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REVIEW

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Attention-deficit/hyperactivity disorder in adolescent and adult candidates for metabolic and bariatric surgery: A systematic review and meta-analysis

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Summary

Aims: Attention-deficit with hyperactivity disorder (ADHD) is associated with obesity and impacts the outcome of metabolic and bariatric surgery (MBS). This study aimed at calculating the prevalence in candidates for MBS, which is yet unclear.

Methods: We conducted a systematic review and meta-analysis, searching three databases from their respective inception to December 2022 for studies reporting the prevalence of ADHD in adolescents and adults assessed before undergoing MBS. The protocol was registered in PROSPERO (CRD42022384914). We adhered to Meta-analysis of Observational Studies in Epidemiology (MOOSE) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines; the quality of studies was assessed with the JBI Critical Appraisal checklist. Random-effect meta-analyses were performed; confidence intervals were computed with a binomial exact method, and the pooled estimate was calculated after double arcsine transformation.

Findings: Fourteen studies (24,455 adults) and three studies (299 adolescents) were selected. The quality of studies was moderate to poor; meta-analyses were performed on subgroups according to the case definition used. The prevalence is 8.94% and 9.90% in adults, and 28.73% in adolescents.

Conclusions: ADHD is three times more frequent in adults and six times more frequent in adolescents than in the general population. Recommendations are provided to improve the quality of future studies and obtain more reliable estimates of prevalence.

KEYWORDS
attention-deficit disorder with hyperactivity/epidemiology, bariatric surgery/psychology, meta-analysis, prevalence, systematic review

Abbreviations: ADHD, attention deficit with hyperactivity disorder; ASD, autism spectrum disorder; ASRS, Adult ADHD Self-Report Scale; MBS, metabolic and bariatric surgery; BMI, body mass index; MOOSE, Meta-analysis of Observational Studies in Epidemiology; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; JBI, Joanna Briggs Institute; WURS, Wender Utah Rating Scale; CAARS-S:S, Conner's Adult ADHD Rating Scale: Short Self-Report Form.

1 | INTRODUCTION

The neurodevelopmental disorders encompass attention-deficit/hyperactivity disorder (ADHD), communication disorders, autism spectrum disorder (ASD), learning disorders, Tourette's disorder, etc..[1,2] Some symptoms may appear early in life. Meta-analyses estimate ADHD affects approximately 5% of school-age children in Europe[3,4], and into adulthood in the majority of cases, affecting around 3% of adults in the general population.[5,6] Although genetics plays a pivotal role in the pathophysiology of ADHD, no single causative gene has been identified to date.[7] The diagnosis of ADHD remains clinical, characterized by higher-than-expected levels of attention difficulties, motor agitation, and impulsivity. To date, no psychological test has demonstrated sufficient specificity and sensitivity to accurately identify patients with ADHD. However, self-rated questionnaires have been proposed to screen adults for ADHD effectively, with the most widely used being the Adult ADHD Self-Report Scale (ASRS).[8]

Obesity has now reached epidemic proportions globally, becoming a significant public health issue across all age groups.[9] As a common chronic disease, it is associated with reduced life expectancy and diminished quality of life. A complex interplay of environmental, pathophysiological, and psychological factors[10] contribute to the onset and persistence of this chronic condition in childhood. It is well established that overweight and obesity in children and adolescents increase the likelihood of obesity in adulthood.[11,12]

