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REVIEW

The association between junk foods consumption and attention deficit hyperactivity disorder in children and adolescents: a systematic review and meta-analysis of observational studies

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Abstract

The adverse effects of junk foods on the risk of attention deficit hyperactivity disorder (ADHD) symptoms were reported in several studies. In this meta-analysis, the association between junk food consumption and the risk of ADHD was investigated in children and adolescents. A comprehensive systematic search was conducted to find all relevant literature via four databases, including PubMed, Web of Science, Scopus, and Google scholar, up to September 2022. Two independent authors screened all documents based on inclusion criteria. The overall effect sizes and related 95% confidence interval (CI) were pooled with the random effect approach. Subgroup analysis was done to measure potential sources of heterogeneity between studies. The quality of the included studies was evaluated with The Newcastle–Ottawa scale (NOS). Nine observational studies with 58,296 children /adolescents were eligible to be include in the meta-analysis. According to the random effect model, there was a positive relation between the consumption of junk foods and ADHD symptoms (odds ratio (OR): 1.24, 95%CI 1.15–1.34, $P < 0.001$, I^2: 37.4%, $P = 0.085$). A similar significant positive association was shown in the subgroups analysis by different junk foods (sweetened beverages/soft drinks, sweets/candies, and other types of junk foods). This meta-analysis finding demonstrated that consuming junk foods, especially sweetened beverages/soft drinks, and sweets/candies is associated with ADHD symptoms.

Keywords ADHD · Hyperactivity · Junk food · Sweetened beverages · Sweets

Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the prevalent and most studied neurodevelopmental disorders affecting children and adolescents that sometimes

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persists until adulthood [1, 2]. It is characterized by hyperactivity, inattention, and impulsivity [3]. Children with ADHD are mainly disturbed by other mental disorders such as depression, anxiety, learning and language problems, poor performance, and anti-social behaviors that impose a different type of burden on families and societies [4, 5]. ADHD diagnoses in boys are twice as common than in girls [6]. The worldwide prevalence of ADHD has increased in recent years [7]. According to previous epidemiological studies, the average prevalence rate of ADHD was reported to be 3.5–7.5% in children and adolescents [6, 8–10]. However, the prevalence rate is varied between 1 and 25% according to the age group, region, or diagnosis methods [11–13].

It is believed that various risk factors, including genetics and environmental factors, contribute to the aetiology of ADHD. There is evidence that diet and lifestyle, among environmental factors, are linked to the risk of ADHD symptoms [14–16]. Association between vitamins such as vitamin D [17], minerals, including zinc and magnesium [18], meditation [19, 20], and Western dietary patterns [21, 22] was evaluated in previous publications. There is an interrelation between ADHD symptoms and dietary habits. Children with inattentive/hyperactivity presentation may be at increased risk of unhealthy eating habits [23]. Some studies have shown children with ADHD may loss eating control and chose unhealthier foods [24, 25], but others found low quality foods may contribute to an increase of ADHD risk [26].

'Junk food' is a term used to characterize unhealthy foods with low nutritional value and dietary fiber due to their high calories, fat, or sugar content [27]. Concerns have been raised regarding the detrimental consequences of a diet high in junk foods, such as metabolic disorders, obesity, and cardiovascular diseases in children [28, 29]. Additionally, excessive consumption of junk food adversely affects children's and adolescents' mental health [30]. Research on the impact of sugar intake and sugar-sweetened beverages on behavioral problems has increased interest in recent years. Some research has discovered a link between sweetened beverages or sugar and children's attention problems [31, 32]. Others do not show a significant association between sugar and unhealthy food consumption and the probability of ADHD [21, 32, 33]. There was no association found in a large cohort between children eating pattern and ADHD [34]. So, the evidence regarding the detrimental effects of unhealthy foods on mental health has not been conclusive. The existing systematic reviews reported the relationship between unhealthy dietary patterns and sugar consumption and ADHD in children [35, 36]. However, there is no comprehensive systematic review regarding the association between different types of junk food consumption and ADHD.

