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Obesity, metabolic profile, and inhibition failure: Young women under scrutiny

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HIGHLIGHTS

- We found a deficiency in inhibition in obese young women versus healthy controls.
- Inhibition impairment could be clearly connected with the development of obesity.
- Glucose/lipid metabolism could be related to this cognitive impairment.

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ABSTRACT

Background: The prevalence of obesity, as well as evidence about this pathology as a risk factor for cognitive decline and dementia in the elderly, is increasing worldwide. Executive functions have been found to be compromised in most studies, although the specific results are dissimilar. Obese young women constitute an interesting study and intervention group, having been found to be unaffected by age and hormonal negative effects on cognition and considering that their health problems affect not only themselves but their families and offspring. The objective of the present study was to compare the executive performance of obese young women with that of a healthy control group. Methods: A cross-sectional study was done among premenopausal women from a public hospital in Buenos Aires. The sample comprised 113 participants (32 healthy controls and 81 obese women), who were evaluated for depressive and anxiety symptoms (Beck Depression Inventory-II and State-Trait Anxiety Inventory) and executive functioning (Trail-Making Test B, Stroop Color and Word Test, Wisconsin Card Sorting Test, and verbal fluency test). Statistical analysis was done by using the SPSS version 20.0 software. Results: Among executive functions, a significant difference was found between groups in inhibition ($p < 0.01$). No correlation was found between psychopathologic measures and Stroop Test Interference results. We found slight correlations between Stroop Test Interference results, waist circumference, fat mass and HDL-cholesterol. In obese group, there was a negative slightly correlation between this cognitive test and 2 h post-load glucose level. Conclusions: Inhibition was decreased in our obese young women group, and glucose/lipid metabolism may be involved in this association. The cognitive impairment is comparable with that described in addictive conditions. Our conclusions support the concept of multidisciplinary management of obese patients from the time of diagnosis. Detecting and understanding cognitive dysfunction in this population is essential to providing appropriate treatment.

1. Introduction

The global obesity epidemic is a cardinal public health problem affecting the patient as a whole (physically, socially, and mentally). The height and weight of the population have been increasing since the 18th century as education and living conditions gradually improved over time. Besides, the increased availability of high-energy density food, consumption of soft drinks, reduced energy expenditures, and marketing techniques designed to seduce and induce consumption have contributed to what some researchers call an "obesogenic" environment [1]. Although weight gain was considered to be beneficial decades ago, today we know that being overweight is dangerous. Severely obese people have been found to die sooner than normal-weight individuals, similarly to smokers and nonsmokers, respectively [2]. Obesity is responsible

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for an estimated 1% to 3% of the total health expenditure in most countries (5% to 10% in the United States), and this cost is predicted to increase rapidly in next years as obesity-related diseases set in [2]. Obesity is classically associated with cardiovascular risk factors, such as diabetes mellitus type 2 (TD2M), hypertension, and dyslipidemia. However, with the increasing medical knowledge on obesity, other associated health problems have become more evident, such as cancer and long-term risk of dementia [3, 4]. Some studies have shown that an elevated body mass index (BMI) is an independent risk factor for cognitive decline, including Alzheimer's disease [5, 6]. Over the past years, there has been increasing evidence that cognitive function (particularly executive functions) may be compromised in the short term in people with an elevated BMI [6–8]; however, the research results are not conclusive. The divergent findings may be attributable to differences in the sample size, age at assessment, inclusion and exclusion criteria of participants, and methods used to assess cognitive status [9].

Most studies are based on the assumption that obesity generates cognitive changes. Accordingly, cognitive impairment may result from known modifiable vascular and lifestyle-related factors, particularly hypertension and lipid parameters, higher levels of reactive oxygen species in the brain, and hormonal changes associated with obesity [10–12]. In fact, insulin resistance has been associated with deficits in memory, executive function, processing speed, verbal fluency, and overall cognitive function [13–15]. Nonetheless, association does not indicate causality, and we can speculate that the relationship may be the opposite: people with lower cognitive performance are at increased risk of developing obesity.

Executive functions are higher order neurocognitive processes that enable individuals to initiate and arrest actions, inhibit and modify behaviors when necessary, and adapt to environmental changes. They are critical for overriding default actions and maintaining goal-directed behavior (for example sustaining the recommended weight or maintaining a calorie restrictive diet). Inhibition of automatic responses, impulsivity and strategic planning—involved in successful self-regulation—are some of these executive functions proposed as related with the vulnerability to obesity [16]).

