

Executive Functions Correlated with Body Mass Index in Overweight Middle-Aged Women

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Abstract

The impacts of excess Body mass index (BMI) on physical health are well known and widely studied, but little is known about the consequences of being overweight or obese on cognitive function. The aim of this study was to correlate the BMI with executive functions in overweight middle-aged women. Seventy overweight middle-aged women between 48 and 64 years of age who are otherwise healthy participated in the study. Demographic and anthropometric variables were evaluated. Four standard neuropsychological tests were applied to assess executive functions, sustained attention, selective attention, and verbal fluency. The mean BMI of the participants was 29.35 and was negatively correlated with categories reached ($r = -0.41$, $p = 0.007$) and positively correlated with the number of errors ($r = 0.43$, $p = 0.005$) of executive function test. Scores of other neuropsychological tests applied showed no correlation with BMI. These findings suggest that BMI impacts the executive functions in overweight women who do not present any signs of disease.

Keywords

Cognition, Executive Functions, Body Mass Index, Overweight, Middle-Aged

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1. Introduction

Excess body weight is currently recognized as one of the most serious public health problems in the world, given its magnitude, rapid growth, and its adverse effect because it significantly increases the risk of chronic degenerative diseases (World Health Organization, 2013). In Mexico, the prevalence of being overweight has tripled, particularly among the adult population. Approximately 73% of the adult population in Mexico has a Body mass index (BMI) greater than 25 kg/m², three-quarters of women over 20 (73%) are overweight, and 61.9% have a waist circumference greater than 80 cm, which is classified as high risk (Barguera, Campos-Nonato, Hernández-Barrera, & Pedroza, 2012). According to the World Health Organization (2010), the BMI is calculated by dividing weight in kilograms by the square of height in meters (kg/m²). The BMI is a simple indication of the ratio between weight and height that is commonly used to identify overweight and obese adult individuals and populations. The WHO defines being overweight as having a BMI equal to or greater than 25, and obese when the BMI is over 30, which implies the gravest consequences for health. High BMI is an important risk factor for cardiovascular disease, diabetes, hypertension, locomotive syndrome, and some cancers (World Health Organization, 2006).

Although the impact of a high BMI on the body of excess is well known and widely studied (Bhurosy & Jee-won, 2014; Moges, Amare, Fantahumand, & Kassu, 2014; Olaiz, Rivera, & Shamah, 2006), and similarly its impacts on health (Zera, McGirr, & Oken, 2011), little is known about the consequences of being overweight or obese on cognitive function (Yesavage et al., 2014). The diverse studies that have linked BMI to cognitive function observe that obesity in old age is associated with lower cognitive scores (Sabia, Kivimaki, Shipley, Marmot, & Singh-Manoux, 2009; Dahl Aslan, Starr, Pattie, & Deary, 2014), but the association between these variables in aging is not yet fully understood. It has also been observed that a high BMI at around 40 years of age precedes a generally lower cognitive ability and cognitive decline in men and women (Dahl et al., 2010). Being either underweight, overweight, or obese have been identified as risk factors for dementia in old age (García-Ptacek, Faxen-Irving, Cermáková, Eriksdotter, & Religa, 2014; Anstey, Cherbuin, Budge, & Young, 2011; Gorospe & Dave, 2007; Gustafson, 2006).

Although most studies establish a relationship between obesity and cognition as risk factors for developing cognitive impairment in different ages and populations, little is known about how the BMI is associated with prefrontal cortex functions in middle-aged women who do not present any other disease. The aim of this study is to correlate BMI with scores of neurocognitive tests measuring executive functions, sustained attention, selective attention, and verbal fluency in middle-aged women.