Research demonstrates that ADHD is linked not only to psychiatric comorbidities but also to common medical and metabolic disorders.[13] Atlfas (2002) was the first to identify a potential link between ADHD and obesity in adults seeking bariatric treatment,[14] which was later confirmed by meta-analyses in children and adults.[15–17] Odds ratio for obesity in ADHD ranged between 1.20 (95% CI = 1.05–1.37)[15] and 1.56 (95% CI = [1.32–1.85])[17] in children and adolescents, and was 1.55 (95% CI = 1.32–1.81) in adults.[15] Nigg et al. (2016) also reported an odds ratio increasing with age group, from 1.13 (95% CI = 1.00–1.27) in those younger than 18 years to 1.37 (95% CI = 1.19–1.58) in adults.[18] In unmedicated patients, odds ratio were higher, ranging from 1.43 (95% CI = 1.23–1.67) in adults and 1.54 (95% CI = 1.22–1.94) in children and adolescents.[17] Higher odds ratios were observed among children and adolescents in Asia (OR = 3.25, 95% CI = [1.70, 6.21]) and Europe (OR = 1.85, 95% CI = [1.61, 2.12]).[17] Prevalence rates of ADHD in children and adolescents were reported at 15.2% (95% CI = 13.1–17.2) for obesity, 24.5% (95% CI = 19.6–29.4) for overweight, and 2.5% (95% CI = 1.2–3.7) for underweight.[16] Moreover, a recent umbrella review of meta-analyses showed that maternal pre-pregnancy overweight and obesity were strongly associated with an increased risk of developing ADHD in a child (OR = 1.62, 95% CI = 1.23–2.14).[19]

These findings appear counterintuitive, as hyperactive individuals are expected to expend excessive energy and thus be lean. However, if the association holds true, psychostimulants used to treat ADHD might be anticipated to reduce the risk of overweight and obesity, as observed. Several factors have been suggested to explain this relationship[20], including genetic factors, fetal programming (birth weight), executive dysfunctions (planning, deficits in response inhibition, impulsivity), psychosocial stress, factors directly related to energy balance (overeating, snacks, food craving, and sugar beverages), and sleep pattern alterations (short sleep, daytime sleepiness).[21] Impaired executive functions may also serve as a barrier to weight loss in adults with ADHD, hence pushing them to seek metabolic and bariatric surgery (MBS).[22]

Until recently, MBS has been associated with durable and sustained weight loss and has thus become an accepted treatment option not only for adults with obesity but also for younger individuals.[23–25] Importantly, MBS may reduce the incidence of chronic comorbid disorders associated with obesity, such as type 2 diabetes, non-alcoholic fatty liver disease, and sleep apnea syndrome.[26]

However, the risks and benefits of MBS in patients with ADHD have not yet been thoroughly explored. A recent meta-analysis focused on the impact of ADHD on body mass index (BMI) change after MBS.[27] They reported a mean prevalence of 20.9% over five studies that included 492 patients, with a considerable variation between studies. A seven-fold prevalence of ADHD in the candidates for MBS is impressive, and updated statistics are needed. There was no significant difference in the mean BMI reduction at follow-up, but the ADHD group had a significant reduction in postoperative follow-up versus non-ADHD patients. Only one study has investigated the outcomes of patients pharmacologically treated for ADHD (with psychostimulants or atomoxetine) before surgery, comparing them to matched controls.[28] Both groups demonstrated similar postoperative risks, weight loss, and remission of comorbid diseases. However, patients with ADHD reported lower health-related quality of life before and after surgery and showed an increased risk of substance abuse and self-harm, particularly if they did not attend follow-up visits.

Järvholm et al. warranted more investigations on adolescents who undergo MBS, because they are more at risk of developing mental health problems, including depression and substance use disorder, than middle-aged adults.[29] The guidelines issued by the American Society for Metabolic and Bariatric Surgery put a strong emphasis on both pre-MBS assessment and post-operative care.[30]

We aimed at performing a systematic review and meta-analysis of the publications that reported the prevalence of ADHD in patients assessed before undergoing MBS, being adolescents or adults. The hypothesis was to report a pooled prevalence of ADHD in those two age groups and to determine whether it is higher than the prevalence of ADHD in the general population.

2 | MATERIAL AND METHODS

The protocol for this systematic review and meta-analysis was registered in PROSPERO under the reference CRD42022384914 and can be requested from the first author. We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines for

extracting and assessing data.[31] This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement.[32]

2.1 | Search strategy

We searched three electronic databases from the database inception to January 2023 for studies that focused on determining the prevalence of ADHD in the two populations of interest, that is adolescents and adults with obesity assessed for that condition before undergoing whatever kind of MBS. We used the following search strings:

- for PubMed: "(ADHD) AND (bariatrics OR (obesity surgery) OR (gastric bypass) OR (gastric sleeve) OR Roux-en-Y OR RYGB OR (sleeve gastrectomy))",
- for Scopus: "TITLE-ABS-KEY ((adhd) AND (bariatrics OR (obesity AND surgery) OR (gastric AND bypass) OR (gastric AND sleeve) OR roux-en-y OR rgb OR (sleeve AND gastrectomy)))"
- for EMBASE: "adhd:ti,ab,kw AND ('bariatrics':ti,ab,kw OR 'obesity surgery':ti,ab,kw OR 'gastric bypass':ti,ab,kw OR 'gastric sleeve':ti,ab,kw OR 'roux-en-y':ti,ab,kw OR 'rygb':ti,ab,kw OR 'sleeve gastrectomy':ti,ab,kw)"

2.2 | Eligibility criteria and study selection

Inclusion criteria were as follows: (1) a study reporting the prevalence of ADHD in the two populations of interest, (2) with no restrictions on publication timeframe, and (3) regardless of language. These conditions enable researchers conducting a meta-analysis to assess geographical variations in results, mitigate potential language biases, understand the sociocultural contexts of the studies, and evaluate the generalizability of the findings across diverse populations.

References were imported from the three electronic databases into an EndNote® library, and duplicates were discarded by automatic searches using different strategies. The first author selected the eligible references based on the title, abstract, and, when deemed necessary, the full text (Figure 1).