Considering that young people have been less exposed to the above-mentioned cognitive risk factors, young women constitute a remarkable study and intervention group. First, because the conditions or events that occur or develop during the reproductive life may have consequences not only on their physical and mental health but also on their reproductive capacity, social functioning, quality of life, and offspring. Second, because this group may be more uniform in terms of age and hormonal status (steroids) that could influence cognitive performance. Focusing on this population and helping them to acquire healthy lifestyles will bring major health benefits later in life, particularly lower mortality and disability from cardiovascular diseases, cerebrovascular diseases, and cancer.

Therefore, we speculated whether there are differences in cognition between obese young women and healthy controls and whether metabolic status is associated with the results. Our hypothesis was that, compared with their peers of normal weight, obese but otherwise healthy young women would have worse performances in tests that evaluate executive functions and that the results would be associated with clinical and biochemical variables. To test our hypothesis, we carried out a cross-sectional study among young women (18–45 years old) who visit a public hospital in the city of Buenos Aires, Argentina. Our first objective was to evaluate the executive performance of obese young women and compare it with that of a healthy control group. We further examined differences in the clinical and biochemical variables and looked for correlations between these variables and cognitive functioning.

2. Subjects and methods

2.1. Patients

All participants were informed about the research procedures and gave their written informed consent to take part in the study. The procedures were approved by the Ethics Committee of Hospital Dr. A. Zubizarreta. The study was carried out at the Assistance and Research Center in Cognitive Neuroscience and Memory Disorders at Hospital Dr. A. Zubizarreta, Buenos Aires, Argentina. Enrolment into the study was done between June 2013 and December 2014. The total sample comprised 115 participants [32 healthy controls (HC) and 83 obese subjects (OB)]. All participants were female, between 18 and 45 years old, and spoke Spanish as their first language. The exclusion criteria in both groups (HC and OB) included: (1) history of chronic medical illness or neurologic condition that might affect cognitive function (rheumatologic disease, HIV infection, liver or kidney insufficiency, T2DM, or known cardiovascular disease), (2) head trauma with loss of consciousness, (3) use of psychoactive medications or drugs, (4) <7 years of education, (5) glucocorticoid chronic treatment or glucocorticoid use 3 months before enrolment, (6) insulin sensitizer administration, and (7) pregnancy or breast-feeding. Healthy controls and obese women were recruited from several sources, including by word of mouth and advertisements in the hospital. Before the assessment, the HC group was asked about lifetime or current presence of an eating disorder or obesity. Comprehensive neurocognitive assessment, as well as psychopathologic, clinical, and biochemical evaluation, was done in all patients.

2.2. Cognitive evaluation

The neuropsychological tests selected are part of a more comprehensive neuropsychological evaluation. The tests were given by a trained psychologist and a trained physician in two consecutive sessions. Patients completed tests in a paper/pencil version, except for Wisconsin Card Sort Test which was given in a computerized version. We chose tests that evaluate some components of executive functions, including response inhibition, strategic planning, and cognitive flexibility. All participants were evaluated with the following neuropsychological tests:

(a) General cognitive ability
- *Mini-Mental State Examination* (*MMSE*) [17, 18]: This is a brief test consisting of a 30-point questionnaire that is widely used to screen for cognitive impairment. It evaluates the following cognitive areas: spatial temporal orientation (10 points), registration (3 points), attention and calculation (5 points), recall (3 points), language (8 points), and visual construction (1 point). Higher scores indicate better performance.
- *Word Accentuation Test* [19]: This test consists of a card with 50 words of low frequency of use. The participant is asked to read the words aloud without regard to their meaning. Each word read correctly with the grapheme-phoneme transcription and correct accentuation is scored 1; the maximum score is 50.

