AI-Based Cognitive Assessment of Memory, Attention and Executive Function in Young Adult Smokers and Non-Smokers: A Cross-Sectional Comparative Study

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Abstract

Background: Cigarette smoking has been associated with adverse neurobiological effects; however, its impact on cognitive functioning in young adults is often underexplored. Chronic exposure to nicotine and other toxic constituents of tobacco smoke may impair attention, memory and executive function. Conventional cognitive screening tools may lack sensitivity for detecting early cognitive changes, highlighting the potential role of artificial intelligence (AI)–based digital assessments. **Objective:** We assessed the viability of digital evaluation and used an AI-based software to compare cognitive function in young adult smokers and non-smokers. **Method:** A cross-sectional comparative study was conducted among 128 healthy participants aged 18– 30 years. Participants were equally divided into smokers (n = 64) and non-smokers (n = 64) using convenience sampling. Cognitive domains including memory, attention, and executive function were assessed using the CogniFit AI-based Cognitive Assessment Battery. Individuals with neurological or psychiatric disorders, head injury, or use of psychoactive substances other than nicotine were excluded. Group comparisons were performed using independent-samples t-test. **Result:** Group scores were compared using independent-samples t-tests. In every domain, smokers performed noticeably lower than non-smokers. In terms of demographics, the nonsmoker group was more gender balanced (47% male, 53% female; $\chi^2(1) = 13.33$, $p < .001$), while 78% of smokers were men and 22% were women. The AI-based assessment effectively distinguished cognitive performance between groups. **Conclusion:** Young adult smokers exhibit significant impairments in key cognitive functions when compared with non-smokers. These variations were successfully identified by the CogniFit AI-based evaluation, indicating that digital tools may enable remote cognitive function screening. Future research should examine how to include these technologies into programs for monitoring cognitive health and quitting smoking.

Keywords: Attention, Cognitive impairment, CogniFit, Digital assessment, Executive function, Memory, Smokers, Smoking

Introduction

In addition to contributing to respiratory and cardiovascular disorders, tobacco use has serious neuropsychological effects, making it a major global public health concern. The central nervous system (CNS) is harmed by oxidative stress, hypoxia, and neuroinflammation brought on by long- term exposure to nicotine and other harmful substances in cigarette smoke [1, 2]. Long-term smokers exhibit cortical thinning, decreased hippocampal volume, and abnormalities in important cognitive domains such working memory, attention, and executive function, according to neuroimaging and neuropsychological data [3, 4]. People who started smoking early or have a history of excessive smoking are most affected.

The main psychoactive ingredient in tobacco, nicotine, activates via nicotinic acetylcholine receptors (nAChRs), which are found all over the brain. Nicotine has both short-term and long- term impacts on cognition by influencing dopaminergic, serotonergic, and noradrenergic neurotransmission [10]. While chronic exposure and abstinence are linked to a decline in these abilities, acute nicotine consumption can momentarily improve attention and memory performance. In order to prevent withdrawal-related cognitive deterioration, smokers frequently experience increased cognitive ability after smoking, which reinforces ongoing use. This biphasic pattern contributes to nicotine dependency. However, heavy smoking eventually causes accelerated age-related decline and long-lasting cognitive impairment. Additionally, the harmful substances included in tobacco smoke, such as formaldehyde, acrolein, benzene, nitrosamines, carbon monoxide, and heavy metals, cause direct neurotoxicity and impair cerebral oxygenation, which exacerbates neuronal dysfunction [10]. The correlations between long-term smoking, altered white matter, and decreased synaptic plasticity are explained by these mechanisms. Additionally, smoking increases inflammatory and oxidative stress markers, which causes vascular impairment and endothelial damage, both of which are closely associated with cognitive decline [11]. Traditional screening techniques like the Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination (MMSE) are frequently unresponsive to modest cognitive abnormalities reported in smokers, particularly in early or subclinical stages, despite the recognised neurobiological connections [4]. They require trained personnel, are influenced by education and language, and cannot easily be deployed for large-scale or repeated assessments.

Recent advancements in artificial intelligence (AI) and digital health tools have transformed cognitive assessment paradigms. AI-based applications, such as CogniFit, provide standardized, self-administered, and algorithm-driven cognitive testing capable of analyzing multiple domains— attention, working memory, executive function, and visuospatial processing—in real time [5, 6]. These systems utilize adaptive algorithms and normative data to detect even mild deviations from baseline performance. Studies on AI-enabled cognitive assessments such as the Integrated Cognitive Assessment (ICA) have shown diagnostic accuracy exceeding 90% (AUC > 0.90) in detecting mild cognitive impairment and early Alzheimer's disease [8]. Such technologies could similarly be applied to smokers, a population at risk of cognitive decline but rarely monitored for early dysfunction.