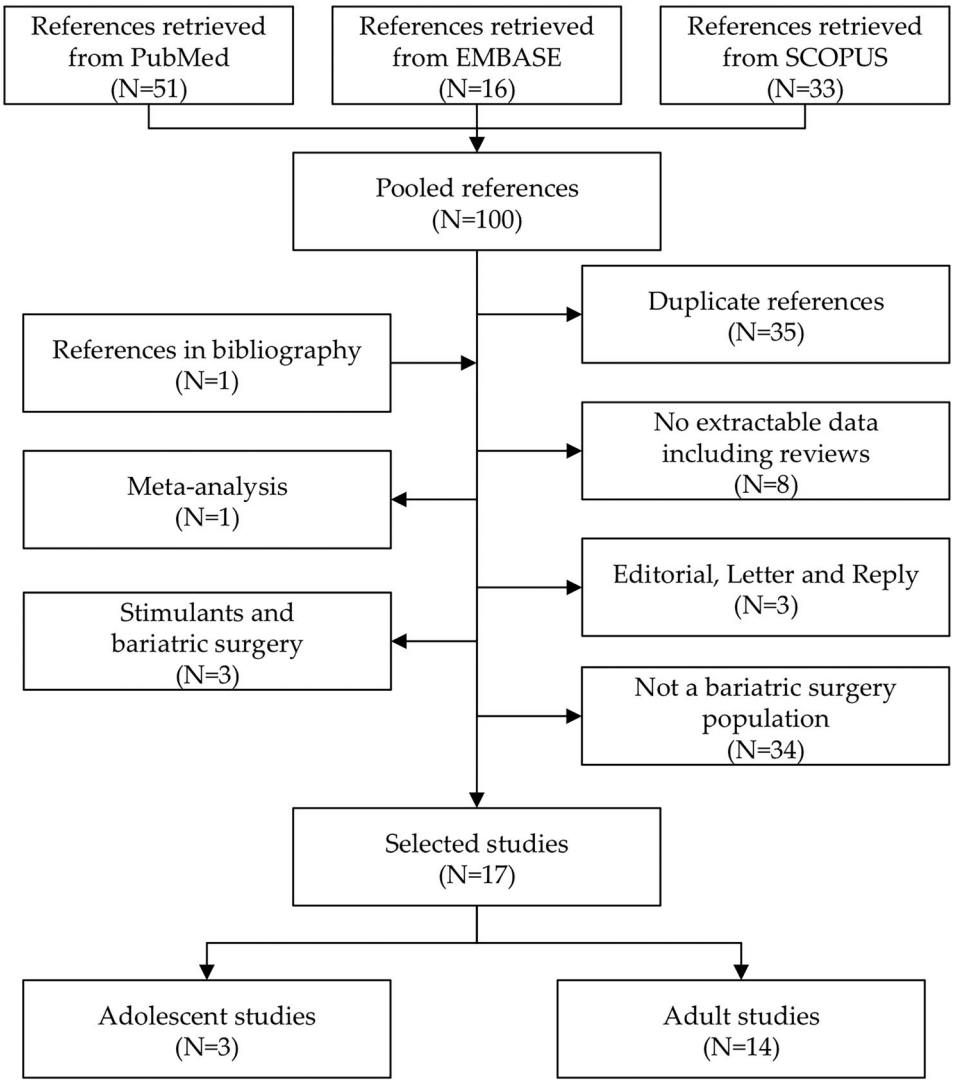

FIGURE 1 Flowchart of the extensive literature search.

2.3 | Data collection and quality assessment

Information from included surveys was extracted on first author's name, year of publication, study location, type of study, type of population and method for selecting the sample, sample characteristics (e.g., sex ratio, age range or mean age), and the method used for diagnosing ADHD (i.e., case definition). Data keyed into an Excel® spreadsheet for statistical analyses in Stata® 15.1.[33]

The Joanna Briggs Institute (JBI) Critical Appraisal checklist for prevalence studies (https://jbi.global/sites/default/files/2019-05/JBI_Critical_Appraisal-Checklist_for_Prevalence_Studies2017_0.pdf) was used for quality assessment. It counts only nine items with four possible answers: "Yes," "No," "Unclear," or "Not applicable." The first two authors appraised the retrieved references, and the differences were resolved by discussion. The following formula was used to help answer the third item ("Was the sample size adequate?"), where $Z = 1.96$ for the conventional level of confidence of 95%, P is the expected prevalence, and d is the precision.[34] The answer was "Yes" if the sample in the survey was greater or equal to the value of n, and "No" otherwise.

$$n = \frac{Z^2 P(1-P)}{d^2}$$

2.4 | Statistical analysis

Random effects meta-analyses were performed on adults and adolescents separately using the `metaprop` command.[35] Random effects were preferred on fixed effects considering obvious sampling differences between samples: i.e., mean age, sex ratio, and mean BMI. Individual study's prevalence is computed as the ratio of the number of cases (n) over the sample size (N) and then transformed on the Freeman-Tukey double arcsine function to stabilize the variances.[35,36] The confidence intervals are computed with an exact binomial method. Hence, a minimalistic command line would be `metaprop n, random ftt cimethod(exact)`.

Cochran's Q (distributed as a χ^2 statistic with the number of studies minus one as the number of degrees of freedom, df) was used to measure heterogeneity; that is, the variation in study outcomes between studies. The power of Q as a comprehensive test of heterogeneity is low when the number of studies is small. A simple transformation ($I^2 = 100\% \times [Q\text{-}df]/Q$) gives the percentage of variation across studies that is due to heterogeneity rather than sampling error and is not affected by the number of studies. By a "rule of thumb," $I^2 = 25\%$ indicates low heterogeneity, $I^2 = 50\%$ moderate heterogeneity, and $I^2 = 75\%$ substantial heterogeneity.[37] However, I^2 depends heavily on the precision of the included studies.[38,39] In case of high heterogeneity, the common option is to subgroup the studies. Finally, the τ^2 statistic, which is the variance of the underlying true outcomes (i.e., the prevalence in this paper) in the "population of studies," is insensitive to the number of studies, and the precision, but does not reflect heterogeneity *per se*.

Data and analysis output are available upon reasonable request to the first author.

3 | RESULTS

3.1 | Studies selected

Figure 1 shows the flowchart of the selection process.

Table 1 lists the 14 studies that met inclusion criteria in adults. They were published from 2002 to 2021.[14,40–52] They were conducted in six countries: Brazil ($k = 1$), Canada ($k = 1$), France ($k = 1$), Turkey ($k = 1$), the USA ($k = 2$), Germany ($k = 3$), and Sweden ($k = 5$). The study sample size ranged from 30 to 22,539 (median = 147) for a total of 24,455 observations. The proportion of women ranged from 72.2% to 92.5% (median = 78.7%) resulting in a male-to-female ratio ranging from .08 to .38 (median = .27). The average age was 40.53 ± 10.94, ranging from 19.70 to 48.30. Finally, two studies reported data for men and women separately both in Sweden.[41,50]

Table 2 lists the three adolescent studies published in 2020 and 2021.[53–55] The study sample size ranged from 48 to 167, with a total of 299 patients. The proportion of girls ranged from 47.6% to 75.4%, resulting in a male-to-female ratio ranging from .33 to 1.10.

