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Association Between Obesity, Executive Functions, and Affective States: An Analysis of Patients from an Endocrinology Clinic

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Abstract

Introduction: Obesity is a multifaceted public health concern with significant cognitive and emotional implications. This study explores the association between obesity, executive function deficits, and affective states in 26 patients (76.9% male; mean age = 41.3 years, SD = 13.0) from an endocrinology clinic in Manizales, Colombia.

Method: This is a non-experimental cross-sectional study that used the BANFE-2 neuropsychological battery and the Hamilton Anxiety and Depression Scales; 96.2% of participants exhibited impaired executive functions, with severe deficits observed in 76.9%.

Results: Key impairments included inhibitory control, cognitive flexibility, and self-monitoring, linked to dysfunctions in the dorsolateral (96.2%) and orbitomedial (50.0%) prefrontal cortex regions. Affective disturbances were prevalent, with 50.0% reporting severe anxiety and 73.1% experiencing depression. Men demonstrated higher rates of moderate-to-severe anxiety (66.7%) and depression (46.7%) compared to women, while non-adherence to treatment was associated with increased anxiety ($p = 0.019$).

Discussion: These findings underscore the critical interplay between neuropsychological deficits and emotional dysregulation in obesity. They suggest that interventions targeting executive functions and affective regulation could enhance outcomes for patients with obesity. This study offers a foundation for developing personalized therapeutic strategies and highlights the need for longitudinal research to establish causal mechanisms.

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1. Introduction

Obesity has been classified by the World Health Organization (WHO) as a significant public health issue or epidemic since the 1990, due to its profound impact on individuals' quality of life, morbidity, mortality rates, and the substantial direct and indirect costs associated with this condition (Arrieta & Pedro-Botet, 2021; National Heart, Lung, & Blood Institute, 1988). It is defined as a condition characterized by a substantial increase in body weight primarily caused by adipose tissue accumulation (Pan American Health Organization - PAHO, 2024), with the WHO defining it as a body mass index (BMI) equal to or exceeding 30. Some researchers identify overweight and obesity as the fifth highest risk factor contributing to global mortality, following hypertension (HTN), smoking, diabetes mellitus (DM), and physical inactivity (Ordoñez Molina, 2019; World Health Organization, 2009).

Various studies have documented the global economic burden of overweight and obesity (OAO) on healthcare systems worldwide. Notably, a study by Okunogbe et al. (2022), analyzing 161 countries, estimated that in 2019, OAO accounted for 2.19% of the global gross domestic product (GDP). Costs ranged from an average of $20 per capita in Africa to $872 in the Americas, and from $6 in low-income nations to $1110 in the USA (NCD Risk Factor Collaboration, 2017; Okunogbe et al., 2022; Ralston et al., 2018). In Colombia, it is estimated that 1.8 million individuals suffer from non-communicable diseases related to excess weight, imposing an annual cost of approximately 5.7 billion Colombian pesos on the General Social Security Health System (SGSSS) (Ordoñez Molina, 2019).

Currently, OAO present a critical public health challenge due to its escalating prevalence across all demographic groups globally, having increased fivefold among children and adolescents (PAHO, 2024; WHO, 2021). Recent research suggests that approximately 40% of the global adult population is affected by overweight and obesity, accompanied by associated health complications (Krzysztoszek et al., 2019; WHO, 2021). This condition is predominantly linked to contemporary lifestyle and dietary habits, which prioritize the consumption of highly processed, energy-dense foods that exceed nutritional requirements. Sedentary behaviors and lack of physical activity exacerbate these factors. Consequently, obesity contributes to a spectrum of adverse medical, social, psychological, and occupational outcomes, establishing it as a significant risk factor for numerous chronic diseases (PAHO, 2024; WHO, 2024), including metabolic syndrome (De Filippo, 2021).

Obesity is recognized as a complex, multifactorial chronic disease that heightens the risk of conditions such as depression, type 2 diabetes, dyslipidemia, cardiovascular diseases, certain cancers, and musculoskeletal disorders (Anstey et al., 2011; Dai et al., 2020). Etiologically,

obesity involves genetic, individual, environmental, and behavioral factors, with the latter notably impacting cognitive functions. Studies indicate that individuals with eating disorders often exhibit diminished cognitive capacities for regulating eating behaviors, evidenced by compromised performance on tasks assessing attention, memory, and particularly executive functions (EFs), which are pivotal in cognitive performance challenges (Arredondo-Urtiz et al., 2021; Favieri et al., 2019; Lentoor, 2022). EFs encompass a higher-order cognitive system integrating skills crucial for selecting goal-oriented behaviors in response to environmental stimuli and demands (Tirapu-Ustárroz et al., 2017).

