysis in the present study further demonstrated significant relationships between metabolic parameters and cognitive scores. The MMSE score showed negative correlations with waist circumference ($r = -0.28$), fasting glucose ($r = -0.31$), triglycerides ($r = -0.22$), and systolic blood pressure ($r = -0.26$), while HDL cholesterol demonstrated a positive correlation with cognitive performance ($r = 0.19$). These findings suggest that worsening metabolic profiles are associated with progressively lower cognitive function.[27,28] Similar correlations have been reported in earlier studies by Liu et al., and Hughes et al., where central obesity and dyslipidaemia were associated with reduced cognitive performance through mechanisms involving vascular dysfunction, impaired cerebral metabolism, and chronic inflammation.[29,30]

Limitations: This study has certain limitations. Being a cross-sectional study, causal relationships between metabolic syndrome and cognitive impairment cannot be established. The study was conducted in a single tertiary care center, which may limit the generalizability of the findings to the broader community population. Cognitive assessment was performed using the Mini-Mental State Examination, which is a screening tool and may not detect subtle domain-specific cognitive deficits.

CONCLUSION

The present study demonstrated a significant association between metabolic syndrome and cognitive impairment among adults attending a tertiary care center. Participants with metabolic syndrome exhibited significantly lower cognitive scores and a higher prevalence of cognitive impairment compared with those without metabolic syndrome. Individual components of metabolic syndrome, particularly hypertension and elevated fasting glucose, showed strong associations with impaired cognitive function. Furthermore, worsening metabolic parameters such as increased waist circumference, elevated triglycerides, and higher blood pressure were negatively correlated with cognitive performance. These findings highlight the importance of early detection and effective management of metabolic risk factors. Integrating cognitive screening into routine clinical evaluation of patients with metabolic syndrome may facilitate early identification and prevention of progressive cognitive decline.

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