

IMPACT OF CENTRAL OBESITY ON COGNITIVE FUNCTIONS IN UNDERGRADUATE MEDICAL STUDENTS: A CROSS-SECTIONAL STUDY

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Received: 24 October 2025, Revised and Accepted: 29 December 2025

ABSTRACT

Objectives: Obesity, particularly central obesity, has been increasingly recognized as a risk factor for impaired cognitive function due to its association with metabolic and neuroinflammatory changes. Among medical students, whose academic and clinical performance relies heavily on executive function, such associations are of particular concern. To examine the relationship between central obesity, assessed by waist-hip ratio (WHR), and cognitive performance in undergraduate medical students using standardized cognitive function tests (CFTs).

Methods: A cross-sectional study was conducted among undergraduate medical students (n=112). Anthropometric indices, including body mass index (BMI), waist circumference (WC), and WHR, were measured. Cognitive function was assessed using standardized tests: Stroop Word (WR), Stroop Color-Word (CW), Stroop Effect, Trail Making Test A and B (TMT-A, TMT-B), and the Grid Concentration Test (GCT). Associations between obesity indices and CFT performance were analyzed using correlation and group comparisons.

Results: The prevalence of central adiposity (elevated WHR) was 39.28%, with a higher prevalence among females (40.48%). Students with higher WHR required significantly longer times to complete Stroop WR, CW, and Stroop Effect tasks ($p < 0.05$), indicating impaired inhibitory control and reduced cognitive flexibility. Moderate positive correlations were observed between WHR and Stroop outcomes, particularly CW and Stroop Effect, while BMI and WC showed minimal associations. TMT-A, TMT-B, and GCT performances were not significantly related to any adiposity indices.

Conclusion: Central obesity, as measured by WHR, is associated with subtle but meaningful impairments in executive function, especially inhibitory control, among healthy individuals too. These findings underscore the value of WHR as a sensitive marker of obesity-related cognitive risk and highlight the need for early lifestyle interventions to safeguard cognitive health and academic performance in future healthcare professionals.

Keywords: Central Obesity, Cognitive functions, Young adults, Executive functions, Waist-hip ratio.

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INTRODUCTION

Overweight and obesity are major global public health concerns, affecting approximately 39% and 13% of adults worldwide, respectively [1]. Although largely preventable, obesity is increasingly reported among medical students. Medical students, expected to serve as role models for healthy lifestyles, show prevalence rates of about 18% for overweight and 9% for obesity [2]. Indian studies report comparable figures, ranging from 15% to 30% [3,4]. Such trends are often attributed to prolonged study hours, academic stress, and limited time for physical activity and self-care [2].

The World Health Organization defines overweight and obesity as "abnormal or excessive fat accumulation" that may impair health [5]. These conditions are broadly categorized into generalized and central obesity. Generalized obesity is usually assessed using body mass index (BMI), while central obesity is measured by waist-to-hip ratio (WHR) [6]. Unlike BMI, WHR reflects fat distribution and better captures central adiposity. Central obesity, defined as excess fat accumulation around the abdomen relative to the hips and limbs, is strongly linked to metabolic syndrome, Type 2 diabetes mellitus, hypertension, and cardiovascular disease, even in individuals with a normal BMI [7]. It has also been increasingly implicated in cognitive decline and dementia risk [6].

Medical education demands high-level cognitive functioning to support advanced problem-solving and critical decision-making. Cognitive

function, including memory, attention, executive ability, and processing speed, is vital for medical students who must integrate and apply complex information in demanding clinical settings [8,9]. Even minor reductions in mental acuity can adversely affect academic performance, clinical judgment, and patient care, and may increase the risk of medical errors. Although the link between obesity and cognitive dysfunction has been studied in chronic illness, evidence in healthy young adults remains limited. A meta-analysis reported that high BMI in midlife increases dementia risk, whereas in late life it may confer some protection [10]. Importantly, individuals with a normal BMI may still exhibit central obesity, a distinct metabolic profile that may differentially affect cognition [11,12]. Fujimoto *et al.* noted that WHR may be a stronger predictor of disease risk than BMI, particularly in Asian populations where body composition and fat distribution differ from Western counterparts [8].

Despite the growing prevalence of central obesity among Indian medical students, its potential impact on cognitive outcomes has not been systematically studied. Therefore, the present study was undertaken to evaluate the impact of central obesity on cognitive performance and to examine its cross-sectional association with cognitive function in this population.

METHODS

Ethical approval

Approval was obtained from the Institutional Ethics Committee (IEC/MAMS/2025/171). Written informed consent was obtained from all

participants after briefing them about the study's purpose, procedures, and implications.