The dorsolateral prefrontal cortex (DLPFC) is pivotal for functions like planning, working memory, verbal fluency, problem-solving, mental flexibility, hypothesis generation, strategic thinking, serialization, sequencing, metamemory, and metacognition (Fernández-Duque et al., 2000; Flores Lázaro & Ostrosky-Shejet, 2012; Flores Lázaro et al., 2014; Maril et al., 2003; Stuss & Alexander, 2000). Conversely, the orbitofrontal cortex (OFC) plays a crucial role in processing and regulating emotions and mood states, as well as in behavioral regulation and decision-making based on risk-benefit assessments (Bechara et al., 2000; A. R. Damasio, 1996; Flores Lázaro et al., 2014; Stuss & Levine, 2002). Collectively, these regions are pivotal for behavioral self-control.

Research indicates that obese individuals exhibit reduced behavioral control, reflected in challenges with emotional self-regulation, diminished self-monitoring abilities, and higher BMI levels (Steward et al., 2018). Specifically, regarding eating behaviors, impaired performance on EFs tasks and related anatomical-functional correlates suggests deficits in planning meal choices, timing of meals, and portion control, potentially exacerbating obesity (Syan et al., 2019). Studies also demonstrate that individuals with obesity, scoring poorly on tasks evaluating executive sub-skills such as inhibitory control (e.g., Stroop-type tasks or mazes), may perform more errors or require extended time for completion. Such findings support the hypothesis that weakened inhibitory control contributes to impulsive eating behaviors, thereby predisposing individuals to overweight and obesity (Da Luz et al., 2017).

Moreover, studies have consistently shown lower performance among obese individuals in tasks evaluating the orbitofrontal circuit, including card games, mazes, Stroop tests, and card sorting tasks. These findings suggest that individuals with obesity may possess lower emotional regulation skills, influencing their reliance on food for emotional management and coping with conflict (Manasse et al., 2014). These observed deficits in EFs among overweight and obese individuals corroborate findings from studies such as Arredondo-Urtiz et al. (2021), highlighting an inverse relationship between EFs performance and excess weight. This implies that compromised executive functioning may correlate with higher body weight, potentially reducing

cognitive efficiency and increasing reliance on emotional cues, thereby impacting dietary regulation behaviors (Table 1).

Given the high prevalence of executive dysfunction and affective disturbances in individuals with obesity, this study aims to elucidate the relationship between executive function impairments and emotional states in patients receiving endocrinological care. We hypothesize that deficits in inhibitory control, cognitive flexibility, and self-monitoring will be significantly associated with heightened symptoms of anxiety and depression. Additionally, we anticipate that executive dysfunction will be more pronounced in individuals with severe obesity and those demonstrating non-adherence to treatment. By delineating these associations, this study seeks to contribute to the development of targeted neuropsychological and affective interventions aimed at optimizing clinical outcomes in obesity management.

Table 1. Relationship between overweight, obesity and executive functioning according to previous literature

Authors	Goal	Method and Country	Findings
Manasse et al. (2014)	To examine executive functioning (EF) in overweight individuals, including those with and without loss of control (LOC) over food intake. This is the subjective inability to control the amount of food consumed, irrespective of the quantity ingested (Tanofsky-Kraff et al., 2009).	The sample comprised 80 women with overweight and obesity (BMI 27.0-45.0 kg/m2), aged 18 to 70 years, who volunteered for a behavioral weight loss trial conducted at a university in the United States from November 2012 to September 2013. Participants, divided into those with (n = 18) and without (n = 62) loss of control (LOC) over food intake underwent a comprehensive assessment. The protocol included a clinical interview and a neuropsychological battery designed to evaluate self-regulatory control, planning abilities,	Individuals with LOC over food intake exhibited poorer performance in tasks assessing planning and self-regulatory control, but showed no significant differences in performance on other tasks. Among overweight individuals, those with LOC over food intake demonstrated relative deficits in EFs compared to their counterparts without this behavior. These findings highlight that deficits specifically in planning and self-regulatory control contribute to dysregulated eating patterns, thereby increasing susceptibility to episodes of LOC.

