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The Stroop Test as a Tool for Assessing Cognitive Dysfunction in Patients with Metabolic Syndrome

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ABSTRACT

Objective: The aim of the study was to evaluate cognitive functions in patients with metabolic syndrome with clinical and metabolic indicators using the Stroop test.

Introduction: Metabolic syndrome is a complex of disorders that includes abdominal obesity, insulin resistance, lipid metabolism disorders and hypertension. MetS negatively affects cognitive functions, including many types of executive functions, information processing speed and word production connections.

Methods: This study was conducted at the Clinical Diagnostic Center of the International Kazakh-Turkish University named after Khoja Ahmet Yasawi in the city of Turkestan. The study included a questionnaire, clinical laboratory tests, and cognitive function assessment. The Stroop test was used to assess cognitive functions. The data obtained during the study were statistically processed using a trial version of SPSS 25.0.

Results: The study involved 552 patients, 276 of whom were diagnosed with MetS and 552 without MetS. Women predominated in the study sample (76,8%, n=424), and the average age of the subjects was 53,07 years. The study included a higher proportion of individuals over 60 years of age (31.2%) and found statistically significant differences by age ($p < 0.001$) among those under 50 years of age. However, statistically significant differences were found by education level, alcohol consumption, and BMI ($p < 0.001$). All participants showed statistically significant differences between clinical and metabolic parameters with test results at $p < 0.001$. The median total score at T1 was statistically significantly lower in patients with metabolic syndrome ($p = 0.002$). T2, T3, and B1 were also statistically significantly higher in the MetS group ($p < 0.001$). Quartile distribution revealed significant differences at T1 ($p = 0.006$), T2 ($p < 0.001$), and T3 ($p = 0.012$). The results of the Stroop quartile distribution showed statistical significance at all three stages with triglyceride levels T1 $p = 0.007$, T2 $p < 0.001$, T3 $p = 0.005$ and with blood pressure indicators at T2 $p = 0.001$, T3 $p = 0.004$ and at B1 $p = 0.037$, 0.033.

Conclusions: As a result, patients with metabolic syndrome exhibit signs of cognitive decline, primarily in attention and executive control, while information processing efficiency remains relatively intact. The study's results demonstrate that cognitive assessment enables the early identification and intervention of modifiable risk factors for cognitive decline. Our findings highlight the need for screening and prevention of cognitive impairment in individuals with metabolic syndrome.

Keywords: cognitive impairment, cognitive control, metabolic syndrome, Stroop test, neuropsychological assessment.

Introduction

Metabolic syndrome (MetS) is one of the most complex medical and social problems of our time, characterized by insulin resistance, central obesity, atherogenic dyslipidemia, and hyperglycemia [1,2]. Epidemiological studies have shown that 20-30% of adults in many countries have MetS, increasing to 30.9% in Asian countries [3, 4]. MetS is a significant risk factor for an impairment in cognitive function and causes microstructural alterations of white matter in the brain. Cognitive impairments represent a serious social and psychological problem, as they reduce a person's social activity, productivity, and quality of life. The prevalence of cognitive impairment among older adults in Kazakhstan is approximately 30% [5]. According to data, MetS activates mediators that influence metabolic processes in the brain. These mediators can be activated by metabolic inflammation and microvascular disorders and impair cognitive function. The pathogenesis is based on insulin resistance, oxidative stress, and chronic inflammation [6]. It has been demonstrated in recent time that parts of MetS (dyslipidemia, hypertension, hyperglycemia and visceral obesity) can cause cognitive impairment [7].

Recent studies from Dintica C. indicate that vascular risk factors might contribute to lifestyle-related cognitive impairment as well as age-related cognitive decline [8]. The majority of studies demonstrate an interesting finding that different parts of MetS can impact on various areas of cognitive functioning. Elevated fasting glucose in adults is associated with impaired cognitive function, especially memory function, due to impaired neuronal energy metabolism, microvascular damage, and reduced cerebral blood flow [9]. The Stroop color and word test is one of the most widely used means to measure cognitive function. From a systematic review of the literature, Scarpin F. et al. demonstrated that the Stroop effect is a reliable and valid method for assessing cognitive control in a wide range of clinical and experimental studies [10]. In a research performed by Schuur M. et al., it was found that the Stroop test is a sensitive tool for assessing executive function impairment as a result of MetS and insulin resistance [11]. Since the influence of individual components of MetS on cognitive function assessed using the Stroop test has been insufficiently studied, the aim of this study is to examine and evaluate the relationship between clinical and metabolic factors and cognitive test results in adults with MetS. The scientific novelty of this study lies in its assessment of the relationship between Stroop test results and components of MetS in adults. This study provides a comprehensive analysis of the influence of clinical and metabolic factors on cognitive function, enabling the early identification of factors associated with cognitive decline in individuals.