Study design and setting

This was a single-center, cross-sectional observational study conducted among Phase I medical students at a tertiary care teaching hospital between August and September 2025. The research was conducted following Strengthening the Reporting of Observational studies in Epidemiology guidelines.

Sample size

The sample size was calculated using Cochran's formula, considering a 95% confidence interval, 5% standard error, and an expected prevalence of obesity among medical undergraduates of 10% [3,4]. After accounting for a 20% non-response rate, the final sample size was set at 120.

Participants

A total of 120 apparently healthy medical students who volunteered were randomly selected. Exclusion criteria: Students with a history of hypothyroidism, epilepsy, psychiatric illness, developmental or neurological disorders, major weight change in the last 6 months, head injury, or recent wrist/finger injuries were excluded from the study.

Data collection

Each participant underwent anthropometric measurements and cognitive function testing (CFT). Based on WHR, participants were grouped into two groups as Non-obese: $WHR \leq 0.85$ and those having Central obesity: $WHR > 0.85$ [13].

Variables

- Anthropometric measurements: Height (m), weight (kg), and waist/hip circumferences (cm) were recorded following CDC Anthropometry Procedures Manual (2009) [14]. Waist circumference was measured at the midpoint between the lowest palpable rib and iliac crest, and hip circumference at the widest portion of the buttocks. BMI was calculated as $\text{weight (kg)}/\text{height}^2 (\text{m}^2)$, and WHR as waist/hip circumference [13].
- CFT: Cognitive domains assessed included processing speed, sustained attention, and executive function. A standardized battery of tests was administered:
 - Stroop color and word test: The Classic Stroop Test, originally described by Stroop (1935), was administered to evaluate selective attention, cognitive inhibition, and processing speed. The task consisted of two standardized conditions – Word Reading (WR) and Color-Word Interference (CWI) – each presented on a separate page. Each page contained 100 items arranged in a 10×10 matrix, consisting of 10 rows and 10 columns. Conditions were administered in the standard sequence (WR → colour naming (CN) → CWI). A brief practice trial preceded each condition. Any errors made in either the WR condition (congruent) or color word interference (incongruent) condition, the examiner stopped the participant and asked the participant to start from the last correct word. The examiner recorded the time taken to complete the task.
- WR condition: The WR page contained 100 color words ("RED," "BLUE," "GREEN," and "YELLOW") printed in black ink. These were arranged in 10 rows and 10 columns. Participants were instructed to read the words aloud rapidly and accurately. The time of execution and errors were recorded.
- CWI condition: The Interference page included 100 color words printed in incongruent ink colors (e.g., the word "BLUE" printed in red ink), arranged in the same 10×10 grid. Participants were instructed to name the ink color, suppressing the automatic tendency to read the word. The total time to complete the task and errors were documented. [15,16]
 - Trail making test (TMT-A and TMT-B): TMT is a widely used neuropsychological assessment tool for evaluating processing speed, visual attention, cognitive flexibility, and executive

functioning. The test consists of two parts: TMT-A and TMT-B, administered using standardized instructions.

- TMT-A (Trail making test part A): TMT-A assesses visual scanning, psychomotor speed, and attention. The test sheet contains 25 circled numbers (1–25) distributed randomly across the page. Participants are instructed to connect the numbers in ascending order as quickly and accurately as possible without lifting the pencil from the paper. If any mistakes were made, the examiner pointed it out and allowed the participant to correct it, while still the timing was noted.
- TMT-B (Trail making test part B): TMT-B measures cognitive flexibility, task switching, divided attention, and set-shifting ability. The sheet includes 25 numbers (1–13) and 12 letters (A–L) arranged randomly. Participants are instructed to alternate sequentially between numbers and letters (1 → A → 2 → B → 3 → C ... → 13 → L). When an error was made, the participant was instructed to return to the last correct circle and continue. Time to complete the task was recorded by the examiner [17].
 - Grid concentration test (GCT): The GCT is a paper-and-pencil measure of sustained attention, visual scanning, concentration, and processing speed. The test consists of a grid containing randomly distributed numbers that the participant must locate and mark in ascending order under time pressure. The standard grid consists of 100 numbers (1–100) arranged in a 10×10 matrix (10 rows and 10 columns). Numbers are placed in non-sequential, random order. Each number appears exactly once. The participants were instructed to identify and mark the numbers in ascending order as quickly and accurately as possible within one minute. The time taken to complete the task and any errors are recorded for analysis. Scoring is based on the largest number correctly identified in sequence within the time limit [18].