Authors	Goal	Method and Country	Findings
		delayed discounting, and working memory.	
Steward et al. (2018)	To examine the associations between food addiction, obesity, and neuropsychological performance.	The study sample comprised 33 adult women with obesity and 36 healthy-weight controls, aged 18 to 55 years. Participants were recruited from the Bariatric and Metabolic Surgery Unit and the Endocrinology and Nutrition Unit at a university hospital in Spain. The protocol included the Yale Food Addiction Scale 2.0v, a validated instrument for assessing addictive food behaviors. Additionally, computerized versions of the Iowa Gambling Task (IGT) and Conners' Continuous Performance Test, second edition (CPT-II), were administered to evaluate decision-making and attention control.	In the group with obesity, higher levels of food addiction severity were negatively correlated with overall scores on the Iowa Gambling Task (IGT), a measure used to evaluate decision-making abilities under ambiguous risk. The IGT involves selecting from various options associated with uncertain contingencies of reward and punishment. Participants with obesity who met the criteria for food addiction exhibited a higher number of omissions and perseveration errors on the Conners' Continuous Performance Test, second edition (CPT-II), which assesses sustained attention or vigilance, compared to those without food addiction.
Segura-Serralta et al. (2019)	To analyze the neuropsychological performance of a sample of patients with weight and eating-related issues. To examine the contribution of various	The sample comprised 288 female participants recruited from three hospitals within the Spanish National Health System. This included 75 participants with obesity, 149 with sexual	Participants with obesity or sexual dysfunction scored lower on executive functioning tests compared to the control group, even after adjusting for age and intelligence. Specifically, individuals with obesity

Authors	Goal	Method and Country	Findings
	executive functions to eating disorders, differentiating between restrictive symptoms and binge/purge behaviors, and comparing these with a healthy control group.	dysfunction, 76 with restrictive eating behaviors, 73 with binge and purge symptoms, and 64 healthy controls. The evaluation protocol incorporated the Wisconsin Card Sorting Test, the Iowa Gambling Task, and the Group Embedded Figures Test to assess set-shifting, decision-making, and central coherence, respectively.	performed worse than those with sexual dysfunction and the control group in the set-shifting task, making more perseverative and non-perseverative errors and completing fewer categories. Those with obesity exhibited impaired executive functioning and showed a preference for immediate reward-based decision-making compared to the other groups.
Syan et al. (2019)	To investigate the relationship between neurocognitive performance, neural activation (during a working memory task), and cortical brain morphometry in a sample of young adults with obesity compared to a control group.	The sample consisted of young adults aged 22 to 35 years with obesity (n = 243, body mass index [BMI] ≥ 30 kg/m2), and a control group of individuals with a normal BMI (n = 469, BMI = 18-24.9 kg/m2). The protocol included a battery of neurocognitive behavioral assessments. Neural activity was measured using blood-oxygen-level dependent (BOLD) imaging during an N-Back task with functional magnetic resonance imaging (fMRI). Cortical morphometry encompassed	The obese group demonstrated poorer performance across multiple neurocognitive assessments including the 9-Hole Pegboard task from the National Institutes of Health (NIH) Toolkit, the Penn Working Memory Task, Delay Discounting, Penn Progressive Matrices, NIH Picture Vocabulary Test, Dimensional Change Card Sort Test, and N-Back Working Memory Task conducted in the scanner, compared to the control group. Additionally, the obese group exhibited significantly higher Blood-Oxygen-Level Dependent

Authors	Goal	Method and Country	Findings
		measurements of volume, thickness, and surface area	(BOLD) activation in brain regions associated with the N-Back task, such as the ventromedial prefrontal cortex, posterior cingulate gyrus, and right precentral gyrus, compared to the control group. Significant morphometric differences were found in the medial orbitofrontal cortex, rostral anterior cingulate cortex, inferior and superior parietal gyri, and temporal pole between the obese and control groups.
Sánchez-SanSegundo, et al. (2021)	To investigate the relationship between overweight and obesity and executive function performance in adults.	The sample consisted of 87 Spanish volunteers, including 34 individuals with overweight and 53 with obesity. The participants' ages ranged from 22 to 63 years (M = 47.14 years; SD = 9.22 years). Obesity measures were assessed using adiposity markers (BMI, body fat, and visceral fat), while executive function was evaluated across five domains: cognitive flexibility, inhibition, monitoring, planning, and working memory.	Obese individuals exhibited lower performance on working memory tasks compared to those who were overweight. Additionally, overweight and body fat were negatively correlated with executive functions related to inhibition and monitoring. Within the obesity subgroup, body fat showed a negative association with both inhibition and working memory.

