

ADHD as a risk factor for obesity. Current state of research

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Summary

Obesity is now a major health concern in both children and adults. According to research from the past 15 years, one of the factors that increase the risk of obesity may be attention-deficit hyperactivity disorder (ADHD). Not all the studies, however, provide unambiguous results. This literature review aims to systematize the results of previous studies on the risk of obesity in people with ADHD. It included articles addressing the issue of relationship between ADHD and obesity published in the years 2004–2016. Finally, 31 surveys fulfilling the selection criteria were qualified for the review. Analysis of the available sources leads to the conclusion that ADHD is a significant risk factor for obesity, which is especially visible in the adult population. Of the disorders associated with ADHD, the greatest modulating impact on the relationship between obesity and ADHD had oppositional defiant disorder, conduct disorder and emotional overeating. Pharmacological treatment, comorbid conditions, but also age and sex must remain important factors controlled in subsequent studies. Future research should focus on more systematic testing of hypotheses explaining the comorbidity of ADHD and obesity.

Key words: ADHD, overweight, obesity

Introduction

Obesity is now considered a civilization disease which entails significant health and economic costs. For this reason, prevention and treatment of obesity are one of the biggest challenges of health care around the world. Research is ongoing on the potential factors that increase susceptibility to the development of obesity in the early stages of ontogeny. In this context, the importance of the possible relationship of attention-deficit/hyperactivity disorder (ADHD) with an increased risk of obesity in children, adolescents and adults is growing [1]. ADHD is one of the most frequently diagnosed neurodevelopmental disorders in children and its prevalence among school-age children is 5–10% [2]. Symptoms related to this disorders are attention deficit, hyperactivity and

impulsivity [3–4]. The etiology of ADHD has not been definitively described, but studies indicate a significant relationship with abnormal genes related to neurotransmission and plasticity of the nervous system [5–6]. Stimulating drugs and cognitive behavioral therapy are the most effective methods to treat the symptoms of ADHD [7].

Research on the relationship of ADHD and obesity have been ongoing since the beginning of the twenty-first century. In 2002, Altfas [8] and Fleming and Levy [9] demonstrated the considerably increased incidence of ADHD in obese adults. Two years later Holtkamp et al. [10] showed that boys with ADHD compared with the population had a higher BMI (Body Mass Index) and had a higher incidence of overweight and obesity. Two recently published reliable meta-analyzes concerning the relationship between ADHD and obesity gave, however, different conclusions. The first of them [11] confirmed the association of ADHD with obesity regardless of age, gender and treatment, whereas the second one [12] indicated a marginal significance of the relationship between obesity and ADHD in children, possible clinical significance of the relationship in teenage girls with comorbid disorders and a clear relationship of both conditions in adults. Contradictory results indicate the objective difficulty of conducting research related to the problem of control of confounders and diversity of possible causes of comorbidity of ADHD with obesity and the need for further research and further systematization of the results.

Therefore, the purpose of this article is an overview of current research findings on the risk of obesity in children, adolescents and adults with ADHD, taking into account the most important variables controlled in the study and the employed methodology.

Methods

The review included articles concerning the relationship between ADHD and obesity published in the years 2004–2016. The works were retrieved using Medline and Scopus databases. The initial selection criteria were as follows: articles presenting original results in English language, including in the title a combination of key phrases: “attention deficit hyperactivity disorder” or “ADHD”, and “overweight or obesity or adiposity or fat”. Out of this collection of articles those that seemed to assess the significance of the relationship between ADHD and overweight and/or obesity were pre-selected on the basis of abstracts. Clinical trials and population-based, cross-sectional, retrospective and prospective (follow up) studies comparing the incidence of overweight and obesity in individuals with a diagnosis of ADHD or ADHD symptoms at any age to a control group or population were included in the review, regardless of the sample size.

