ORIGINAL RESEARCH ARTICLE

Association between Metabolic Syndrome and Cognitive Function: A Cross-sectional Study among Adults Attending a Tertiary Care Center in Tamil Nadu

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Abstract

Background: Metabolic syndrome (MetS), a cluster of cardiovascular risk factors including central obesity, dyslipidemia, hypertension, and hyperglycemia, has been associated with various adverse health outcomes. Emerging evidence suggests a potential link between MetS and cognitive decline, though findings remain inconsistent.

Aim: To assess the association between MetS and cognitive function among adults attending a tertiary care center.

Materials and methods: A cross-sectional observational study was conducted from June to August 2023 at the noncommunicable disease (NCD) clinic of a tertiary care hospital in Tamil Nadu. A total of 200 participants aged above 45 years were recruited using consecutive sampling. MetS was diagnosed using the revised NCEP ATP III criteria. Cognitive function was assessed using the Tamil-translated Mini–Mental State Examination (MMSE), with thresholds adjusted for education. Data were analyzed using SPSS v26.0, and comparisons were made using independent *t*-tests.

Results: The mean age of participants was 55.21 years, with a slight male predominance (54.5 %). MetS was present in 78% of participants. The mean MMSE score was 22.55 ± 3.90 in those with MetS and 23.39 ± 4.18 in those without MetS, with no statistically significant difference ($p > 0.05$). No significant differences were found across MMSE subcomponents either.

Conclusion: This study did not find a statistically significant association between MetS and cognitive function using MMSE. However, given the complexity of this relationship, further research using sensitive cognitive assessments and longitudinal designs is recommended.

Keywords: Cognitive dysfunction, Cross-sectional studies, Metabolic syndrome, Mini–Mental State Examination, Risk factors, Tertiary care centers.

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Introduction

Metabolic syndrome (MetS) is an increasingly prevalent disorder characterized by a group of cardiovascular risk factors, including central obesity, elevated arterial pressure, hyperglycemia, hypertriglyceridemia, and reduced levels of high-density lipoprotein cholesterol. First conceptualized as "Syndrome X" by Reaven in 1988, MetS has since been recognized by multiple international health organizations, including the World Health Organization (WHO), the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III), and the International Diabetes Federation (IDF), each proposing diagnostic criteria centered around obesity, insulin resistance, hypertension, and dyslipidemia.[1,2]

Metabolic syndrome has detrimental effects on cardiovascular health, which are well established by several studies. Recent research throws light on the systemic effects of this MetS, especially on cognitive functioning. Research suggests that MetS may lead to decreased cognitive function in various domains, including memory, executive function, attention, and processing speed. The cumulative effect of the components of MetS may exert a synergistic effect, increasing the risk of mild cognitive impairment, vascular dementia, and even Alzheimer's disease.[3] However, the findings remain inconsistent, with variability depending on study design, cognitive assessment tools, population characteristics, and duration of follow-up.

Most cognitive studies to date have utilized binary MetS diagnostic criteria, without accounting for the severity or continuum of the metabolic derangements. To address this limitation, newer scoring systems such as the Metabolic Syndrome Severity Score (MSSS) have been introduced, offering a continuous measure of metabolic burden and potential prognostic utility. Although MSSS has been linked to cardiovascular outcomes and type 2 diabetes, its application in cognitive research remains limited.

Given the global rise in both metabolic disorders and neurodegenerative conditions, understanding the relationship between MetS and cognitive function has become a pressing public health priority. Clarifying this association could pave the way for early identification of at-risk individuals and targeted interventions to mitigate cognitive decline.

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Materials and Methods

This study was conducted as a cross-sectional observational study over a period of 3 months, from June to August 2023, in the noncommunicable disease (NCD) clinic of a tertiary care center in Tamil Nadu. The study population comprised patients aged above 45 years, of both genders, who were attending the NCD outpatient clinic during the study period. A total of 200 participants were recruited using a consecutive sampling technique. All participants who met the inclusion criteria and gave informed consent were enrolled in the study.

Participants with a known history of psychiatric disorders, dementia, neurological diseases, or substance abuse, such as drug addiction or heavy alcohol use, were excluded to avoid confounding factors that could independently affect cognitive function. Prior to the commencement of data collection, institutional ethical clearance was obtained, and informed consent was taken from all participants. The confidentiality and anonymity of the data collected were strictly maintained throughout the study.

Data were collected using a predesigned and pretested structured questionnaire that included sections on sociodemographic details, medical history, and lifestyle characteristics. A thorough clinical examination was carried out, which included measurement of height, weight, body mass index (BMI), waist circumference, and blood pressure (both systolic and diastolic) using standardized techniques. Anthropometric measurements were taken using calibrated instruments to ensure accuracy.