2. Method

This study employs a non-experimental, cross-sectional design to examine the relationship between executive function deficits and affective disturbances in individuals with obesity receiving endocrinological care. This design is appropriate as it allows for the simultaneous assessment of cognitive and emotional profiles, facilitating the identification of associations without experimental manipulation. Given the study's objective of exploring correlations rather than establishing causality, a non-experimental approach is methodologically suitable. Additionally, a cross-sectional design provides an efficient and clinically relevant means of data collection, capturing real-world cognitive and emotional patterns in a population where long-term follow-up may be challenging. By enabling subgroup comparisons based on obesity severity and treatment adherence, this approach offers a nuanced understanding of the variability in executive dysfunction and affective symptoms. While it does not establish causal relationships, the findings will serve as a foundation for future longitudinal and experimental research aimed at elucidating the mechanisms underlying cognitive and emotional impairments in obesity (Hernández Sampieri et al., 2014).

2.1 Sample

A total of 90 patients attended a specialized clinical consultation at an Endocrinology Medical Center in Manizales during 2023 for obesity-related concerns. Patients who met the WHO's diagnostic criteria for obesity and satisfied the study's predefined inclusion criteria were invited to participate. During the medical assessment, the research objectives were explained, and those who provided informed consent were enrolled, ensuring anonymity and confidentiality. The final sample comprised 26 patients who regularly attended the clinic, including 20 men (76.9%) and 6 women (23.1%), all middle-aged adults. Regarding sociodemographic characteristics, 34.6% had technical or technological education, while most were right-handed (88.5%), married (53.8%), and non-smokers (92.3%). None of the participants reported allergies, alcohol abuse, or psychoactive substance use. However, 11 individuals (42.3%) had a diagnosis of hypothyroidism, and 25 (96.2%) did not adhere to their prescribed endocrine treatment plan (see Table 2). Notably, previous research has utilized similar sample sizes to investigate the relationship between obesity and neurocognitive performance. For instance, a recent study examined 175 females, comparing obese individuals to normal-weight controls, and found significant differences in memory, attention, and executive function tasks (Lentoor, 2022). Another study conducted a systematic review analyzing multiple studies on executive function deficits in obese individuals, highlighting the relevance of sample sizes in this research context (Fitzpatrick et al., 2013). These precedents support the adequacy of our sample size.

2.2 Inclusion Criteria

- Adults aged 18 years and older with neurotypical development, as confirmed by their academic and professional history.
- Body mass index (BMI) of 30 or higher (≥ 30).
- Residency in the city of Manizales.
- Attendance at a minimum of four appointments in the endocrinology service.
- Signed informed consent.

2.3 Exclusion Criteria

- Adults with diagnosed psychiatric comorbidity, according to the medical history report.
- Adults who have missed scheduled medical appointments.
- Individuals who do not wish to participate in the research.

2.4 Assessment Tools

2.4.1 Neuropsychological Battery for Executive Functions and Frontal Lobes (BANFE-2)

This battery is designed for evaluating Spanish-speaking populations and includes normative data for subjects aged 6 to 80 years. It encompasses multiple neuropsychological tests with high convergent validity, and its construct validity is well-documented in the literature (García Fernández et al., 2014). The evaluation involves administering 15 tasks, recording 45 indicators (e.g., number of correct responses, number of errors, execution time, percentage of correct responses). These values are converted into normalized scores (mean = 10, SD = 3), enabling the determination of whether an individual's performance is within the normal range or indicative of impairments.

The battery provides four indices by summing the scores, expressed as normalized scores (mean = 100, SD = 15): three indices related to the functioning of prefrontal brain circuits (Orbitomedial Brain Circuit Functioning Index, Anterior Prefrontal Brain Circuit Functioning Index, and Dorsolateral Brain Circuit Functioning Index) and a Global Executive Functioning Index (Flores Lázaro et al., 2014).

2.4.2 Hamilton Anxiety Scale

This 14-item scale is administered through a semi-structured interview to assess the severity of an individual's anxiety. Each item is rated on a scale from zero (0), indicating the absence of symptoms, to four (4), indicating very severe or debilitating symptoms. The total score is calculated by summing the individual scores of the 14 items, resulting in a range from 0 (no

anxiety) to 56 points (sever anxiety). This scale is considered the gold standard for evaluating anxiety and has demonstrated robust psychometric properties in numerous studies (Hamilton, 1959, 1960, 1967; Lobo et al., 2002; Worboys, 2013). This study utilized the standardized Spanish version of the scale (Lobo et al., 2002).

2.4.3 Hamilton Depression Scale

The Hamilton Depression Rating Scale (HDRS), initially developed by Hamilton in 1960, has been validated for Spanish-speaking populations by Ramos-Brieva and Cordero-Villafafila (1988). This scale is intended for use with patients previously diagnosed with depression, aiming to quantitatively assess the severity of depressive symptoms through a clinical interview.