Considering the widespread consumption of junk foods among children and adolescents, we conducted this systematic review and meta-analysis to investigate the association between junk food consumption and symptoms of ADHD in children and adolescents.

Methods

Search strategy

This systematic review aimed to assess the relationship between junk food consumption and ADHD in children and adolescents, and the reporting of this study was according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline. The systematic review was registered in Alborz University of Medical Sciences (code: 2130–01–05–1401) with the Ethics Code: IR.ABZUMS.REC.1401.135. We systematically searched PubMed/ Medline, ISI Web of Science, and SCOPUS databases for studies on junk food consumption and ADHD in children published up to September 2022. The search keywords used were: "sweetened drink*" OR "sweetened beverage*" OR snack* OR "processed food*" OR "junk food*" OR "soft drinks" OR "sugared beverages" OR "fried foods" OR "instant foods" OR sweets OR "fast food" AND "attention deficit hyperactivity disorder*" OR ADHD OR "attention-deficit/hyperactivity disorder*" OR "attention deficit disorders with hyperactivity" OR "attention deficit disorder*" OR hyperactivity. Only full-text articles published in English were included in this study. In addition, the reference lists of retrieved papers were also checked to find any relevant publications that were missed during the systematic search.

Inclusion and exclusion criteria

The retrieved articles were screened by two independent investigators. All observational studies (cohort, case–control, cross-sectional) evaluating the relationship between junk food consumption and ADHD in children and adolescents were considered eligible for inclusion in this study. The exclusion criteria were: (1) interventional studies, letters, comments, editorials, reviews, meta-analyses, and in vitro and animal studies; (2) studies conducted on adults; (3) studies that have examined the dietary pattern, not the consumption of different types of junk food.

Data extraction

Following a three-stage evaluation process that included titles, abstracts, and full texts, the detailed information of each eligible study was extracted using a data collection form. To evaluate the possible correlation between ADHD and junk food, the presented effect sizes (odds ratios

(OR), relative risks (RR)) and their 95% confidence intervals (CIs) were retrieved. If they were available, the most adjusted risk estimates were used. The other informative data of the included articles (studies year, first author and design, participants' characteristics, features of exposures, and outcome) was gathered. Two researchers independently conducted each step, including studies screening and data extraction. The researchers' disagreements were solved through the conversation until an agreement was reached.

Quality assessment of studies

The quality assessment was conducted using an adapted version of the Newcastle–Ottawa Quality Assessment Scale (NOS) for cohort and case–control/cross-sectional studies [37]. There are three categories on the scale: selection, comparability, and outcome. An investigation may receive a maximum of one star for each numbered item in the selection and outcome sections and two stars for comparability. From our review of the relevant literature, we know that studies with a NOS score of 7 or higher are generally accepted as "good or high" quality [19].

Statistical analysis

In this meta-analysis, any used risk estimates RR or OR and their 95% CI, which were used for the determination of the association between ADHD and junk foods in observational studies, were pooled via the 'metan' commend and random effect model to calculate ORs and 95%CI. Both Cochran's Q test and the I^2 statistic were used to evaluate the degree of heterogeneity present in the included studies. Subgroup analysis to determine the potential source of heterogeneity was done. The kind of junk food, design of the included studies, sex of participants, consumption frequency (moderate ≥ one time a day, high ≥ 2 times a day), and quality of studies were considered sources of heterogeneity. In terms of publication bias, we used Egger and Begg's test. The meta-analysis was conducted with the Stata, version 14 software. A P-value level ≤ 0.05 was considered to be statistically significant.

Results

Study characteristics in this systematic review

A total of 657 documents were found with an exact systematic search. After eliminating duplications and title/abstract screening, 640 records were excluded, and 17 articles were evaluated with full text. Consequently, ten studies according to the study inclusion criteria were included. One study did not provide 95% CI data despite reporting effect size, so it has been excluded from the meta-analysis. Reviews, clinical trials, animal studies, and studies that did not report relevant effect size data were excluded. The paper selection process is described in Fig. 1.

