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Correlation of executive functions, academic achievement, eating behavior and eating habits in university students of Mexico City

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Introduction: Young adults between 18 and 25 years of age are in an important transitional time and university students are considered vulnerable given that they generally maintain an unhealthy lifestyle characterized by poor diet quality and meal skipping. The aim of the present study was to evaluate the relationship between executive functions, academic achievement, eating behavior, eating habits, and BMI in university students.

Methods: Undergraduate university students (18–25 years) who lived in Mexico City were included in the sample; executive function, eating habits, eating behavior and academic achievement were measured.

Results: 1903 university students (1,038 women, 865 men), with a mean age of 20.65 years (SD ±1.66), participated in the study. Spearman's r correlation analysis revealed that there is a significant correlation between all variables of interest, with the most significant correlations found with academic achievement, emotional eating, and eating habits.

Discussion: Our study confirms previous findings in the association between EF, eating habits, eating behavior, and academic achievement in university students, and also provides a first approach to the association between UP food intake, overall meal skipping (breakfast, lunch, and/or dinner) and EF.

KEYWORDS

executive function, eating habits, eating behavior, academic achievement, university students

1 Introduction

Executive Functions (EF) refer to a set of higher-order cognitive abilities necessary to examine and archive a goal (Cristofori et al., 2019), enable forethought and goal-directed behavior (Yang et al., 2018), support cognitive control (La Marra et al., 2022b), and allow inhibition of strong dominant responses/ interfering stimuli, or resistance to temptations (La Marra et al., 2022a). EF also denote a family of top-down mental processes that are needed to concentrate and pay attention (Diamond, 2013). There is a general consensus that there are three core EF: inhibition or inhibitory control (the ability to suppress impulsive behavior), cognitive flexibility (the ability to reconfigure the mind and switch between tasks, and also develop different solutions for a particular problem), and working memory (the ability to manipulate information temporarily); additionally, other EF that have been proposed are decision making, verbal fluency, planning, and problem solving (Diamond, 2013; Yang et al., 2018; Cortés Pascual et al., 2019; Cristofori et al., 2019).

EF activity has consistently been associated with activity of the frontal lobes (Gilbert and Burgess, 2008; Cristofori et al., 2019), specifically, prefrontal cortex (PFC) activity and function, including the dorsolateral prefrontal cortex (dlPFC), medial prefrontal cortex (mPFC), ventrolateral prefrontal cortex (vlPFC), orbitofrontal cortex (OFC) and the lateral prefrontal cortex (lPFC), and also to anterior cingulate cortex (ACC) activity (Salehinejad et al., 2021; Friedman and Robbins, 2022; La Marra et al., 2022a). Also, there is consistent evidence that PFC volume and thickness are positively associated with EF performance (Yuan and Raz, 2014). Haz clic o pulse aquí para escribir texto.

Research indicates that there is an association between better EF and higher academic achievement in childhood and adolescence (Bailey et al., 2018). In this regard, EF has been demonstrated to significantly predict an increase in academic achievement in reading, mathematics, social studies, and science in male adolescents (Latzman et al., 2010). Furthermore, a longitudinal study demonstrated that EF measured during kindergarten showed a significant effect in predicting academic achievement in the second grade (Oberer et al., 2018). In university students, a significant relationship has been found between grade point average (GPA) and auditory-verbal working memory (WM), indicating that WM abilities are linked with academic achievement (Gropper and Tannock, 2009). Additionally, it has been demonstrated that the main EFs involved in academic achievement in university students are WM, planning, inhibitory control, cognitive flexibility (Besserra-Lagos et al., 2018), and verbal fluency (Jiménez-Puig et al., 2019).