The HDRS exhibits robust psychometric properties, with Cronbach's alpha values for the 17-item version reported at 0.72 (Ramos-Brieva & Cordero-Villafafila, 1988), closely mirroring the original study by Hamilton (1960) which reported a value of 0.77. Subsequent studies have reported higher Cronbach's alpha values, ranging from 0.76 (Rehm & O'Hara, 1985) to 0.90 (Yesavage et al., 1982).

Each item on the scale offers between 3 and 5 possible responses, with scores ranging from 0-2 or 0-4 points, respectively. The total score can therefore range from 0 to 52 and different cutoff points can be employed for analysis according to the Clinical Practice Guidelines by the National Collaborating Centre for Mental Health (NICE) (2005).

2.5 Statistical Analysis Plan

The statistical analysis followed a rigorous descriptive and inferential approach to examine the relationships between executive function deficits and affective disturbances in individuals with obesity. First, BANFE scores were coded and normalized for consistency. Anxiety, depression, total orbitomedial, total anterior prefrontal, total dorsolateral, and total executive function scores were initially treated as quantitative variables and later categorized into qualitative variables based on established norms. Descriptive statistics were used to summarize quantitative variables (mean, standard deviation, minimum, and maximum values), while qualitative variables were reported as frequencies and percentages. The Shapiro-Wilk test (Razali & Wah, 2011) assessed normality, guiding the selection of statistical methods. For bivariate analyses, the chi-square test (Wayne & Cross, 2013) evaluated associations between categorical variables, while Pearson's correlation coefficient was used for normally distributed data and Spearman's correlation coefficient for non-normally distributed data (Wayne & Cross, 2013). All analyses were conducted using Jamovi version 2.4.1, ensuring methodological rigor and reproducibility.

3. Results

3.1 Anxiety and Depression

Analysis of anxiety and depression showed that 13 individuals (50.0%) experienced severe or very severe anxiety, and 10 (38.5%) had moderate anxiety. Only 7 participants (26.9%) were free from depression. Additionally, 50.0% of participants showed severe or mild-to-moderate impairment in the orbitomedial index, 6 individuals (23.1%) in the anterior prefrontal index, nearly all (25 participants, 96.2%) in the dorsolateral index, and 24 participants (92.3%) in the total executive functions score (see Table 2).

3.2 Demographic and Clinical Characteristics

The average age of the participants was 41.3 years (SD = 13.0 years). They had an average weight of 89.7 kilograms (SD = 10.8 kg), a height of 1.6 meters (SD = 0.07 m), and a mean BMI of 35.3 kg/m² (SD = 3.97 kg/m²), as detailed in Table 3.

This version emphasizes clarity and adheres to academic conventions, including the proper presentation of statistical data and findings.

Table 2. Frequencies and Percentages of Evaluated Variables

Variable	Category	Frequency	Percentage
Sex	Male	20	76.9 %
	Female	6	23.1 %
Education	Graduate School	3	11.5 %
	Undergraduate	4	15.4 %
	Elementary School	6	23.1 %
	High School	4	15.4 %
	Technical Education	9	34.6 %
Laterality	Right	23	88.5 %
	Left	3	11.5 %
Marital Status	Married	14	53.8 %
	Divorced	2	7.7 %
	Single	6	23.1 %
	Cohabiting Couple	4	15.4 %
Tobacco Use	No	24	92.3 %
	Yes	1	3.8 %
	Did not answer	1	3.8 %
Alcohol use disorder	No	26	100.0 %
Allergies	No	26	100.0 %

Variable	Category	Frequency	Percentage
Hypothyroidism	No	15	57.7 %
	Sí	11	42.3 %
Adherence to treatment	No	25	96.2 %
	Yes	1	3.8 %
Psychoactive Substances	No	26	100.0 %
Socioeconomic status	1	2	7.7 %
	2	8	30.8 %
	3	10	38.5 %
	4	4	15.4 %
	5	1	3.8 %
	6	1	3.8 %
Anxiety	Mild	3	11.5 %
	Moderate	10	38.5 %
	Severe	13	50.0 %
Depression	Non-depressed	7	26.9 %
	Mild	6	23.1 %
	Moderate	6	23.1 %
	Severe	5	19.2 %
	Extreme	2	7.7 %
Orbitomedial Prefrontal Cortex (Score)	Severe deficit	10	38.5 %
	Moderate Deficit	3	11.5 %
	Normal	13	50.0 %
Anterior Prefrontal cortex (Score)	Normal	18	69.2 %
	Superior Performance	2	7.7 %
	Moderate deficit	4	15.4 %
	Severe deficit	2	7.7 %
Dorsolateral Prefrontal Cortex (Score)	Severe deficit	19	73.1 %
	Moderate deficit	6	23.1 %
	Normal	1	3.8 %
Total Score Executive Functions	Severe deficit	20	76.9 %
	Normal	2	7.7 %
	Moderate deficit	4	15.4 %

