Clinical Nutrition 41 (2022) 1770–1780

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Meta-analyses

Dietary intakes among people with vs without food addiction: A systematic review and meta-analysis

Cristina Reche-García [a], Carmen Piernas [b, c], Alejandro Martínez-Rodríguez [d], Alejandra Sánchez-Guerrero [a], Juan José Hernández-Morante [a, *]

[a] Eating Disorder Research Unit. Universidad Católica San Antonio de Murcia (UCAM), 30107, Murcia, Spain
[b] Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, UK
[c] Department of Biochemistry and Molecular Biology II, Faculty of Pharmacy Institute of Nutrition and Food Technology, University of Granada, Granada, Spain
[d] Department of Analytical Chemistry, Nutrition and Food Science, University of Alicante, 03690, Alicante, Spain

ARTICLE INFO

Article history:
Received 24 January 2022
Accepted 20 June 2022

Keywords:
Food-addiction
YFAS
Dietary intake
Obesity
Energy intake

SUMMARY

Background & aims: Individuals with food addiction (FA) may experience addictive behaviours like those observed in other substances of abuse, which may affect their dietary intake habits. In fact, previous studies have reported associations between FA and dietary patterns, but this evidence has not been quantitatively summarised before. Therefore, this study aimed to explore differences in dietary intakes among adults with vs without food addiction.

Methods: A systematic-review and meta-analysis was conducted. Interventional or observational studies evaluating dietary intakes associated with FA that used the Yale Food Addiction Scale (YFAS) were explored. PubMed, WoS and SCOPUS databases were searched up to September 2021, and selected articles were confirmed manually. Potentially eligible studies were checked independently by two researchers. YFAS and dietary habits were obtained from the studies selected by the search protocol. Standardized mean differences were retrieved and random effects meta-analyses were used for those studies reporting quantitative data.

Results: From 162 potentially appropriate studies, 16 studies were finally included, all of which used cross-sectional designs. FA was generally related to higher intakes of total fat, proteins, sugar, and processed/energy-dense foods. The meta-analysis revealed that this association was only statistically significant in overweighted/obese individuals ($P < 0.001$ in all cases), while in those studies that included the general population (all weight categories), this association was not evident ($p = 0.18$).

Conclusions: Being addicted to food was not associated with a higher energy intake in the general population. However, among those with overweight or obesity, FA was associated with higher energy and nutrient consumption. This provides evidence on the influence of addictive behaviours on dietary intake patterns of people with excess body weight and reinforces the concept of food addiction and its influence in the development of obesity.

Systematic review registration: PROSPERO registration number CRD42020212866.

1. Introduction

Food addiction (FA) is a behavioural disorder characterized by symptoms related to loss of self-control, overconsumption, or continued intake of highly palatable foods despite the negative consequences of these behaviours, as well as the incapacity to stop despite the desire to do so [1]. While FA is not yet recognized in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) [2], there are many similarities with substance use disorders. There is

* Corresponding author. Eating Disorders Research Unit, Catholic University of Murcia (UCAM), Campus de Guadalupe, 30107, Murcia. Spain.
E-mail addresses: carmen.piernas-sanchez@phc.ox.ac.uk (C. Piernas), amartinezrodriguez@gcloud.ua.es (A. Martínez-Rodríguez), jjhernandez@ucam.edu (J.J. Hernández-Morante).

https://doi.org/10.1016/j.clnu.2022.06.033
0261-5614/

also growing evidence suggesting that some forms of obesity are related to food addiction behaviours [3]. FA has been related to severe obesity [4], overeating and consumption of certain foods, particularly highly processed, highly palatable foods [5]. Moreover, neuroimaging research has shown that highly processed foods involve reward-related neural circuitry in the same way as drugs of abuse [6]. However, it is unclear how addiction affects the regulation of food intake and how FA influences weight gain, therefore, the potential role of the addictive process in appetite regulation is an area of emerging interest.

Although, as commented above, FA is not yet recognized as a mental disorder, in a previous systematic review, the prevalence of a FA 'diagnosis' measured using the Yale food addiction scale (YFAS) varied from 11.0% in normal weight individuals, to around 25% in adults with overweight or obesity [7]. FA diagnosis was higher in adults aged >35 years, overweight/obese, and female participants. The YFAS questionnaire is a validated tool to assess FA [8] that measures eating patterns over the past year and operationalizes FA according to the DSM-V diagnostic criteria for substance use disorder by modelling these criteria in relation to eating behaviours, for example: "Substance taken in large amounts and for longer periods than intended; Persistent desire or repeated unsuccessful attempts to quit; Excess time/activity to obtain, use, recover food; Important social, occupational, or recreational activities given up or reduced; continued use despite knowledge of adverse consequences (e.g. failure to fulfil role obligation, use when physically hazardous); Tolerance (marked increase in amount; marked decrease in effect); Characteristic withdrawal symptoms; substance taken to relieve withdrawal" [9].

Scientific evidence about food addiction is recent and scarce, with the first study on the validation of YFAS conducted in 2009 and some evidence on the associations between FA and dietary or food intake habits emerging since then. Earlier studies have suggested that FA could act in an analogous way to other substance addictions [10], with repeated exposures to palatable food diminishing the brain response to dopamine release [7]. However, a detailed assessment of the nutritional composition, including specific foods (i.e., high-sugar, high-fat), or dietary components (micro and macro nutrients) were not reported in those studies [7,10,11]. This is a key point since identifying potentially addictive foods and dietary profiles will be important in understanding FA and will help identify therapy options, especially relevant for patients with obesity.

To date, only one meta-analysis has been carried out that showed a positive association between food addiction and mental health symptoms (depression and anxiety) [12], while five other reviews have focused on measures of prevalence [7,13–15]. However, no previous studies have systematically reviewed the evidence with regards to FA and dietary intake patterns. The primary aim of this systematic review and meta-analysis was to investigate differences in dietary intakes among adults with vs without food addiction. Secondly, we explored subgroup differences across weight status.

2. Material & methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed (SupportingTable S1) [16]. The present systematic review was registered in PROSPERO (CRD42020212866).

2.1. Data sources and literature search

Suitable articles published up to September 2021 were searched in the PubMed database. The Medical Subject Headings (MeSH) search terms employed in the present review were ("food addiction" [All Fields] AND "YFAS" [All Fields] AND (food intake OR FFQ OR diet* recall OR diet* assessment) [All Fields] NOT ("bariatric surgery" [All Fields]) [MeSH Terms]. Title, abstract, and keywords were carefully checked to find pertinent papers. At the same time, a similar search was performed in the Web of Knowledge (WoS) and SCOPUS databases to look for additional papers using the same search terms (see supporting information). Reference lists of selected manuscripts were manually checked.

