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Executive functioning in obese individuals waiting for clinical treatment

Fátima Gameiro[1], Maria Victoria Perea[2], Valentina Ladera[2], Beatriz Rosa[1] and Ricardo García[2]
[1] Universidade Lusófona de Humanidades e Tecnologias and [2] Universidad de Salamanca

Abstract

Background: Executive functions have an important role in human behavioural regulation and can be a determinant of eating behaviour. Our aim was to study the different components of executive functions in obese individuals waiting for clinical treatment, comparing them with normoweight subjects with similar socio-demographic characteristics. **Method:** A total of 114 adults (76 obese and 38 normoweight) completed a neuropsychological battery that included tasks of conceptualization and abstraction, motor programming, response maintenance, inhibition and resistance, problem solving, cognitive flexibility, and verbal fluency. **Results:** There was a statistically significant difference between groups for all the dimensions of the executive functions evaluated, with the obese group showing poorer performance compared to normoweight. **Conclusions:** Obese individuals demonstrated poorer executive functions than normoweight individuals.

Keywords: Executive functions, neuropsychological assessment, obesity, survey descriptive study.

Resumen

Funcionamiento ejecutivo en sujetos obesos en espera de tratamiento clínico. **Antecedentes:** las funciones ejecutivas tienen un papel importante en la regulación del comportamiento humano y pueden ser un determinante en la conducta alimentaria. El objetivo fue estudiar diferentes componentes de las funciones ejecutivas en individuos obesos en espera de tratamiento clínico, comparándolos con individuos con normopeso con características sociodemográficas similares. **Método:** participaron 114 adultos (76 obesos y 38 con normopeso) que completaron una batería neuropsicológica que incluyó tareas de conceptualización y abstracción, programación motora, manutención de respuesta, control inhibitorio, resolución de tareas, flexibilidad cognitiva y fluencia verbal. **Resultados:** existen diferencias estadísticamente significativas entre los grupos en todas las tareas del funcionamiento ejecutivo evaluadas. El grupo de los obesos obtuvo puntuaciones más bajas que el grupo con normopeso. **Conclusiones:** los individuos sujetos obesos revelan peor funcionamiento ejecutivo que los con normopeso.

Palabras clave: funciones ejecutivas, evaluación neuropsicológica, obesidad, estudio descriptivo.

Obesity is a multi-determined chronic disease with physical, psychological, social and cultural repercussions (Carnell, Gibson, Benson, Ochner, & Geliebter, 2012). It is associated with negative health sequelae and can lead to hypertension, diabetes, metabolic syndrome and nonalcoholic fatty liver disease, which develops hepatocarcinoma among others complications (Ahmed, 2015).

The World Health Organization reports that in 2014 more than 1.9 billion adults were overweight, including 600 million who were obese. Obesity has been associated with reduction of total brain volume (Gunstad et al., 2008), especially in frontal lobe areas (Campoy et al., 2011), and poorer cognitive performance (Epstein, Lin, Carr, & Fletcher, 2012). Volkow, Wang, Fowler, and Telang (2008) found a negative correlation between Body Mass Index (BMI) and metabolic activity in prefrontal cortex and anterior cingulate gyrus measured with PET (Positron Emission Tomography), which is positively correlated with executive test performance.

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Corresponding author: Fátima Gameiro
Psychology Faculty
Universidade Lusófona de Humanidades e Tecnologias
2749 Lisbon (Portugal)
e-mail: fatima.gameiro@ulusofona.pt

Previous studies using brain imaging suggest that obese subjects show abnormal patterns of brain activation in the presence of food stimuli: differences between obese (OB) and normoweight (NW) individuals have been found in two brain circuits, the limbic and paralimbic areas, which are associated with the activation of salience and reward processes in normal eating behaviour, and the prefrontal areas, which support cognitive control processes (Maayan, Hoogendoorn, Sweat, & Convit, 2011).