Biochemical parameters, including fasting blood sugar (FBS), serum triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C), were measured after an overnight fast using an automated biochemical analyzer in the hospital's central laboratory. MetS was diagnosed based on the revised National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria.[4]

Cognitive function was assessed using the Tamil-translated version of the Mini–Mental State Examination (MMSE), a widely used and validated cognitive screening tool. The MMSE consists of 30 items that evaluate various domains of cognition, including orientation, registration, attention and calculation, recall, language, and visuospatial skills, with a total possible score ranging from 0 to 30. Cognitive impairment was categorized based on educational status, as follows: an MMSE score of <17 for participants with no formal education, <22 for those with 1–6 years of schooling, and <26 for those with more than 6 years of education. All data were compiled and statistically analyzed using SPSS software version 26.0 for Windows. Quantitative variables, such as MMSE scores and metabolic parameters, were expressed as mean and standard deviation, while qualitative variables, like the presence of MetS, were presented as frequencies and percentages. To compare the means between participants with and without MetS, an independent samples t-test was used. A *p*-value of <0.05 was considered statistically significant.

Results

Among the 200 participants enrolled in the study, the mean age was 55.21 years. In terms of gender distribution, there were 109 males (54.5%) and 91 females (45.5%). With regard to educational status, 21 participants (10.5%) were illiterate, 47 (23.5%) had primary education, 86 (43%) had completed secondary education, and 46 (23%) had attained higher secondary education. Considering marital status, the majority of the participants, 196 (98%), were married, while only 4 (2%) were unmarried (Table 1).

The average height of the study participants was 164.5 ± 7.3 cm, the mean body weight was 70.1 ± 10.86 kg, and the mean body mass index (BMI) was 25.81 ± 3.38 kg/m^2. The average waist circumference recorded was 84.51 ± 7.42 cm (Fig. 1).

Based on the BMI classification, 8 participants (4%) were found to be underweight, while 43 participants (21.5%) had a normal BMI. A significant proportion, 88 participants (44%), were classified as overweight, and 61 participants (30.5%) fell into the obese category (Fig. 1). The mean heart rate of the participants was 78.65 ± 6.37 bpm. The average systolic blood pressure was recorded at 139.03 ± 24.43 mm Hg, and the mean diastolic blood pressure was 85.67 ± 7.94 mm Hg. The mean fasting blood sugar level was 113.04 ± 38.77 mg/dL. The mean triglyceride level was 142.99 ± 21.51 mg/dL. The average level of high-density lipoprotein cholesterol (HDL-C) was 42.62 ± 5.69 mg/dL.

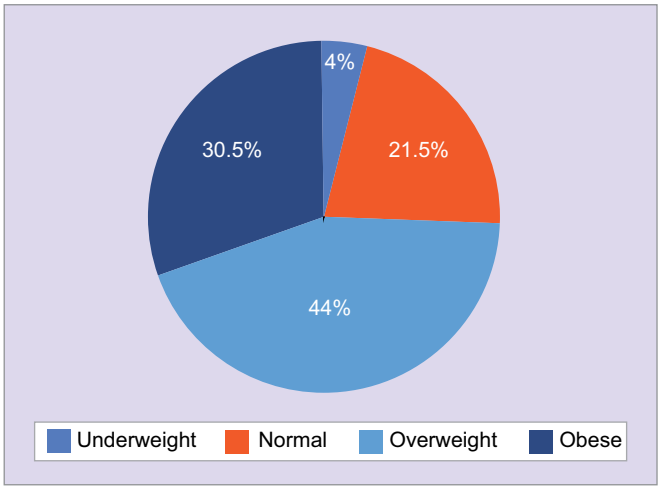

Fig. 1: Categorization of participants based on BMI

Table 1: Demographic profile of the study participants

Demographic profile of the participant		*Frequency (n = 200)*	*Percentage*
Mean age (in years)		55.21	6.99
Sex	Male	109	54.5
	Female	91	45.5
Education	Illiterate	21	10.5
	Primary	47	23.5
	Secondary	86	43
	Higher secondary	46	23
Marital status	Married	196	98
	Single	4	2

Table 2: Comparison of mean MMSE scores between participants with and without MetS

Group	*MMSE Mean ± SD*	*N*	*p-value (independent samples t-test)*
With MetS	22.55 ± 3.90	156	$p = 0.232$
Without MetS	23.39 ± 4.18.	44	