2.2. Eligibility criteria

The PICOS criteria used to identify the research question is shown in Table 1. Studies that satisfied the following criteria were eligible: studies in human populations, without bariatric surgery; with a diagnosis of food addiction (measured via the Yale Food Addiction Scale (YFAS) questionnaire) compared to participants without food addiction; with available data on dietary and food intake measurements; and using interventional or observational study designs. Articles in English were retrieved. There were no date limits. Those studies conducted on individuals with a mental or psychological disorder or other medical conditions were excluded. Previous works performed among people with bariatric surgery were also excluded.

2.3. Selection process and data extraction

Two researchers (C.R.G. and J.J.H-M.) separately screened the titles and abstracts of all studies retrieved to find articles that accomplished the eligibility criteria. The full texts of selected articles were obtained and independently evaluated by the same authors. Conflicts were discussed and reconciled.

Data from all retrieved articles were obtained by one researcher (J.J.H.M.) and confirmed by another (C.R.G.). Extracted data included type of study, study population, study information, and evaluation food and dietary intake instruments. Discrepancies were identified and resolved by consensus.

2.4. Quality assessment

Study quality and risk of bias was determined using Evidence Analysis Manual Academy of Nutrition and Dietetics [17]. Based on these criteria, two researchers, C.R.G. and J.J.H.M. assigned each article a quality rating of positive, neutral, or negative, discussing any conflictive rankings until reaching agreement. The risk of bias tool evaluates the following dimensions: "research question, selection, study groups comparable, withdrawals, blinding, intervening factors, outcomes: measurements valid and reliable, statistical analysis, conclusions supported by results, funding, or sponsorship". Overall quality was identified as positive when the paper clearly describes inclusion/exclusion criteria, risk of bias, generalizability, and other relevant issues; a negative evaluation indicates that these issues have not been clearly explained in the manuscript; finally, a neutral evaluation reflects that the manuscript is neither strong nor weak.

Table 1
PICOS criteria for inclusion and exclusion of studies.

Parameter	Description
Population	Humans, without a bariatric surgery
Intervention	Food addiction
Comparison	Without food addiction
Outcome	Dietary and food intake measures
Setting	Interventional or observational designs

2.5. Analysis of dietary intake among people with vs without food addiction

A series of meta-analyses were conducted for studies that reported dietary intake data for individuals with and without food addiction. Main outcomes were related to total daily energy and macronutrient intakes from studies that collected detailed dietary measurements. Meta-analyses were performed when at least two studies reported the same outcomes. A subgroup analysis by weight status (overweight/obesity vs general population spanning all weight categories) was conducted. The meta-analysis was conducted based on *a priori* random-effects models, considering the heterogeneity across study populations, and outcome evaluation methods. All variables include in the meta-analysis (total energy and macronutrient intakes) were group to calculated standardized mean differences (SMDs) with 95% CIs. Statistical heterogeneity was assessed with the I^2 statistic. The strength of evidence was evaluated by the accuracy of the 95% CIs, which permitted significant differences to be found and heterogeneity to be determined. All data derived from the meta-analyses were obtained through the Review Manager (RevMan) software, version 5.3 (Cochrane Community).

3. Results

3.1. Search results

The first literature search returned 206 potentially suitable studies (Figure 1). Eighty studies were discarded after titles and abstracts screening. Duplicates were also removed. The remaining 126 manuscripts were carefully reviewed. Finally, 16 studies met the inclusion criteria to be included in this systematic review, of which eleven studies examined food and dietary intake in all weight categories and five were focused only on people with overweight/obesity. Fourteen studies used a cross-sectional design, one a double-blind crossover design, and one employed a descriptive analytical study design. A detailed overview of studies that investigated the relation between food and dietary intake in all weight categories is provided in Table 2, and those studies focused exclusively on overweight/obesity populations is described in Table 3.

The 16 studies that examined food addiction and dietary habits included a total of 133766 participants. Most participants were adults, but four studies were exclusively conducted in children and adolescents [18–21]. All reviewed studies used YFAS questionnaire as food addiction diagnostic tool, although two studies also employed the additional items about specific foods of the YFAS (first version) for addiction assessment [22,23]. All studies evaluated dietary intake pattern through self-reported questionnaires. A food frequency questionnaire collecting information about food intake, frequency of consumption or portion size, was used in eight studies [4,10,20,21,23–26]. One study used Food Craving Questionnaire, appetite ratings, snack consumption, and favourite snacks [11]. The forced-choice task of 35 foods was also employed in two studies [27,28]; while other studies used standardized questions derived from the New South Wales Health Survey [29]; list of drinks (with and without sugar) [18]; an eating habits questionnaire [19], or a measure of snaking frequency as a surrogate measurement of overeating [30] (SupportingTable S2).

3.2. Food intakes and food addiction in the general population

The first study that evaluated the association between Food Addiction (FA) and dietary intake was conducted in 2015 by Pedram et al. [26]. In that study, a higher intake of total fat and protein was reported in people diagnosed with FA. Later, a study conducted in undergraduates by Schulte et al., showed a higher intake of highly processed foods in those individuals with FA [27]. These authors also described that higher symptomatology of food addiction was associated with higher intake of glucose-rich foods, which is consistent with the importance of dose and rate of absorption in the addictive potential of drugs of abuse [27]. Similar observations were delivered by the study of Pursey et al., 2015, where the authors described an association between higher intakes of wholegrain products and lower odds of FA diagnosis, while higher intakes of energy-dense foods were related to higher FA symptom scores [25].

Burrows et al. concluded that frequent vegetable intake was related to a decreased likelihood of FA diagnosis, while the opposite situation was true for high sugar intake (including consumption of sweets and soft drinks), and snack foods [29]. In the study conducted by Markus et al., FA was more frequent in people with preference for high-fat savoury and high-fat sweet foods [22]. Similarly, the large population study of Lemeshow et al. observed that food addiction was positively associated with consumption of many hypothesized positively reinforcing foods that included a combination of carbohydrates and fats, such as snacks, “fast food” and candy bars [24]. Ayaz et al. also described that high fat/high sugar foods were more likely to be consumed by people with FA [23].

Not only specific foods or nutrients were related to FA, but also several dietary habits have been proposed to be mediating the association between food intake and FA. For example, YFAS score has been described as a predictor of craving highly processed foods [28]. Burrows et al., 2017 also concluded that eating breakfast regularly was associated with a decreased likelihood of FA [29]. FA has been positively associated with an increased number of calories consumed at dinner and post-dinner [19]. Frequent snacking, described as eating and drinking outside of breakfast, lunch or dinner, has also been associated with FA symptomatology in the study of Khine et al. [30].

Three studies conducted in the general population (all weight categories) were included in meta-analyses of mean total energy intakes, carbohydrate, total fat, protein saturated fat and sugar [23,25,26]. Overall, there were no significant differences in total mean energy intakes between individuals with vs without FA (SMD = 117.93, 95%CI, −56.12 to 291.98; $p = 0.18$, Figure 2).