The EF development showed that in early childhood and continues throughout adolescence and into early adulthood (Theodoraki et al., 2020; Maidana Miguel et al., 2023) and improvement with interaction social (Perry et al., 2019). In this regard, young adults between 18 and 25 years of age are in an important transitional time; therefore, this period has been associated with an increased risk for weight gain given that weight-related behavioral patterns and food choices change substantially during this time (Sogari et al., 2018; Stok et al., 2018). Furthermore, university life represents a change in an individual's development, which can influence their lifestyle, which is why this population is considered vulnerable due to factors such as long school hours, shortness of time and money, available food, moods and stress (Jiménez-Diez and Ojeda-Lopez, 2017). In this regard, in a longitudinal study it was shown that college students (recruited at 18 years old) did not meet the recommended guidelines for exercise and dietary patterns, which resulted in a significant (but modest) weight gain during the 4 years of college (Racette et al., 2008).

Studies indicate that college students generally maintain an unhealthy lifestyle characterized by poor diet quality and meal skipping (Huang et al., 1994; Pendergast et al., 2016; Bernardo et al., 2017; Lorenzoni et al., 2021), and by the consumption of alcoholic beverages, high-calorie foods such as sweets, ultra-processed, fried and fast foods, and a low consumption of fruits and vegetables (Arroyo Izaga et al., 2006; Jiménez-Diez and Ojeda-Lopez, 2017; Sámano et al., 2019; Al-Awwad et al., 2021; Deossa-Restrepo et al., 2021), which reflects in diet imbalances with a deficient consumption of macro and micronutrients (Rizo-Baeza et al., 2014). In this regard, a recent study showed that only 17.4% of Spanish university students maintain a healthy diet (Ramón-Arbués et al., 2021); furthermore, it has been shown that 80.2% of new university students in Mexico have a diet that is classified as "unhealthy," 19.7% as "needs changes," and only 0.1% are placed in the "healthy" range (Muñoz-Cano et al., 2015). Additionally, being male, younger age, academic load and poor time management have been identified as risk factors predictors of poor diet quality in college students (Deossa-Restrepo et al., 2021; Lorenzoni et al., 2021; Ramón-Arbués et al., 2021). In this regard, studies indicate that there is a cognitive effect derived from skipping breakfast and poor quality of diet and consumption of hypercaloric and ultra-processed foods. In this regard, it has been reported that low quality breakfasts in university students also impact performance in cognitive tasks (Sámano et al., 2019); additionally, a statistically significant relationship has been found between the amount of fried foods consumed per day with the presence of hyperactivity in high school students in Mexico City (Moreno Altamirano et al., 2021). Furthermore, it has been shown that higher academic performance is associated with a higher quality of the diet, which indicates that there is a relationship between the quality of the diet and academic performance (Whatnall et al., 2019).

Nowadays, the relationship between EF and eating behaviors has been studied (Smith et al., 2020; Favieri et al., 2021). In this regard, EF has been associated with the self-regulation of eating behavior in three ways: eating behavior as a predictor of EF, EF as determinants of eating behavior, or EF influenced by outside situational or long-run variables Z (Dohle et al., 2018). Particularly, EF problems have been associated with moderate to high levels of disordered eating behaviors in teens (Cecilia-Costa et al., 2021). Furthermore, studies suggest that working memory plays an important role in self-regulation of eating behavior (Sánchez-Sansegundo et al., 2021). However, most studies have focused on the effect of diet and academic performance at early ages, at the elementary and secondary school level, and there is little information regarding this relationship particularly in university students; additionally, studies evaluating the association between EF and academic achievement have mainly focused on childhood and adolescence, and research with university students is limited. Therefore, the aim of the present study was to evaluate the relationship between executive functions, academic achievement, eating behavior, and eating habits in university students. The hypothesis is that there is a significant association between eating behavior, eating habits, executive function, and academic achievement in university students.

2 Methods

2.1 Participants

The questionnaire was distributed to a sample of undergraduate college students, and snowball sampling was used. Our inclusion criteria were university students at undergraduate level, age range 18–25 years old who lived in Mexico City and agreed to participate voluntarily. The exclusion criteria for our study were participants outside of the age range (18–25 years old) and students that were not at undergraduate level (graduate, diploma, etc.). People who did not wish to participate after reading the informed consent and non-valid responses were also excluded. A total of 1903 students (1,038 women, 865 men), participated in the present study, with a mean age of 20.65 years (SD ±1.66).