Methods

The study was conducted at the Clinical Diagnostic Center of the International Kazakh-Turkish University named after Khoja Ahmet Yasawi in the city of Turkestan. During the research, data on the participants were collected in a patient examination form, which contained brief information about the study, a written voluntary informed consent form, passport and socio-demographic data. MetS was defined according to the criteria of International Diabetes Federation (IDF 2005): dyslipidemia (HbA1C ≥ 5.7%) or previously diagnosed type 2 diabetes, high blood pressure (systolic ≥ 130 mmHg and/or diastolic ≥ 85 mmHg), dyslipidemia defined as triglyceride level ≥ 1.7 mmol/L or low HDL level (< or = 1.03 mmol/L in men, less than or equal to 1.3 mmol/l in women) and abdominal obesity (waist circumference ≥ 102 cm in men, waist circumference ≥ 88 cm in women) [12]. Anthropometric measurements were performed: height (in meters), weight (in kilograms), waist circumference (in centimeters) on standardized calibrated scales, as well as blood pressure (systolic and diastolic) in mm Hg. Art. using a standard mercury tonometer. Waist circumference was measured using a retractable tape measure midway between the upper iliac crest and the lower edge of the rib cage at mid-exhalation. Laboratory tests included determination of fasting blood glucose, triglycerides and high-density lipoprotein in a venous blood sample taken overnight on an empty stomach. In the tables, the indicators are presented as categorical variables ("yes/no"), where the value "yes" indicated the presence of the corresponding pathological condition, including abdominal obesity, hypertriglyceridemia, decreased levels of high-density lipoproteins, hyperglycemia and arterial hypertension according to the criteria of the IDF and the value "no" reflected the absence of these disorders. Inclusion criteria: age ≥ 18 years, presence of MetS according to IDF criteria. Exclusion criteria: patients requiring urgent care, patients with chronic serious illnesses, patients with mental disorders, children under 18 years of age and pregnant women.

Assessment of cognitive functions

The classic Stroop test (standard color/word test) was used to assess cognitive status. The Stroop test or Stroop effect is named for the psychologist John Ridley Stroop, who first described this phenomenon in his doctoral thesis in the 1930s. The Stroop test is a method for measuring the inhibition of responses and is called both a diagnostic technique and a means of predicting cognitive rigidity and flexibility. It has the names of different colors printed on paper in various colors [13-15]. The color of printed text isn't the same as the color indicated by the words. The patient is presented with three pictures in sequence. Words are printed in black ink in the first picture. It is written as one hundred words, denoting the names of four basic colors. Normally, the basic colors used in the text are "red," "blue," "green" and "yellow." The patient must read the words quickly. In the second stage, you can see the multicolored stars of the same colors in an individual photograph. The patient is required to name the colors of the stars as quickly as possible. The third stage consists of one hundred names for colors that do not match the ink colors. For instance, the word "yellow" is spelled in red ink, and the word "green" is spelled in blue ink. The patient is required to accurately and rapidly name the colors of as many of the words he or she sees within a specific period (seconds). This exercise permits scrutiny of concentration, reaction time and cognitive flexibility. The test, the response time for the participant is recorded (seconds/minutes), and recorded in a special form (T1, T2, T3). The last scores are summed up as (B1 = T3 − T2, B2 = T2 / T1). The meaning of the Stroop test

Table 1 Grouping of Stroop test scores by quartiles

STROOP test	1- quartiles (Q1)	2- quartile (Q2)	3- quartile (Q3)	4- quartile (Q4)
T1, sec.	≤45	46-50	51-59	>60
T2, sec.	≤65	66-75	76-86	>87
T3, sec.	≤99	100-118	119-143	>144
B1	≤28,50	28,51-41	41,01-58	>58
B2	≤1,23	1,24-1,42	1,43-1,70	>1,70

parts: T1 – reading speed; T2 – attention and color naming; T3 – cognitive control, interference; B1 – interference index (T3–T2); B2 – information processing efficiency (T2/T1). The Stroop test results were divided into four quartiles (Q1–Q4) depending on the total score (task completion time) (Table 1).