Smokers, a group at risk of cognitive deterioration but seldom checked for early dysfunction, could also benefit from such devices. AI-driven cognitive tests have several advantages over conventional techniques, including reduced examiner bias, automated scoring, remote monitoring, and the ability to follow cognitive improvement over time [6, 7]. Additionally, behavioural treatments like chatbots for quitting smoking and neurofeedback programs are being incorporated into AI platforms more and more, with encouraging outcomes in terms of engagement and success in quitting [9]. An innovative method of preventive neurorehabilitation is the combination of AI- based detection and digital therapeutic delivery.

There is a compelling case for using AI-based tools to assess smokers' cognitive abilities given the established connection between smoking and cognitive deterioration and the constraints of traditional testing. Using the CogniFit AI-based cognitive-assessment program, the current observational study attempts to evaluate smokers' cognitive performance and compare the results with those of non-smokers. This research aims to detect early cognitive abnormalities, enable prompt intervention, and support public health initiatives targeted at reducing smoking-related neurocognitive decline by utilising AI's analytical precision and scalability.

Methodology

The Department of Physiotherapy at SGT University (an affiliated hospital) in Gurugram, India, used a cross-sectional comparative design. Convenience sampling was used to select 128 participants (mean age ~23 years, ages 18–30). The non-smoker group included 64 people who had never smoked, whereas the smoker group included 64 people who had smoked daily for at least six months (≤100 cigarettes/week). There were both men and women present. Adequate digital literacy and the capacity to use a smartphone for testing were prerequisites for inclusion. A history of neurological or psychiatric conditions (such as epilepsy, schizophrenia, or major depression), current use of psychoactive drugs (apart from nicotine), a diagnosis of dementia or cognitive impairment, a history of severe head trauma, and untreated visual or motor impairments that would prevent test use were all exclusion criteria. Every participant gave their informed consent. Using a tablet or smartphone, participants remotely completed the CogniFit Cognitive Assessment Battery (CAB PRO). A verified online cognitive test, the CAB PRO assesses executive function, memory, attention, reasoning, and coordination. Completing the entire online test takes about 30 to 40 minutes.

Under the guidance of a therapist, raw scores in the three main domains—memory, attention, and executive function—were recorded.