Total carbohydrate ($p = 0.60$), sugar ($p = 0.61$) and total protein ($p = 0.28$) intakes were also similar in people with or without FA (Figure 3A and B, Supporting Figure S1), but total fat and saturated fat intakes were statistically significantly higher in the FA group (total fat, $p = 0.009$, Figure 3C) (saturated fat $p = 0.0001$, Figure S1).

3.3. Food intake and food addiction among people with overweight/obesity

For studies that exclusively evaluated people with overweight or obesity, in 2014, Davis et al. showed a higher appetite consumption of snacks among people with FA, which was independent of using methylphenidate, a dopamine and norepinephrine reuptake inhibitor prescribed for ADHD treatment [11].

The study carried out by Pedram et al., in 2015, reported that total calorie intake and the percent of energy from total fat and carbohydrates was higher in individuals with FA and overweight/obesity [26]. Moreover, in that study, a higher intake of sugar, minerals (including sodium, potassium, calcium, and selenium), total fat as well as some of its components (i.e., saturated, monounsaturated, omega-6, omega-3, and trans-fat), vitamin D and γ-

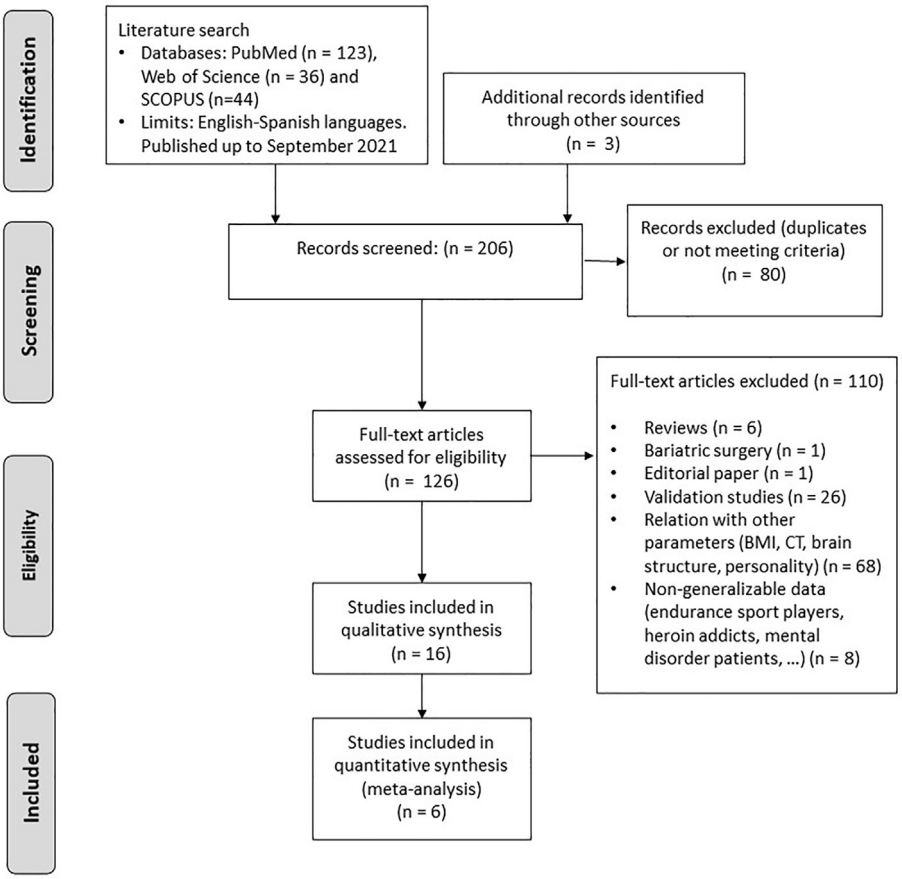

Fig. 1. Flow diagram of the literature search process.

tocopherol was also observed in people with FA. Keser et al. showed that a higher frequency of consumption of French fries was associated with a 2.3-fold increase in risk of developing FA among children and adolescents with obesity [20]. There were other foods which were associated with increased odds of developing FA, including chocolate, ice cream, carbonated beverages, white bread, rice, candy, chips, and pasta, in decreasing order [20]. More recently, Schulte et al. in a study performed on adolescent girls with obesity, described a greater consumption on the FA group of total daily energy intake as well as total fat, saturated fat, *trans* fat, carbohydrates, sugar and added sugar; with the strongest association found for *trans*-fat, a nutrient most frequently found in highly processed foods [21]. Consistent observations were observed in the study of Moghaddam et al., where adult women with FA and obesity were characterized by higher dietary intakes of energy, carbohydrate, protein, fat, and cholesterol [4].

Three studies conducted among people with overweight/obesity reported detailed dietary intake measurements and were included in the meta-analysis [4,21,26]. A great number of significant differences were observed among people with vs without FA in the subgroup with overweight/obesity. There was a significant higher energy intake in people with FA compared to those without FA (SMD = 604.75, 95%CI, 465.64 to 743.85; $p < 0.0001$, Figure 2). Similarly, carbohydrate, total fat and protein intakes were significantly higher in FA individuals with overweight/obesity ($p < 0.0001$ in all cases, Figure 3), as well as saturated fat intake ($p < 0.0001$, Figure S1). In contrast, although sugar intake was higher in people with FA (SMD = 62.43, 95%CI, −9.11 to 133.96, $p = 0.09$), the high heterogeneity of the included studies made it unfeasible to reach statistical significance (Figure S2).

3.4. Heterogeneity of the reported outcomes

The heterogeneity of the meta-analysis performed to evaluate differences regarding total energy intakes (Figure 2) was low for the overweight/obesity studies ($I^2 = 25\%$), but moderate when all weight groups were evaluated ($I^2 = 65\%$), and ever higher when both groups were pooled ($I^2 = 96\%$). The heterogeneity of carbohydrate data was also high, both in overweight/obesity ($I^2 = 61\%$), all weight ($I^2 = 84\%$) and total heterogeneity of both groups ($I^2 = 99\%$). On the contrary, heterogeneity for the total protein analysis was lower ($I^2 = 0\%$), probably for the lack of data of the study of Schulte et al. [21]. The heterogeneity of studies focused on the general population was moderate ($I^2 = 68\%$), and the pooled heterogeneity was even higher ($I^2 = 78\%$). Data regarding total fat intake in overweight/obesity studies was very low ($I^2 = 0\%$), but in this case, the homogeneity was a consequence of the data described in those studies. Again, the heterogeneity of the general population studies was high ($I^2 = 77\%$), and the pooled heterogeneity was of $I^2 = 79\%$.

It can be concluded that when all weight categories were included in the meta-analysis, the I^2 obtained was high, which suggests that the subgroup analysis was more adequate, therefore, all meta-analysis should be interpreted in this line.

3.5. Risk of bias

The data derived from the Evidence Analysis Manual Academy of Nutrition and Dietetics showed that all except one study included in the present systematic review had overall positive quality, suggesting a high validity of the included studies. Only one

Table 2
Overview of studies investigating the relation between food and dietary intake in food addiction including all weight categories.