2.2 Materials and procedures

A cross-sectional correlational study was carried out in a group of undergraduate students from public and private universities within Mexico City. Between March and April 2023 undergraduate students

were invited to participate in the study; informed consent was provided in accordance to the National Bioethics Commission (Comisión Nacional de Bioética) of the Health Department of México (Secretaría de Salud de México) (Comisión Nacional de Bioética, 2014); students voluntarily agreed or disagree to participate in the present study after being informed of the aim of the study, data analysis and safekeeping, estimated time of participation, and ensuring that their participation would be anonymous.

2.2.1 Executive functions in university students questionnaire

To evaluate executive function, the Executive Functions in University Students Questionnaire (EFUSQ) was used (López-Cárdenas and Ramos-Galarza, 2021). This questionnaire consists of 37-items designed to evaluate executive functions in college students based on everyday situations in a university education context. Subjects evaluate in a 5-point Likert frequency scale how often the behavior occurs (0: never [nunca], 1: almost never [casi nunca], 2: occasionally [en ocasiones], 3: frequently [con frecuencia], 4: very frequently [con mucha frecuencia]). It consist of seven dimensions which are: (1) executive system of attentional control for tasks (EF-1), (2) behavior supervision and monitoring for learning system (EF-2), (3) conscious and voluntary regulation of emotions system (EF-3), (4) behavior verification for learning system (EF-4), (5) conscious regulation of behavior system (EF-5), (6) organization of elements to solve tasks system (EF-6), and (7) executive system for decision making (EF-7). It is a valid instrument with an overall Cronbach's alpha of 0.73.

2.2.2 Academic achievement

Academic achievement was measured with the self-reported grade-point average (GPA) in a 0-to-10 (zero to ten) point scale up to their current semester.

2.2.3 Eating behavior

To measure eating behavior, the Eating Behavior and Physical Activity Scale (EBPAS) was used (Chávez-Hernández and Salvador-Ginez, 2023). It is a 30-item scale that evaluates eating and physical activity habits. It is divided in 7 factors that evaluate eating behavior (focused on ultra-processed foods), emotional eating, and everyday physical activity habits. Subjects rate on a 5-point Likert scale how often they consume foods or perform activities included in each statement (1: never [nunca], 2: almost never [casi nunca], 3: sometimes [a veces], 4: almost always [casi siempre], 5: always [siempre]). It is a valid instrument with an overall Cronbach's alpha of 0.763 and presents a construct validity with sufficient level of explanation (explained variance = 70.83%). For the purpose of the present study, we only included the following dimensions which evaluate eating behavior and emotional eating: (1) Consumption of foods with front-of-pack warning labels (CFP), (2) Influence of front-of-pack warning labels (IFP), (3) Emotional overeating (EOE), and (4) Emotional undereating (EUE).

2.2.4 Eating habits

Eating habits was measured by a frequency questionnaire. Participants were asked to respond how often they consume within one-week items from a list of foods and also how often do they skip meals (breakfast, lunch and dinner). Items were then classified in the following categories: (1) Healthy food intake: foods included in the healthy and sustainable dietary guidelines for Mexicans (e.g., fruits and vegetables, carbohydrates, and protein) (SSA, INSP, GISAMAC, and UNICEF, 2023); (2) Ultraprocessed (UP) food intake: foods classified as ultraprocessed based on the NOVA classification (e.g., fast food, ready-to-eat foods, packaged salty snacks, etc.) (Monteiro et al., 2016, 2019; Elizabeth et al., 2020); and (3) Meal skipping: frequency of skipping breakfast, lunch and/or dinner during the week.

2.2.5 Body mass index (BMI).

BMI was calculated dividing the self-reported weight (in kg) by height (in m) squared and categorized in four groups according to the World Health Organization (WHO) criteria (Weir and Jan, 2019; WHO, 2021): underweight <18.5, normal weight 18.5–24.9, overweight 25–29.9, and obesity ≥30 kg/m^2. This variable was used to describe participants in the present study in order to have an accurate description of the sample and further understand findings.