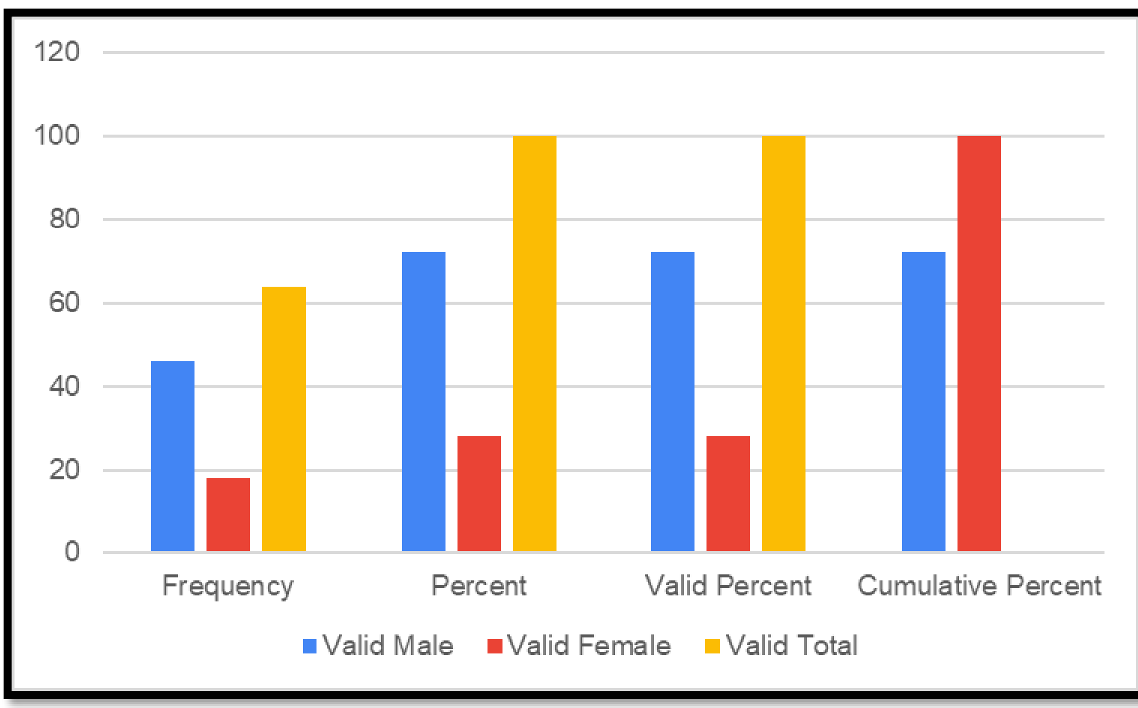
Results

Statistical analysis was performed in SPSS. Demographic comparisons (age and gender) between groups used t-tests. Independent-samples t-tests compared smokers vs. non-smokers on each cognitive domain. All tests were two-tailed with significance level $\alpha = 0.05$.

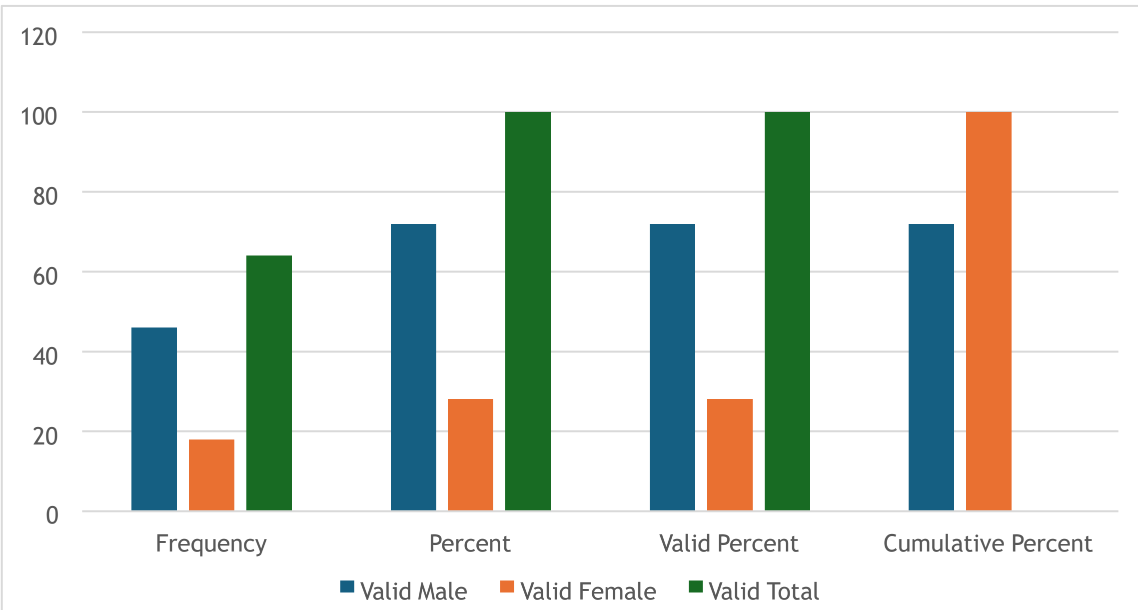
The final sample (N = 128) had a mean age of 23.9 years (SD = 3.0) and did not differ significantly by group (smokers M = 23.7, SD = 3.2; non-smokers M = 24.1, SD = 2.8; $t(126) = -0.75$, $p = .45$).

Frequency of gender of smokers and non- smokers

		Frequency of gender of Smokers (Group A)			
	Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	46	71.9	71.9	71.9
	Female	18	28.1	28.1	100.0
	Total	64	100.0	100.0	



		Frequency of gender of Non-smoker (Group B)			
	Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	38	59.4	59.4	59.4
	Female	26	40.6	40.6	100.0
	Total	64	100.0	100.0	



Mean of age and gender of smokers and non-smokers

Mean of gender and age of subjects of smokers		
	Age	Gender
Mean	23.03	1.28
N	64	64
Std. Deviation	2.976	0.453

Mean of gender and age of subjects of Non- Smokers		
	Mean	Gender
Mean	23.27	1.41
N	64	64
Std. Deviation	2.577	0.495