(b) Executive functions
- Verbal fluency (VF) [20] (mental flexibility). The participant is instructed to say as many words as possible from a phonemic category (for example, words that begin with the letter P) in 60 s. The score is the number of correct words said.
- *Wisconsin Card Sorting Test* (*WCST*) [21] (strategic planning, organized searching, using environmental feedback to shift cognitive sets, directing behavior toward achieving a goal, and modulating impulsive responding). Some stimulus cards are presented to the participant, who is instructed to match the cards but not how to match them; the participant is then told whether a particular match is right or wrong. The WCST evaluates the correct responses, number of errors, categories completed, and trials to complete first categories.
- *Stroop Color and Word Test* (*SCWT*) *Interference* [22] (cognitive flexibility, reaction to cognitive pressures, selective attention, processing speed, and inhibition of automatic responses). A positive score in this test indicates that the participant has

adequately inhibited automatic responses; a negative score means the participant has worse inhibition than expected.
- *Trail-Making Test B* (*TMT-B*) [23] (impulsivity, visual attention, and motor speed). The score in this test indicates how much time it took the participant to complete the directions. A longer time indicates worse performance.

2.3. Psychopathologic measures

All participants were evaluated with the following instruments:

- *Beck Depression Inventory-II* (*BDI-II*) [24]: This is a 21-question multiple-choice self-report inventory for assessing the existence and severity of symptoms of depression.
- *State-Trait Anxiety Inventory* (*STAI*) [25]: This is a 40-item measure that indicates the intensity of feelings of anxiety. It distinguishes between state of anxiety (i.e., a temporary condition experienced in specific situations) and trait anxiety (i.e., a general tendency to perceive situations as threatening).

2.4. Clinical and laboratory assessments

The weight, height, BMI (weight/height^2, kg/m^2), blood pressure (BP; mm Hg), waist circumference (WC; cm), hip circumference (HipC; cm), and fat mass percentage of all subjects were determined on the day of consultation. WC was measured at exactly half the distance between the lower costal margin and the iliac crest. The blood pressure was taken twice, in sitting position, on the first day of the study evaluation, and the systolic and diastolic blood pressure values used were the averages of those two measurements. The fat mass percentage (FMP) was estimated by using a bioimpedanciometer from OMRON®. Baseline blood samples were collected after a 12-h fast in the early follicular phase or amenorrhea; all biochemical measurements were centralized at a single laboratory. The levels of blood glucose, liver enzymes, LDL-cholesterol, triglycerides, and HDL-cholesterol (HDL-c) were measured by using standard automated kinetic enzymatic assays (Vitros 250 chemistry analyzer; Johnson & Johnson). The OB group also underwent a 2 h 75 g glucose tolerance test (OGTT). The levels of fasting serum insulin and thyrotropin (TSH) (Access® 2 immunoassay; Beckman Coulter) were also determined. A kinetic nephelometric assay was used to measure the level of ultra-sensitive *C*-reactive protein (us-CRP).

The MetS definition proposed by the National Cholesterol Education Program Adult Treatment Panel (ATPIII) was used [26]. Insulin resistance was determined based on the homeostasis model assessment of insulin resistance (HOMA-IR) [27], which was computed by multiplying the fasting insulin (mUI/l) by the fasting glucose (mmol/L) divided by 22.5 [28]. We also calculated the weight-to-height ratio (WHtR) [29] as an indicator of abdominal fat (>0.5 indicating abdominal obesity) and the TG/HDL-C ratio (THR) [30] to provide a simple approach to identifying individuals at increased cardiometabolic risk.

2.5. Statistical analysis

Statistical analysis was done by using the SPSS version 20.0 software. Normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) were performed and most of the variables didn't follow a normal distribution. Therefore, continuous variables were summarized as median values (quartiles 25–75), and nonparametric tests were applied for comparisons. Categorical variables were summarized as frequencies and percentages. The correlation coefficient used was Spearman's rho; statistical significance was set at $p < 0.05$. Linear regression analysis was performed for variables with statistically significant correlation.

3. Results

3.1. Demographic, clinical, and biochemical characteristics

Table 1 shows the demographic and clinical characteristics of the participants. Our sample consisted of 115 women. Two patients in the OB group were diagnosed with T2DM (fasting glucose >126 mg/dl twice); they were eliminated from the study and referred to a specialist. Thus, the analysis included 113 patients: 81 obese women and 32 HC. The groups did not differ significantly in either age or educational level.

Unsurprisingly, the women in the OB group had significantly larger WC, HipC, BMI, fat mass percentage, systolic BP, and diastolic BP measurements. Seven participants (8.5% of the OB group) were taking antihypertensive medication. As expected, the WHtR was significantly different between groups ($p < 0.001$), although the median in HC was >0.5 in both groups. Among the OB women, 67.2% had metabolic syndrome.