2.3 Statistical analysis

Data obtained was analyzed using the statistical program Prism 9 for macOS (version 9.3.1; GraphPad Software LLC, San Diego, CA, USA). Normality tests (Kolmogorov-Smirnoff) were performed, and correlation analysis (Spearman's correlation, r_s) was used to quantify the relationship between variables of interest.

3 Results

A total of 2,192 responses were obtained. People who did not wish to participate after reading the informed consent ($n = 90$), and 180 participants who were outside of the age range (18–25 years old) were excluded; additionally, 19 participants were eliminated for non-valid responses (see Figure 1). The final sample for the study consisted of 1903 participants (1,038 women, 865 men), with a mean age of 20.65 years (SD ±1.66); furthermore, 127 participants (6.67%) were in the underweight BMI range, 1,257 (66.05%) in the normal weight, 423 (22.23%) in the overweight and 96 (5.04%) in the obese range. Table 1 shows the sample's characteristics.

Kolmogorov-Smirnoff tests were performed to assess normality and results indicated that data did not pass normality tests ($p < 0.0001$). Therefore, for correlation analysis, Spearman's rho was used to identify the relationship between variables of interest.

3.1 Correlation analysis

Spearman's correlation analysis revealed that there are significant weak correlations between all variables of interest (r_s range-0.20 – 0.36). The most significant correlations were found with GPA, with eating habits (healthy food intake, UP food intake and meal skipping), and with emotional eating (EOE and EUE).

Spearman's correlation matrix between academic achievement (GPA), eating habits, EF and eating behavior are shown in Table 2. Results indicate that there is a positive correlation between academic achievement (GPA) and EF dimensions 1, 2, 4, 5, 6, and 7. Regarding eating habits, Healthy food intake showed a significant positive correlation with all EF dimensions, and also a significant negative correlation with EUE; UP food intake has significant positive

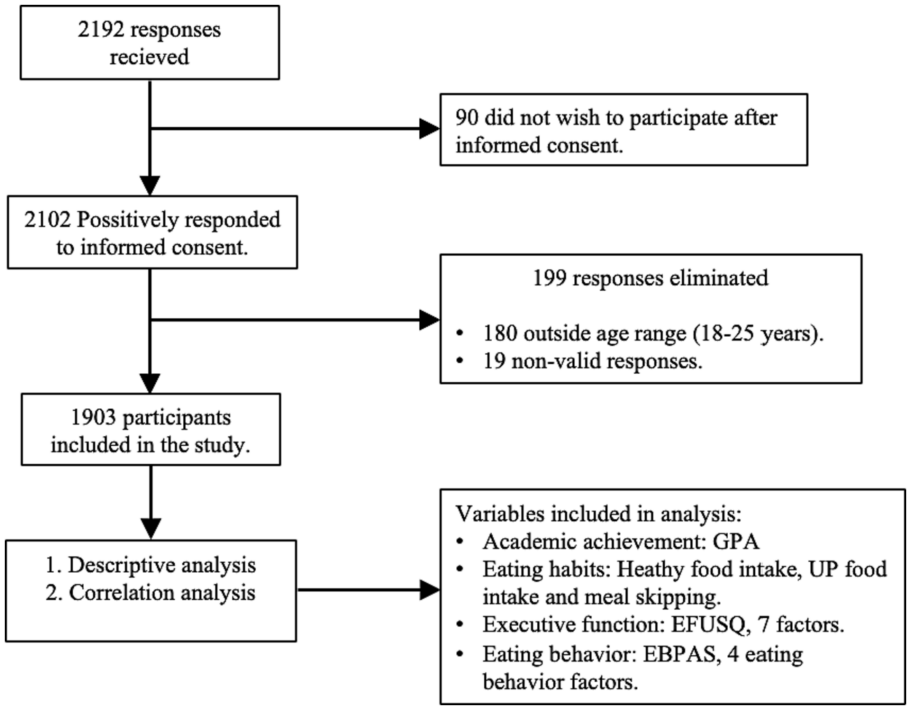

FIGURE 1
Flowchart of participants included in the study. GPA, Grade-Point-Average; UP Food, Ultraprocessed food; EFUSQ, Executive Functions in University Students Questionnaire; EBPAS, Eating Behavior and Physical Activity Scale.

correlation with IFP and EOE, and significant negative correlations with EF2, 3, 4, 5, 6, and 7, and with CFP; meal skipping showed a significant positive correlation with EUE, EOE and IFP, and significant negative correlation with EF1, 3, 4, 5, 6, and 7.