The relation between weight and brain functioning has also been suggested by authors who proposed that OB patients may have neural circuitry and neurobiological pathways in common, narrowly correlated to the food reward system. Thus, the obesity level depends of the severity of this functioning (Figlewicz, Bennett-Jay, Kittleson, Sipols, & Zavosh, 2011). Additionally, neuroimaging studies corroborate the finding that alterations in dopamine circuits are implicated in eating behaviors (Avena, Rada, & Hoebel, 2008). According to the model of food intake (Volkow et al., 2008), overeating is the result of instability among reward/saliency, motivation/drive, learning/conditioning, and inhibitory control/emotional regulation/executive function circuits related to behavior, motivation and those implicated in inhibition response. In vulnerable subjects, the ingestion of elevated amounts of food can change the balance between such circuits, increasing the reinforcing value of food and reducing the activity of the circuits related to control and inhibition, which can trigger impulsive behavior and compulsive food ingestion (Avena & Bocarsly, 2011). Neuropsychology researchers are focused on the influence of cognitive functions on eating behaviour (Calvo, Galioto, Gunstad, & Spitznagel, 2014). According to Lu and colleagues (2012), NW individuals showed higher global cognitive function, assessed by Mini-Mental State Examination, compared to OB subjects. Several studies (e.g., Duchesne et al., 2010; Restivo, McKinnon, Frey, Hall, & Taylor, 2016) have found that OB adults have lowered performance in several dimensions of executive functions (EF). These functions play a crucial role in the regulation of behavior, emotions, thoughts, and thereby enable self-control (Verdejo, & Bechara, 2010). A number of studies have shown that OB subjects, when compared to NW, have lower EF (Campoy et al., 2011; Restivo et al., 2016), particularly in planning, problem solving, and cognitive flexibility (Bickel, Jarmolowicz, Mueller, Gatchalian, & McMlure, 2012; Lokken, Boeka, Yellumahanthi, Wesley, & Clements, 2010; Malmir, Geravand, Jamalomidi, Janjani, & Seydi, 2014; Siervo et al., 2011), attention maintenance and inhibitory control (Lokken & Boeka, 2009; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Siervo et al., 2011), and decision making (Calvo et al., 2014; Fagundo et al., 2012; Siervo et al., 2011).

Because the majority of studies investigating the relationship between OB and domains of EF are cross-sectional rather than longitudinal, the question of directionality of the relationship remains unresolved (Maayan et al., 2011). Changes in EF can predict weight gain (Nederkoorn et al., 2010) and may be an important determinant of dietary behaviour throughout life (Hall, 2012). Taken together, these findings support evidence of a robust association between obesity and EF impairment, and suggest that neuropsychological evidence can provide an accurate understanding of the determinants of eating behaviour.

Previous research has explored a limited number of dimensions of EF. In this paper, we report a study running a broader battery of executive tests. To our knowledge, no comprehensive research covering the executive functioning profile of OB individuals has been done to date. In order to achieve a more extensive approach of executive functioning in obesity, the purpose of this study is to examine different dimensions of EF in OB patients waiting for a clinical treatment. We measured the following dimensions of EF: conceptualization and abstraction, motor programming, response maintenance and distractibility, inhibition ability and resistance to interference, problem solving and learning capacity, cognitive flexibility, and verbal fluency. OB subjects were compared to socio-demographically equivalent NW subjects in all these dimensions. Subjects presenting eating behaviour disorders (EBD), emotional maladjustment, and cognitive deterioration were excluded.

Method

Participants

A total of 114 adults, 76 obese (24 male and 52 female) and 38 normoweight (11 male and 27 female) participated in this study. The obese group consisted of participants with a BMI greater than 30 kg/m² and without EBD. All the OB subjects had been previously diagnosed by an endocrinologist, according to the criteria of the International Classification of Diseases (ICD-10), had a previously established BMI, had a diagnosis no older than 6 months, and were undergoing evaluation to have bariatric surgery. The comparison group was composed of normo-weight subjects, with BMIs ranging from 18 kg/m² to 24.9 kg/m², and without EBD.

Demographic characteristics are presented in Table 1. No differences between groups were found for demographic variables.