All tests were preceded by a pilot run to ensure clarity of instructions. Testing was scheduled during a week without academic assessments to minimize stress-related confounders.

Statistical analysis

Data were compiled and analyzed using descriptive and inferential statistics. Qualitative data were expressed as frequencies and percentages, while quantitative data were presented as mean±standard deviation. Mean task completion times were compared between groups (with and without central obesity) using Student's unpaired t-test. Correlation analysis assessed the relationship between central obesity and cognitive performance. A $p < 0.05$ was considered statistically significant.

RESULTS

A total of 120 students were recruited for the study, out of which 2 were excluded, and 6 declined participations thus 112 participants formed the final study cohort. Out of 112 participants, 68 were non-obese ($WHR \leq 0.85$) while 44 suffered from central obesity ($WHR > 0.85$). The mean age of the participants was 18.95 ± 0.98 years, with a male-to-female ratio of 1:3.

Table 1: Baseline anthropometric characteristics of study participants

Variable	WHR ≤ 0.85 (n=68)	WHR > 0.85 (n=44)	p-value	Cohen's d
Height (cm)	163.61±9.51	164.19±7.36	0.14	0.06
Weight (kg)	64.67±13.48	70.32±19.19	0.007*	0.34
BMI	24.87±4.73	26.03±5.86	<0.001**	0.21
WC (cm)	40.93±17.58	54.95±28.07	0.006*	0.60
HC (cm)	51.76±22.22	60.48±32.55	0.15	0.32
WHR	0.65±0.24	0.93±0.11	<0.001**	1.32

Values are mean±standard deviation. WC: Waist circumference, HC: Hip circumference, BMI: Body mass index, WHR: Waist-to-hip ratio. * $p < 0.05$, ** $p < 0.01$, Cohen's d shows effect size: 0.2=Small, 0.5=Medium, ≥ 0.8 =Large, Positive d indicates higher mean in WHR > 0.85 group

Table 2: Comparison of cognitive test scores between WHR groups

CFTs	WHR ≤0.85 (n=68)	WHR >0.85 (n=44)	t-statistic	p-value	Cohen's d
TMT-A (sec)	29.10±7.27	31.70±7.34	-1.36	0.177	0.36
TMT-B (sec)	66.82±15.51	70.57±24.98	-0.64	0.526	0.17
SWR (sec)	16.84±2.61	17.27±2.42	-4.31	<0.001**	0.17
SCW (sec)	45.0±9.80	70.29±13.73	-2.97	0.004*	0.83
Stroop effect (CW-WR) (sec)	27.74±9.27	49.76±13.96	-9.05	<0.001**	1.85
GCT (sec)	14.18±4.16	14.95±3.98	-0.98	0.332	0.19

Values are mean±standard deviation. CFT: Cognitive function testing, TMT: Trail making test, SWR: Stroop word reading, SCW: Stroop color-word, GCT: Grid concentration test. *p<0.05, **p<0.01, Cohen's d interpretation: 0.2=small, 0.5=medium, ≥0.8=large, Positive d indicates higher mean in WHR >0.85 group

Participants with WHR >0.85 had significantly higher body weight, BMI, waist circumference, and WHR compared to those with WHR ≤ 0.85 (p<0.05 for all; Cohen's d=0.21–1.32). Height and hip circumference did not differ significantly between groups (p=0.14 and 0.15, respectively), with small effect sizes as depicted in Table 1.

Participants with WHR > 0.85 performed worse on Stroop WR (SWR), Stroop Color-Word (SCW), and Stroop Effect tests compared to those with WHR ≤ 0.85 (p<0.05; Cohen's d 0.17–1.85). No significant differences were observed in TMT-A, TMT-B, or GCT scores. Effect sizes indicate that the largest differences were observed for Stroop Effect (Cohen's d=1.85) and SCW (Cohen's d=0.83) as depicted in Table 2.

Correlation analysis demonstrated that WHR had stronger associations with CFT outcomes than BMI or waist circumference. Notably, WHR correlated significantly with SCW (r=0.39, p<0.05) and Stroop Effect (r=0.36, p<0.05).

Participants' WHR was significantly associated with SWR, SCW, and Stroop Effect scores after adjusting for age and gender (p<0.05 for all). No significant associations were observed for TMT-A, TMT-B, or GCT scores. Among covariates, age was significantly associated only with GCT (p=0.010), and gender was significantly associated only with SWR (p=0.026). Effect sizes (R²) indicate that the strongest association of WHR was with SCW (R²=0.180), followed by SWR (R²=0.171) and Stroop Effect (R²=0.142) as depicted in Table 4.