Statistical analysis

IBM SPSS 25 software (IBM SPSS Inc., Chicago, Illinois) was used for statistical analysis. Statistical analysis of binary data was conducted in several stages. The McNemar test (analysis of 2×2 contingency tables) was used to assess the significance of changes in paired samples. Nominal comparative values were compared using the chi-square (χ^2) test. Mixed logistic regression was applied for a more in-depth analysis, taking into account the influence of additional factors and random effects. The normality of the distribution of quantitative variables was assessed using the Shapiro–Wilk test. Quantitative data are presented as means (M) and standard deviations (SD); variables with a nonparametric distribution were expressed as the median Me (Q1–Q3) (25th and 75th percentiles). The Mann–Whitney U test was used to compare indicators between two independent groups. Differences were considered statistically significant at a p-value <0.05.

Ethical Approval and Informed Consent

All participants were provided with detailed information about the objectives, methodology, potential risks, and expected benefits of the study. Before consenting, participants were informed in simple and understandable language so that they could understand their participation in the study. The purpose and methods of the study, the voluntary nature of participation in the study, the confidentiality of information obtained from the participant, and the potential risks and benefits of the study were explained. The study protocol was approved by the Institutional Research Ethics Committee of the International Turkish-Kazakh University named after Hodja Ahmet Yassawi (December 23, 2025, No. 49). All procedures and methods were conducted in accordance with the ethical principles of the Declaration of Helsinki.

Results

Table 2 presents the sociodemographic and clinical characteristics of the participants. All participants were divided into two groups based on the presence of MetS: the MetS group and the non-MetS group. The study revealed a higher proportion of women than men (76.8% vs. 23.2%). The mean age of the

Table 2 Socio-demographic and clinical characteristics of participants with and without MetS (n=552)

Parametres		Total n=522 (%)	With MetS n, %	Without MetS n, %	p-value
Gender	Men	128 (23,2)	63 (23%)	65 (24%)	
	Women	424 (76,8)	213 (77%)	211 (76%)	>0.9
Age	up to 40 years	83 (15)	66 (23.9%)	17 (6.2%)	
	40-49 years	134 (24,3)	81 (29.3%)	53 (19.2%)	
	50-59 years	163 (29,5)	71 (25.7%)	92 (33.3%)	<0.001
	60 years and older	172 (31,2)	58 (21.0%)	114 (41.3%)	
Education level	High	383 (69,4)	173 (63%)	210 (76%)	
	Low	169 (30,6)	103 (37%)	66 (24%)	<0.001
Job	Mental work	313 (56,7)	140 (51%)	173(63%)	
	Physical work	239 (43,3)	136 (49%)	103 (37%)	0,006
Marital Status	Married	493 (89,3)	243 (88%)	250 (91%)	
	Single	59 (10,7)	33 (12%)	26 (24%)	<0.001
Smoking	Yes	53 (9,6)	27 (9.8%)	26 (9.4%)	
	No	499 (90,4)			>0.9
Alcohol drinking	Yes	102 (18,5)	68 (25%)	34 (12%)	
	No	450 (81,5)			<0.001
Clinical characteristics					
Body mass index (BMI)	Normal weight	135 (24,5)	23 (8,3%)	112 (41%)	
	Overweight	185 (33,5)	87 (32%)	98 (36%)	<0.001
	Obesity (I, II, III degrees)	232 (42)	166 (60%)	66 (24%)	
Waist circumference, cm (WC)	Yes	435 (78,8)	263(95%)	172 (62%)	
	No	117 (21,2)			<0.001
Triglycerides, mmol/L (TG)	Yes	231 (41,8)	190 (69%)	41 (15%)	
	No	321 (58,2)			<0.001
HDL, mmol/L	Yes	290 (52,5)	212 (77%)	78 (28%)	<0.001
	No	262 (47,5)			
Glucose, mmol/L	Yes	182 (33)	152 (55%)	30 (11%)	<0.001
	No	370 (67)			
High blood pressure, mmHg (HBP)	Yes	307 (55,6)	224 (81%)	83 (30%)	<0.001
	No	245 (44,4)			
Systolic blood pressure (SBP)	Yes	222 (40,2)	167 (61%)	55 (20%)	<0.001
	No	330 (59,8)			
Diastolic blood pressure (DBP)	Yes	193 (35)	147 (53%)	46 (17%)	<0.001
	No	359 (65)			