Also as expected, the women in the OB group had significantly higher degrees of IR, as measured by the HOMA-IR ($p < 0.01$), higher levels of THR ($p = 0.001$), and a worse lipid profile than the HC. The obese women also had significant elevations in a plasma acute phase reactant marker of inflammation (us-CRP) ($p < 0.001$) (Table 2). The endocrine evaluation yielded significantly different fasting serum insulin concentrations, but no differences in TSH were found between groups.

3.2. Cognitive performance and neuropsychiatric symptoms

Among the executive functions evaluated, we found significant differences between groups in the SCWT Interference ($p < 0.01$) (Table 3). As reported elsewhere [31, 32], the psychopathologic measures showed higher scores in the OB group (BDI-II, $p < 0.05$; state anxiety, $p < 0.01$; trait anxiety, $p < 0.05$) (Table 4). Considering that depression and other neuropsychiatric symptoms could be associated with inhibition and attention failure, we analyzed correlations between the SCWT Interference and the BDI-II and STAI results; no significant correlations were found. Therefore, we assumed that the psychopathologic evaluation did not influence the SCWT results.

3.3. Cognitive performance and biochemical and clinical variables

In view of the differences in cognitive evaluation, we looked for correlations between the SCWT Interference and biochemical and clinical variables reflecting the metabolic status, in the whole sample. We detected a significant negative correlation between SCWT Interference and WC (rho = −0.282; $p < 0.01$) and also with FMP (rho = −0.295; $p = 0.005$; Fig. 1). Regarding biochemical variables, there was a positive correlation between SCWT Interference and HDL-c (rho = 0.244; $p < 0.05$).

In addition, among obese women, we detected a significant negative correlation between SCWT Interference and the 2 h post-load glucose (rho = −0.314; $p < 0.05$) (Fig. 2). We have also performed a linear regression analysis between these variables and we found significant results ($R^2 = 0.07$; Beta −0.085; $p = 0.04$). No significant correlation was found - among OB patients - between Stroop Test Interference and BMI (rho = −1.181; $p = 0.13$) neither age (rho = −0.23; $p = 0.06$).

Despite that in this study both groups - obese and normal-weight women - didn't differ in terms of age, we looked for it as a potential confounding factor on cognitive function. We performed a multiple logistic regression to calculate the odds ratio (OR) of being obese in relation to SCWT interference. We included age and SCWT interference as covariates. In this model, SCWT interference OR for obesity was 0.89 (95% CI: 0.808–0.979, $p = 0.017$), suggesting a slight protective effect and age didn't result in a confounding factor (OR 1.02, 95% CI: 0.952–1.092, $p = 0.58$).

Table 1
Demographic and medical characteristics.

	Obese group Median (P25–P75)	Healthy control group Median (P25–P75)	Mann-Whitney *U* test
Age (years)	30.00 (25.5–38)	26.50 (21–34,75)	996.0
Education level (years)	12.00 (9–12.5)	12.00 (7.5–12)	1170.0
BMI (kg/m^2)	35.81 (33.45–40.34)	22.56 (20.21–23.75)	0.0***
WC (cm)	111.00 (104–121)	82.00 (74–86.25)	6.0***
HipC (cm)	120.00 (113.88–125.25)	94.00 (87.5–96)	6.0***
Systolic BP (mm Hg)	123.00 (110–140)	110.00 (98–110)	312.0***
Diastolic BP (mm Hg)	80.00 (70–90)	60.00 (60–70)	267.0***
Fat mass %	40.00 (37.78–43.73)	24.20 (19.6–29.65)	0.0***
WHtR	0.69 (0.65–0.75)	0.51 (0.47–0.54)	16.0***

BMI, body mass index; WC, waist circumference; HipC, hip circumference; BP, blood pressure; WHtR, waist-to-height ratio.
*** $p < 0.001$.

Finally, we looked for differences between obese women with and without metabolic syndrome, considering that cardiovascular risk factors may be involved in cognitive decline. However, we found no significant differences in the test scores between the groups.

4. Discussion

Accumulating evidence suggests that cognitive dysfunction, particularly executive dysfunction, is related to extreme weight conditions [8, 33]. Our objective was to evaluate the executive performance of obese young women and compare it with that of a healthy control group. We also studied differences in clinical and biochemical variables and looked for correlations between these and cognitive functioning.