This systematic review included two cohorts, two case controls, and six cross-sectional studies. The included studies were published between 2006 and 2022. The studies were conducted in Korea [4, 23, 33, 38], Taiwan [31], Norway [39], the United Kingdom [27], the United States [40], Spain [19], and China [41]. The study participants' age was between 3 and 15 years. All studies were carried out on both genders, and eight studies presented overall effect sizes; additionally, in two studies [39, 41], effect sizes were reported for both genders separately, and one study [31] reported effect sizes for boys. The association between sweets/candy or sweetened beverages consumption and the risk of ADHD was assessed in eight studies. However, four studies evaluated the relationship between fast foods or other junk foods and ADHD [23, 27, 33, 38]. A food frequency questionnaire (FFQ) [4, 19, 27] or a prepared questionnaire was applied to collect dietary intake information. The included studies used different tools such as the strengths and difficulties questionnaire (SDQ) [27, 40, 41], Swanson, Nolan, and Pelham, 4th revision (SNAP-IV) [31], the Korean ADHD rating scale (K-ARS) [4, 23], Conner abbreviated teacher rating scale (CATRS-10) [33], Hopkins Symptom Checklist (HSCL-10) [27], and the ADHD rating scale-IV (ADHD RS-IV) [19, 38] for the assessment of ADHD symptoms in children or adolescents. Four studies [27, 39–41] assessed hyperactivity as an ADHD symptom, and others investigated the association of ADHD and dietary habits as a primary outcome. Eight studies have reported more than 1–2 times consumption of junk foods per day, and ≥ 7 times/day was reported in one study [40]. The eligible studies are presented in Table 1.

Meta-analysis findings

In the meta-analysis, we retained nine studies with 58,296 children /adolescents. One study didn't report effect size in the overall study population and just reported in both sexes separately; we first combined the sex effect sizes to obtain an overall effect size [39]. Thirteen overall effect sizes were reported in the ten eligible studies. We used the random-effect procedure and adjusted OR for the meta-analysis. The overall analysis of all available effect sizes of junk foods has shown a significant association between junk food consumption and ADHD symptoms in children /adolescents (OR: 1.24, 95%CI: 1.15–1.34, P < 0.001). The heterogeneity (I^2) was under 50%, p = 0.085 (Fig. 2). Furthermore, the pooled effect sizes of studies have reported a non-significant positive link between the consumption of junk foods and ADHD symptoms in boys (OR: 1.14; 95% CI: 0.99, 1.33, p < 0.001) ($I^2 = 0$, p = 0.682) (Table 2). Combining two ORs from two