The inclusion criteria were: (a) not presenting anorexia or bulimia nervosa symptomatology, defined by a score of 20 or lower in the Eating Attitudes Test (EAT-26; Gross, Rosen, Leitenberg, & Willmuth, 1986); (b) not presenting binge eating disorder, defined by a score of 17 or lower in the Binge Eating Scale (BES; Greeno, Marcus, & Wing, 1995); (c) not being on any kind of diet; (d) aged between 18 and 60; (e) a minimum of 4 years of formal education; (f) no clinical history of neurological alterations, neuropsychological, or clinical psychopathologies; (g) not having undergone any obesity-related surgical procedure; (h) no prior history of alcohol or drug abuse or dependence on psychotropics; (i) not having emotional maladjustment, evaluated by Symptom Check-List- 90- R (SCL-90-R; Derogatis & Lazarus, 1994); and (j) no global cognitive deficit assessed from Mini Mental State Examination scores (MMSE; Folstein, Folstein, & McHugh, 1975). Forty-seven participants were excluded for not meeting the inclusion criteria.

Instruments

The *Frontal Assessment Battery* (FAB; Dubois, Slachevsky, Litvan, & Pillon, 2000) measures global frontal performance. It consists of six sub-scales: Similarities, Lexical Fluency, Motor Series, Conflicting Instructions, Go No Go, and Prehension Behaviour, scored from 0 to 3. Total scores range from 0 to 18.

Table 1
Demographic characteristics by group

	NW		OB	
	M	**SD**	**M**	**SD**
Age	40.53	10.75	43.24	9.05
Years of education	n	%	n	%
4-5	3	2.60	9	17.90
6-8	15	13.20	19	16.70
9-11	14	12.30	32	28.10
12-14	4	3.50	10	8.80
+15	2	1.80	6	5.30
Marital status				
Single	9	7.90	11	9.60
Married	19	16.70	56	49.10
Divorced/Separated	6	5.30	7	6.10
Widower	4	3.50	2	1.80
Professional situation				
Student	1	.90	1	.90
Domestic	2	1.80	5	4.40
Active	34	29.80	58	50.90
Retired	1	.90	6	5.30
Unemployed	0	.00	4	3.50
Sick leave	0	.00	2	1.80
Gender				
Female	27	23.70	52	45.60
Male	11	9.60	24	21.10

Note: NW = Normoweight subjects; OB = Obese subjects; Age: Age in years; n = Number of participants; % = Percentage

The FAB presented optimal interrater reliability (k = .87; p<.001) and a *Cronbach*'s α = .78, which indicated an adequate internal consistency, and good discriminant validity.

Action fluency (Goodglass & Kaplan, 1983) evaluates the subject's capacity to evoke words that designate a verbal action in one minute (Perea, Ladera, & Rodríguez, 2005). The score is the sum of correct responses. This test presents good convergent and discriminant validity.

The *Color Trails Test* (CTT; D'Elia, Satz, Uchiyama, & White, 1996) was used to assess sustained attention and cognitive flexibility. It consists of two parts, CTT1 and CTT2, composed of numbers presented in yellow and pink circles. Participants were invited to connect numbers in an ascending order as quickly as possible; CTT2 requires participants to alternate between numbers and colors. The CTT1 and CTT2 scores are based on execution time. Psychometric analyses of reliability, measured by temporal stability, demonstrated high scores for CTT1 (r = .644; p<.001) and CTT2 (r = .787; p<.001) over a brief period of time. In short, CTT exhibited good validity.

The *Stroop Neuropsychological Screening Test* (Stroop; Trenerry, Crosson, DeBoe, & Leber, 1988) consists of two tasks. In the colour task (C), which evaluates a highly automatic skill, participants read a list of words presented in different colours. In the colour word task (CW), which evaluates the capacity to inhibit a previous learned answer, participants identified these colours, with the particularity that the word designates one colour and is printed in a different colour. For both tasks, scores are obtained by execution time and errors. The temporal stability of the Stroop test is excellent (r = .90) and presents a good index of criteria validity.