sample was 53.07 years. No differences in gender distribution were observed between the MetS and non-MetS groups ($p > 0.9$). A higher proportion of individuals over 60 years of age participated in the study (31.2%), and statistically significant differences in age were identified ($p < 0.001$). An increase in the proportion of patients with MetS was also observed among people younger than 50 years of age (23.9% vs. 6.2% and 29.3% vs. 19.2%). This may reflect a trend toward earlier onset of the disease. At the same time, statistically significant differences in educational level were identified ($p < 0.001$). Among participants with MetS, individuals with a lower level of education were more common (37% vs. 24%). Occupations also differed, among people with MetS, those engaged in mental work were more common. Conversely, physical laborers were more common among people with MetS (49% vs. 37%; $p = 0.006$). The prevalence of smoking and alcohol consumption was very low. Similarly, there were no statistically significant differences ($p > 0.9$) regarding smoking. Alcohol consumption was significantly more common among participants with MetS (25% vs. 12%; $p < 0.001$). BMI values differed significantly between the groups ($p < 0.001$).

Participants with MetS were significantly more likely to be obese (60% vs. 24%), while a normal BMI was more common among participants without MetS (41% vs. 8.3%). Participants with MetS were significantly more likely to have: abdominal obesity (95% vs. 62%; $p < 0.001$), hypertriglyceridemia (69% vs. 15%; $p < 0.001$), hyperglycemia (55% vs. 11%; $p < 0.001$) and low HDL levels (77% vs. 28%; $p < 0.001$), HBP (81% vs. 30%; $p < 0.001$), SBP (61% vs. 20%; $p < 0.001$) and DBP (53% vs. 217%; $p < 0.001$). Statistically significant differences were observed in all participants.

Table 3 Distribution of Stroop test scores between participants with and without MetS

Indicators	Me (Q1–Q3)	MetS/ no	MetS / yes	p-value[2]
	n = 552[1]	n = 276[1]	n = 276[1]	
STROOP T1	52.00 (43.00–66.25)	10.0 (8.0–12.0)	10.0 (7.5–11.0)	0.002
STROOP T2	83.00 (67.00–102.00)	50 (41–60)	56 (45–70)	<0.001
STROOP T3	125.00 (101.00–154.00)	78 (65–99)	87 (70–111)	<0.001
STROOP B1	40.41 (29.99–55.00)	120 (97–146)	132 (108–159)	<0.001
STROOP B2	1.60 (1.30–1.80)	1.55 (1.30–1.90)	1.60 (1.30–1.80)	0.9

[1]n (%); Median (Q1–Q3)
[2]Pearson's Chi-squared test; Mann–Whitney U test; Independent-Samples T Test

The study analyzed Stroop test performance scores in participants with and without MetS. The total sample consisted of 552 individuals, divided into two equal groups: those with MetS (n = 276) and those without MetS (n = 276). Table 3 presents the median values of the total Stroop test score: 52.00 for T1, 83.00 for T2, and 125.00 for T3. Additionally, the median interference score for B1 was 40.41, and for B2, 1.60. It was found that statistically significant differences between the groups were detected for most Stroop test indices. Thus, the reading time index (T1) was statistically significantly lower in patients with MetS ($p = 0.002$), indicating a reduction in baseline information processing speed. The T2 score, reflecting attention and the ability to name colors, was significantly higher in the MetS group ($p < 0.001$), indicating reduced attention span and slowed cognitive processing. A similar trend was observed for the T3 index ($p < 0.001$), which characterizes cognitive control and the ability to suppress interfering stimuli, indicating impaired executive functions in patients with MetS. The interference index (B1) was also statistically significantly higher in the MetS group ($p < 0.001$), indicating an increased interference effect and a reduced capacity for cognitive inhibition. At the same time, the information processing efficiency index (B2) did not show statistically significant differences between the groups ($p = 0.9$), which may indicate the preservation of relative cognitive efficiency against a background of general slowing of processes. Consequently, patients with MetS exhibit signs of impaired cognitive function, primarily in the areas of attention and executive control, while information processing efficiency remains relatively intact.