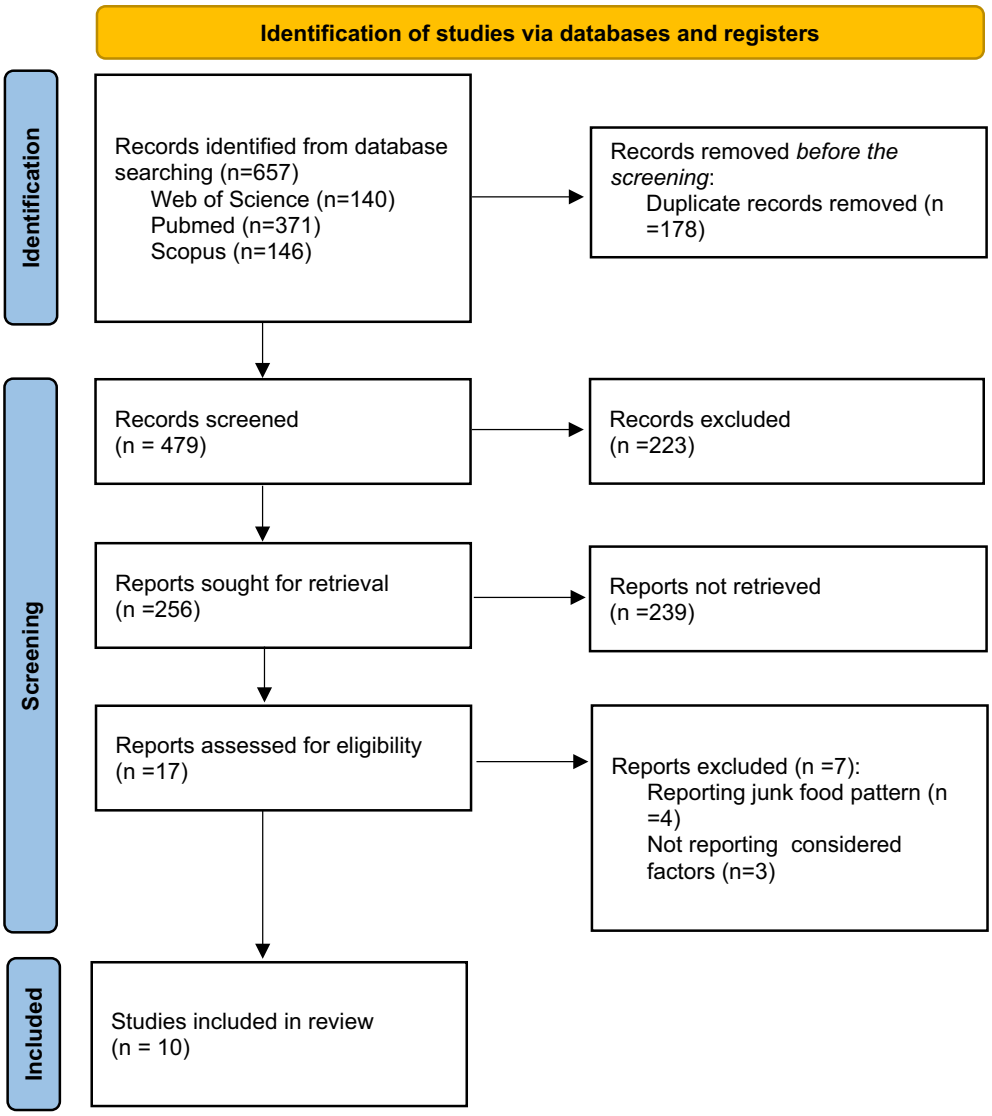

Fig. 1 The flowchart of study selection

included studies conducted on girls showed no conclusive association (Table 2).

The effect sizes were pooled based on the different kinds of junk foods as subgroup analysis. In terms of sweetened beverages/soft drinks, combining 6 effect sizes from 6 studies revealed a significant relationship between sweetened beverages/soft drinks consumption and ADHD symptoms (OR:1.25, 95%CI:1.09 to − 1.44, $I^2 = 54.8\%$, $p = 0.050$). Also, the same relationship was identified for sweets/ candies (OR: 1.37, 95%CI: 1.23 to − 1.52, $I^2 = 0$, $p = 0.895$) and other types of junk foods (OR: 1.17, 95%CI: 1.07 to − 1.27, $I^2 = 0$, $p = 0.792$) (Table 2). We found that both moderate and high amounts of junk food consumption were associated with ADHD symptoms in children /adolescents (OR: 1.24, 95%CI: 1.1 to − 1.39 and OR: 1.26, 95%CI: 1.11 to − 1.43) (Table 2). The quality of studies and study design were considered as potential sources of heterogeneity. In terms of the studies' quality, in high-quality studies junk food consumption was associated with ADHD (OR: 1.24, 95%CI: 1.13 to − 1.35). The overall effect size and heterogeneity did not change significantly according to the study design, although the association was not statistically significant in case–control studies. The effect sizes, and 95%CIs, were illustrated in Table 2. The subgroup analysis forest plots were presented as supplementary files.