The *Wisconsin Card Sorting Test* (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is a measure of executive function which requires cognitive flexibility. It consists of four cards packs and 128 response cards. Participants must derive the correct card sorting principle using the information transmitted by the examiner. Several scores can be calculated. In this study we scored the number of completed categories, total errors, perseverative responses, non-perseverative errors, trials to complete first category, failure to maintain set, and the percentage of conceptual responses. The WCST is a reliable and valid test. The interrater reliability rates we calculated were all higher than .80 and presented good discriminant validity.

Procedure

The psychiatry services, endocrinology and obesity services of different hospitals were contacted. The study was approved by the institutional Ethics Committee. Participants signed an informed consent and were informed about the study prior to participation. Anonymity and confidentiality were guaranteed, and participants were aware that they could quit at any time during participation. Subjects were assessed individually by a trained clinical neuropsychologist during a 60-minute session. An anamnesis was performed in order to obtain demographic and clinical information and the BMI was reassessed.

Data analysis

All data analyses were performed with the SPSS program, version 20.0. In order to test possible differences between OB and NW groups for demographic variables, we first ran Chi-square tests for gender, years of education, professional situation, and marital status, and a t-Student test for age. Second, because

Table 2
Differences between normoweight and obese groups for all dimensions of executive functions

Dimensions of EF	NW		OB		t(p)
	M	DS	M	DS	
Conceptualization					
FAB-Similarities	2,58	0,55	2,18	0,76	2.84(.002)
Motor programming					
FAB-Motor series	2,87	0,34	2,26	0,96	4.92(.000)
Response maintenance					
WCST-Failure to maintain set	0,37	0,59	1,25	1,43	-4.63(.000)
Inhibition ability					
FAB- Go No Go	2,74	0,69	2,08	1,27	3.59(.001)
FAB-Sensitivity to Interference	2,92	0,27	2,11	1,33	5.13(.000)
Stroop CW-Execution time	114,50	11,80	119,22	3,22	-2.42(.020)
Problem solving					
WCST-Number of non perseverative errors	9,37	6,68	19,97	11,24	-6.30(.000)
WCST-Number of trials to complete first category	13,42	4,30	28,13	32,41	-3.89(.000)
Cognitive flexibility					
WCST-Number of perseverative responses	14,66	9,22	36,97	21,66	-7.69(.000)
WCST-Number of categories completed	5,74	0,69	3,63	1,92	8.52(.000)
WCST-Number of total Errors	22,89	14,01	51,29	24,53	-7.85(.000)
WCST-Percentage of conceptual level responses	69,99	12,74	46,45	21,91	7.23(.000)
CTT2-Execution time	85,45	21,16	131,80	74,96	-5.01(.000)
Verbal fluency					
FAB- Lexical fluency	2,92	0,27	2,38	0,75	5.59(.000)
AF- Number of action verbs	16,37	3,82	11,33	4,02	6.41(.000)

Note: NW = Normoweight subjects; OB = Obese subjects; EF = Executive functions; t = Independent samples t-Student test; FAB = Frontal Assessment Battery; WCST = Wisconsin Card Sorting Test; Stroop CW = Stroop Colour Word Task; CTT2 = Color Trails Test 2; AF = Action Fluency emotional maladjustment and mental status can have a negative effect on cognitive performance, we also ran *t*-Student tests for the Mini Mental State Examination and SCL-90-R scores. Third, we conducted a series of *t*-Student test for independent samples to compare OB and NW groups for EF dimensions evaluated in this study. For this analysis, the following outcomes were selected: (a) scores in Similarities, Motor Series, Sensitivity to Interference, Go No Go, and Lexical Fluency subtests from FAB; (b) number of failure to maintain set, non-perseverative errors, trials to complete first category, perseverative responses, categories completed, total of errors, and percentage of conceptual responses from WCST; (c) CW execution time in the Stroop; (d) execution time in the CTT2; and (e) number of action verbs in the Action Fluency Test. Confidence level was defined at .05.