The Spearman's correlation matrix between GPA and eating habits (healthy food intake, UP food intake and meal skipping) is shown in Table 3. Results indicate that there are significant negative correlations between meal skipping and GPA, and between healthy food intake and meal skipping. Also, positive significant correlation between meal skipping and UP food intake is shown.

The Spearman's correlation matrix between EF and eating behavior is shown in Table 4. Results indicate that CFP has a significant positive correlation with EF1; IFP showed significant negative correlations with EF1 and 4; EOE has significant negative correlation with all EF dimensions; EUE showed significant negative correlations with EF1, 2, 3, 5, 6, and 7.

4 Discussion

The aim of the present study was to evaluate the correlation between eating habits, eating behavior, EF and academic achievement in undergraduate university students. Statistical analysis revealed that there is a significant weak correlation between all variables. The most significant correlations were found with EF, academic achievement, emotional eating and eating habits. These findings confirm previous reports that indicate eating habits, eating behavior and EF correlate significantly with academic achievement.

The association between EF and academic performance has consistently been demonstrated. In this regard, several studies have linked working memory as the main EF to be involved in academic performance, and planning, inhibitory control and cognitive flexibility in a minor measure (Besserra-Lagos et al., 2018). Additionally, it has also been shown that verbal fluency is significantly correlated with academic performance in college students (Jiménez-Puig et al., 2019), and that attention, planning and self-control, and self-monitoring predict first year progress in university students (Baars et al., 2015). Our results indicate that academic achievement is positively related to EF in university students, which confirms findings from previous studies.

Our findings indicate that emotional eating behavior is significantly associated with EF. Particularly, emotional overeating shows negative correlation while emotional undereating associates positively with EF. It is important to note that EF can be linked to the self-regulation of eating behavior in three ways: eating behavior as a predictor of EF, EF as determinants of eating behavior, or EF influenced by outside situational or long run variables Z (Dohle et al., 2018). In this regard, low working memory has been shown to interact with boredom emotional eating, but not with eating in response to depression and anxiety/anger, in college students (Ferrell et al., 2020). On the other hand, studies suggest that working memory, one of the core EF, plays an important role in self-regulation and emotional regulation of eating behavior, and that lower working memory is associated with higher intake of calorie-dense foods and snack foods (Sánchez-Sansegundo et al., 2021). Furthermore, evidence shows emotional eating is determined by emotional control, which can be considered a top-down EF (Vervoort et al., 2020). Additionally, studies have shown that emotional eating is correlated with dlPFC activity, a region involved in self-control, goal directed behavior, and inhibitory control, and also, that higher emotional eating scores are associated with increased responses in the OFC and insula, regions

TABLE 1 Sample characteristics, mean (±SD).