2. Method

2.1. Participants

A total of 70 healthy postmenopausal women with a median age of 53 years (age range 48 - 64), with more than a year of amenorrhea without hysterectomy, apparently healthy, right-handed, with minimum primary education, without hormone replacement therapy and without diabetes, hypertension, epilepsy, sclerosis, or alcoholism, who were also not under any drug treatment affecting the central nervous system, with no signs of dementia, participated in a correlational and cross-sectional study. The characteristics of participants such as age, height, weight, education level, and Body mass index were obtained. The research was approved by the Ethics Committee of the Department of Medical Sciences of the University of Guanajuato in accordance with the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 1964) for research on human beings. Each participant had signed a letter of informed consent before the study session began.

2.2. Neuropsychological Evaluation Instruments

Four standard neuropsychological tests that measure prefrontal functions (Phillips, 1997) were used to evaluate the correlation with BMI. Each test was administered during a session and was distributed randomly. Neuropsychological tests are described below according to the skills they represent.

2.2.1. Executive Functions

The Wisconsin Card Sorting Test (WCST) (Heaton, 1981) was used to evaluate executive functions of the frontal cortex. The performance of the WCST produces physiological activation in a network of regions including

the dorsolateral prefrontal cortex, the inferior parietal lobule, and the posterior portion of the inferior temporal cortex (Berman et al., 1995). The WCST is an abstract reasoning and problem solving test that involves the use of working memory to form a cognitive set and apply a conceptual strategy but also that necessitates maintenance and then shifting of the set when appropriate. The stimuli were shown on a screen facing the subjects. The WCST requires subjects to discover the principle under which a deck of cards must be sorted. The standard material consists of cards bearing geometric figures that vary in color (red, green, blue, or yellow), form (triangle, star, cross, or circle) and number (1, 2, 3 or 4 items). Four reference cards are aligned in front of the subject throughout the test. Another deck of cards serves as response cards. The subject is instructed to place each response card in front of 1 of the 4 reference cards, wherever she thinks it should go. After each response, she is told whether the response was “right” or “wrong” but not where the card should have gone. The subject’s goal is to obtain as many “right” responses as possible. Initially, cards must be sorted according to color. When performance is successful, the sorting rule is changed, from color to form or number; the subject must recognize the change and discover the new correct rule. We analyzed the following results provided by the WCST in a computerized version: 1) the number of categories completed, refer to effectiveness of measured cognitive function; 2) the number of correct responses (trials), taking into account the ability to reach successful or unsuccessful outcomes; 3) perseverative errors refer to the number of errors committed by the subject by pursuing an criterion which has received the information that is not valid; 4) errors refer to the number of incorrect answers.

2.2.2. Selective Attention

A computerized version of the Stroop test was used to examine selective attention ability (Stroop, 1935). Performance of this test activates the frontal and cingulate cortices (Swick & Jovanovic, 2002). This test entails multiple cognitive processes including selective attention, response inhibition, interference control, and response speed. The test requires that subjects rapidly shift the perceptual set when viewing the names of colors that appear in matching or non-matching colors. The test consists of a sequence of words that denote the colors green, blue and red and that are displayed in the same colors on the screen. The subjects were instructed to perform the task in two trials. In the first trial, the subject should ignore the text color and press the ← button if the GREEN word appears, the ↓ button for the BLUE word, and the → button for the RED word. In the second trial, the subject should ignore the meanings of the word and press the same buttons according to text color. Reaction time, number of correct responses, number of no responses and number of errors were computed.

2.2.3. Sustained Attention

A computerized version of the Continuous Performance Test (CPT) was used to examine the ability to sustain attention (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). Performance of CPT activates the right frontal and parietal lobes (Manly & Robertson, 1997). The sustained attention test consists of 150 alphabet letters displayed continuously in a random sequence, one at a time, for 50 milliseconds on a video screen. The inter-trial interval ranged randomly from 5 to 7 seconds. The subjects were instructed to perform the test with two different levels of difficulty. In the first level, the letter “S” pattern was selected as the target stimulus, and the subject was asked to press the “enter” button on the keyboard as soon as possible each time the target stimulus was perceived. In the second level, this instruction was maintained, and the subject was asked to press the “enter” button only when the target stimulus was preceded by a specified item, the letter “A”. Reaction time, omissions, errors and correct responses were computed.