In comparison with other investigations, our study has some particular features and advantages in testing our hypothesis. First, considering that the existence of differences in oxidative stress, brain structure, and functioning between men and women has been previously reported [34, 35], limiting our sample to young women eliminated any possible gender-related bias. Second, T2DM patients were excluded from our analysis, making the obese group more homogeneous. Third, our sample of nonpregnant reproductive-age women (18–45 years old) diminished age, metabolic, and hormonal mechanisms that may be involved in cognitive decline [12, 14, 36–38]. Additionally, we included a control group from the same center and the same period. Finally, the present work included a more in-depth evaluation of executive outcomes, as well as a more detailed clinical and biochemical assessment, compared with other studies [6, 8].

Two major findings were observed in this study. First, in our group of obese young women of reproductive age without comorbidities we have detected decreased inhibition compared with healthy controls. Second, we have found biochemical and clinical variables (glucose metabolism abnormalities, HDL-c, WC and FMP) that may be associated with this result.

Inhibitory control involves being able to control one's attention, behavior, thoughts, or emotions to dominate a strong internal predisposition and instead execute what is more appropriate or necessary. Without inhibitory control, people would be at the mercy of old habits of thought or action, impulses, and/or external stimuli that pull them this way or that [39]. In adults, this executive function of inhibition may be assessed by using the SCWT. Our results showed a deficiency in inhibition in obese young women versus a healthy control group, measured by SCWT. Several studies have evaluated cognition performance in obese and/or diabetic patients. However, most of these works focused on either adolescents or middle-aged adults, and the majority described cognitive outcomes or metabolic variables but not both. Fergenbaum et al. [40], in a study in a Canadian First Nations population, chose the clock-drawing test for a general evaluation of cognitive performance and the Trail-Making Tests A and B for an assessment of executive functions. They concluded that obese patients had lowered cognitive performance of an executive origin. Fagundo et al. [8] found that obese adolescents have dysfunctional executive profiles, which may play a role in the development and maintenance of the disorder. In a study among healthy adults (20–89 years old), Gunstad et al. [6] concluded that obese adults had poorer performances in executive function tests compared with normal-weight adults and that BMI was inversely related to performance in all cognitive tests. Sims et al. [41] designed a study to assess the inhibition of executive processes, set-shifting, and negative eating behaviors in severely obese African-Americans. They found reduced inhibition (assessed by SCWT) in that obese population.

In the present study, we found a negative correlation between the 2 h post-load glucose and the SCWT Interference scores in obese group. Therefore, we propose that a glucose metabolism disorder may

Table 2
Biochemical assessment.

	Obese group Median (P25–P75)	Healthy control group Median (P25–P75)	Mann-Whitney *U* test
Fasting serum insulin (IU/ml)	11.50 (5.76–17.73)	6.85 (3.94–9.02)	240.0**
Fasting serum glucose (mg/dl)	96.10 (91.33–103.48)	90.00 (83.65–95.05)	178.5**
2 h post-load glucose (mg/dl)	109.10 (101.10–119.10)	–	–
HbA1c%	5.60 (5.20–6.05)	5.30 (4.80–5.40)	103.0*
HDL-c (mg/dl)	42.40 (36.10–49.10)	50.70 (44.78–58.15)	267.0***
LDL-c (mg/dl)	104.54 (74.32–121.15)	85.55 (77.00–114.85)	431.0
Triglycerides (mg/dl)	156.35 (93.93–197.63)	98.70 (72.88–142.88)	334.5**
TSH (μIU/ml)	1.82 (0.99–2.31)	1.28 (0.94–1.84)	468.0
us-CRP (mg/dl)	0.55 (0.41–0.91)	0.28 (0.16–0.39)	89.0***
HOMA-IR	2.48 (1.19–4.40)	1.49 (0.81–1.99)	179.0**
THR	3.71 (2.38–4.72)	1.92 (1.29–3.36)	271.0***

HbA1c, glycated hemoglobin; HDL-c, HDL-cholesterol; LDL-c, LDL-cholesterol; TSH, thyrotropin; us-CRP, ultrasensitive C-reactive protein; HOMA-IR, homeostasis model assessment insulin resistance; THR, triglycerides/HDL ratio.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 3
Neurocognitive performance.