The paper excluded (1) articles on the relationship between ADHD and BMI level, when the diagnosis of overweight or obesity was not made according to any worldwide accepted criterion, and (2) articles that did not compare the frequency of overweight/obesity in subjects with ADHD and in the control group or population. (3) Studies that evaluated the symptoms of ADHD or ADHD prevalence in obese people were also excluded.

In the review, a particular attention was paid to factors such as socioeconomic status, age, sex, pharmacological treatment, and comorbid conditions.

The relationship of ADHD with overweight and obesity

The use of a combination of key phrases allowed the selection of 206 works. On the basis of article titles 123 works were rejected, and on the basis of abstracts – another 44. Finally, 31 studies were classified to the review (Table 1).

Table 1. Comparison of prevalence of overweight and obesity between individuals with ADHD and control group or population. Studies from the years 2004–2016

	First author	Date	Sex	N	Age (years)	Prevalence of overweight/obesity and odds ratio (ADHD as independent variable and obesity as dependent variable)	Significance of results and comments
1	Holtkamp et al. [10]	2004	♂	ADHD: 97	5.5–14.7	Overweight ^a : 19.6%; Obesity ^a : 7.2%.	Significantly increased risk of overweight and obesity in comparison to the population norm
2	Curtin et al. [35]	2005	♂+♀	ADHD: 98, ASD: 42	2–18	At risk of overweight ^b : ADHD = 29%, ASD = 35.7%, reference group = 31%; overweight ^b : ADHD = 17.3%, ASD = 19%, reference group = 16%	No differences compared to the population norm
3	Lam, Yang [18]	2007	♂+♀	General: 1,429	13–17	Obesity ^b : OR = 1.07	Weak but significant relations between ADHD symptoms severity and obesity
4	Warring et al. [13]	2008	♂+♀	ADHD: 5,680, without ADHD: 5,7204	5–17	Overweight ^b : OR = 1.51	Statistically significant relation between ADHD and overweight
5	Chen et al. [19]	2009	♂+♀	ADHD: 4,848, without ADHD: 41,859	10–17	Obesity ^b : ADHD = 18.9%, CG = 12.2%	The prevalence of obesity was significantly increased in adolescents with ADHD in comparison to healthy population
6	Pagoto et al. [27]	2009	♂+♀	Total: 6,737	18–44	Overweight ^c : ADHD = 33.9%, CG = 28.8%, OR = 1.58; obesity ^c : ADHD = 29.4%, CG = 21.6%, OR = 1.81	Significant relation between ADHD and overweight and obesity

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7	Chun et al. [20]	2010	♂+♀	ADHD: 20, without ADHD: 407	Mean = 9.2	Overweight ^f : ADHD = 15%, CG = 20.4%; obesity ^f : ADHD = 45%, CG = 17.2%	Statistically significant relation between ADHD and obesity
8	de Zwaan et al. [21]	2011	♂+♀	ADHD: 77 without ADHD: 1,556	18–64	Overweight ^f : OR = 0.86, obesity ^f : OR = 2.37	Statistically significant relation between ADHD and obesity
9	Dubnov–Raz et al. [40]	2011	♂+♀	ADHD: 275, without ADHD: 51	6–16	Overweight ^b : ADHD = 19%, CG = 35%; obesity ^b : ADHD = 7%, CG = 16%	The prevalence of obesity was significantly decreased in individuals with ADHD in comparison to the control group
10	Fuemmeler et al. [22]	2011	♂+♀	Total: 15,197	Mean = 28.9	Overweight ^c : ADHD = 27.3%, CG = 29.3%, OR = 1.05; obesity ^c : ADHD = 41.5%, CG = 36.3%, OR = 1.21	Significant association between ADHD symptoms severity and obesity
11	Kim et al. [23]	2011	♂+♀	ADHD: 6,134, without ADHD: 60,573	6–17	Obesity ^b in boys: ADHD = 24.9, CG = 21.6%, OR = 1.42; in girls: ADHD = 21.9%, CG = 16%, OR = 1.85	Significant relations between ADHD and obesity was found both in boys and girls
12	Reda, El-Hadidy [36]	2011	♂+♀	ADHD: 30, without ADHD: 15	6–18	Obesity ^b : ADHD = 47%, CG = 30%	Insignificant differences
13	Byrd et al. [37]	2012	♂+♀	ADHD: 412, without ADHD: 2,638	8–15	Obesity ^b : ADHD = 21.6%, CG = 18.3%, OR = 1.18	Insignificant differences
14	Erhart et al. [28]	2012	♂+♀	ADHD:101, without ADHD: 2,313	7–17	Overweight ^a : ADHD = 19.8%, CG = 10%; obesity ^a : ADHD = 8.9%, CG = 6.7%, OR = 1.7 (for overweight + obesity)	Statistically significant relation between ADHD and overweight/ obesity
15	Cortese et al. [14]	2013	♂+♀	ADHD: 616, without ADHD: 34,037	≥20	Obesity ^c : ADHD = 34.88%, CG = 27.13%, OR = 1.44	Lack of significant relations between ADHD in adults and obesity. Significant association was found between ADHD symptoms severity in childhood and obesity in adult woman