Table 3. Statistical Measures Used in the Study

St. measure	Variable			
	Age	**Weight**	**Height**	**BMI**
Mean	41.3	89.7	1.60	35.3
Median	38.5	90.0	1.59	35.0
Standard Deviation	13.0	10.8	0.0675	3.97
Mínimum	21.0	72.0	1.45	24.0
Maximum	78.0	108.0	1.79	42.0

When performing the chi-square test between variables (see Table 4), the following results were observed:

- Men were more likely to experience moderate, severe, or very severe anxiety, whereas women were more likely to experience mild anxiety.
- Men exhibited symptoms of various forms of depression, while women did not show indicators of depression.
- Non-adherence to treatment was associated with a higher likelihood of experiencing some form of anxiety.

Table 4. Test of Independence Between Qualitative Variables

Cross-Tabulated Variables	**p-value**	**Conclussion**
Sex vs. Anxiety	0.003	Men tended to exhibit moderate, severe, or very severe anxiety, while women were more likely to experience mild anxiety.
Sex vs. Depression	0.01	Men were more likely to experience various forms of depression, while women generally did not exhibit signs of depression.
Tobacco use vs. DLPC	<0.001	Individuals who did not smoke tended to show severe impairment in the dorsolateral index.
Tobacco use vs. Executive Functions	0.013	Individuals who did not smoke were more likely to exhibit severe impairments in the overall executive function score.
Adherence to treatment vs. Anxiety	0.019	Individuals who did not adhere to the treatment were more likely to exhibit some form of anxiety.

The normality test (Table 5) determined the appropriate type of correlation to apply in the correlation matrix (Table 6). The findings were as follows:

- Greater levels of anxiety are associated with higher levels of depression and increased scores in the anterior prefrontal region.
- Higher levels of depression are associated with increased scores in the anterior prefrontal region.
- Increased scores in the orbitomedial region are correlated with higher total executive function scores.
- Increased scores in the dorsolateral region are correlated with higher total executive function scores.

Table 5. Shapiro-Wilk Normality Test

Variable	**p-value**
Age	0.214
Weight	0.343
Height	0.318
BMI	0.179
Total	0.700
Total Score depression	0.327
Total Score orbitomedial region	**0.001**
Total Score prefrontal anterior region	0.129
Total dorsolateral region	**0.001**
Total score executive functions	**< 0.001**

Table 6. Spearman correlation Matrix

Variable	**Correlation p-value**	**Age**	**Weight**	**Height**	**BMI**	**Total anxiety**	**Total depression**	**Total orbitomedial**	**Total prefrontal anterior**	**Total dorsolateral**
Weight	Rho de Spearman	-0.294								
	Valor p	0.145								
Height	Rho de Spearman	-0.083	0.401							
	Valor p	0.688	**0.042**							

Variable	Correlation p-value	Age	Weight	Height	BMI	Total anxiety	Total depression	Total orbitomedial	Total prefrontal anterior	Total dorsolateral
BMI	Rho de Spearman	0.024	0.537	-0.217						
	Valor p	0.908	**0.005**	0.286						
Total anxiety	Rho de Spearman	-0.166	0.158	-0.442	0.399					
	Valor p	0.418	0.44	**0.024**	**0.044**					
Total depression	Rho de Spearman	-0.148	-0.146	-0.553	0.242	0.83				
	Valor p	0.471	0.475	**0.003**	0.234	**<0.001**				
Total orbitomedial	Rho de Spearman	-0.364	0.373	0.066	0.107	0.066	-0.037			
	Valor p	0.067	0.061	0.748	0.603	0.749	0.858			
Total prefrontal anterior	Rho de Spearman	0.167	-0.111	-0.36	0.446	0.624	0.508	-0.043		
	Valor p	0.416	0.59	0.071	**0.022**	**<0.001**	**0.008**	0.834		
Total dorsolateral	Rho de Spearman	0.612	-0.202	-0.147	0.041	-0.101	-0.098	0.126	0.105	
	Valor p	**<0.001**	0.322	0.474	0.843	0.622	0.633	0.539	0.61	
Total score executive functions	Rho de Spearman	0.344	-0.045	-0.225	0.013	0.056	0.04	0.494	0.086	0.836
	Valor p	0.085	0.828	0.268	0.948	0.787	0.845	**0.01**	0.677	**<0.001**