Table 4 Distribution of Stroop test quartiles in participants with and without MetS

	Total n = 552	MetS/ no n = 276	MetS / yes n = 276	p-value
STROOP T1				0.006
Q1	163 (29.5%)	91 (33%)	72 (26%)	
Q2	102 (18.5%)	59 (21%)	43 (16%)	
Q3	88 (15.9%)	46 (17%)	42 (15%)	
Q4	199 (36.1%)	80 (29%)	119 (43%)	
STROOP T2				<0.001
Q1	127 (23%)	77 (28%)	50 (18%)	
Q2	96 (17.4%)	57 (21%)	39 (14%)	
Q3	74 (13.4%)	26 (9.4%)	48 (17%)	
Q4	255 (46.2%)	116 (42%)	139 (50%)	
STROOP T3				0.012
Q1	125 (22.6%)	74 (27%)	51 (18%)	
Q2	92 (16.7%)	53 (19%)	39 (14%)	
Q3	155 (28.1%)	72 (26%)	83 (30%)	
Q4	180 (32.6%)	77 (28%)	103 (37%)	
STROOP B1				0.3
Q1	134 (24.3%)	71 (26%)	63 (23%)	
Q2	156 (28.3%)	79 (29%)	77 (28%)	
Q3	151 (27.4%)	79 (29%)	72 (26%)	
Q4	111 (20.1%)	47 (17%)	64 (23%)	
STROOP B1				0.6
Q1	90 (16.3%)	43 (16%)	47 (17%)	
Q2	101 (18.3%)	51 (18%)	50 (18%)	
Q3	191 (34.6%)	90 (33%)	101 (37%)	
Q4	170 (30.8%)	92 (33%)	78 (28%)	

Table 4 presents a cross-tabulation of the Stroop test results, broken down by quartiles (Q1–Q4), for the groups with and without MetS. The results of the first stage (T1), which measured reading speed and duration, showed that the largest proportion of values fell within the Q4 quartile (36.1%). At the same time, participants with MetS were more likely to experience a decrease in reading speed: the proportion of subjects in Q4 was 43% compared to 29% in the group without MetS, indicating statistically significant differences ($p = 0.006$). Significant differences were also identified in subsequent test stages: at stage T2 ($p < 0.001$) and stage T3 ($p = 0.012$). The data indicate marked impairments in executive functions and cognitive control in individuals with metabolic syndrome. It is likely that participants with MetS spent more time completing

Table 5 Relationship between quartile groups of the Stroop test and clinical characteristics