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16	Cortese et al. [24]	2013	♂	Childhood ADHD: 111, without childhood ADHD: 111	Mean = 41	Overweight ^a : ADHD = 54.2%, CG = 53.3%; obesity ^c : ADHD = 29.2%, CG = 21.6%; OR = 1.49 (adults with ADHD)	Lack of significant relations between ADHD in adult men and obesity. Significant association was found between ADHD in childhood and obesity in adult men (OR = 2.99)
17	Filers et al. [15]	2013	♂+♀	ADHD: 372	5–17	Overweight + obesity ^a (prevalence in following age groups: 5–9, 10–12, 13–17 years): boys with ADHD – 11.6%, 20.2%, 18.8%, population – 14.3%, 13%, 14.4%, OR: 0.81, 1.55, 1.31; girls with ADHD – 4.8%, 28%, 0%, population – 18.7%, 15%, 16.6%. OR: 0.26, 1.87, 0.11; obesity ^b : boys with ADHD – 1.2%, 3.2%, 1%, population – 2.6%, 2.3%, 2.6%, OR: 0.46, 1.39, 0.38; girls with ADHD – 0%, 12%, 0%, population – 3.8%, 2.6%, 2.8%, OR: 0.12, 4.61, 0.13	Significantly higher prevalence of overweight in comparison to population was found in boys with ADHD aged 10–17 years and girls aged 10–12 years. Significantly lower prevalence of overweight and obesity in comparison to population was found in girls in all other age groups
18	Yang et al. [29]	2013	♂+♀	ADHD: 158	7–10	Overweight ^b : ADHD = 17.1%, population = 4.5%; obesity ^b : ADHD = 12%, population = 2.1%; OR (overweight + obesity) = 2.19	Statistically significant relation between ADHD and overweight and obesity
19	Bener et al [41]	2013	♂+♀	ADHD: 1,331, without ADHD: 1,331	<18, Mean = 10.63	Overweight ^b : ADHD = 7.7%, CG = 9.4%; obesity ^b : ADHD = 4.6%, CG = 7.7%	Statistically significant relation between ADHD and lower prevalence of overweight/obesity
20	Khalife et al. [25]	2014	♂+♀	Total: 8,106	Mean = 16	Obesity ^b : OR = 2.01	Symptoms of ADHD in 8 years old children predicts increased risk of obesity at the age of 16 years
21	Kim et al [30]	2014	♂+♀	ADHD: 932, without ADHD: 11,418	5–13	Obesity ^b : OR = 1.46	Statistically significant relation between ADHD and obesity