3.2 | Quality of studies

The overall quality of the included studies is moderate to low, as revealed by the items of the JBI Critical Appraisal Checklist below.

Item 1: All the included studies analyzed a sample frame correctly representing the target population (i.e., patients assessed before undergoing BS).

Item 2: None of the included studies adopted random sampling from a population. Study samples were made up of consecutive series or retrospectively from medical records. There was one multicentric study,[55] and one study based on a national register.[52]

Item 3: According to Naing et al. (2006), only four studies included enough patients regarding the prevalence rate they reported.[41–43,52]

Item 4: None of the studies reported sufficient detail so that other researchers can determine if it is comparable to the population of interest to them. In one study, 46 patients (33% of the total sample) were younger than 18 years and nevertheless considered as adults.[50] Most studies did not even report age and BMI separately for males and females. Few studies briefly reported the education level, the type of occupation, or the marital status.[41–45,51]

Item 5: The coverage of the identified sample is overall insufficient: three studies included at least 90% of the patients initially approached,[14,44,54] and one had only 12% as it focused on patients who attended at least one post-surgical follow-up visit.[47] The non-included patients were never described in any way.

TABLE 1 Characteristics of studies on adult samples included in the meta-analysis ($N = 1739$).

Author	Country	Type of study	Men/ women	M: F	ADHD/ non-ADHD	Prevalence 95% IC	Method for identifying ADHD
Alfonsson et al. (2012)	Sweden	Prospective study between August and December 2010. 217 adults visited the obesity clinic and volunteered to participate in.	50/137	.36	19/168	10.16% [6.23, 15.41]	ASRS v1.1 Screener Dichotomized items w/o details
Alfonsson et al. (2013)	Sweden	Prospective study between June 2010 and February 2011. 276 adults visited the obesity clinic and volunteered to participate in.	67/178	.38	21/224	8.57% [5.38, 12.80]	ASRS v1.1 Screener Dichotomized items w/o details
Alfonsson et al. (2014)	Sweden	Prospective study not dated. 177 adults eligible for bariatric Roux-en-Y surgery were approached.	28/101	.28	9/120	6.98% [3.24, 12.83]	ASRS v1.1 Screener Dichotomized items w/o details
Altfas et al. (2002)	United States	Systematic retrospective review of medical records of adults in 2000	22/193	.11	59/156	27.44% [21.59, 33.92]	A psychiatrist performed semi-structured interviews according to DSM-IV criteria
Dreber et al. (2015)	Sweden	Prospective study between September 2012 and November 2014. 236 young adults (16–25 years) with BMI ≥ 35 kg/m^2 or BMI ≥ 30 kg/m^2 with obesity-related comorbidities	33/132	.25	21/144	12.73% [8.81, 18.80]	ASRS v1.1 Screener ≥ 4 dichotomized items
El Archi et al. (2021)	France	Prospective study. All consecutive bariatric surgery adult candidates between July 2016 and December 2020	66/216	.31	23/259	8.16% [5.24, 11.99]	WURS-25 ≥ 46 (childhood) and ASRS v1.1 Screener (adult) ≥ 4 dichotomized items
Gruss et al. (2012)	Germany	Prospective study. 124 consecutive bariatric surgery adult candidates between March 2008 and October 2009	31/85	.36	14/102	12.07% [6.76, 19.42]	WURS-k ≥ 30 (childhood) and ADHD-Self Rating Scale≥15 (adult)
Lagerros et al. (2020)	Sweden	National register study of patients undergoing bypass surgery between 2008 and 2012.	5578/16961	.33	314/22225	1.39% [1.24, 1.56]	ICD-10 ADHD diagnostic (F90.0) prior to surgery
Marchesi et al. (2017)	Brazil	Retrospective study. 122 patients selected among those who had undergone Roux-en-Y bariatric surgery between November 2011 to May 2013	3/37	.08	15/25	37.50% [22.73, 54.20]	ASRS v1.1 full 6 "positive" inattention items and/or 6 "positive" hyperactivity items
Müller et al. (2012)	Germany	Prospective study. 118 consecutive bariatric surgery adult candidates with BMI ≥ 35 kg/m^2 between November 2009 and November 2010	25/65	.38	8/82	8.89% [3.92, 16.77]	WURS-k ≥ 30 (childhood) and ADHD-Self Rating Scale ≥ 15 (adult)
Nielsen et al. (2017)	Germany	Retrospective study. 120 bariatric surgery adult candidates.	NR	NR	10/110	8.33% [4.07, 14.79]	WURS-k ≥ 30 (childhood) and ADHD Index *T* score ≥ 65
Steinmann et al. (2011)	United States	A retrospective chart review of adults who had undergone bariatric Roux-en-Y surgery from 2005 to 2009.	21/99	.21	2/118	1.67% [0.20, 5.89]	Licensed psychologist or psychiatrist (DSM-IV not mentioned)
Taymur et al. (2016)	Turkey	Prospective study. 200 bariatric surgery adult candidates between 2013 and 2014	34/143	.24	34/143	19.21% [13.69, 25.79]	WURS-25 (childhood) No cutoff value reported