Reference	Type of study	Population and participant characteristics	Study information	Food and dietary intake instruments	Results
Khine et al. (2019)	Cross-sectional	N = 574 university students, 78.5% female. Age (M = 20.8 years, SD = 1.8). BMI categories: Underweight 8.6%, normal weight 83.4%, overweight 7.0%, obese 1.0%.	Validated Japanese version of YFAS 2.0	Desire to overeat and Snacking frequency self-reported	Food addiction (FA) diagnosis was associated with a frequent desire to overeat ($p = 0.007$), and frequent snacking ($p = 0.003$).
Ayaz et al. (2018)	Cross-sectional	N = 851 adults. 57.7% female. Age 34.6 ± 12.8 years (Age range 19–65 years) BMI 25.2 (BMI range: 16.2 –45.7) BMI categories: Underweight 9.41%, normal weight 47.23%, overweight 27.73%, obese 15.63%.	Investigates possible differences in eating patterns, altered eating behaviours, obesity, and the number of FA symptoms.	Additional YFAS items	Food Addicted women showed higher total daily energy intake, protein and fat intakes that non-addicted females ($p < 0.05$). Participants with FA had more problems with foods with high amounts of fat and sugar.
Lemeshow et al. (2018)	Cross-sectional	N = 123.688 adult women. Age Range: 25–55 years BMI categories: normal weight 43.35%, overweight 31.63%, obese 25.02%.	Evaluated the association between food consumption and food addiction	Modified version of YFAS and FFQ	Food addiction was positively associated with consumption of foods like hamburgers (OR 4.08 (2.66–6.25), French fries (OR 2.37 (1.59–3.51) and pizza (OR: 2.49 (1.67–3.69) ($p < 0.001$ in all cases)
Richmond et al. (2017)	Cross-sectional	N = 107.42.9% women. Age 8.34 ± 2.7 years (range 4 –16 years of age) BMI 20.39 ± 6.18 BMI categories: Underweight 4.8%, normal weight 43.5%, overweight 14.5% and 37.1% were obese.	Studies the association between FA and objectively measured food consumption	Demographic and Eating Habits Questionnaire	The number of FA symptoms, but not BMI (measured as percentile), were positively associated with an increased number of calories, but only those consumed at dinner and later (post-dinner). This association was observed only in younger children, which indicates that age significantly moderated this relationship.
Markus et al. (2017)	Cross-sectional	N = 1495 college students, 1046 women and 449 men. Age between 18 and 30 years; 21.6 ± 3 years. BMI categories: 84.4% of the participants were normal weight, 13.1% were overweight and 2.5% were obese.	Evaluates the prevalence of FA and the addiction to specific foods (high fat or high sugar). Also determines the relationships with BMI and depression.	Follow parts to the YFAS and additional items	People with preference for the combined high-fat savoury and/or high-fat sweet foods (30%) had higher FA prevalence that people with preference specifically to Sugary foods (5%). Moreover, BMI was positively associated with the number of YFAS symptoms, which was only significant in participants reporting to have YFAS problems for high –fat savoury and/or high-fat sweet
Burrows et al. (2017)	Cross-sectional	N = 1344, 75.7% female. Mean age 39.8 ± 13.1 years (range 18 –91 years) BMI 27.7 ± 9.5. BMI categories: 45.2% of the participants were normal weight, 26% were overweight and 28.8% were obese.	Investigates FA in a group of Australian adults through the revised Yale Food Addiction Survey (YFAS) 2.0 tool. Also investigates if FA was associated with dietary intake, personality traits and other mental health issues	Dietary intake was assessed using standardized items derived from the New South Wales Health Survey	Vegetable intake decreased the risk of severe FA. The study showed that addictive food behaviours are associated with a complex pattern of worse quality dietary choices and with a clustering of mental health problems, mainly depression.
Mies et al. (2017)	Cross-sectional	N = 2653.61.2% girls. Age ranged from 14 to 21 years. BMI categories: Underweight 7.9%, normal weight 77.3%, overweight 12.8%.	Examines the prevalence of food addiction and the relationship between FA symptoms and substance of abuse use, and the intake of sugary, while controlling for	List of drinks (including drinks with and without sugar) on a daily or weekly basis. Indicating the number of servings per day or week and measure of grams of sugar	FA symptoms were positively associated with smoking, alcohol use, cannabis use and sugar intake.

			gender, age, educational level, and weight category.		
Polk et al. (2017)	Cross-sectional	N = 216.61.6% were female (n = 133). Age ranged from 19 to 75 years (M = 38.15, SD = 14.02). BMI categories: Underweight 2.8%, normal weight 43.1%, overweight 28.7%, obese 25.4%.	Evaluates the relationship of highly processed foods with craving and liking, and whether these associations differ by FA symptomology, cognitive restraint, or BMI.	35 foods were systematically selected depending on processing and composition (fat, protein, sugar, carbohydrate and fibre content). Foods were categorized as processed, highly processed, and minimally processed	Highly processed foods were usually related to higher craving (stronger for individuals who exhibited indicators of FA), but not significantly associated with elevated liking
Pursey et al. (2015)	Cross-sectional	N = 462.86% female. Adults 18−35 years (M = 25.1, SD = 4.0). BMI categories: underweight 5.4%, normal weight 72.9%, overweight 13.9%, obese 7.8%.	Evaluates in young adults whether intakes of specific foods are associated with FA, and to describe the associated nutrient intake profiles.	Dietary intake composition was evaluated via the Australian Eating Survey food frequency questionnaire	Higher intakes of whole-grain products were related to lower probability of FA diagnosis. On the other hand, higher intakes of fat were associated with higher probability of FA. Moreover, higher intakes of energy-dense, low quality foods were related to higher FA scores.
Schulte et al. (2015)	Cross-sectional	Two studies. Study one: 120 undergraduates, 67.5% girls. Age: 18−23 years (mean = 19 years, SD = 1). BMI (mean = 23.03, SD = 3.20)/ Study two: 384 adults. Aged 18 −64 (M = 31.14, SD = 9.61), 40.6% females. BMI 26.95 ± 6.21. BMI categories not stated.	Investigates initial evidence for the foods and food issues implicated in addictive-like eating	Forced-choice task of 35 foods with variable nutritional composition	Processed foods or foods with high amounts of fat and/or refined carbohydrates (like white flour and sugar), were most associated with FA behaviours. Food processing was a positive predictor for whether a food was associated with problematic, FA behaviours
Pedram et al. (2013)	Cross sectional	n = 652, 63.7% women. Age: 44.3 ± 12.9 years (20−90 years). BMI: 27.4 ± 5.4 kg/m2 (17.1 −54.2 kg/m^2). BMI categories not stated.	Investigation of FA in a Canadian Region and the relationships with gender and BMI.	Food frequency questionnaire (macronutrient intake-protein, fat and carbohydrate-) Willet Food Frequency Questionnaire (FFQ)	People with FA reported higher intake of fat (+2.3%, p = 0.04) and protein (+1.1%, p = 0.04). BMI was associated with FA symptoms (r = 0.36, p < 0.001), waist hip ratio (r = 0.15, p < 0.001), percent body fat (r = 0.31, p < 0.001), and trunk fat (r = 0.32, p < 0.001).