	Obese group Median (P25–P75)	Healthy control group Median (P25–P75)	Mann-Whitney *U* test
MMSE	28 (27–29)	29 (27.5–29)	609.0
WAT-50	31 (23.75–36)	26 (23.25–32.75)	518.0
Verbal fluency	11 (8.5–14)	10 (8–13.50)	454.5
TMT-B	90 (70–107.5)	96 (69.25–114.25)	491.5
SCWT interference	−1.63 (−5.8–2.18)	1.85 (0.62–4.96)	379.0**
WCST complete categories	4 (2–7)	6 (3–8)	375.5
Total correct WCST	84 (64–93)	92 (72–98)	351.0
% correct WCST	65.62 (50.78–74.21)	71.87 (56.25–76.56)	376.0
Failed WCST	44 (35–64)	36 (30–56)	363.0
% failed WCST	34.37 (25.78–49.21)	28.12 (23.43–43.75)	374.0

MMSE, Mini-Mental State Examination; WAT-50, Word Accentuation Test; TMT-B, Trail-Making Test B; SCWT, Stroop Color and Word Test; WCST, Wisconsin Card Sorting Test.
** $p < 0.01$.

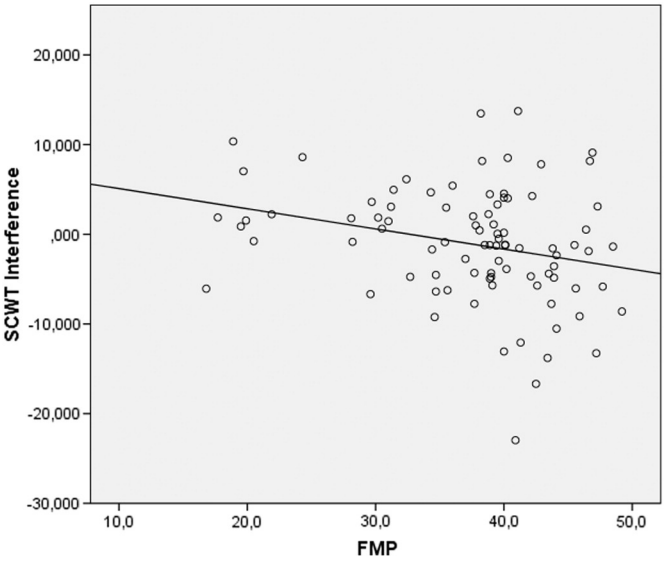

Fig. 1. Scatterplot: Stroop Interference and FMP.

be involved in the inhibition's test performance. Some evidence from the literature has linked glucose metabolism disorders to cognitive dysfunction [14]. Yesavage et al. [42] studied the associations between cognition, hypertension, T2DM, sleep-disordered breathing, and obesity; they found that worse executive functions and auditory verbal memory were linked to diabetes and other cardiovascular risk factors in men but not directly to obesity. Recently, Kesse-Guyot et al. [43] carried out a longitudinal study to examine the cross-time associations between metabolic syndrome status and cognitive performance in ageing adults; they reported that blood glucose was negatively associated with the composite cognitive score and with executive functioning. Moreover, Weinstein et al. [44] found that hyperglycemia and subtle brain injury were associated with impaired attention and memory even in young adults, indicating that brain injury is an early manifestation of impaired glucose metabolism. Impaired fasting glucose, an important metabolic syndrome component, is often a precursor of T2DM, which has been strongly linked to cognitive dysfunction in adults. In relation to this last implication, it is important to emphasize that the glucose tolerance test detects an impairment in early phase insulin release, a condition that occurs early in the development of T2DM, even before fasting hyperglycemia is found [45]. Insulin resistance is assumed to be a common denominator of metabolic disorders and cognitive dysfunctions. Low insulin levels in the brain can contribute to a decrease in acetylcholine concentration and have detrimental effects on the glutamatergic pathways, which establish neuronal plasticity [46]. There is evidence from the literature about the link between obesity with a chronic low-grade inflammatory state: overloaded and hypertrophied adipocytes start a cascade that includes adipokines, activation of macrophages, and overexpression of proinflammatory genes. Abnormal brain lipid metabolism, neuroinflammation, oxidative stress, insulin resistance and impaired vascular reactivity are conditions involved elsewhere in cognitive dysfunction [46–48]. In agreement, we found a negative correlation between SCWT interference and FMP and WC, and a positive correlation between this same cognitive test and HDL-c.