2.2.4. Verbal Fluency

The Word Fluency Test (Benton, Hamsher, Varney, & Spreen, 1983) was used to evaluate the spontaneous generation of words according to an initial given letter. This test reflects function in the left frontal lobes (Parks et al., 1988). The word production test consisted of asking subjects to write as many words as they could that begin with the alphabet letters F, L, and M, excluding proper nouns, numbers, and the same word with a different suffix, in 1 min. The score was the sum of three 1 min trials with different letters.

2.3. Data Analysis

Levene’s test was applied to test the normal distribution of the variables prior to the application of the statistical analysis: 1) descriptive statistics were used for the description of the variables of the participants’ characteristics,

2) a Spearman correlation was used to correlate the neuropsychological test scores against BMI. Differences were considered significant at $p < 0.05$.

3. Results

3.1. Characteristics of the Participants

Table 1 describes the characteristics of women participating in the study. The median age was 53 years, average education length of 9 years, weight 69 kg, height 1.56 m, and BMI 29.35.

3.2. Correlation

Table 2 describes the correlation between BMI and neuropsychological test scores. Scores of the neuropsychological test of sustained attention, selective attention and verbal fluency showed no correlation with BMI. These results demonstrate that there is not sufficient evidence to support the conclusion of a linear correlation. Scores of the Wisconsin Card Sorting Test showed significant correlations with BMI. The Body mass index was negatively correlated with categories reached ($r = -0.41$, $p = 0.007$). The scatterplot in **Figure 1** depict a pattern of decreasing values of number of categories reached correspond to increasing values of BMI. The Body mass index was positively correlated with the number of errors ($r = 0.43$, $p = 0.005$). The scatterplot in **Figure 2** depict a pattern of increasing values of number of errors correspond to increasing values of BMI.

Table 1. Characteristics of the participants.

| | Median (range) |
|--------------------------------------|-----------------------|
| Age (years) | 53 (48 - 64) |
| Education | 9 (6 - 15) |
| Size (m) | 156 (146 - 164) |
| Weight (kg) | 69 (65 - 74) |
| Body mass index (kg/m ²) | 29.35 (23.50 - 38.44) |

Table 2. Correlation between Body mass index and neuropsychological test scores.

| Neuropsychological tests | BMI | <i>p</i> |
|------------------------------|-------|----------|
| Sustained attention | | |
| Correct responses | -0.27 | 0.08 |
| Errors | 0.25 | 0.12 |
| Omission | 0.10 | 0.28 |
| Reaction time | -0.18 | 0.55 |
| Selective attention | | |
| Correct responses | -0.13 | 0.43 |
| Errors | 0.20 | 0.22 |
| Reaction time | -0.11 | 0.52 |
| Verbal fluency | 0.12 | 0.25 |
| Wisconsin card sorting test | | |
| Number of categories reached | -0.41 | 0.007* |
| Number of errors | 0.43 | 0.005* |
| Perseverative errors | 0.10 | 0.55 |

* p value < 0.05 .