Table 3
Overview of studies investigating the relation between food addiction and the food and dietary intake focused exclusively on people with overweight/obesity.

Reference	Type of study	Population and participant characteristics	Study information	Food and dietary intake instruments	Results
Moghaddam et al. (2019)	Descriptive-analytical study	N = 244 women with obesity. Age range 18–60 years (39 ± 10.2). BMI 36.37 (30, 78.3)	Assess the prevalence of FA and its associations with plasma oxytocin levels and anthropometric and dietary variables	S-FFQ 147 food items	FA was associated with obesity, dietary intakes of energy, carbohydrate, protein, fat, cholesterol, and plasma oxytocin level
Schulte et al. (2018)	Cross-sectional	181 adolescents with obesity (122 girls). Aged: 12–16 years (M = 13,75, SD = 1.35). BMI (M = 38.15, SD = 7.45)	Examines the prevalence of FA and its convergent validity with percent overweight, eating-related concerns, and self-reported dietary intake	Block food frequency questionnaire (FFQ)	FA symptomatology was related to greater consumption of all nutrient characteristics evaluated (calories, fat, saturated fat, trans fat, carbohydrates, sugar, added sugar). The strongest association was found for *trans*-fat.
Pedram et al. (2015)	Cross-sectional	N = 58 (29 FA and 29 NFA). 83% women. Age: 42 ± 8.9 years NFA and 42.5 ± 9.4 years FAA. BMI: NFA 32 ± 4.42, FA 32.5 ± 6.	To evaluate potential biomarkers, including several hormones and neuropeptides, involved in appetite regulation and metabolism, and nutrient composition	Willet Food Frequency Questionnaire (FFQ)	Total calorie intake, fat intake and carbohydrate intake was higher in people with FA. The FA individuals consumed more sugar, minerals (including sodium, potassium, calcium, and selenium), fat and fat families (saturated, monounsaturated, omega 3 and 6 and trans-fat), vitamin D and γ-tocopherol compared to the NFA group.
Keser et al. (2015)	Cross-sectional	100 adolescents and children with overweight or obesity. 63% were girls. Age range 10–18 years. FA age 14.6 ± 2.07, NFA age 13.9 ± 1.96. BMI between 1 and > 3 SDS from National standards.	Investigates the relationship between obesity parameters and FA to evaluate the prevalence of FA among obese children and adolescents	Food frequency questionnaire (FFQ)	The most related to food addiction symptoms were chocolate, ice cream, carbonated beverages, French fries, white bread, rice, candy, chips, and pasta, in decreasing order of frequency. Children and adolescents with a frequent feeling of hunger shoed a 2.2-fold increase in FA risk ($p < 0.05$). FA prevalence was higher in obese and overweight adolescents, which indicates that FA plays an important role in childhood obesity
Davis et al. (2014)	Doble blind crossover design	N = 136.67.6% female. Healthy adults. Age: 25–50 years. BMI: FA group 34.6 ± 7.0 kg/m^2, non-FA group 33.8 ± 8.4 kg/m^2	Participants randomised to oral methylphenidate or placebo. Methylphenidate inhibits appetite and diminishes binge episodes. Participants could eat	General FCQ- State; Subjective appetite ratings, Snack food consumption; Favourite snack foods.	FA group showed higher food cravings and subjective appetite ratings than non-FA

Table 3 (*continued*)

Reference	Type of study	Population and participant characteristics	Study information	Food and dietary intake instruments	Results
		26% food addicts and 20% control group smokers.	ad *libitum* as much of snack food as desired 3 h post drug administration.		group ($p < 0.0001$). Methylphenidate reduced snack food intake in the non-food addiction group (compared to placebo) ($p < 0.0001$) but there was no effect on the food addicts.

study was classified as of neutral quality. None of the studies were classified as high risk of bias for the selection procedure (Supporting Table S3). Although there were few studied to detect asymmetry, funnel plots were calculated for each outcome (information available as supporting Figure S2).

4. Discussion

The present review was conducted to investigate differences in dietary habits among people with food addiction (FA) compared to those without FA. We found no evidence of significant differences in total daily energy intake and macronutrients distribution between people with vs without FA in the general population. However, among people with overweight or obesity, those with FA eat significantly more energy, total fat, saturated fat, protein, and carbohydrates than those without FA.

Previous evidence has shown that those diagnosed with FA tend to consume more processed foods [28] or foods with high amounts of fat and/or refined carbohydrates (like sugar or white flour) [27], as well as foods combining high-fat savoury and/or high-fat sweet foods as opposed to sugary foods only [22]. Another study reported higher intakes of chocolate, ice cream, sugary drinks, French fries, white bread, rice, sweets, French fries, and pasta, in decreasing order, among people with FA [20]. To reinforce these observations, a large population including data from the NHANES cohort have showed a positive association between FA diagnosis and the consumption of foods such as snacks, fast-food and candy bars [24].

When studies including the general population were evaluated, the results suggested that people with vs without FA consumed similar amounts of energy and macronutrients (carbohydrates, fat, and protein), although it is noticeable that there is a tendency to consume higher amounts of calories and fats in people with FA, a question pointed out in the study of Pedram et al. [10]. Our results support the hypothesis that normal weight individuals could generate compensatory behaviours (i.e., increased physical activity, or dieting behaviours, etc.) to balance the large energy and macronutrient consumption related to FA. In fact, compulsive overeating behaviours are observed in several disorders characterized by compensatory weight control behaviours [31,32]. In addition, it has been described that people with FA present an associated dependence to do more exercise [33], which all together may potentially explain our observations.

In studies which focused on people with overweight/obesity, those with FA showed significantly higher intakes of calories, fat, carbohydrates and sugar [26,27]; as well as several minerals, omega-3 and omega-6 fats, vitamin D and γ-tocopherol [26]; proteins and cholesterol [4]. Perhaps, in people with overweight/obesity, compensatory mechanisms are not present or are not able to overcome the excess caloric intake, which has been theorised before. Several hypotheses may be involved in these observations. Volkow et a. previously described that the brain pathways involved in food addiction and the loss of control and overconsumption of food intake share the similar neuronal mechanisms in people with obesity [34]. A common feature of the consumption of drugs of abuse and obesity is the alteration of brain dopamine (DA) signalling, which modulate the behavioural responses to external cues. The dopamine neurons in midbrain nuclei project to nucleus accumbens, limbic (amygdala and hippocampus) and cortical regions (prefrontal cortex, cingulate