Results

No statistically significant differences between the groups were found for age $t(112) = -1.42$, $p = .160$, years of education $\chi^2(4) = 2.72$, $p = .606$, marital status $\chi^2(3) = 7.35$, $p = .062$, professional situation $\chi^2(5) = 5.01$, $p = .415$, or gender $\chi^2(1) = .08$, $p = .774$. OB and NW groups did not differ in terms of emotional adjustment, $t(112) = -.30$, $p = .762$, or mental status, $t(112) = 2.05$, $p = .063$.

For EF analysis, results from *t*-Student tests showed statistically significant differences between OB and NW groups for all dimensions evaluated (see Table 2). OB group performed lower than the NW group in Similarities ($p = .002$), Motor Series ($p<.001$), Go No Go ($p = .001$), Sensitivity to Interference ($p<.001$), Number of categories completed ($p<.001$), Percentage of conceptual responses ($p<.001$), Lexical Fluency ($p<.001$), and Number of action verbs ($p<.001$). The NW group revealed lower scores than OB group in failure to maintain set ($p<.001$), time in seconds in Stroop CW ($p = .020$), number of non perseverative errors ($p<.001$), number of trials to complete first category ($p<.001$), number of categories completed ($p<.001$), and execution time in seconds in CTT2 ($p<.001$). The higher scores obtained by obese subjects indicate their difficulties in each task. In order to exclude alternative explanations of these results, gender differences for EF dimensions within each group were examined by running a *t*-Student test for independent samples. Within NW group no statistically significant gender differences were found for any of dimensions evaluated. In OB group there was a statistically significant difference between gender for perseverative responses, $t(112) = -2.39$; $p = .019$. Women achieved higher average scores ($M = 32.09$; $SD = 23.57$) than men ($M = 23.77$; $SD = 13.25$), indicating a higher level of cognitive inflexibility.

Discussion

The aim of this study was to examine the different components of EF in OB individuals waiting for clinical treatment, comparing them with NW people. In all dimensions of the EF evaluated, the performance of the OB group was inferior to that of the NW individuals, which indicates that OB subjects have poorer EF.

Regarding conceptualization and abstraction, the OB group achieved lower scores in the Similarities subtest, which indicates their difficulties in abstract thinking and in anticipating the consequences of behaviour. These difficulties can explain those related to thinking about the consequences of their eating behaviour, the possible repercussions of a well-balanced diet, and the cost/benefit evaluation of an eating behaviour.

The lower scores on the Motor Series by the OB group indicate their difficulties in motor programming. Similar findings have also been found in previous studies (Fagundo et al., 2012; Lokken et al., 2010), and confirm the importance of programming in eating behaviour. In fact, a well-balanced diet and ingestion demand the development of a prospective plan, the anticipation of results, and the trial of complete sequences of eating behaviour. The presence of poor programming in OB subjects, may produce poor performance in following a diet and in programming what they are going to ingest. In addition, their conceptualization and abstraction difficulties can also play an important role in the way that OB subjects may not understand the benefits of a diet.

Our results reveal that the OB individuals have more difficulty in maintaining sets in the WCST, and also presented greater difficulties in the Go No Go and Sensitivity to Interference subtests. Likewise, they had a longer execution time in the CW Stroop task. These results indicate that the OB subjects report, respectively, difficulties in response maintenance and distractibility, cognitive interference and a decrease in the inhibition capacity. Similarly, Lokken and Boeka (2009) reported the existence of differences in attention maintenance between these OB and NW groups. Higher rates of distractibility and more difficulty in response maintenance may lead OB subjects to higher-vulnerability situations. For these subjects it will be very hard to maintain a consistent eating response, such as following well-a planned diet (Bickel et al., 2012), and to focus on an eating program, or to avoid overeating behaviour in a high-caloric environment. Our finding that obesity is associated with cognitive interference and inhibition capacity decrease is consistent with results of previous studies (Lokken & Boeka, 2009; Siervo et al., 2011) that also reported difficulties in inhibitory control, poor self-control, and high levels of impulsivity. By presenting difficulties in inhibitory control, OB people can be more vulnerable to ingesting food without control and have more difficulty in inhibiting eating behaviour when they are exposed to food.