Our conclusions support the hypothesis that even in young—otherwise healthy—women, obesity and obesity-induced metabolic dysfunction are related to worse cognitive performance, although further studies are needed to determine the causal relationship between impaired glucose/lipid metabolism and cognitive dysfunction in this population.

Some limitations of the current study should be mentioned. First, only females were included in the study; thus, the results are not applicable to males. Second, our sample consisted only of women consulting in an urban public hospital, with limited education and a low income level. Lastly, the cross-sectional study design does not allow the deduction of a cause-and-effect relationship between glucose disorder or obesity diagnosis and inhibition response.

Given our results, it is worth mentioning that obesity, similarly to addiction, is linked to exposure to powerful reinforcers. Feeding, as well as drug use, involves learned habits and preferences that are stamped by the reinforcing properties of powerful and repetitive rewards (fast sensory outputs, slow post-ingestive consequences, and pharmacologic effects) [49]. When humans eat, the brain receives

Table 4
Psychopathologic measurements.

	Obese group Median (P25–P75)	Healthy control group Median (P25–P75)	Mann-Whitney *U* test
BDI-II	20 (15.5–28)	14 (7.75–22.5)	305.5*
STAI-Trait	34 (20–40)	20 (13.5–31)	337.0*
STAI-State	25 (17.75–37)	15 (9.5–30)	295.5**

BDI-II, Beck Depression Inventory-II; STAI, State Trait Anxiety Inventory.
* $p < 0.05$.
** $p < 0.01$.

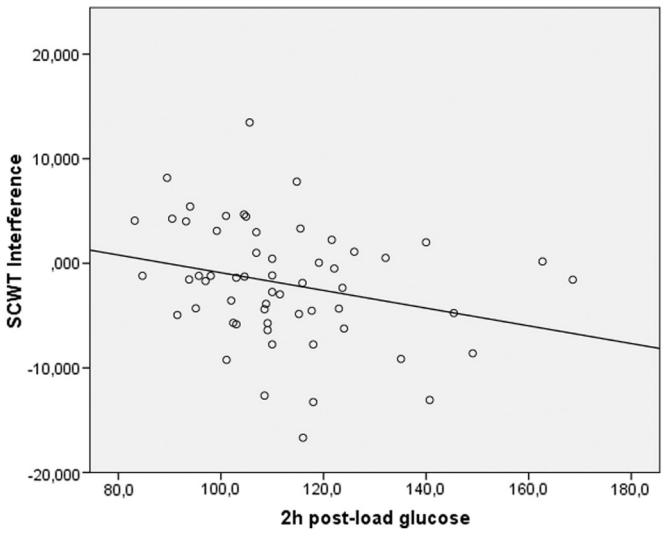

Fig. 2. Scatterplot: Stroop Interference and 2 h post-load glucose.

input from hormonal and neural signals that are integrated in different structures. The afferent stimuli eventually reach the nucleus accumbens (NA), striatum, thalamus, and neocortex, which sense and discriminate tastes and textures, assigning a reward value to them. NA, a forebrain structure, is connected to the amygdala and orbitofrontal cortex, lateral hypothalamus, and ventral tegmental area. This last structure releases dopamine and is implicated in the motivational aspects of feeding [50]. The repeated activation of NA, by dopamine, has also been observed in different kinds of addictions. These neurochemical systems play specific roles in different aspects of food seeking, intake, and reward; thus, the inhibition of consequent automatic responses is essential to restraining food consumption. Our results are in agreement with this knowledge: alterations in inhibition (linked to the prefrontal lobe) could be clearly connected with the development or maintenance of obesity.

5. Conclusions

In summary, in our study, obesity in young women was associated with cognitive impairment. Additionally, glucose metabolism, lipid profile, FMP and WC may be associated with this finding. Our results provide further evidence that obesity management should be multidisciplinary and that the professionals in treatment groups should be involved in the complexity of this area. We argue that detecting and understanding cognitive dysfunction in this population is essential to setting an appropriate treatment and may be an interesting research line. The early prevention and treatment of obesity even without other associated diseases is therefore imperative to prevent further serious consequences.

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