	Total	BMI range			
		Underweight	Normal weight	Overweight	Obesity
N (F / M)	1,903 (1,038 / 865)	127 (96 / 31)	1,257 (700 / 557)	423 (198 / 225)	96 (44 / 52)
Age, mean (±SD)	20.65 (1.66)	19.98 (1.30)	20.55 (1.65)	20.94 (1.63)	21.36 (1.99)
BMI, mean (±SD)	23.46 (3.79)	17.56 (0.78)	22.16 (1.78)	26.82 (1.25)	33.50 (4.10)
GPA, mean (±SD)	8.753 (0.66)	8.88 (0.61)	8.78 (0.67)	8.70 (0.62)	8.50 (0.67)
Eating habits					
Healthy food intake, mean (±SD)	3.04 (0.56)	3.035 (0.56)	3.06 (0.57)	2.98 (0.52)	2.88 (0.53)
UP food intake, mean (±SD)	2.05 (0.54)	2.11 (0.48)	2.03 (0.55)	2.05 (0.55)	2.17 (0.52)
Meal skipping, mean (±SD)	1.86 (0.81)	1.81 (0.78)	1.83 (0.81)	1.89 (0.83)	2.08 (0.78)
Executive functions in university students questionnaire					
Executive system of attentional control for tasks, mean (±SD)	20.06 (5.57)	20.46 (6.06)	20.03 (5.43)	19.93 (5.90)	20.39 (5.22)
Behavior supervision and monitoring for learning system, mean (±SD)	22.31 (4.06)	23.21 (3.94)	22.32 (3.98)	22.09 (4.36)	22.01 (3.86)
Conscious and voluntary regulation of emotions system, mean (±SD)	19.53 (4.46)	19.64 (4.80)	19.48 (4.31)	19.73 (4.80)	19.15 (4.47)
Behavior verification for learning system, mean (±SD)	8.89 (2.37)	9.06 (2.70)	8.99 (2.32)	8.69 (2.40)	8.24 (2.33)
Conscious regulation of behavior system, mean (±SD)	12.63 (2.48)	13.28 (2.10)	12.60 (2.50)	12.61 (2.49)	12.15 (2.55)
Organization of elements to solve tasks system, mean (±SD)	11.86 (2.84)	12.03 (2.67)	11.89 (2.78)	11.74 (3.10)	11.82 (2.64)
Executive system for decision making, mean (±SD)	11.64 (2.42)	11.71 (2.71)	11.59 (2.35)	11.78 (2.56)	11.57 (2.31)
Eating behavior and physical activity scale, eating behavior dimensions					
Consumption of foods with front-of-pack warning labels, mean (±SD)	2.45 (1.22)	2.02 (1.11)	2.50 (1.23)	2.44 (1.23)	2.37 (1.10)
Influence of front-of-pack warning labels, mean (±SD)	3.23 (1.00)	3.47 (0.99)	3.19 (0.99)	3.24 (1.04)	3.29 (0.97)
Emotional overeating, mean (±SD)	2.76 (1.03)	2.55 (1.01)	2.69 (1.00)	2.92 (1.08)	3.17 (1.16)
Emotional undereating, mean (±SD)	2.86 (1.24)	3.20 (1.31)	2.85 (1.23)	2.83 (1.23)	2.66 (1.15)

BMI, Body Mass Index; GPA, Grade-Point-Average (1 to 10 scale); UP, Ultraprocessed foods.

involved in appetitive, reward and emotion processing (for a detailed review see Godet et al., 2022).

The present study shows that healthy food intake is positively associated with EF. In this regard, it has been demonstrated that better EF is associated with healthier eating behavior by increasing fruits and vegetables intake and reducing saturated fat consumption (Allom and Mullan, 2014), and inhibitory control and planning have been shown to increase fruit and vegetable consumption (Wyckoff et al., 2017); additionally, inhibitory control has also been reported to predict dietary recommendations, such as eating fruits (Walø-Syversen et al., 2019). Furthermore, EF has been negatively associated with saturated fat intake, and positively with carbohydrates and cholesterol intake (de Los Remedios Moreno-Frías and Solís-Ortiz, 2022).

Our results also indicate that there is a significant negative correlation between EF and UP food intake. On this point, evidence indicates that among older adults consumption of UP foods in inversely associated with EF performance (Cardoso et al., 2022); furthermore, a recent longitudinal study showed that higher consumption of UP foods was associated with a higher rate of EF decline after 8 years of follow-up in middle-aged adults (Gomes Gonçalves et al., 2022); additionally, among children and adolescents aged 6–18 years studies indicate that there is an inverse association between EF and consumption of snack foods, sugar-sweetened beverages and red/processed meats (Cohen et al., 2016). However, no studies were found which evaluated the link between EF performance and UP food intake in university students or young adults. Therefore, to our knowledge, the present study is the first to assess this correlation, which is of the upmost importance to understand given the high availability of these products.