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22	Pauli-Pott et al. [38]	2014	♂+♀	pure ADHD: 144, ADHD +ODD/CD: 63, pure ODD/CD: 50, CG (adjustment disorders): 103	6–12	Obesity ^a : OR = 1.49	Insignificant relations
23	Cook et al. [39]	2015	♂+♀	Total: 45,897	10–17	Obesity ^b : ADHD without learning disorders – OR = 0.87; ADHD + learning disorders – OR = 2.09	Statistically significant relation between ADHD and obesity was found only in individuals with comorbid learning disorders
24	Hanć et al. [16]	2015	♂	ADHD: 219, without ADHD: 396	6–18	Overweight ^a : ADHD = 17.3%, CG = 8.3%, OR = 2.42; obesity ^a : ADHD = 5%, CG = 5.6%, OR = 0.90	Statistically significant relation between ADHD and overweight
25	Hanć et al. [17]	2015	♂	ADHD: 112, without ADHD: 308	Mean = 11.2	Overweight ^a (in 2 nd , 4 th , 6 th year of age and based on the last measurements performed between 7 and 18 year of age): ADHD – 7.14%, 15.18%, 16.07%, 17.86%, CG – 13.64%, 13.96, 9.74%, 8.77%; obesity ^a : ADHD – 3.57%, 2.68%, 3.57%, 5.36%; CG – 6.49%, 5.19%, 5.84%, 4.22%	Overweight/obesity prevalence was lower in boys with ADHD in comparison to the control group at the age of 2 years. Significant association between ADHD and increased prevalence of overweight was found when boys were aged 7–18 years
26	Kwak et al. [31]	2015	♂+♀	ADHD: 164, without ADHD: 2,008	≥18	Overweight + obesity ^a : ADHD = 30.2%, CG = 18.8%	Statistically significant relation between ADHD and overweight/obesity
27	Racicka et al. [32]	2015	♂+♀	ADHD: 408	7–18	Overweight ^a : ADHD = 14.71%, population = 12.83%; obesity ^a : ADHD = 8.37%, population = 2.76%	Statistically significant relation between ADHD and overweight and obesity
28	Türkoğlu et al. [33]	2015	♂+♀	ADHD: 300, without ADHD: 75	7–17	Overweight ^a : ADHD = 30.3%, CG = 5.3%; obesity ^a : ADHD = 13.7%, CG = 4%	Statistically significant relation between ADHD and overweight and obesity

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29	Aguirre Castaneda et al. [26]	2016	♂+♀	ADHD: 336, without ADHD: 5,718	2–34	Obesity ^c : ADHD = 34.4%, CG = 25.1%	Statistically significant relation between ADHD and higher prevalence of obesity was found in adults. However, it did not appear in earlier stages of life
30	Kummer et al. [34]	2016	♂+♀	ADHD: 23, ASD: 69, without ADHD and ASD: 19	ADHD: 5–15, ASD: 2–18, CG: 5–15	Overweight ^b : ADHD = 17.5%, CG = 0%; obesity ^b : ADHD = 17.4%, CG = 5.3%	Statistically significant relation between ADHD and overweight and obesity
31	Nigg et al. [12]	2016	♂+♀	ADHD: 6,209, without ADHD: 37,587	10–17	Overweight ^b (in following age groups: 10–13, 14–17 years): boys with ADHD – 18%, 15%; CG – 17.9%, 13.8%; girls with ADHD – 17.3%, 15.4%; CG – 16%, 11%; obesity ^b : boys with ADHD – 21.5%, 15.6%; CG – 20.9%, 13.4%; girls with ADHD – 16.6%, 14.2%; CG – 14.3%, 7.6%	Statistically significant relation between ADHD and obesity was found in girls aged 14–17 years.