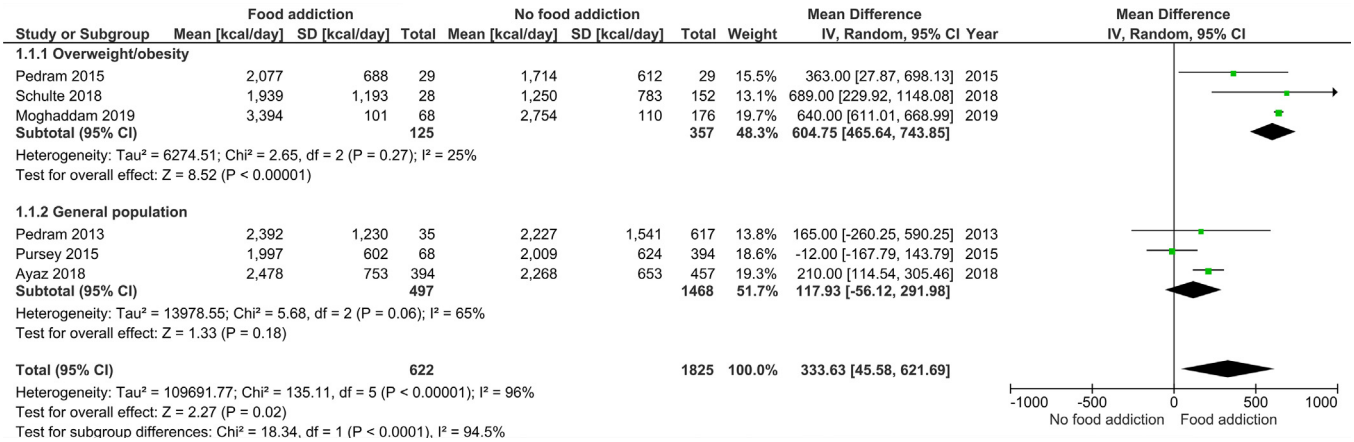

Fig. 2. Random-effects meta-analysis of standard mean differences (SMDs) and 95% CIs for studies that included data from total daily energy intake. Meta-analysis categories included (upper section) overweight/obesity and (lower section) general population. Combined data for each group correspond to the SMD and 95% CI. The size of the data markers indicates the weight assigned to each study in the meta-analysis. Squares correspond to the SMD, while bars correspond to the 95% CI, and diamonds indicate the pooled analysis.

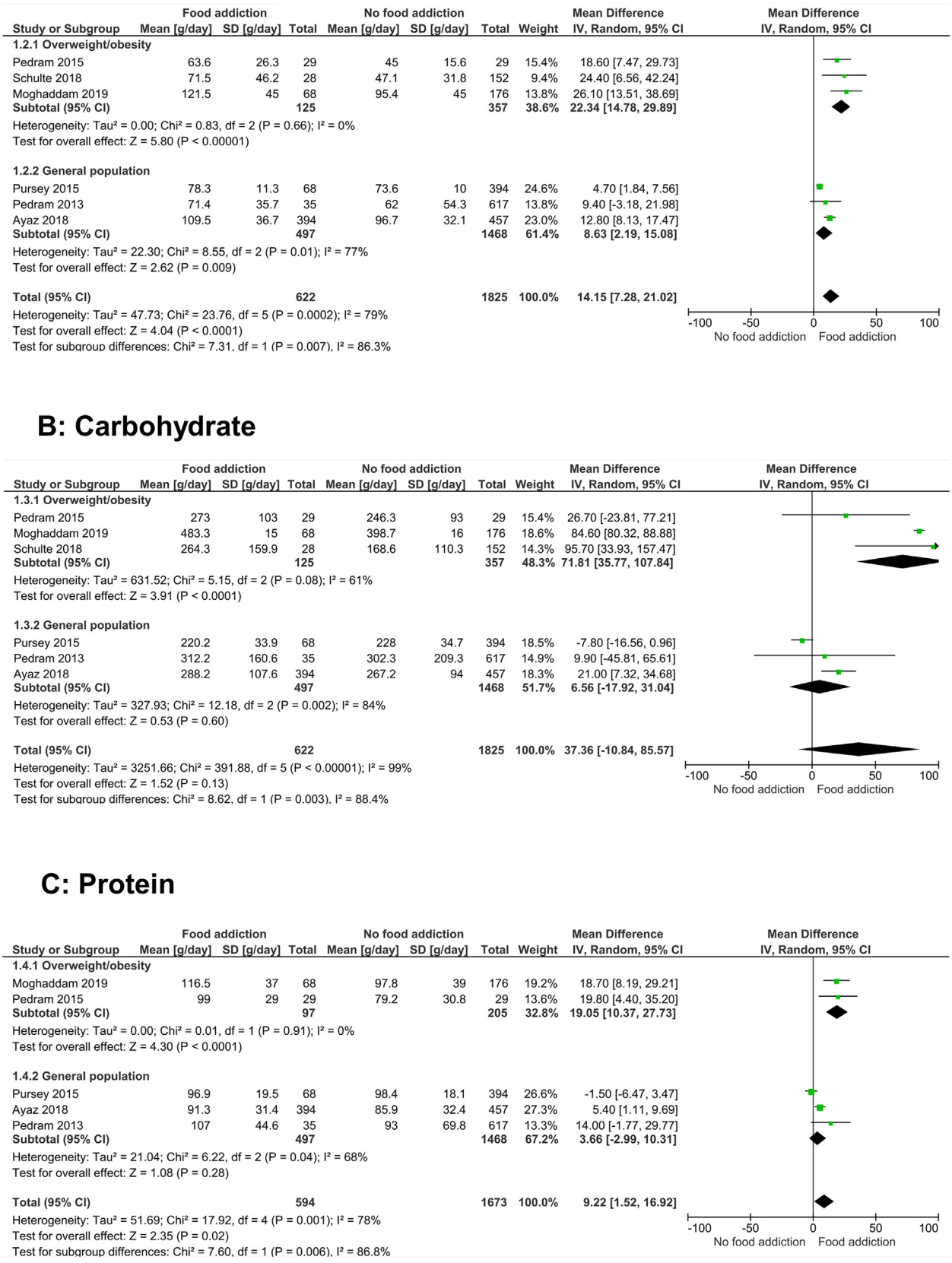

Fig. 3. Random-effects meta-analysis of standard mean differences (SMDs) and 95% CIs for studies that included data from total fat (A), carbohydrate (B) and protein (C) intakes. Meta-analysis categories included (upper section) overweight/obesity and (lower section) general population. Combined data for each group correspond to the SMD and 95% CI. The size of the data markers indicates the weight assigned to each study in the meta-analysis. Squares correspond to the SMD, while bars correspond to the 95% CI, and diamonds indicate the pooled analysis.

gyrus, temporal pole) and regulate the motivation necessary to carry out behaviours needed for survival [34,35]. To achieve its functions, DA neurons receive afferent signals from neuronal regions involved with autonomic responses, memory emotional reactivity, arousal and executive functioning (prefrontal cortex and cingulate) through many different neurotransmitters and other neuropeptides. Thus, it is not surprising that an impairment of the neurohormonal factors implicated in addictive processes were also implicated in food intake [36].