DISCUSSION

This study examined the relationship between central obesity and cognitive function among undergraduate medical students using standardized CFTs. The findings are particularly relevant given the increasing prevalence of obesity among medical students and the growing evidence linking obesity with cognitive deficits [19].

The principal findings revealed that the prevalence of central adiposity, as indicated by elevated WHR, was 39.28%, with a higher proportion among females (40.48%). These results are consistent with previous studies on Indian medical students [4]. Individuals with higher WHR required significantly more time to complete cognitive tasks compared to those with lower WHR, as shown in Table 2. Notably, all components of the Stroop test (WR, CW, and Stroop Effect) showed statistically significant differences, suggesting impaired inhibitory control and reduced cognitive flexibility in students with higher central fat distribution. This was further supported by moderate positive correlations between WHR and Stroop outcomes (particularly CW and Stroop Effect), with weaker yet notable correlations observed for SWR. These findings indicate that even basic attentional processes and processing speed may be subtly affected. In contrast, performance on TMT-A, TMT-B, and the GCT demonstrated minimal associations with central obesity indices (WHR, WC, or BMI).

The Stroop test is a sensitive measure of executive function, particularly inhibitory control and cognitive flexibility, skills critical for maintaining focus and filtering distractions, both essential for academic and clinical performance. The observed deficits are consistent with earlier studies. Segura *et al.* reported reduced executive functioning and processing

Table 3: Pearson's correlation between anthropometric measures with CFT scores

CFTs	WHR (r)	WC (cm)	BMI (r)
TMT-A	0.06	0.02	0.10
TMT-B	0.01	0.33	0.10
SWR	0.29	0.28	0.00
SCW	0.39*	0.04	0.14
Stroop Effect	0.36*	0.01	0.15
GCT	0.08	0.29	0.08

r=Pearson's correlation coefficient. CFT: Cognitive function testing, WC: Waist circumference, BMI: Body mass index, WHR: Waist-to-hip ratio, TMT: Trail making test, SWR: Stroop word reading, SCW: Stroop color-word, GCT: Grid concentration test. *Significant at p<0.05

speed in obese individuals, while Van den Berg *et al.* observed similar impairments in middle-aged obese adults [20,21]. Fabea *et al.* highlighted reduced processing speed in young obese adults, and Umayal *et al.* documented declines in attention and delayed recall in young obese males [22,23]. Song *et al.* found worse inhibitory control among obese adolescents, while Catoira *et al.* demonstrated poor inhibitory control in young obese females compared to normal-weight peers [24,25]. Similarly, Gameiro *et al.* reported consistently poorer executive function across domains in obese individuals [26].

Our results showed stronger correlations between WHR and executive function outcomes compared with BMI or WC, reinforcing WHR as a more accurate and sensitive marker of central adiposity and its cognitive effects. This finding aligns with prior evidence. Ameen *et al.* did not find any association between BMI and cognitive performance, highlighting BMI's limitations as an obesity marker [27]. Similarly Hartanto *et al.* demonstrated that WHR is a superior predictor of executive dysfunction compared to BMI [28]. Huang *et al.* further showed that visceral fat, but not BMI, was associated with impaired cognitive control in young adults [29], while Schwartz *et al.* reported similar associations in adolescent females [30]. Lin *et al.* also observed that abdominal obesity, defined by WHR, correlated with poorer cognitive performance in a large adult cohort, whereas BMI and HC did not [31].

The biological plausibility of these associations is supported by evidence linking visceral adiposity to neuroinflammation, insulin resistance, vascular dysfunction, and altered lipid metabolism, all known contributors to cognitive impairment. The prefrontal cortex, which governs inhibitory control, cognitive flexibility, and working memory, is particularly vulnerable to these metabolic insults. The Stroop test, being sensitive to prefrontal cortical activity, captures such impairments effectively [32]. Neurobiological studies further support this mechanism: obesity-induced inflammation, characterized by elevated proinflammatory cytokines and reduced protective factors such as adiponectin and brain-derived neurotrophic factor, negatively impacts synaptic plasticity and cortical structure [19]. Opel *et al.* demonstrated reduced temporofrontal cortical thickness in obese individuals, while Shekhtman *et al.* identified reduced hippocampal and frontal gyrus volumes associated with abdominal fat [33]. These structural and biochemical alterations may underlie the inhibitory control deficits observed in our cohort.