Legend: ♂ – male; ♀ – female; CG – control group; ADHD – individuals with diagnosis of attention-deficit/hyperactivity disorder or ‘being of risk of ADHD’ or having high level of hyperactivity, impulsivity and attention deficit symptoms; ASD – autism spectrum disorder; ODD – oppositional defiant disorder; CD – conduct disorder; OR – odds ratio, ^a – overweight and obesity were diagnosed based on 90th and 97th percentile for BMI; ^b – overweight and obesity were diagnosed based on 85th and 95th percentile for BMI; ^c – overweight and obesity were diagnosed based on BMI = 25 and BMI = 30; ^d – overweight and obesity were diagnosed based on 90th and 97th percentile for BMI; ^e – overweight and obesity were diagnosed based on IOTF guidelines; ^f – overweight and obesity were diagnosed based on other, country-specific criteria; * – information on overweight/obesity prevalence and/or OR were given based on available data. OR is a result of analyzes not adjusted for the remaining variables, if any Adjusted OR (written in italics) was given when only multivariate analyzes were conducted in the study. In the situation where data were available for both treated and non-treated children, the prevalence and OR for the non-treated subgroup were provided. When separate analyzes were performed for ADHD subtypes, only the OR for the mixed subtype is included in the table.

Fifteen (48%) of them were population-based studies. Works presenting the results of retrospective data analysis ($n = 5$, 16%) and prospective studies were equally represented ($n = 5$, 16%). 27 (87%) studies examined both male and female subjects. Children under 7 years of age were studied in 12 (29%) works (mostly they were aged 5–6 years), school children (7–9 years) were studied in 20 (64%) works, teenagers (aged 10–18 years) were studied in 24 (77%) works, and adults (≥ 18 years) in 7 (23%) works. In most studies ($n = 26$; 84%) BMI was calculated by direct measurement of height and weight, in other studies the data of height and weight was given by the

subjects or their parents. 85th and 95th percentiles of BMI were used as the criteria for the diagnosis of overweight and obesity in 9 (29%) works. In 7 (23%) works subjects were selected based on an assessment of obesity diagnosed using a 95th percentile. 90th and 97th percentiles were used for the diagnosis of overweight and obesity in 3 (10%) works, and the criteria of the International Obesity Task Force in 5 (16%).

Prevalence of overweight and obesity in both: individuals with ADHD (overweight: min. = 7.14%, max. = 54.2%; obesity: min. = 0%, max. = 47%) and control groups (overweight: min. = 0%, max. = 53.3%; obesity: min. = 2.1%, max. = 36.3%) varied between studies. Arithmetic means for the prevalence of overweight and obesity were 20.38% and 15.45% for ADHD samples and 17.02% and 11.70% for reference groups. Odds ratios (OR) estimated in the studies show to what extent ADHD increases the risk of obesity. Mean ORs calculated based on available data were 1.48 (min. = 0.86, max. = 2.42), 1.41 (min. = 0.12, max. = 4.61) and 1.30 (min. = 0.11, max. = 2.19) for overweight, obesity and overweight/obesity.

Regardless of the adopted methodology and controlled variables, the vast majority of the works (77% of the research under review) show that ADHD is a statistically significant risk factor for overweight (16%) [13–17], obesity (32%) [12, 18–26] or both overweight and obesity (29%) [10, 27–34]. Some works (16%) did not show association of ADHD with excess body weight [35–39] in the analyses in which the confounding variables were controlled, and the least numerous group (6%) showed a lower risk of overweight and/or obesity in subjects with ADHD in comparison with the reference group [40, 41].

To summarize these analyzes, most of the works were of cross-sectional and population-based nature. In most articles researchers evaluated obesity in school-age children and adolescents of both sexes on the basis of direct measurements of height and weight. More than two-thirds of the studies indicated an increased risk for overweight (by almost 50%) and obesity (by 40%) in patients with ADHD. However, since 22% of the studies did not show an association of obesity with ADHD or indicated reduced incidence of obesity in children with ADHD, it is necessary to conduct further research, especially on the mechanisms linking both disorders.