	WC yes/no n = 552	TG yes/no n = 552	Glucose yes/no n = 552	HDL yes/no n = 552	HBP yes/no n = 552	SBP yes/no n = 552	DBP yes/no n = 552
STROOP T1							
Q1	127 (77,9%) 36 (22,1%)	65 (39,9%) 98 (60,1%)	54 (33,1%) 109 (66,9%)	80 (49,1%) 83 (50,9%)	84 (51,5%) 79 (48,5%)	60 (36,8%) 103 (63,2%)	55 (33,7%) 108 (66,3%)
Q2	81(79,4%) 21(20,6%)	30 (29,4%) 72 (70,6%)	35 (34,3%) 67 (65,7%)	52 (51%) 50 (49%)	49 (48%) 53 (52%)	37(36,3%) 65(63,7%)	31 (30,4%) 71 (69,6%)
Q3	65(73,9%) 23 (26,1%)	37 (42%) 51 (58%)	20 (22,7%) 68 (77,3%)	45 (51,1%) 43 (48,9%)	50 (56,8%) 38 (43,2%)	31 (35,2%) 57 (64,8%)	24 (27,3%) 64 (72,7%)
Q4	162 (81,4%) 37 (18,6%)	99 (49,7%) 100 (50,3%)	73 (36,7%) 126 (63,3%)	113 (56,8%) 86 (43,2%)	124 (62,3%) 75 (37,7%)	94 (47,2%) 105 (52,8%)	83 (41,7%) 116 (58,3%)
p-value	0,54	***0,007***	0,124	0,49	0,067	0,94	0,062
STROOP T2							
Q1	90 (70,9%) 37 (29,1%)	43 (33,9%) 84 (66,1%)	34 (26,8%) 93 (73,2%)	65 (51,2%) 62 (48,8%)	51 (40,2%) 76 (59,8%)	34 (26,8%) 93 (73,2%)	29 (22,8%) 98 (77,2%)
Q2	72 (75%) 24 (25%)	25 (26%) 71 (74%)	35 (36,5%) 61 (63,5%)	45 (46,9%) 51 (53,1%)	50 (52,1%) 46 (47,9%)	41 (42,7%) 55 (57,3%)	35 (36,5%) 61 (63,5%)
Q3	62 (83,8%) 12 (16,2%)	35 (47,3%) 39 (52,7%)	27 (36,5%) 47 (63,5%)	40 (54,1%) 34 (45,9%)	54 (73%) 20 (27%)	40 (54,1%) 34 (45,9%)	39 (52,7%) 39 (47,3%)
Q4	211 (82,7%) 44 (17,3%)	128 (41,8%) 127 (49,8%)	86 (33,7%) 169 (66,3%)	140 (54,9%) 115 (45,1%)	152 (59,6%) 103 (40,4%)	107 (42%) 148 (58%)	90 (35,3%) 165 (64,7%)
p-value	***0,031***	***<0.001***	0,35	0,57	***<0.001***	**0,001**	***<0.001***
STROOP T3							
Q1	95 (76%) 30 (24%)	43 (34,4%) 82 (65,6%)	34 (27,2%) 91 (72,8%)	63 (50,4%) 62 (49,6%)	59 (47,2%) 66 (52,8%)	39 (31,2%) 86 (68,8%)	36 (28,8%) 89 (71,2%)
Q2	68 (73,9%) 24 (26,1%)	28 (30,4%) 64 (69,6%)	31 (33,7%) 61 (66,3%)	44 (47,8%) 48 (52,2%)	41 (44,6%) 51 (55,4%)	30 (32,6%) 62 (67,4%)	25 (27,2%) 67 (72,8%)
Q3	123 (79,4%) 32 (20,6%)	72 (46,5%) 83 (53,5%)	51 (32,9%) 104 (67,1%)	86 (55,5%) 69 (44,5%)	94 (60,6%) 61 (39,4%)	62 (40%) 93 (60%)	54 (34,8%) 101 (65,2%)
Q4	149 (82,8%) 31 (17,2%)	88 (48,9%) 92 (51,1%)	66 (36,7%) 114 (63,3%)	97 (53,9%) 83 (46,1%)	113 (62,8%) 67 (37,2%)	91 (50,6%) 89 (49,4%)	78 (43,3%) 102 (56,7%)
p-value	0,303	***0,005***	0,38	0,63	***0,004***	***0,002***	***0,018***
STROOP B1							
Q1	104 (77,6%) 30 (22,4%)	58 (43,3%) 76 (56,7%)	41 (30,6%) 93 (69,4%)	69 (51,5%) 65 (48,5%)	69 (51,5%) 65 (48,5%)	45 (33,6%) 89 (66,4%)	42 (31,3%) 92 (68,7%)
Q2	126 (80,8%) 30 (19,2%)	65 (41,7%) 91 (58,3%)	41 (26,3%) 115 (73,7%)	88 (56,4%) 68 (43,6%)	86 (55,1%) 70 (44,9%)	63 (40,4%) 93 (59,6%)	48 (30,8%) 108 (69,2%)
Q3	115 (76,2%) 36 (23,8%)	57 (37,7%) 94 (62,3%)	60 (39,7%) 91 (60,3%)	74 (49%) 77 (51%)	81 (53,6%) 70 (46,4%)	57 (37,7%) 94 (62,3%)	51 (33,8%) 100 (66,2%)
Q4	90 (81.1%) 21 (18,9%)	51 (45,9%) 60 (54,1%)	40 (36%) 71 (64%)	59 (53,2%) 52 (46,8%)	71 (64%) 40 (36%)	57 (51.4%) 54 (48,6%)	52 (46,8%) 59 (53,2%)
p-value	0,69	0,58	0,068	0,62	0,22	***0,037***	***0,033***
STROOP B1							
Q1	68 (75,6%) 22 (24,4%)	34 (37,8%) 56 (62,2%)	30 (33,3%) 60 (66,7%)	48 (53,3%) 42 (46,7%)	47 (52,2%) 43 (47,8%)	38 (42,2%) 52 (57,8%)	37 (41,1%) 53 (58,9%)
Q2	76 (75,2%) 25 (24,8%)	41 (40,6%) 60 (59,4%)	31 (30,7%) 70 (69,3%)	59 (58,4%) 42 (41,6%)	61 (60,4%) 40 (39,6%)	41 (40,6%) 60 (59,4%)	34 (33,7%) 67 (66,3%)
Q3	156(81,7%) 35 (20,6%)	81 (42,2%) 110 (57,6%)	65 (34%) 126 (66%)	101 (52,9%) 90 (47,1%)	112 (58,6%) 79 (41,4%)	77 (40,3%) 114 (59,7%)	65 (34%) 126 (66%)
Q4	135 (79,4%) 35 (20,6%)	75 (44,1%) 95 (55,9%)	56 (32,9%) 114 (67,1%)	82 (48,2%) 88 (51,8%)	87 (51,2%) 83 (48,8%)	66 (38,8%) 104 (261,4%)	57 (33,5%) 113 (66,5%)
p-value	0,51	0,78	0,95	0,44	0,33	0,96	0,62