Our study also indicates a significant negative correlation between EF and meal skipping. Evidence indicates that correct nutritional intake in breakfast improves long term cognitive performance (Affinita et al., 2013), and studies indicate there is a link between regular breakfast consumption, better diet quality, and healthy behaviors, which suggest EF may play a role in the regulation of these behaviors (Widaman et al., 2016); also, it has been shown that having breakfast just before a cognitive task is correlated with cognitive performance (Peña-Jorquera et al., 2021), and studies indicate that adults who consume breakfast show a memory advantage (Galioto and Spitznagel, 2016). However, breakfast is the most commonly skipped meal among young adults (Pendergast et al., 2016), and poor breakfast quality has been associated with worse cognitive interference performance in university students (Sámano et al., 2019); furthermore, a study revealed that among nursing technician students 53.8%

TABLE 2 Results of Spearman's correlation analysis between GPA, eating habits, executive function and eating behavior.

	GPA	Eating habits		
		Healthy food intake	UP food intake	Meal skipping
Executive functions in university students questionnaire				
EF1	0.22***	0.09**	−0.05	−0.14***
EF2	0.32***	0.09**	−0.18***	−0.11***
EF3	0.04	0.14***	−0.08**	−0.18***
EF4	0.25***	0.09***	−0.16***	−0.08**
EF5	0.18***	0.12***	−0.15***	−0.11***
EF6	0.12***	0.12***	−0.15***	−0.16***
EF7	0.13***	0.10***	−0.10***	−0.13***
Eating behavior and physical activity scale, eating behavior dimensions				
CFP	0.01	0.04	−0.08**	0.02
IFP	0.01	−0.01	0.36***	0.13***
EOE	0.02	−0.02	0.16***	0.16***
EUE	0.04	−0.07*	0.06	0.26***

GPA, Grade-Point-Average (1 to 10 scale); EF1, Executive system of attentional control for tasks; EF2, Behavior supervision and monitoring for learning system; EF3, Conscious and voluntary regulation of emotions system; EF4, Behavior verification for learning system; EF5, Conscious regulation of behavior system; EF6, Organization of elements to solve tasks system; EF7, Executive system for decision making; CFP, Consumption of foods with front-of-pack warning labels; IFP, Influence of front-of-pack warning labels; EOE, Emotional overeating; EUE, Emotional undereating. Asterisks indicate significant correlation between variables (*$p \leq 0.05$; **$p \leq 0.01$; *** $p < 0.001$).

TABLE 3 Results of Spearman's correlation analysis between GPA and eating habits.

	GPA	Healthy food	UP foods	Meal skip
GPA	1.00	0.04	−0.04	−0.05*
Healthy food		1.00	0.12***	−0.27***
UP foods			1.00	0.23***
Meal skip				1.00

GPA, Grade-Point-Average (1 to 10 scale). Asterisks indicate significant correlation between variables (*$p \leq 0.05$; **$p \leq 0.01$; *** $p < 0.001$).

skipped breakfast, and 60% of students reported attention and memory problems, which may indicate a relation between these indicators (Morales Ojeda et al., 2020).

Nevertheless, it is important to note that studies associating meal skipping and cognitive performance have mainly focused on breakfast, not considering lunch and/or dinner. To our knowledge, the present study provides a first approach to the correlation between overall meal skipping (breakfast, lunch and/or dinner) and EF in university students.

TABLE 4 Results of Spearman's correlation analysis between executive function and eating behavior.