Quality assessment and publication bias

According to the NOS scale, all included papers were of high quality (NOS score of 7 or more), and only one study received a score below 7. Overall, most studies have well-reported descriptions of comparability, and outcome section,

Table 1 Characteristics of the included studies on the association between junk food and the ADHD symptoms gender (1), age, family economic situation, parental education level, parental parenting behaviors, screen time, sleep duration, body mass index, physical activities time, plain water consumption

	Study characteristics					Outcome characteristics					Quality assessment score
	Study/year/country	Design	Sample size	Population	Mean age/age range	Kind of food	Frequency	Dietary intake assessment	Outcome/assessment tool	OR (95%CI)	
1	Geng 2020/China	Cross-sectional	27 987	Preschooler children	3–6	Sweetened-beverages	≥ 2 times/day	PQ	Hyperactivity/SDQ	1.11 (0.99–1.26)	9
2	Kim 2011/Korea	Cross-sectional	107	Elementary school children	–	Cookie & chio sweets Bewarage fast food	–	PQ	ADHD/CATRS-10	–	7
3	Kim 2018/Korea	Cross-sectional	16,831	Elementary school children	9.2	Instant noodles Bevarage Fast food	≥ 1 time/day	Web-based Q	ADHD/K-ARS	1.47 (0.9–2.38) 1.75 (1.33–2.29) 1.11 (0.6–2.06)	10
4	Lee 2022/Korea	Cohort	535	Preschooler children	6	Sweets	Q4 (over75%)/day	FFQ	ADHD/K-ARS	1.37 (1.23–1.52)	7
5	Lien 2006/Norway	Cross-sectional	5498	10th-grade students	15	Soft Drinks	2–3 times/day	PQ	Hyperactivity/HSCL-10	Boy:1.38 (0.88, 2.17) Girl: 1.5 (0.94, 2.39)	8
6	Park 2012/Korea	Cross-sectional	986	Children	9.1		≥ 1 times/day	MDA	ADHD/ADHD RS-IV	1.41 (0.73, 2.1) 0.74 (0.01, 1.5)	10
7	Ríos-Hernández 2017/Spain	Case–control	Case:60 Control:60	Children and adolescent	9.3	Soft drinks/sweets	1–6 times/day	FFQ	ADHD/ADHD RS-IV	0.73 (0.29, 1.8)	6
8	Schwartz 2015/USA	Cross-sectional	1649	Middle school students	12.4	Sweetened-beverages	≥ 7 times/day	PQ	Hyperactivity/SDQ	1.14 (1.04, 1.25)	9
9	Wiles 2009/UK	Cohort	4430	Children	4.6	Junk food	≥ 1 time/day	FFQ	Hyperactivity / SDQ	1.16 (1.07, 1.27)	8
10	Yu 2016/Taiwan	Case–control	Case:101 Control:159	Children and adolescent	9.2	Sweetened-beverages	≥ 7 servings/week	PQ	ADHD/SNAP-IV	3.7 (1.29, 10.6)	7