Table 3: Distribution of MMSE score by MetS status

MetS status	*Number of participants with MMSE <24*	*Number of participants with MMSE ≥24*	*Total participants*
With MetS	89	67	156
Without MetS	25	19	44

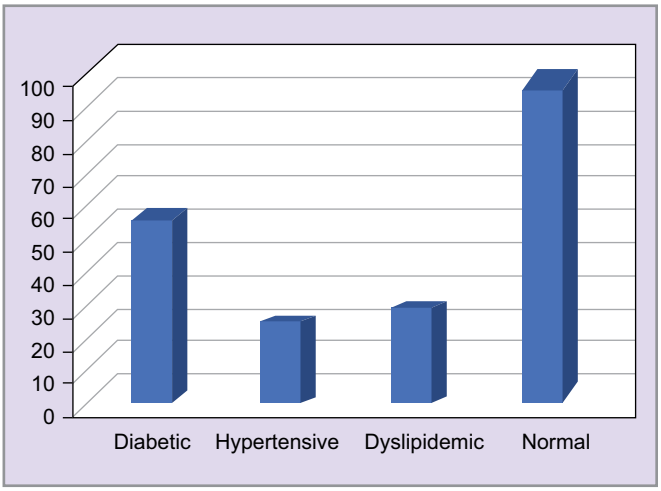

Fig. 2: Distribution of patients based on diagnosis

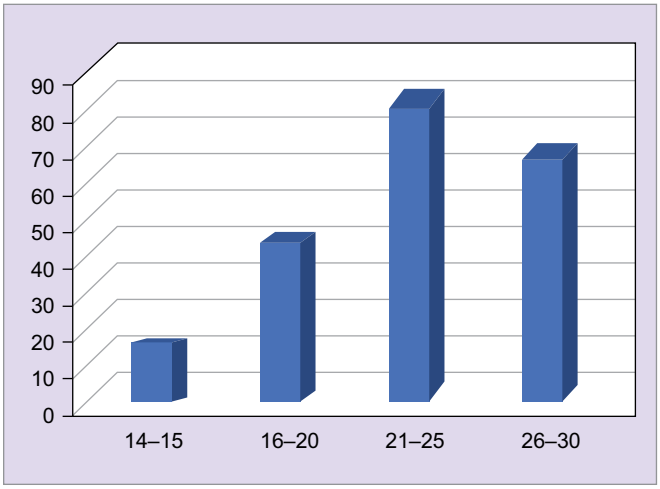

Fig. 3: Distribution of participants based on MMSE score

Out of the total 200 patients, 55 (27.5%) were diagnosed with diabetes, 22 (11%) were hypertensive, and 27 (13.5%) had dyslipidemia. A total of 96 patients (48%) were found to be normal, without any of the above conditions (Fig. 2). Based on the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria, 156 participants (78%) met the criteria for MetS (i.e., presence of 3 or more diagnostic criteria), while the remaining 44 participants (22%) did not.

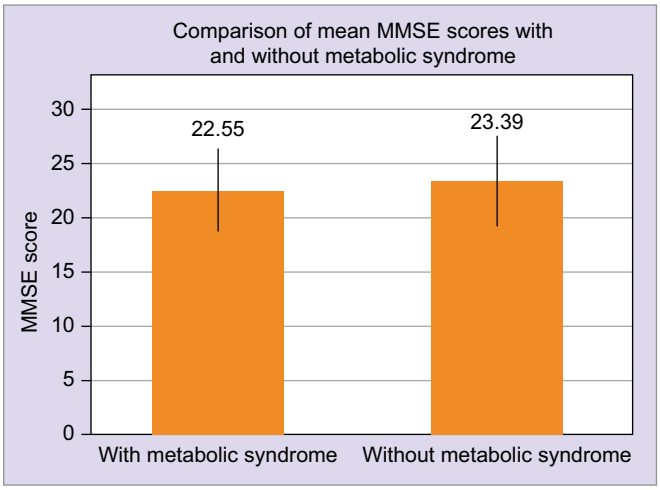

Fig. 4: Comparison of mean MMSE scores with and without MetS

Among the 200 study participants, 12 individuals (6%) had MMSE scores ranging from 14 to 15. A total of 40 participants (20%) scored between 16 and 20, while 81 participants (40.5%) had scores in the range of 21–25. The remaining 67 participants (33.5%) scored between 26 and 30 on the MMSE (Fig. 3). The mean MMSE score among those with MetS was 22.55 ± 3.90, and for those without MetS was 23.39 ± 4.18 (Fig. 4 and Table 2). There was no significant difference in mean MMSE scores between participants with and without MetS ($p > 0.05$). The odds of having a low MMSE score (<24) were similar between participants with and without MetS, indicating no significant association between MetS and cognitive impairment in this sample (Table 3). Further comparison of MMSE subcomponents, including orientation, registration, attention and calculation, recall, and language, also revealed no statistically significant differences between participants with and without MetS.