the Stroop test tasks, reflecting reduced efficiency in cognitive information processing. Significant differences were also observed in subsequent stages of the test: at stage T2 ($p < 0.001$) and stage T3 ($p = 0.012$). The data indicate marked impairments in executive functions and cognitive control in individuals with MetS. Participants with MetS likely took longer to complete the Stroop test tasks, reflecting reduced efficiency in cognitive information processing. Quartile distribution analysis confirmed a statistically significant association between cognitive test scores and the presence of MetS. The largest number of observations at stages T2 and T3 also fell into quartile Q4, indicating lower cognitive performance in this group. At stage T3, the largest proportion of participants (32.6%) required more than two minutes to complete the task. At the same time, no statistically significant differences were found for stages B1 and B2.

Table 5 presents an analysis of the relationship between clinical and metabolic parameters and the results of the Strup test. Among all clinical and metabolic parameters, triglyceride levels differed statistically significantly in the first stage (p=0.007). In the second stage of the test, attention and the ability to name colors were assessed; in people with MetS, TG and BP levels, as well as SBP and DBP, were statistically significantly higher in all quartiles (p=0.007). In the second stage, participants with HBP showed higher Stroop test scores in Q4 than participants without MetS (59.6% vs. 40.4%). In contrast, participants with elevated SBP and DBP showed higher scores than participants without MetS (58% vs. 42%, 64.7% vs. 35.3%). The results suggest that HBP may be associated with a decline in cognitive function. No statistically significant differences in glucose and HDL levels were found. In the third stage, participants with HBP scored higher on the Stroop test in Q3-Q4 than participants without MetS (60.6% vs. 39.4%, 62.8% vs. 37.2%). This, in turn, may be associated with chronic hypertension, which can lead to impaired executive function and reduced information processing speed. In addition, elevated TG levels were more prevalent among individuals without MetS across all quartiles and were statistically significant (p=0.005). A longer time taken to complete the test is more likely to reveal interference effects, which may indicate reduced cognitive control, slowed information processing, and difficulties in suppressing automatic responses. In the first interference effect (B1) of the Stroop test, no statistically significant differences were found between clinical parameters and groups ($p > 0.05$) except for SAD and DAD. In participants without MetS, SAD and DAD scores were higher at the Q2 and Q3 levels. The differences between quartiles were statistically significant ($p = 0.037$, $p = 0.033$). In the final stage (B2) of the Stroop test, no statistically significant differences in clinical parameters were found.

Discussion

In this study, we assessed cognitive function in participants with and without MetS using the Stroop test. Women constituted the majority of participants in our study. The group with MetS differed in terms of age, with a statistically significant difference ($p < 0.001$) observed in the number of participants under 50 years of age. This is due to the fact that the prevalence of metabolic syndrome is increasing among the younger population. 76% of participants with a college education were included in the group without MetS. Participants with secondary and lower levels of education differed depending on the presence of MetS. The majority of alcohol consumers were people with MetS. The results obtained in this study are consistent with data from international studies confirming the association between MetS and impaired cognitive function, particularly in the domains of attention and executive control. A number of foreign studies have shown that components of MetS are associated with a decline in executive functions, as assessed, among other methods, by the Stroop test. Yates et al. demonstrated that an increase in the number of MetS components is associated with impaired performance on cognitive tasks, including interference tests [16]. This is consistent with our findings regarding elevated T3 and B1 scores in patients with MetS. Similar results were obtained in a study by Segura et al., where patients with MetS exhibited reduced cognitive flexibility and increased interference [17]. This confirms the impairment of executive control identified in our sample. Large population-based studies also demonstrate an association between MetS and the risk of cognitive decline. A study by Wu et al. showed that MetS more than doubles the risk of cognitive impairment (OR = 2.39) [18]. In addition, Aljondi et al. identified an association between MetS and reduced psychomotor speed and attention [19], which is consistent with our results for the T1 and T2 measures. At the same time, results may vary across specific clinical groups. For example, in a study by Viscogliosi et al., no significant differences in cognitive function were found in patients with chronic obstructive pulmonary disease depending on the presence of MetS [20]. Pathophysiological mechanisms may include vascular and metabolic disorders. According to a review by Tune et al., insulin resistance, inflammation, and endothelial dysfunction play a key role in the development of cognitive impairments in MetS [21]. Thus, the results of the present study confirm international data and indicate a predominant impairment of executive functions and inhibitory control in MetS.