Problem solving and learning were also compromised in the OB group. Obese participants made more nonperseverative errors and needed more trials to complete the first category in WCST. A similar pattern of results was found in previous studies (Jarmolowicz et al., 2012; Malmir et al., 2014). Our results also point to a lower capacity to use new strategies in problem solving, which could be crucial when implementing a diet plan. In particular, these findings can be useful for understanding the difficulties in learning and maintaining new nutritional programs. By presenting more difficulties in establishing new behavioural repertoires and by being less able to use operative strategies, OB subjects reveal an impairment in anticipating the results of a problem solving behaviour, which would have been useful for improving their eating habits.

According to our results, obese subjects made more perseverative responses in the WCST, completed fewer categories, committed more perseverative and non perseveratives errors, and obtained lower scores on conceptual level responses in WCST. In addition, OB participants were also slower in completing the CTT2, which confirms results of the WCST. This pattern of performance indicates cognitive inflexibility and is consistent with previous studies (Bickel et al., 2012; Duchesne et al., 2010; Malmir et al., 2014; Siervo et al., 2011). Other studies (Campoy et al., 2011; Lokken & Boeka, 2009) supported the fact that obese subjects present low cognitive flexibility, which confirms that lower levels of flexibility is a characteristic of those subjects. It is possible that cognitive flexibility could play an important role in the process of adherence to some new nutritional guidelines. If so, according to results from this study, obese adults are in a disadvantageous situation because of their difficulties in changing or shifting. When faced with alternative nutritional guidelines, they will probably tend to continue the previous regime because their poorer cognitive flexibility does not facilitate the process of change. It is important to note that within OB group, gender differences were observed for perseverative responses. Women, who represent the majority of participants in this group, reported a higher rate of perseverative responses than males. Although the evaluation of cognitive flexibility implies complementary outcomes, this result must be interpreted with caution.

The score in the lexical and action fluency tasks suggests that OB participants have difficulties in lexical fluency. This can be explained by the level of cognitive flexibility, which is lower in the OB group than in the NW group. It is possible that when asked to name words, obese subjects tend to extract words of the same category and remain focused on this category, due to their difficulties in shifting.

In conclusion, in all FE dimensions analysed the results of the OB subjects waiting for clinical treatment were inferior to those of NW individuals, which indicates poorer executive functioning and is consistent with previous studies reporting decreased frontal lobe areas (Campoy et al., 2011; Restivo et al., 2016). These findings seem to confirm the relevance of EF in the development and/or maintenance of obesity. Impaired performance on executive functioning measures may provide an early indicator of future difficulty complying with post-surgical recommendations and permanently incorporating appropriate lifestyle changes.

The evaluation of several dimensions of EF is the main strength of this study. However some limitations need to be highlighted. The use of a convenience sample that may not be representative of the obese population must be considered. It would be desirable to collect a sample with gender-balanced OB and NW groups of participants. The lack of decision-making and planning assessment was another weakness. Nevertheless, it is important to note that the skill of planning can be considered a complex ability that relies on other functions (Miyake et al., 2000). The use of BMI as the only indicator of adiposity may be also a limitation of this study.

In future studies, it would be interesting to compare obese subjects waiting for clinical treatment and obese subjects that did not look for treatment, and also several groups that present different levels of obesity regarding EF. The assessment of adiposity through anthropometric measurements should be considered. It would be also interesting to use neuroimaging techniques to evaluate brain activity and run longitudinal studies to understand the question of directionality in the relationship between obesity and EF.

OB subjects are a fast-growing group. It makes sense and it is crucial the development of a global intervention, integrating bariatric surgeries, drugs, and psychological interventions. A better definition of the cognitive profile of OB patients, particularly EF, through neuropsychological assessment, could play an important future role in the detection of its changes and in design therapies and rehabilitation processes.

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