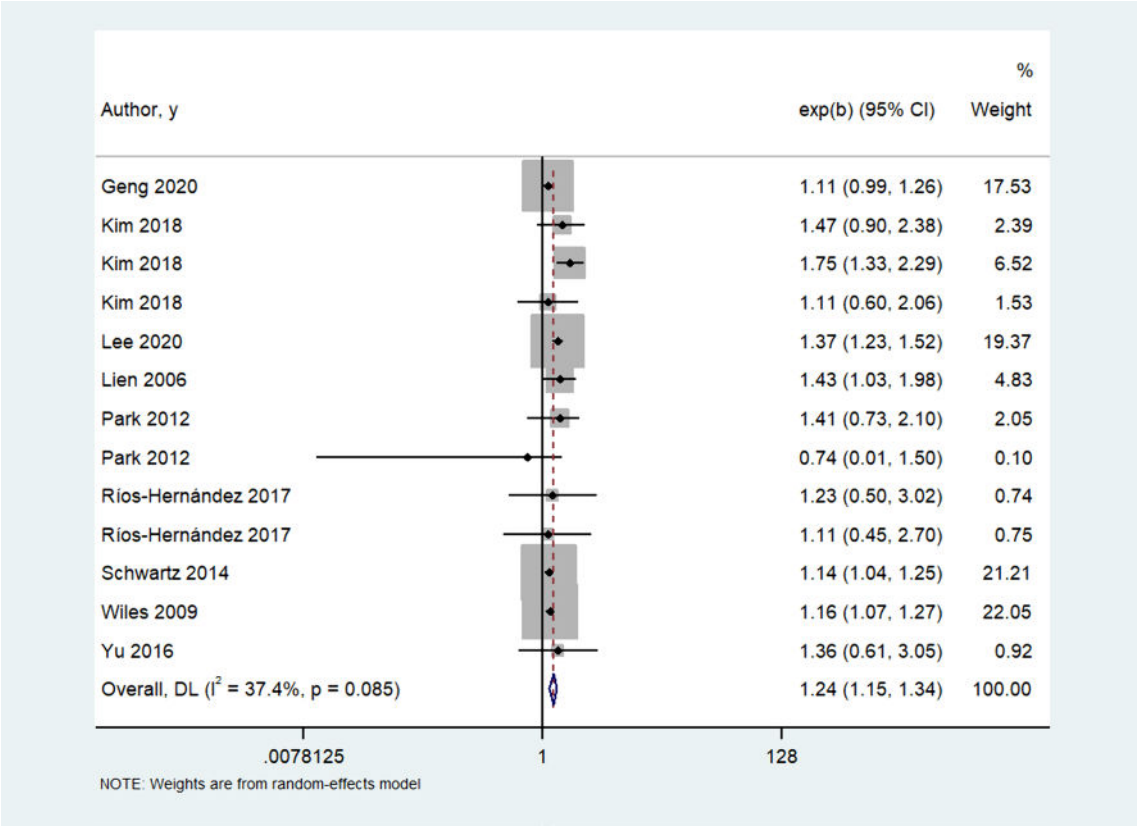

Fig. 2 Forest plot of association between junk food constume and ADHD symptoms

Table 2 Subgroup analysis for the association of junk food consumption and ADHD

Subgroup	Effect sizes (n)	Pooled OR (95%CI)	Heterogeneity			
			Chi-square	I^2 %	P-value	Model
Overall	13	1.24 (1.14, 1.34)	≤0.00	37.4	0.085	Random
Kind of food						
Beverages	6	1.25 (1.09, 1.44)	≤0.00	58.8	0.05	Random
Sweets	3	1.37 (1.23, 1.52)	≤0.00	0.0	0.89	
Junk	4	1.17 (1.07, 1.27)	≤0.00	0.0	0.79	
Frequency of consumption						
Moderate	8	1.24 (1.10, 1.39)	≤0.00	34.8	0.15	Random
High	5	1.26 (1.11, 1.43)	≤0.00	46.0	0.16	
Study design						
Cohort	2	1.26 (1.07, 1.48)	0.006	82.6	0.02	Random
Cross-sectional	8	1.25 (1.11, 1.42)	≤0.00	43.2	0.09	
Case–control	3	1.24 (0.75, 2.04)	0.824	0.0	0.94	
Gender						
Boy	3	1.14 (0.99, 1.33)	0.076	0.0	0.68	Random
Girl	2	1.18 (0.90, 1.57)	0.191	0.41	0.22	
Study quality						
≥7 score	8	1.24 (1.13, 1.35)	0.001	50.3	0.03	Random
<7 score	1	1.17 (0.62, 2.20)	0.872	0.0	0.87	

n number, *OR* odds ratio, *CI* confidence interval

the almost missing score was for items of the selected category. As indicated in Table 3, the studies performed well in measuring the quality overall.

The publication bias was assessed by Egger & Begg's test. The funnel plot from both tests showed that it is quite symmetrical, and no publication bias for any variable was demonstrated (coefficient = 1.11, standard error = 0.72, P = 0.16, 95% CI = −0.53, 2.76). Data are shown in Fig. 3.