Another hypothesis that could partially explain our observations is an alteration in cognitive control as a consequence of a deterioration in executive functions. Scientific evidence has previously shown a relationship between increased body fat and impaired executive functions [37]. In this line, we described alterations in executive functions such as working memory or decision-making in people with obesity [38], and a treatment aimed at improving these functions could potentially improve the effectiveness of dietary treatment in people with obesity [38]. The meta-analysis conducted by Yang et al. also described moderated effects of obesity on working memory and decision-making [39], although as they described, there are not enough studies of people with overweight/obesity to make strong claims about the interaction between obesity and executive functions. In any case, a different interaction between body weight, control of addictive behaviours and executive functions can be proposed, which would ultimately serve to carry out compensatory mechanisms that prevent the development of obesity (this information is summarized in the Supporting Figure S3).

Several limitations of the present work should be commented. Although the data derived from the studies retrieved have provided evidence on the significant differences in dietary intakes in overweight/obese people with FA compared to those without FA, the weak cross-sectional design of the included studies does not allow to establish causality and to conclude that FA increases the intake of high-fat and high-sugar foods or that the intake of these foods leads to the development of this addiction. Prospective cohort studies may be necessary to confirm the direction of this hypothesis.

While the main objective of this work was to compare dietary intake patterns by presence or absence of FA, on some occasions, the studies retrieved did not provide the necessary information to carry out a more in-depth evaluation of the dietary data. This occurred because either the eating habits were evaluated through questionnaires that didn't estimate total nutrient intakes (e.g., macronutrient, micronutrient and/or total energy intakes), or because nutritional information was not always provided. Therefore, the meta-analysis only included 6 out of the 16 studies. In addition, we reported a high degree of heterogeneity in the meta-analysis, especially regarding energy intakes and carbohydrate in the general population. This could have been influenced by differences in study design and methods, or because they included different populations, age stages or for having used different tools for dietary evaluation, which limits the interpretation of the results described in the present study. In addition, it should be noted that the studies which included the general population measured FA and dietary behaviours in people across all weight categories, which may induce some bias in the results obtained; therefore, only meta-data on people with overweight/obesity may be considered more reliable. Finally, although the main databases of scientific information have been employed, articles not included in either Pubmed, WoS or SCOPUS or those published in other languages different to English may have also evaluated these aspects.

5. Conclusion

Food addiction (FA) appears to have a significant effect on eating habits, which was especially evident in people with overweight/obesity. Concretely, among people with overweight/obesity, FA was related to higher intakes of total daily energy intake and all macronutrients, as well as processed and energy-dense foods among people with overweight/obesity, but not in the general population including all weight categories. However, the heterogeneity of the studies included in the meta-analysis will force us to take these observations with some caution. Although undoubtedly new research is needed to know the precise physiological and metabolic mechanisms by which a food addiction induces greater food intake in people with overweight/obesity, at the moment, it might be of great interest to consider not only the patients' daily energy expenditure, but also their addictive behaviours related to food, in order to increase the effectiveness of hypocaloric diets. Further research should determine the precise role of potential compensatory behaviours that may affect dietary behaviour and weight outcomes.

Author contributions

Cristina Reche-García: Conceptualization; Data curation; Methodology; Supervision. *Carmen Piernas:* Data curation; Formal analysis; Methodology. *Alejandro Martínez-Rodríguez:* Data curation;; Supervision; Validation. *Alejandra Sánchez-Guerrero:* Data curation. *Juan José Hernández-Morante:* Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization. Writing - original draft; Writing - review & editing: all authors contributed equally.

Funding statement

This work was partially funded by PMAFI-19/21 project from the Support for Research Help Program of the Catholic University of Murcia. C.P.'s time on this research was funded by the National Institute of Health Research (NIHR), Applied Research Collaborations at Oxford Health NHS Foundation Trust.

Conflict of Interest

None of the authors have nothing to declare.

Acknowledgments

All authors have read and approved the final manuscript. C.R.G., J.J.H-M., and C.*P. and* conceived and designed this work and collected and analysed the data. All authors participated in the writing or critical revision of the manuscript and reviewed, revised, and approved the final version.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnu.2022.06.033.

References

[1] Gearhardt AN, White MA, Potenza MN. Binge eating disorder and food addiction. Curr Drug Abuse Rev 2011;4:201–7. https://doi.org/10.2174/1874473711104030201.
[2] Cooper R. Diagnosing the diagnostic and statistical manual of mental disorders. ed. Karnac Books; 2014.
[3] Carter A, Hardman CA, Burrows T. Food addiction and eating addiction: scientific advances and their clinical, social and policy implications. Nutrients 2020;12. https://doi.org/10.3390/nu12051485.
[4] Moghaddam SAP, Amiri P, Saidpour A, Hosseinzadeh N, Abolhasani M, Ghorbani A. The prevalence of food addiction and its associations with plasma oxytocin level and anthropometric and dietary measurements in Iranian women with obesity. Peptides 2019;122:170151. https://doi.org/10.1016/j.peptides.2019.170151.