The importance of socio-economic status, gender and age

Many works included control for variables that could affect the body size. In all of the works which included control for demographic factors and socio-economic status [12–14, 16, 17, 19, 21–25, 27, 28, 30, 37, 39, 40] as well as ethnicity of patients [13, 14, 19, 27, 37, 39], the relationship between ADHD and overweight/obesity remained statistically significant.

In several studies, the ADHD-obesity relationship remained significant when age was controlled [13, 19, 22, 27, 28, 30, 32, 37, 38, 40] and in most studies which controlled sex [13, 18, 19, 22, 23, 25, 27, 28, 30, 32, 37–40]. One study indicated the relationship between severity of ADHD in childhood with obesity in adult females, but not in men [14], and in three other studies the relationship between ADHD and obesity depended both on gender and age [12, 15, 26]. Aguirre Castaneda et al. [26] studied

subjects aged 2–34 years of both sexes and showed a relationship between ADHD and obesity only in women over the age of 20. Filers et al. [15] demonstrated a higher incidence of overweight in boys with ADHD in the age group 10–17 years, and in girls aged 10–12, compared to population. In this study, boys aged 5–9 years did not differ from population and the girls were less often diagnosed with overweight and obesity. Lower incidence of overweight and obesity than in population was also found in the group of girls aged 13–17 years. Different results were obtained in the study of Nigg et al. [12] in which the higher incidence of obesity in population was demonstrated only in girls aged 14–17 years. A similar dependence was not shown in young girls (10–13 years) and boys, regardless of their age. A stronger relationship between ADHD and obesity in subjects, regardless of gender, at pubertal age, in comparison to younger children was showed by Yang et al. [29]. A retrospective, longitudinal study of Hanč et al. [16] indicated a similar trend in the development of obesity. It showed that the incidence of obesity is higher in boys with ADHD in school age and in pubertal phase compared to the control group. Overweight and obesity occurred, however, in the group of ADHD patients with lower incidence when the boys were 2 years old, and at a similar rate to the control group, when the boys were 4 and 6 years old.

The results of some studies indicate the possibility of occurring factors linking ADHD to obesity, or accumulation of their effects or consolidation in phases of ontogenesis following the early childhood (preschool age). The prevalence of obesity in the group of ADHD patients, as compared to those without ADHD or population, seems to increase in adolescents and adults. Some studies also indicate gender differences. The relationship of age and sex with obesity in patients with ADHD remains unclear and requires further investigation. The relationship between ADHD and obesity remained statistically significant when socio-economic status was being controlled.

Pharmacological treatment and comorbid disorders

One of the side effects of treatment with stimulants, which are drugs of the first choice in ADHD, may be suppression of growth in height and weight, and even weight loss [42]. Because the diagnosis of obesity is based on the appropriate classification of BMI calculated on the basis of height and weight, it must be assumed that treatment with stimulants may reduce the incidence of obesity in children with ADHD. For this reason, many studies evaluating the ADHD–obesity relationship monitored the effect of treatment on this phenomenon [10, 12, 13, 15–17, 23, 26, 29, 32, 33, 35, 37–40]. Curtin et al. [35] and Byrd et al. [37] showed, as expected, the relationship between pharmacotherapy and a lower incidence of overweight in children with ADHD. Warring and Lapane [13] showed, in turn, increased percentage of overweight among untreated children with ADHD compared to children without ADHD. Interesting results were obtained by Racicka et al. [32]. In the group of patients with ADHD, higher incidence of obesity was associated with the use of OROS methylphenidate. According to the authors, this may be related to changes in eating habits. Patients taking drugs can eat more often at night, when the drugs no longer affect the level of symptoms and suppress appetite. In other studies, the ADHD–obesity relationship remained significant regard-

less of whether the children were medically treated or not [10, 12, 15–17, 23, 26, 29, 33, 38–40]. In some of these works the treatment was, however, important moderator of the strength of the ADHD–obesity relationship [39]. Although most of the results show that obesity in people with ADHD does not depend on the pharmacotherapy, psychotropic drugs, because of their possible effects on growth and body weight, are an important factor that requires to be controlled in subsequent studies.