Discussion

This systematic review and meta-analysis evaluated the association between consuming junk foods and ADHD symptoms in children and adolescents. The study finding revealed that consuming any kind of junk foods was associated with ADHD symptoms in the study population. A similar significant positive relationship was shown in the subgroups analysis by type of junk food. At the same time, the strongest association was detected in the sweets/ candies categories. However, due to a limited number of studies that evaluated the association separately based on sex, a meaningful relationship was not shown in the subgroup analysis.

Several investigations have proven that dietary intake or habits can affect mental health and are associated with behavioral problems [4, 42]. A significant positive link between the consumption of fast food, soft drinks, or sweets and attention-deficit/hyperactivity symptoms was reported in previous studies [23, 27]. The Del-Ponte et al. systematic review and meta-analysis, in line with our results, showed that unhealthy dietary patterns characterized mainly through the high content of sugar, sweets, fast foods, and soft drinks consumption have associated with increased odds of ADHD [35]. Shareghfarid et al. showed that adherence to unhealthy dietary patterns such as Western foods were linked to elevated odds of ADHD [26]. In addition, consistent with our findings, a recent meta-analysis indicated that drinking sweetened beverages was linked to the higher odds of ADHD symptoms. However, no relationship was observed between dietary sugars and the probability of developing ADHD symptoms in this study [36]. Moreover, the earlier systematic review did not discover a correlation between using sweetened drinks, desserts, and other sweets and ADHD [43].

The possible mechanisms of the relationship between junk foods and ADHD were elucidated by the harmful effects of high-fat, sugar, or ultra-processed foods on brain health [44]. As mentioned, junk foods are foods with high fat or high sugar content and usually have low-nutritional value [27]. Research has mainly focused on the cognitive damage brought on by the intake of two main components of diets, namely saturated fats and simple sugars [45]. Glucose metabolism is tightly intertwined with the function and development of the brain [46]. Both acute and chronic exposure to simple carbohydrates and saturated fatty acids has a

Table 3 Quality of assessments of included studies

Study	Selection	Comparability	Outcome/ exposer	Overall
Cross-sectional/case–control studies				
Geng [41]	4	2	3	9
Kim [23]	5	2	3	10
Kim [13]	2	2	3	7
Park [38]	5	2	3	10
Schwartz 2014	4	2	3	9
Ríos-Hernández [19]	2	2	2	6
Yu [31]	2	2	3	7
Lien [39]	3	2	3	8
Cohort Studies				
Lee 2020	2	2	3	7
Wiles [27]	3	2	3	8

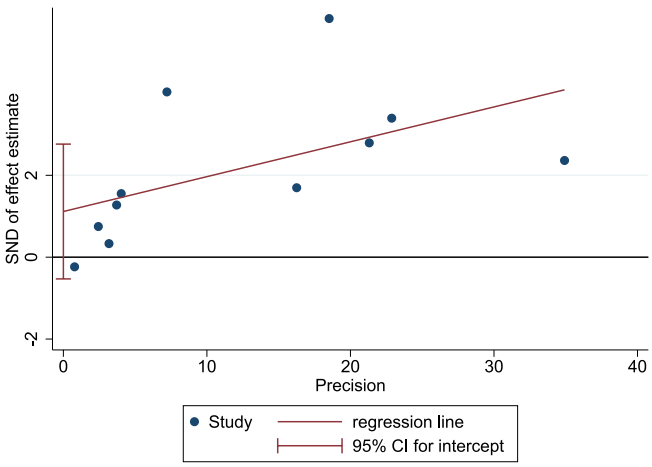

Fig. 3 The funnel plot of publication bias test

negative effect on hippocampal-independent and dependent memory performance [47, 48]. It has been proposed that hippocampus functions are linked to glycemic control and insulin sensitivity [49]. The hippocampus may be affected directly or indirectly by the neurophysiological changes caused by consuming high sugar that impaired glucoregulation, decreases neurotrophin levels, causes neuroinflammation, and damages the integrity of the blood–brain barrier's structure [50].