[5] Brownell Kelly D, Gold MS. Food and addiction: a comprehensive handbook. 2012.
[6] Schulte EM, Yokum S, Jahn A, Gearhardt AN. Food cue reactivity in food addiction: a functional magnetic resonance imaging study. Physiol Behav 2019;208. https://doi.org/10.1016/j.physbeh.2019.112574.
[7] Pursey KM, Stanwell P, Gearhardt AN, Collins CE, Burrows TL. The prevalence of food addiction as assessed by the Yale Food Addiction Scale: a systematic review. Nutrients 2014;6:4552–90. https://doi.org/10.3390/nu6104552.
[8] Gearhardt AN, Corbin WR, Brownell KD. Development of the yale food addiction scale version 2.0. Psychol Addict Behav 2016;30:113–21. https://doi.org/10.1037/adb0000136.
[9] American Psychiatric Association. Diagnostic and statistical manual of mental disorders-V. 4th ed. Arlington, United Sates: American Psychiatric Publishing; 2000.
[10] Pedram P, Wadden D, Amini P, Gulliver W, Randell E, Cahill F, et al. Food addiction: its prevalence and significant association with obesity in the general population. PLoS One 2013;8. https://doi.org/10.1371/journal.pone.0074832.
[11] Davis C, Levitan RD, Kaplan AS, Kennedy JL, Carter JC. Food cravings, appetite, and snack-food consumption in response to a psychomotor stimulant drug: the moderating effect of "food-addiction. Front Psychol 2014;5:403. https://doi.org/10.3389/fpsyg.2014.00403.
[12] Burrows T, Kay-Lambkin F, Pursey K, Skinner J, Dayas C. Food addiction and associations with mental health symptoms: a systematic review with meta-analysis, vol. 31. England: Blackwell Publishing Ltd; 2018. https://doi.org/10.1111/jhn.12532.
[13] Hauck C, Cook B, Ellrott T. Conference on "Optimal diet and lifestyle strategies for the management of cardio-metabolic risk" International Early Research Championship Food addiction, eating addiction and eating disorders. 2019. https://doi.org/10.1017/S0029665119001162.
[14] Penzenstadler L, Soares C, Karila L, Khazaal Y. Systematic review of food addiction as measured with the yale food addiction scale: implications for the food addiction Construct. Curr Neuropharmacol 2019;17:526–38. https://doi.org/10.2174/1570159X16666181108093520.
[15] Constant A, Moirand R, Thibault R, Val-Laillet D. Meeting of minds around food addiction: insights from addiction medicine, nutrition, psychology, and neurosciences. Nutrients 2020;12:3564. https://doi.org/10.3390/nu12113564.
[16] McInnes M, Moher D, Thombs B, McGrath T, Bossuyt P, Clifford T, et al. Preferred reporting items for a systematic review and meta-analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. JAMA 2018;319:388–96. https://doi.org/10.1001/JAMA.2017.19163.
[17] Academy of Nutrition and Dietetics. Evidence analysis manual: steps in the Academy evidence analysis process. 2016.
[18] Mies GW, Treur JL, Larsen JK, Halberstadt J, Pasman JAJA, Vink JM. The prevalence of food addiction in a large sample of adolescents and its association with addictive substances. Appetite 2017;118:97–105. https://doi.org/10.1016/j.appet.2017.08.002.
[19] Richmond RL, Roberto CA, Gearhardt AN. The association of addictive-like eating with food intake in children. Appetite 2017;117:82–90. https://doi.org/10.1016/j.appet.2017.06.002.
[20] Keser A, Yuksel A, Yesiltepe-Mutlu G, Bayhan A, Ozsu E, Hatun S. A new insight into food addiction in childhood obesity. Turk J Pediatr 2015;57:219–24.
[21] Schulte EM, Jacques-Tiura AJ, Gearhardt AN, Naar S. Food addiction prevalence and concurrent validity in African American adolescents with obesity. Psychol Addict Behav 2018;32:187–96. https://doi.org/10.1037/ADB0000325.
[22] Markus CR, Rogers PJ, Brouns F, Schepers R. Eating dependence and weight gain; no human evidence for a "sugar-addiction" model of overweight. Appetite 2017;114:64–72. https://doi.org/10.1016/j.appet.2017.03.024.
[23] Ayaz A, Nergiz-Unal R, Dedebayraktar D, Akyol A, Pekcan AG, Besler HT, et al. How does food addiction influence dietary intake profile? PLoS One 2018;13. https://doi.org/10.1371/journal.pone.0195541.
[24] Lemeshow AR, Rimm EB, Hasin DS, Gearhardt AN, Flint AJ, Field AE, et al. Food and beverage consumption and food addiction among women in the Nurses' Health Studies. Appetite 2018;121:186–97. https://doi.org/10.1016/J.APPET.2017.10.038.
[25] Pursey KM, Collins CE, Stanwell P, Burrows TL. Foods and dietary profiles associated with "food addiction" in young adults. Addict Behav Reports 2015;2:41–8. https://doi.org/10.1016/j.abrep.2015.05.007.
[26] Pedram P, Sun G. Hormonal and dietary characteristics in obese human subjects with and without food addiction. Nutrients 2015;7:223–38. https://doi.org/10.3390/nu7010223.
[27] Schulte EM, Avena NM, Gearhardt AN. Which foods may Be addictive? The roles of processing, fat content, and glycemic load. PLoS One 2015;10:e0117959. https://doi.org/10.1371/journal.pone.0117959.
[28] Polk SE, Schulte EM, Furman CR, Gearhardt AN. Wanting and liking: separable components in problematic eating behavior? Appetite 2017;115:45–53. https://doi.org/10.1016/j.appet.2016.11.015.
[29] Burrows T, Hides L, Brown R, Dayas CV, Kay-Lambkin F. Differences in dietary preferences, personality and mental health in Australian adults with and without food addiction. Nutrients 2017;9. https://doi.org/10.3390/nu9030285.
[30] Khine MT, Ota A, Gearhardt AN, Fujisawa A, Morita M, Minagawa A, et al. Validation of the Japanese version of the yale food addiction scale 2.0 (J-YFAS 2.0). Nutrients 2019;11:1–13. https://doi.org/10.3390/nu11030687.
[31] Kekic M, McClelland J, Bartholdy S, Chamali R, Campbell IC, Schmidt U. Bad things come to those who do not wait: temporal discounting is associated with compulsive overeating, eating disorder psychopathology and food addiction. Front Psychiatr 2019;10:978. https://doi.org/10.3389/fpsyt.2019.00978.
[32] de Vries S, Meule A. Food addiction and bulimia nervosa: new data based on the yale food addiction scale 2.0. Eur Eat Disord Rev 2016;24:518–22. https://doi.org/10.1002/ERV.2470.
[33] Hauck C, Schipfer M, Ellrott T, Cook B. The relationship between food addiction and patterns of disordered eating with exercise dependence: in amateur endurance athletes. Eat Weight Disord 2020;25:1573–82. https://doi.org/10.1007/S40519-019-00794-6.
[34] Volkow ND, Wang G-JJ, Tomasi D, Baler RD. Obesity and addiction: neurobiological overlaps. Obes Rev 2013;14:2–18. https://doi.org/10.1111/j.1467-789X.2012.01031.x.
[35] Volkow Nora D, Wang Gene-Jack, Baler Ruben D. Reward, dopamine and the control of food intake: implications for obesity. Trends Cognit Sci 2011;15:37–46. https://doi.org/10.1016/J.TICS.2010.11.001.
[36] van de Giessen Elsmarieke, Celik Funda, Schweitzer Dave H, van den Brink Wim, Booij Jan. Dopamine D2/3 receptor availability and amphetamine-induced dopamine release in obesity. J Psychopharmacol 2014;28:866–73. https://doi.org/10.1177/0269881114531664.
[37] Brady Cassandra C, Vannest Jennifer J, Dolan Lawrence M, Kadis Darren S, Lee Gregory L, Holland Scott K, et al. Obese adolescents with type 2 diabetes perform worse than controls on cognitive and behavioral assessments. Pediatr Diabetes 2017;18:297–303. https://doi.org/10.1111/PEDI.12383.
[38] Galindo Muñoz JS, Morillas-Ruiz JM, Gómez Gallego M, Díaz Soler I, Barberá Ortega M del C, Martínez CM, et al. Cognitive training therapy improves the effect of hypocaloric treatment on subjects with overweight/obesity: a randomised clinical trial. Nutrients 2019;11:925. https://doi.org/10.3390/nu11040925.
[39] Yang Y, Shields G, Guo C, Liu Y. Executive function performance in obesity and overweight individuals: a meta-analysis and review. Neurosci Biobehav Rev 2018;84:225–44. https://doi.org/10.1016/J.NEUBIOREV.2017.11.020.