In many studies the following mental disorders comorbid with ADHD, were evaluated as possible obesity correlates: mood disorders [12, 21, 22, 24, 27, 29, 32, 37], anxiety disorders [14, 21, 29, 33], oppositional defiant disorder and conduct disorder [10, 12, 15–17, 25, 32, 37], learning disorders [39], and binge eating [21, 27]. One study showed the relationship of obesity with co-occurring depression in girls at the pubertal age [12]. Symptoms of anxiety disorders tend to be associated with a lower incidence of overweight and obesity in children and adolescents with ADHD [33]. Several studies indicated a clear relationship between obesity in subjects with ADHD and comorbid oppositional defiant disorder and behavioral disorders [12, 25, 32, 33, 38]. Cook et al. [39] showed, however, that the ADHD–obesity relationship was statistically insignificant when the analysis controlled for problems in learning. In another study, de Zwaan et al. [21] found that among the controlled comorbid disorders only binge eating have been partially mediating association between ADHD and obesity in adults. In the study of Pagoto et al. [27], the ADHD–obesity relationship was losing statistical significance when analyzes controlled for binge eating in the 12 months preceding the survey. These results are consistent with neuroimaging research suggesting that neurobehavioral network of ADHD, obesity and binge eating overlaps. All three disorders appear to be related to dysfunction in network responsible for reward processing (cortico-basal ganglia network including prefrontal cortex with orbitofrontal area, as well as midbrain, ventral and dorsal striatum and amygdala), response inhibition (premotor and prefrontal to striatal and cerebellar circuits, frontotemporal networks), emotional processing (amygdala, insula, ventral striatum, orbitofrontal cortex) and regulation (e.g., anterior cingulate cortex, dorsolateral, ventrolateral and medial prefrontal cortex) [43].

Conclusions

This paper reviews studies on relationship between ADHD and an increased risk of obesity. Most of the studies indicate that ADHD is an important factor in the development of obesity, regardless of pharmacological treatment, socio-economic status, and most of the disorders associated with ADHD. The risk of overweight is higher by 50% and the risk of obesity is higher by 40% in individuals with ADHD in comparison to the healthy individuals. The ADHD–obesity relationship is becoming stronger with age: from a lack of dependence or lower incidence of obesity in pre-school children with ADHD compared with their peers, to a high incidence of obesity in adults. Although most of the studies indicate that the ADHD–obesity relationship is independent of other factors controlled in the analyzes, some of the works discussed in the review justify consideration of the following factors in future studies: age and

sex, drug treatment and comorbid disorders, especially oppositional defiant disorder, conduct disorder and binge eating. Since the majority of previously published works were of cross-sectional nature, it is also necessary to attempt to assess the long-term phenomenon of the ADHD–obesity relationship and its conditioning. It will be then possible to determine the direction of the observed relationship.

The discrepancy in results suggests a lack of a binary relationship between ADHD and obesity, and points to the significant role of unspecified mediators, which were out of control in previous studies. So far, several hypotheses were proposed to explain the increased incidence of obesity in people with ADHD. It has been suggested that the underlying factors of the ADHD–obesity relationship may be: common genes [44, 45], neurobiological features [46] and deficits in executive functions conditioned by them [47], fetal programming [16], sleep disorders (circadian rhythm disruption) and abnormal eating habits [48], high-fat diet [49], reduced physical fitness and activity [39, 50], and stress [17, 51]. It has been also suggested that association between ADHD and obesity may be a side effect of adaptation to the environmental conditions of poor diet [52]. Such explanations appear to be promising, but so far few studies have tested the proposed mechanisms and their results are not conclusive. Further research should therefore be targeted on a more systematic testing of hypotheses to explain the co-occurrence of ADHD and obesity.

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