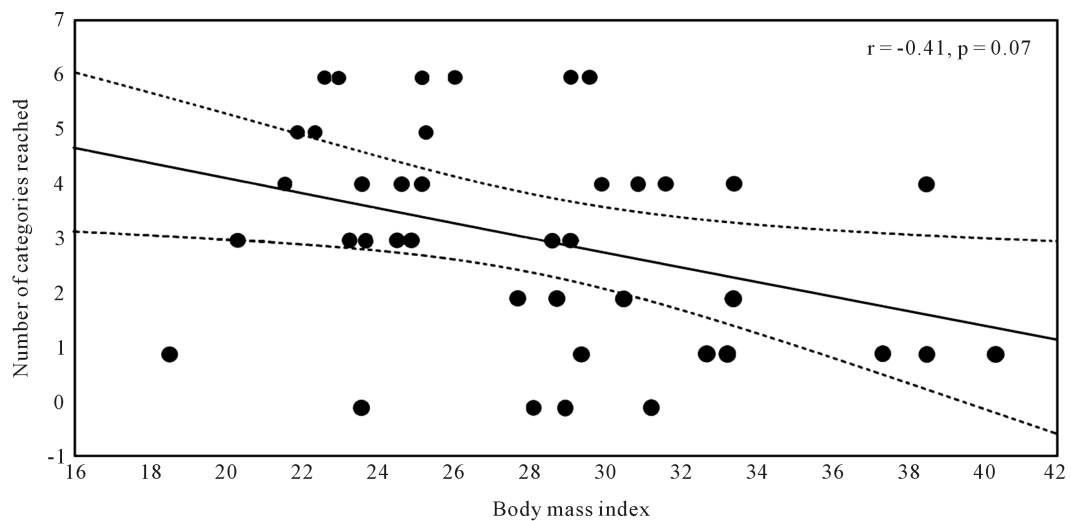


Figure 1. This figure shows the correlation between the number of categories reached in the Wisconsin card sorting test and the Body mass index.

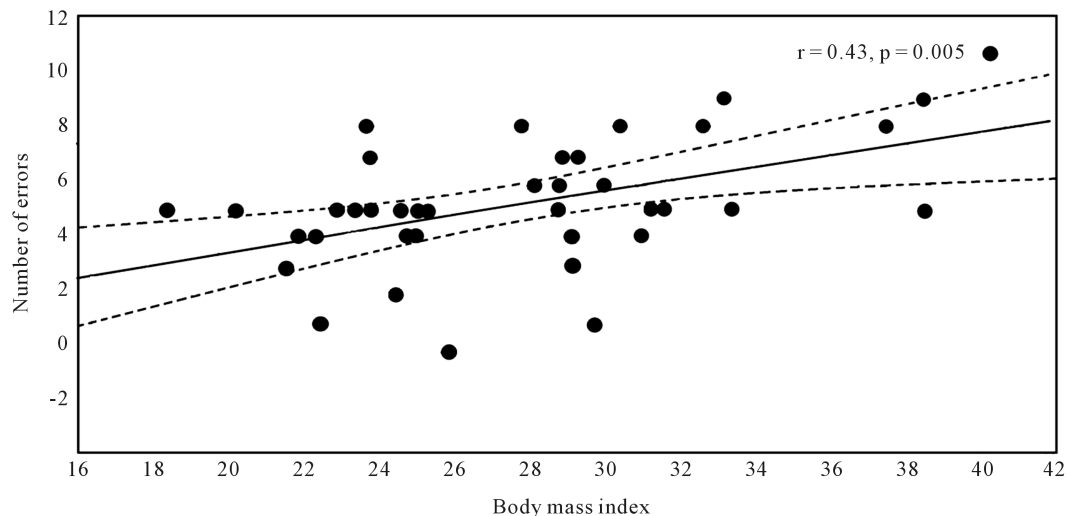


Figure 2. This figure shows the correlation between the number of errors made in the Wisconsin card sorting test and Body mass index.

4. Discussion

This study found significant correlations between BMI and some executive functions in middle-aged women who are overweight, suggesting the relationship between height and weight impact the prefrontal cognitive functions. Although rates of correlation between two variables does not indicate causality, the correlations indicate that as the BMI increases, the number of errors increases, and the number of categories achieved during the test that measures executive functions (WCST), suggesting that BMI has an impact on executive functions. Interestingly, we found no correlations with the other functions of attention and verbal fluency evaluated. Some studies have reported an influence of BMI on cognition ([Singh-Manoux et al., 2012](#)). A prospective longitudinal study over 26 years based on a middle-aged and elderly sample population found that BMI in midlife was associated with a risk of incident dementia assessed by cognitive and emotional influence on decision-making, numeracy and attention ([Tolppanen, Ngandu, K  reholt, Laatikainen, Rusanen, & Kivipelto, 2014](#)). A prospective meta-analysis found that a high risk for Alzheimer's diseases, vascular dementia, and any other dementia is associated with an overweight BMI, compared to a healthy BMI in middle age ([Anstey, Cherbuin, Budge, & Young, 2011](#)). Another longitudinal study among people aged 11 - 90 years of age found weak associations be-

tween BMI, age, and cognitive function, however low intelligence at the age of 11 years predicted obesity at age 79 (Dahl Aslan, Starr, Pattie, & Deary, 2014).