4. Discussion

Executive functions are crucial for regulating and verifying the most complex forms of human behavior. They encompass essential functions such as emotional regulation, abstract thinking, social behavior, and metacognition (Flores Lázaro et al., 2014). In the context of obesity, inhibitory control (IC) plays a predominant role in curbing impulses and regulating behavior. The importance of metacognitive function in monitoring and controlling one's cognitive processes has also been highlighted (Rodrigue et al., 2018). It is posited that deficits in cognitive control contribute to the maintenance of obesity (Cunningham et al., 2024; Kollei et al., 2018).

The results of this study indicated severe and moderate impairment in 50% of patients concerning inhibitory control and emotional regulation, which are key functions of the orbitomedial cortex. Inhibitory control is responsible for monitoring and directing attention,

behavior, thoughts, and emotions to override interfering or predominant responses, both internally and externally (Koay & Van Meter, 20233). Therefore, failures in IC denote significant issues that may manifest in behaviors such as disordered consumption of high-calorie foods, chaotic habits, and increased vulnerability in managing daily events, particularly those with a high emotional load.

Scientific literature indicates that individuals with eating behavior problems, such as obesity, are not necessarily associated with experiencing negative emotions themselves but rather with a lack of adaptive strategies to regulate negative affect (Dingemans et al., 2017). An important observation in this study was that 96.2% of cases exhibited significant impairments in cognitive flexibility, self-monitoring, metacognition, and planning, corresponding to dorsolateral cortex functioning. These domains are crucial for acquiring new habits, detecting problems to solve, self-evaluation, and the motivation to achieve medium- and long-term goals, postponing immediate gratification regarding food.

Allom and colleagues' (2018) study highlights that the main factors contributing to obesity are unhealthy eating and sedentary behavior, which are difficult to change in the long term. Cognitive flexibility is essential for individuals with obesity to interrupt unhealthy habits and adopt new behaviors aligned with weight loss goals.

Literature reviews, such as the one by Smith, Mason, Johnson, Lavender and Wonderlich (2018), suggest that there are generally variable patterns of neurocognitive deficits in different eating disorders, with limitations regarding the lack of prospective designs and insufficient data to associate neurocognition with other relevant behavioral constructs. Generally, it is considered that the anatomical-functional correlates of the Orbitofrontal and Dorsolateral brain circuits are mainly associated with behavioral self-control. The lateral prefrontal region provides the cognitive basis for different behavior patterns, orientation, and reasoning. Additionally, this region aids in planning, organizing daily routines, and task-shifting.

The results contrast with the finding that 70% of patients performed normally in meta-memory, attention, abstract comprehension, and figurative understanding, corresponding to anterior prefrontal lobe structures. This suggests that three-quarters of the patients studied can understand and judge their behaviors, but such knowledge seems insufficient for improving habits, given the significant role of emotional control and impulse inhibition.

In a study of the cognitive profile of obese patients with food addiction, significant correlations were found between depressive and anxiety symptoms and metacognitive difficulties. These patients showed lower scores in inhibition/cognitive flexibility and had significant difficulties learning from past mistakes, which could maintain unhealthy habits (Rodrigue et al., 2018).

These findings are intriguing considering studies such as Cai and Bidulescu's (2023), which confirmed through brain imaging that visual and verbal cues associated with high-sugar foods and beverages elicit greater preferences and emotional activation. This makes it harder for overweight individuals to abstain from or resist unhealthy foods.

This study found an association between obesity and the occurrence of anxiety and depression in half of the cases, aligning with the emotional regulation difficulties observed in most subjects. Higher anxiety and depression levels were associated with lower performance in meta-memory, attention, abstract comprehension, and figurative understanding, corresponding to anterior prefrontal lobe structures. This may significantly contribute to cognitive distortions, coping styles, and cognitive processing characteristic of patients with these pathologies. These results are consistent with Da Luz et al.'s (2017) findings that dysfunctional cognitions can be associated with unhealthy eating behaviors in obese individuals. However, such dysfunctional cognitions are more commonly associated with mental health difficulties than with the patients' weight alone.

A recent study corroborates the bidirectional relationship between depression, anxiety, and obesity issues (Cai & Bidulescu, 2023). It also highlights the possible link between obesity and depression through various neuroimmunoendocrine pathways, such as immune-inflammatory activation, gut microbiota, neuroplasticity, dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, and neuroendocrine regulators of energy metabolism, including adipocytokines and lipokines (Milaneschi et al., 2019).