Table 4: Multiple linear regression models predicting cognitive function test scores from WHR, adjusted for age and gender

Cognitive test	Predictor	β (Estimate)	SE	t	p-value	R ²
TMT-A	WHR	2.034	2.903	0.701	0.485	0.034
	Age	0.125	0.734	0.170	0.865	
	Gender (M-F)	3.422	1.922	1.780	0.078	
TMT-B	WHR	-1.727	7.840	-0.220	0.826	0.008
	Age	-1.806	1.980	-0.911	0.364	
	Gender (M-F)	-0.241	5.190	-0.047	0.963	
SWR	WHR	-3.346	0.926	-3.610	<0.001*	0.171
	Age	-0.456	0.234	-1.950	0.054	
	Gender (M-F)	-1.384	0.613	-2.260	0.026*	
SCW	WHR	-21.489	4.720	-4.548	<0.001*	0.180
	Age	-0.860	1.200	-0.719	0.474	
	Gender (M-F)	-4.998	3.130	-1.598	0.113	
Stroop effect	WHR	-18.143	4.490	-4.040	<0.001*	0.142
	Age	-0.403	1.140	-0.355	0.723	
	Gender (M-F)	-3.614	2.970	-1.215	0.227	
GCT	WHR	0.828	1.568	0.528	0.598	0.083
	Age	-1.043	0.397	-2.629	0.010*	
	Gender (M-F)	-1.011	1.039	-0.974	0.332	

Values are regression coefficients (β)±standard error. WHR: Waist-to-hip ratio, TMT: Trail making test, SWR: Stroop word reading, SCW: Stroop color-word, GCT: Grid concentration test. R² represents the proportion of variance explained by the model. *p<0.05

Interestingly, TMT and GCT performance remained largely unaffected. This may be attributable to the young, high-functioning nature of the participants, whose cognitive reserve could buffer subtle deficits. Moreover, higher WHR has been associated with elevated proinflammatory cytokines like interleukin-6 and tumor necrosis factor-alpha associated with poorer performance on executive tasks, including Stroop test based on interference control, whereas TMT and GCT placing greater demands on visual search and psychomotor speed, were supposedly less affected in our cohort [34]. While studies by Prickett *et al.* [35] and Elias *et al.* [36] reported memory and decision-making impairments in obese individuals, differences in test sensitivity and sample characteristics could likely to account for these variations.

Taken together, our findings suggest that central adiposity, even in the presence of normal BMI, may be associated with subtle but meaningful impairments in executive function among medical students. These results highlight the importance of incorporating WHR as a routine screening tool for obesity-related health risks and underscore the need for early lifestyle interventions targeting central obesity to preserve cognitive health and optimize academic and clinical performance in future healthcare professionals.

Future implications

Given that executive functioning is critical for medical education, even subtle deficits associated with central obesity may impact learning and clinical decision-making. These findings emphasize the importance of routine WHR measurement in young adults and the need for early lifestyle interventions targeting central adiposity to preserve cognitive health and academic performance.

Limitations

This study has certain limitations. Its cross-sectional design precludes causal inference. The single-center setting and relatively small sample limit generalizability. Participants were young medical students with high baseline cognitive reserve, which may have masked subtle deficits. Only a limited battery of CFTs was used. Although multiple linear regression was performed to adjust for age and gender, multiple comparisons across six cognitive tests and three obesity indices increase the risk of Type I error, which should be considered when interpreting the findings. In addition, potential confounders such as socioeconomic status, stress, sleep quality, and physical activity were not controlled. Finally, WHR, while practical, is a surrogate measure; advanced imaging could provide more accurate assessment of visceral adiposity.

CONCLUSION

Central obesity, as measured by WHR, was significantly associated with impaired executive function, particularly inhibitory control, among undergraduate medical students. These findings highlight the cognitive risks posed by abdominal fat accumulation, even in apparently healthy young individuals. WHR may serve as a sensitive biomarker for screening obesity-related cognitive effects and underscores the need for preventive strategies targeting central adiposity in medical student populations.

ACKNOWLEDGMENT

We extend our heartfelt thanks to the undergraduate medical students who volunteered to participate; without whose cooperation, this work would not have been possible. We are also grateful to the institutional authorities for providing the necessary facilities to carry out this research.

AUTHOR'S CONTRIBUTION

The first author was involved in conceptualization, data collection, and drafting the initial manuscript. The second and the third authors are involved in the revisions of the manuscript along with the results analysis, and the forth author is involved in the drafting of the final manuscript and data analysis.

CONFLICTS OF INTEREST

Nil.

FUNDING

Nil.

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