The WCST test applied in this study involves the assessment of skills related to abstract reasoning, the use of cognitive strategies for problem-solving, planning, working memory, organization and goal-directed behavior (Heaton, 1981). All these functions are known as executive functions attributed to the prefrontal cortex (Nauta, 1971; Stuss, Benson, Clermont, Della Malva, Kaplan, & Weir, 1986; Goldman-Rakic, 1987; Fuster, Bauer, & Jervey, 1985; Petrides, 1991; Damasio & Tranel, 1993). This study observed that BMI was correlated with executive functions in a group of middle-aged women who do not present any disease. It has been reported that these executive functions are particularly affected in vascular dementia (Desmond, 2004), a type of dementia that affects the vascular system, being overweight is a major risk factor for vascular diseases (Kopelman, 2000) and can influence executive functions through the vascular pathway.

There are several hypotheses about the causes of the relationship between BMI and cognitive functions. One such suggests a direct action of adiposity in neuronal tissue through pro-inflammatory mediators produced by adipocytes and endocrine messengers that respond to food ingestion (Funahashi, Yada, Suzuki, & Shioda, 2003; Harvey, 2003; Bray, 2014). Adipose tissue is known as a source of pro-inflammatory cytokines in obese humans and in animal models due to receptor insensitivity to leptin. Most obese people have an altered adipose tissue function caused by the interaction of genetic and environmental factors, which lead to hypertrophy, hypoxia, and a variety of inflammatory processes in the adipose tissue. Visceral fat accumulation may be considered a consequence of a dysfunction of adipose tissue, characterized by changes in cell function, increased lipid storage and secretion of pro-inflammatory molecules such as cytokines, and inflammatory and pro-coagulant peptides (Blüher, 2009; Gutiérrez, Puglisi, & Hasty, 2009). One study found that levels of interleukins 1 β (IL1 β) correlated with adiposity and cognitive impairment (Erion et al., 2014). Inflammation, particularly chronic low-grade inflammation seems to affect several brain functions, from the early development of the brain to the development of neurodegenerative and psychiatric diseases, associated with cognitive deficits and dementia (Wärnberg, Gomez-Martinez, Romeo, Diaz, & Marcos, 2009). Another hypothesis focuses on the factors involved in arteriosclerosis and vascular factors involved in dementia. Cardiovascular diseases are associated with obesity, Alzheimer, and vascular dementia (Decarli, 2004).

5. Conclusion

In conclusion, the results found in this study indicate a relationship between BMI with executive functions in overweight women who are otherwise healthy. These correlations were of great interest since the female participants showed no metabolic disorders such as diabetes, hypertension, high fat nor high cholesterol, they were only overweight. Therefore, we must pay attention to diet and exercise for weight loss and its impact on cognition.

There are some limitations that must be addressed in the present study. This study was conducted in a specific sample of the middle-aged women with overweight. The study did not include middle-aged women with underweight and with and diagnosis of other diseases like early dementia, which must be included in future approaches. Another limitation of the study was that it only included a group of women between 48 and 65 years. Others studies must include individuals of different ages and gender. Prospective and longitudinal designs that include treatments to improve cognitive function and weight reduction may contribute to improve understanding of cognitive decline and obesity.

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Contribution of Author

Silvia Solís-Ortiz conceived, designed, and conducted the study, analyzed the data and wrote the manuscript. Mayra Gutierrez-Muñoz, Lisette Morado-Crespo, Silvia Aurora Trejo-Bahena, Linaloe Kala ran the study. All authors read and approved the final manuscript.

Conflict of Interests

The authors declare no conflicts of interest.

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