Regarding gender differences, although the sample was not balanced in terms of the number of men and women, given that it was a convenience sample with a higher representation of men, the findings showed that men tended to exhibit higher levels of anxiety and depression than women included in the study. Likewise, individuals who did not adhere to the treatment, mostly women, exhibited higher anxiety levels. These results align with a study indicating that emotional regulation deficits and negative emotions predispose to emotional eating, or compensatory eating as stress relief. Overeating is associated with body weight complications and eating disorders. Although this behavior appears present in both sexes, individuals with greater difficulty understanding and managing emotions seem more likely to engage in this behavior as a stress-coping mechanism (Dakanalis et al., 2023).

Regarding obesity's metabolic comorbidities, they are extensive and diverse. For example, various studies demonstrate a higher association with metabolic syndrome (visceral over adiposity, hypertension, dyslipidemia, dysglycemia) and hypothyroidism in different degrees. In the latter case, increased body fat is associated with increased thyroid echogenicity (ultrasound finding) and reduced expression of the TSH receptor (thyroid-stimulating hormone) in thyroid

cells, as well as altered deiodinase function in the adipose tissue of obese patients. This leads to reduced production and tissue activation of thyroid hormones, contributing to decreased body energy expenditure and increased fat deposition, among other effects (Biondi, 2023). Therefore, in this study's first phase, more than half of the cases (57.7%) presented with primary hypothyroidism.

5. Study Limitations and Future Research Directions

This study has several limitations that should be acknowledged. The small sample size, due to the limited number of patients who completed all assessments, may restrict the generalizability of the findings. Additionally, the underreporting of comorbidities commonly associated with obesity may have influenced the accuracy of the results. Furthermore, the cross-sectional design prevents the establishment of causal relationships, limiting conclusions about the directionality of the observed associations. However, this study provides a critical foundation for future research, particularly longitudinal studies that examine the impact of medical and psychotherapeutic interventions on executive function and affective regulation in individuals with obesity. Future studies should aim to control for and enhance cognitive domains linked to maladaptive behaviors, as addressing executive dysfunction may improve both treatment adherence and emotional well-being. Despite these constraints, the present findings offer valuable empirical evidence on the interplay between obesity, executive dysfunction, anxiety, and depression, contributing to the development of targeted intervention strategies for this population.

6. Conclusions

Obesity is highly comorbid with issues related to impulse control and self-regulation, which stem from deficiencies in inhibitory control, emotional regulation, metacognition, self-monitoring, and decision-making necessary for acquiring new habits and behaviors. These deficiencies hinder the development of healthy habits that are essential for achieving weight loss goals. Additionally, the study found that anxiety and depression occurred in half of the cases.

Various regions of the frontal cortex, which are responsible for executive functions, are linked with problematic behaviors in individuals with obesity. Identifying failures in the subcomponents of these executive functions can enhance our understanding of the underlying mechanisms contributing to the development and/or maintenance of psychiatric disorders, disordered behaviors, and associated symptoms.

This study highlights the intricate relationship between executive dysfunction, affective disturbances, and obesity, underscoring the need for targeted, evidence-based interventions in clinical practice. The significant impairments observed in inhibitory control, cognitive flexibility,

and self-monitoring suggest that deficits in executive function may contribute to poor self-regulation, disordered eating behaviors, and treatment non-adherence (Pace & Muzi, 2019). To address these challenges, cognitive remediation strategies, including executive function training and digital interventions, have shown promise in enhancing self-regulatory capacities and improving long-term weight management (Biolcati et al., 2021). Given the complexity of obesity and its neuropsychological underpinnings, a multidisciplinary, personalized treatment approach that integrates behavioral, cognitive, and pharmacological interventions is warranted. Future research should prioritize longitudinal studies to establish causal mechanisms and evaluate the sustained efficacy of interventions that target executive function deficits and emotional dysregulation (Iasonidou et al., 2023). Incorporating executive function rehabilitation and psychological support into standard obesity care may enhance treatment adherence and clinical outcomes, offering a more comprehensive framework for managing this multifaceted condition.

Ethical approval

The study was performed with human subjects in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments and the study procedure was approved by the ethics committee of the Universidad de Manizales

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any potential conflict of interest.

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Author Contributions

DL: Conceptualization, methodology, investigation, writing original draft, project administration. DM: conceptualization, resources, writing – review and editing, supervision. SRPM: Validation, resources, writing – review and editing. DAPM: Methodology, software, formal analysis, data curation.

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