Comparison between smokers and non smokers of memory score, attention score and executive function by independent t- test

outcomes		N	Mean	Std. Deviation	Std. Error Mean
Memory Score	Smokers	64	242.27	26.565	3.321
	Non-smokers	64	468.81	43.707	4.838
Attention Score	Smokers	64	360.84	21.195	2.649
	Non-smokers	64	498.81	46.707	5.838
Executive function Score	Smokers	64	239.52	25.740	3.217
	Non-smokers	64	501.80	46.712	5.839

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Memory Score	Equal variances assumed	25.317	.000	38.196	126	.000	256.547	6.717	269.839	243.255

	Equal variances not assumed			38.196	99.899	.000	256.547	6.717	269.873	243.221
Attention Score	Equal variances assumed	43.215	.000	21.519	126	.000	137.969	6.411	150.657	125.281
	Equal variances not assumed			21.519	87.892	.000	137.969	6.411	150.710	125.227
Executive function Score	Equal variances assumed	26.821	.000	39.341	126	.000	262.281	6.667	275.475	249.088
	Equal variances not assumed			39.341	98.028	.000	262.281	6.667	275.511	249.051

Interpretation of independent t-test

The independent samples 1-lest shows a significant difference ($p<.0001$) between srmokers and non smokers in memory, attention, and executive function scores. Smokers performed significantly worse across all cognitive domains, with large mean differences and confidence intervals confirming the effect.

Discussion

Using an AI-based cognitive assessment tool (CogniFit), the current study investigated the effects of smoking on cognitive performance. It discovered a statistically significant decrease ($p < 0.001$) in all cognitive domains, including memory, attention, and executive function, between smokers and non- smokers. These findings show that higher cognitive functions are negatively impacted by long-term exposure to nicotine and other harmful substances found in cigarette smoke. The results are in accordance with earlier research that connected tobacco use to deficiencies in particular cognitive areas such working memory, attention, and executive functioning as well as a general deterioration in cognitive abilities [1,2,3].

The primary psychoactive ingredient in tobacco, nicotine, first stimulates the brain by activating nicotinic acetylcholine receptors (nAChRs), which increases alertness and attention. On the other hand, long-term neuronal damage, altered neurotransmitter release, and receptor desensitization result from prolonged nicotine exposure [9]. According to Castaldelli-Maia et al, there is a biphasic impact in which long-term exposure to nicotine causes a lasting deterioration in cognitive function but short-term use momentarily enhances attention [19]. This neuroadaptive theory is supported by the lower mean cognitive scores among smokers in the current study, which also confirms that the perceived short- term cognitive "boost" from smoking conceals gradual neurodegeneration.

The findings of Li et al. and Pushpa and Kanchana, who discovered that chronic smokers significantly performed worse on tests of decision-making, inhibition, and working memory, are consistent with the observed decline in executive function and memory scores among smokers [13,15].

Neurotoxic effects on the prefrontal cortex and hippocampus, areas essential for executive processing and memory formation, are the main cause of these abnormalities. The neurostructural foundation of the current findings is supported by neuroimaging studies, which showed cortical thinning, decreased hippocampus volume, and disturbed white matter integrity in smokers [3,11].

Mechanistically, oxidative stress, inflammation, and vascular dysfunction may be the cause of smoking- related cognitive impairment. Tobacco smoke's carbon monoxide and free radicals cause endothelial damage and cerebral hypoxia, which results in neuronal death and decreased cerebral perfusion [2]. The early exposure to tobacco smoke increases the risk of dementia later in life and speeds up neurovascular aging[14]. The notable variations in AI-based cognitive performance between smokers and non-smokers in this study can be explained by these biological processes. Cerebral hypoperfusion and neuronal death result from oxidative stress, endothelial dysfunction, and neuroinflammation caused by nicotine and other tobacco components [17]. A dose-response relationship between cumulative smoking exposure and cognitive decline was found in longitudinal data from the NEDICES Study (2023), indicating that increasing pack-year exposure causes quantifiable impairments in processing speed and attention [18].

This study contributes new knowledge to the field by using CogniFit an Al-based cognitive evaluation instrument. Despite their widespread use, traditional screening techniques like the MMSE and MOCA are constrained by linguistic bias, subjective grading, and low sensitivity to subtle cognitive changes.