The findings are consistent with other scientific data, which indicate a link between metabolic syndrome and impairments in cognitive functions, specifically executive control, information processing speed, and attention. According to a number of researchers, the presence of metabolic syndrome is associated with a decline in cognitive performance, particularly in tasks requiring a high degree of cognitive control. This is consistent with the results of the present study, which show a shift in the distribution toward the unfavorable quartile (Q4) and an increase in task completion time. The results from stages T2 and T3, where statistically significant differences were identified, can be explained by impaired inhibitory control and cognitive flexibility. Foreign studies have shown that patients with MetS demonstrate a more pronounced interference effect on the Stroop test, which is associated with prefrontal cortex dysfunction [22]. From a neurobiological perspective, these impairments may be attributable to vascular and metabolic changes. Studies using neuroimaging show that MetS is associated with changes in white matter and reduced cerebral blood flow, which, in turn, affect cognitive function [23]. Additional data confirm the role of inflammatory processes and insulin resistance as key mechanisms of cognitive decline in MetS. In particular, it has been shown that chronic inflammation and metabolic disorders increase the risk of cognitive decline and dementia [24]. This may explain the increase in the proportion of participants requiring more than 2 minutes to complete tasks at the T3 stage. Furthermore, meta-analytic studies demonstrate that metabolic disorders are associated with impaired performance across multiple cognitive domains, including attention, information processing speed, and executive functions [25]. This is fully consistent with the present findings, which indicate the complex nature of cognitive impairments in individuals with MetS.

The results of the quartile distribution (T1, T2, T3) of Stroop showed a statistically significant association with triglyceride levels. This may point to a possible role of lipid metabolism disorders in the decline of executive functions, particularly cognitive control and the ability to suppress interference. Accordingly, our results generally align with those of other cross-sectional studies conducted on samples from other populations. Parthasarathy V. et al. associated elevated TG levels with impaired attention, information processing speed and executive functions. The results suggest that dyslipidemia may contribute to the development of endothelial dysfunction, chronic inflammation, and cerebrovascular changes, which negatively affect cognitive processes over a long period of time [26].

In a cross-sectional study, Mehra et al. investigated the association between mild cognitive impairment and MetS in patients with hypertension. They found a positive correlation between low HDL levels and high total cholesterol levels [27]. Butcher et al. conducted a cross-sectional study among men. The results showed that during the Stroop test, participants' cardiovascular response intensified as the task became more complex; their heart rates increased and their blood pressure rose [28]. HBP has a negative impact on the neurocognitive domains of auditory and verbal memory. This may be associated with the chronic nature of MetS, which is often accompanied by a reduced quality of life, limitations in physical activity, and an increased risk of cardiovascular disease [8]. Our data are consistent with the results of Dintica's studies, which also show statistical significance in the T2, T3, and B1 categories of the Stroop test. HBP in middle age is associated with a number of changes in the brain that are linked to cognitive impairment in later life. This means that cognitive functions also slow down with age and participants require more time to complete the test than was allotted to them. In summary, the results of this study confirm the findings of international literature and indicate that metabolic syndrome negatively impacts cognitive functions, particularly executive control and information processing speed. The absence of statistically significant differences at stages B1 and B2 is likely due to the fact that these stages reflect simpler cognitive processes, which remain relatively intact compared to more complex executive functions.

The results of the study have important practical implications for the health system. Each of the identified associations confirms the need for early detection of cognitive impairment in people with MetS. Kouvar et al., came to the conclusion that early detection of metabolic syndrome can help prevent or slow down the decline of cognitive functions. The results obtained by us agree with these studies [29]. They expand the existing ideas about the influence of components of the metabolic syndrome on cognitive functions. Thus, they confirm the importance of controlling metabolic parameters as potentially modifiable risk factors for cognitive disorders.

In this article, we examined the use of the Stroop test to assess cognitive functions with clinical and metabolic indicators, particularly attention and executive control, in patients with MetS. However, it does not fully assess all components of cognitive function.

Conclusion

The results of the study showed that the presence of metabolic syndrome had a significant negative effect on the Stroop test result. The results indicate the need for screening and prevention of cognitive impairment in individuals with MetS. Further studies are needed to confirm the association between MetS and cognitive problems, as well as to identify the specific mechanism underlying this association. The results of the study indicate the importance of identifying modifiable risk factors associated with individual components of the metabolic syndrome, such as high systolic and diastolic blood pressure, triglyceridemia.

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