	Eating behavior and physical activity scale, eating behavior dimensions			
	CFP	IFP	EOE	EUE
Executive functions in university students questionnaire				
EF1	0.10***	−0.09**	−0.14***	−0.13***
EF2	−0.05	−0.05	−0.17***	−0.11***
EF3	−0.01	−0.02	−0.19***	−0.20***
EF4	0.03	−0.07*	−0.08**	0.01
EF5	−0.03	−0.05	−0.15***	−0.09**
EF6	−0.05	−0.05	−0.19***	−0.12***
EF7	−0.02	−0.03	−0.16***	−0.17***

GPA, Grade-Point-Average (1 to 10 scale); EF1, Executive system of attentional control for tasks; EF2, Behavior supervision and monitoring for learning system; EF3, Conscious and voluntary regulation of emotions system; EF4, Behavior verification for learning system; EF5, Conscious regulation of behavior system; EF6, Organization of elements to solve tasks system; EF7, Executive system for decision making; CFP, Consumption of foods with front-of-pack warning labels; IFP, Influence of front-of-pack warning labels; EOE, Emotional overeating; EUE, Emotional undereating. Asterisks indicate significant correlation between variables (*$p \leq 0.05$; **$p \leq 0.01$; *** $p < 0.001$).

Interestingly, in our sample, even though meals were reportedly skipped one or two times per week on average, dinner was the most skipped meal, followed by breakfast, and lunch being the least skipped meal (data not shown). This indicates the importance of analyzing overall meal skipping.

Results from the present study are consistent with previous studies that indicate that there are significant correlations between academic achievement and eating habits (healthy food intake, UP foods intake and meal skipping). In this regard, in Mexico City high school students, evidence indicates that there is a relationship between the amount of fried foods consumed per day with the presence of hyperactivity (Moreno Altamirano et al., 2021); furthermore, in university students, academic performance has been associated with a higher quality of the diet (Whatnall et al., 2019) and with a frequency of three to four meals per day (Ibarra Mora et al., 2019), while consumption of UP food was associated with lower academic achievement during COVID-19 (Bravo Salinas et al., 2021). However, few studies have evaluated the overall eating habits with academic achievement in university students, a contribution of the present study. Additionally, it is relevant to analyze these variables in the post-COVID era given the lifestyle changes that have occurred in university students when returning to in-person classes.

The present study provides evidence of the relation between academic achievement, eating habits, eating behavior and EF in a large sample of college students. However, some limitations should be considered. First, self-report EF questionnaires, like the one used in the present study, present some limitations, such as the influence of other variables like anxiety and depression (which were not considered in the present study), and it has been proposed that they may not be as representative of EF as when measured with neuropsychological tests (Buchanan, 2016). Another limitation of the present study is that GPA was self-reported by participants in the study and may not be as reliable as GPA obtained from university databases. Additionally,

anthropomorphic measures (height and body weight) to obtain BMI were also self-reported by participants. In this regard, it is also important to consider that, while the World Health Organization (WHO) uses BMI as an indicator of overweight and obesity (WHO, 2021), it may be an inaccurate measure for body fat percentage (BFP), which could be a more reliable indicator of overweight and obesity, along with other variables associated with BFP, such as waist circumference and waist stature ratio (Flegal et al., 2009). Furthermore, students in the present study were in the majority within the normal weight BMI range (1257), compared to overweight and obesity (425 and 96 respectively), which could have influenced the weak correlations found in the present study given that studies indicate alterations in EF present mainly in the overweight/obesity groups (Favieri et al., 2019; Segura-Serralta et al., 2020; La Marra et al., 2022a). In this regard, future research should include a larger overweight and obesity sample of college students in order to confirm associations found in the present study, as well as include other measures such as BFP, waist circumference and waist stature ratio in order to provide a more accurate measure of overweight and obesity. Additionally, when using self-report EF questionnaires, future research should include anxiety and depression as covariables, given that the aim of the present study did not consider this.

Overall, our study is consistent with previous findings in the association between EF, eating habits, eating behavior, and academic achievement in university students, and also provides a first approach in the association between UP food intake, overall meal skipping (breakfast, lunch and/or dinner) and EF in a population that has been known to be considered at risk given the life-style changes that come with university life. The present research contributes to clarify the association between these variables in a population that has been considered vulnerable. This knowledge is relevant to understand the interplay between these variables in order to promote healthy habits contributing to the well-being and success of university students.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by General Research Vice-Rectory of Universidad Panamericana, Mexico City. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MC-H: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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