Discussion

The present study aimed to assess the association between MetS and cognitive function, as measured by the MMSE, among 200 participants. Barik et al. found MetS in 10.7% of males and 20.3% of females, linked to age, obesity, and low physical activity in women.[5] In contrast, the current study showed a much higher overall prevalence (78%) with no noted gender difference. Both studies confirm age and high body mass index (BMI) as key risk factors. The average height and body weight of the participants suggest a relatively average body composition, though the mean BMI of 25.81 kg/m^2 places the majority of participants in the overweight (44%) and obese (30.5%)

categories. These figures highlight a concerning trend of overweight and obesity in the study population. The mean MMSE score among individuals with MetS was 22.55 ± 3.90, while it was slightly higher among those without MetS (23.39 ± 4.18). However, this difference was not statistically significant ($p > 0.05$), and no significant variations were observed in any of the MMSE subcomponents. These findings suggest that in this population, MetS did not significantly impact global cognitive functioning as assessed by MMSE.

Our findings are in contrast to several large-scale studies and reviews that have reported a significant association between MetS and cognitive decline. For instance, Zuo et al. conducted a prospective study among 3,63,231 participants and found that MetS was significantly associated with poorer performance in cognitive domains such as fluid intelligence and prospective memory.[6] Furthermore, in individuals aged ≥60 years, MetS was linked with increased risk for all-cause dementia and particularly vascular dementia, with a clear dose–response relationship based on the number of MetS components. Their study also highlighted structural brain changes associated with MetS, such as reduced brain volumes and altered white and gray matter integrity.

Similarly, Yates et al. reviewed literature and concluded that MetS adversely affects multiple cognitive domains in adults, with brain imaging studies implicating ischemic changes and structural alterations in areas such as the hippocampus and frontal lobes. They proposed several underlying mechanisms, including neuroinflammation, oxidative stress, and insulin resistance-induced cerebrovascular dysfunction.[7]

Despite these associations observed in other studies, our findings align more closely with those of Assunção et al., who reported heterogeneity in the relationship between MetS and cognitive impairment across 25 reviewed studies. Their analysis pointed out that while hyperglycemia was consistently linked with cognitive deficits, the role of MetS as a whole was inconclusive due to variations in study design, age of populations, and diagnostic criteria used.[8]

Moreover, Koutsonida et al., in their systematic review of 30 longitudinal studies, found that the majority did not show a significant link between MetS and decline in specific cognitive domains.[9] This heterogeneity was attributed to differences in cognitive tests, MetS definitions, and study populations. They emphasized the need for standardized methodologies in future research.

The study by Oh et al. found that participants with MetS scored significantly lower in specific cognitive tests (e.g., verbal fluency, word list learning) based on the CERAD-K, even after adjusting for confounding variables.[10] This suggests that while global measures such as MMSE may not capture subtle cognitive impairments, more detailed neuropsychological tests might reveal domain-specific deficits associated with MetS.

Tahmi et al. also noted that while cross-sectional studies generally found associations between MetS and lower cognitive function, longitudinal findings were less consistent.[11] They highlighted that the association varies by age, sex, genetic factors, and individual MetS components, with hypertension, abdominal obesity, and hyperglycemia being the most predictive of cognitive decline.

A key limitation of this study is the use of the MMSE as the sole measure of cognitive function. While widely used, the MMSE may lack the sensitivity to detect subtle or domain-specific cognitive impairments, potentially underestimating the cognitive impact of MetS. Moreover, unmeasured confounding factors such as genetic predisposition, dietary patterns, and psychosocial influences may have contributed to the lack of a significant association observed in this study.[12]

Conclusion

While the present study did not demonstrate a statistically significant association between MetS and cognitive decline as measured by MMSE, the findings do not negate the potential impact of MetS on brain health. Literature suggests a complex relationship, with several studies highlighting specific cognitive domains and brain structures affected by MetS. It can be noted that the use of a more comprehensive and sensitive neuropsychological test battery may yield more accurate insights into subtle cognitive impairments associated with MetS. Future studies should consider employing more sensitive cognitive testing tools, longitudinal designs, and account for individual MetS components and confounding variables with a larger sample size to better elucidate this relationship.

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