AI-based tests, on the other hand, use data analytics and adaptive algorithms to produce objective, quantifiable assessments of cognitive [5,6]. Al systems can identify subtle cognitive changes earlier than traditional assessments, according to Islam and Yang, which is consistent with the considerable group differences observed in our study [5]. Additionally, Modarres et al. revealed that the therapeutic relevance of AI-based integrated cognitive tests was supported by their diagnostic accuracy of over 90% in identifying moderate cognitive impairment [7].

The study's conclusions have significant clinical ramifications. The motivation, planning, and decision- making processes necessary for a successful smoking cessation are all impacted by cognitive impairment. Early detection of smoking-related cognitive deterioration can facilitate focused therapies meant to enhance working memory, self-control, and attention. The BMC Psychology (2025) procedure showed that selfcontrol and smoking cessation outcomes can be enhanced by combining cognitive retraining with better sleep consolidation [19]. Early diagnosis of cognitive impairment may be made possible by integrating Albased cognitive assessment into smoking cessation programs, enabling physiotherapists and clinicians to customize therapies. To track cognitive recovery after cessation or therapeutic intervention, Al-based tests can also be incorporated into rehabilitation regimens [6,8].

Despite these encouraging findings, there are certain limitations to this study. Study cannot prove a link between smoking and cognitive deterioration because study is cross-sectional. Potential confounders like education, nutrition, and alcohol intake were not completely controlled, and the sample was restricted to a single geographic area. To monitor cognitive changes before and after quitting smoking and to investigate whether these impairments are reversible, more longitudinal studies with larger, more diverse samples are required. Furthermore, the mechanisms behind smoking-related cognitive deterioration may be further clarified by integrating Al-based assessment with neuroimaging or biomarker research.

In conclusion, this study offers compelling evidence that long-term smoking is linked to notable deficits in executive function, memory, and attention as determined by an Al-based cognitive test. The results support the neurobiological theory that smoking impairs cognitive processing by causing oxidative stress, cortical shrinkage, and neurotransmitter imbalance. The findings demonstrate the possibility for early screening, preventive intervention, and continuous monitoring of those at risk of smoking-related cognitive deterioration using AI-driven cognitive assessment tools like CogniFit. Personalized intervention, early detection, and better long-term cognitive outcomes could all be facilitated by incorporating such technologies into physiotherapy and rehabilitation practices. Digital cognitive tests have considerable promise for diagnosing people with mild cognitive abnormalities and measuring later risk [16]. This implies that, in the case of smoking, we may be able to identify at-risk individuals earlier and customize interventions based on their cognitive profile.

Limitations

It is important to notice a few limitations. First, the cross-sectional design prevents causal inferences; we cannot establish that smoking induced the cognitive deficiencies. We matched groups by age and got rid of any big confounding factors, but it's still possible that other things, like education or socioeconomic position, played a role. Second, the sample was a convenience sample limited to ages 18–30. This limits generalizability to broader populations (e.g., older smokers, or non-Indian samples). Third, there was a gender imbalance in the smoking group (mostly men), which may induce bias but matches real-world trends. We did not specifically account for gender in our analysis, despite the fact that gender was statistically different between groups (as stated); future research should make sure that sampling is balanced or employ covariate adjustments. Fourth, we were unable to evaluate dose-response effects since smoking status was self-reported and we did not measure nicotine dosage or duration (e.g., pack-years). Lastly, even though CogniFit is an advanced tool, its proprietary algorithms are not entirely transparent; confidence would be bolstered by replication with other cognitive batteries. Not withstanding these drawbacks, the cohort's consistent and noteworthy outcomes in every category offer compelling proof of cognitive differences between smokers and non-smokers.

Conclusion

In conclusion, our study shows that, in comparison to non-smokers, young adults who smoke have notable deficits in memory, attention, and executive function. An AI-powered, app-based cognitive exam was used to identify these deficiencies, demonstrating the potential of digital tools for neurocognitive screening. In this case, the application of CogniFit proved practical and successful. Our results imply that even in early adulthood, smoking is linked to quantifiable cognitive loss. They also show how AI-driven platforms can help with early identification and intervention. For instance, regular app-based testing could find smokers with cognitive impairments who might benefit from more extensive quitting support or cognitive training. As technology develops, including these digital tests into wellness and healthcare initiatives may help keep an eye on those who are at risk and reduce the cognitive hazards that come with smoking. Future studies should investigate the long-term application of these instruments to monitor cognitive trajectories and assess the results of interventions.

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