Both cognitive prerequisites and food choices might be affected by blood glucose imbalance [51]. After eating meals high in sucrose, the body responds by producing elevated quantities of insulin, causing blood glucose levels to drop to the point where cerebral activity is impaired. As a result, the body releases catecholamines, glucagon, growth hormone, and glucocorticoids, which increase glucose levels to compensate [47]. The recurrent and rapid rises and falls in blood sugar caused by high dietary glycemic load have an impact on insulin demand and glucose tolerance [52]. Numerous cognitive abilities, including attention, a hallmark of ADHD, are impaired by hypoglycemia [51]. On the other hand, prior research has indicated that people with ADHD also have abnormal brain dopamine signaling [53, 54]. The high ingestion of sugar or sweeteners causes increased dopamine release in the brain in a dose-dependently manner [55, 56]. Chronic sugar consumption over weeks or months significantly leads to a downregulation in D_2 receptors extracellular acetylcholine in the nucleus accumbens [57]. The suppression of frontal cortex regulatory mechanisms and disruption of the striatal dopaminergic system lead to attention-deficit/hyperactivity disorder [58]. Furthermore, studies have shown that high fat and high sugar intake increased apoptosis and impaired hippocampal neurogenesis by increased serum levels of pro-neuroinflammatory cytokines such as TNF-α [57, 59, 60].

According to our results, both moderate and high amounts of junk food consumption were equally associated with ADHD. As we know, there is no systematic review that has evaluated the association between the amount of sugar or other junk food consumption and ADHD/hyperactivity. In contrast, observational studies have detected dose-dependently effects of sugar intake on mood dysfunctions. Even after adjusting for potential confounding variables, a dose–response association between soft drink intake and hyperactivity was discovered among Norwegian students [39]. A similar relation was seen between sugar-sweetened beverages and ADHD in the Yu et al. study [31]. Also, in the Lee et al. study, high consumption of junk foods showed a higher odds of ADHD symptoms than low intake [61]. There was not the same scale in the estimation of consumption frequency; in addition, the intake frequency category between studies was different. Most studies have defined high junk food intake as consumption more than 1–2 times /day, and ≥ 7 times/day was addressed in one study. Therefore, it seems that consumption ≥ 1 time a day is strongly associated with the development of ADHD.

This manuscript was a comprehensive systematic review and meta-analysis evaluating the relationship between junk food consumption and ADHD symptoms. There was no considerable heterogeneity between studies despite the difference in design, dietary intake assessment tools, frequency of consumption, and diagnostic methods. Therefore, the meta-analysis results may be conclusive. Most of the studies included in the meta-analysis were high quality, which is a strength point in interpreting our findings. It is important to highlight that there are certain limitations of this study. A few observational studies were available that assessed the relation between ADHD and junk food intake, particularly in some subgroups; there are not enough studies to determine conclusive results. Dietary intake was assessed with variable tools in studies. Food frequency questionnaires or prepared questionnaires with different frequency consumption categories were used in various studies. Since the category of consumption frequency was different between studies, it was hard to have a subgroup analysis according to the frequency of use. On the other hand, the questionnaires were administered by parents, guardians, or healthcare staff which, might potentially cause bias in the estimation of dietary intake. Besides, different assessment tools were used to diagnose ADHD symptoms, so using different ways of scoring might affect the results. Since, the meta-analysis has included observational studies, the association found in the research cannot be proven causal. Also, the results should be interpreted with caution due to the language restriction on document selection.

Conclusion

This meta-analysis of observational studies adds the strong evidence linking the consumption of junk foods, particularly, sweetened beverages/soft drinks and sweets/candies, with ADHD symptoms in children and adolescents. However, the study did not evaluate the causality of the relationship. So, to identify causality and the dose–response effects of junk food consumption on the development of ADHD, further studies are warranted.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00787-024-02521-8.

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Author contributions M.Q and H.E designed the protocol and conducted a systematic search. M.KH and M.H collection, analysis, and drafted the manuscript. R.S and B.H contributed to the selection of the

studies and F.S.M assessed the quality of included studies. All authors read and approved the final version.

Data availability Data available upon request.

Declarations

Conflict of interest The authors declare no competing interests.

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