(Continues)

TABLE 1 (Continued)

Author	Country	Type of study	Men/ women	M: F	ADHD/ non-ADHD	Prevalence 95% IC	Method for identifying ADHD
Williamson et al. (2018)	Canada	Prospective study. 37 bariatric surgery adult candidates with BMI ≥ 40 kg/m^2 or BMI ≥ 35 kg/m^2 and obesity-related comorbidities between October 2014 and September 2015	6/24	.25	6/24	20.00% [7.71, 38.57]	ASRS v1.1 Screener ≥ 4 dichotomized items

Legend: "w/o" means without. "NR" means not reported. "ASRS" means Adult ADHD Self-Rating Scale, which is different from the ADHD-Self Rating used in the German studies. "WURS-25" means Wender Utah Rating Scale 25 items version, which is different from "WURS-k" means Wenter Utah Rating Scale *kurtz* version (21 items) used in the German studies. The ADHD Index *T* score is one of the score of the Conners' Adult ADHD Rating Scale - Self-Report: Short Version (CAARS-S:S).
Abbreviation: ADHD, attention-deficit with hyperactivity disorder.

TABLE 2 Characteristics of studies on adolescent samples included in the meta-analysis ($N = 299$).

Author	Country	Type of study	Boys/ Girls	M:F	ADHD/ non-ADHD	Prevalence	Method for identifying ADHD
Björk et al. (2021)	Sweden	Prospective study. 50 participants included in the Swedish Adolescent Morbid Obesity Surgery 2 (AMOS2). Aged between 13 and 16 years, Tanner stage≥3, and BMI ≥ 35 kg/m^2.	13/35	.37	25/23	52.08% [37.19, 66.71]	5 to 15 questionnaire (parent version) (≥p90 of attention and concentration, and/or of over-activity and impulsivity domains)
Leib et al. (2020)	Israel	Prospective study. 84 adolescents with severe obesity (BMI ≥ 120% of the 95th percentile, or ≥35 kg/m^2, whichever was lower	44/40	1.10	24/60	28.57% [19.24, 39.47]	Interview of parents by the child and adolescent psychiatrist or psychologist according to DSM-IV criteria
Williams et al. (2020)	USA	Retrospective study. 172 adolescents undergoing laparoscopic sleeve gastrectomy between February 2010 and May 2017	41/126	.33	38/129	22.76% [16.63, 29.87]	Pre-existing diagnoses, but no classification reported

Legend: "p90" means 90th percentile.
Abbreviation: ADHD, attention-deficit with hyperactivity disorder.

Item 6: A clinical interview with a psychiatrist or a psychologist is recommended for diagnosing ADHD. In four studies, a psychologist or a psychiatrist made the diagnosis of ADHD, or ICD-9 and ICD-10 codes of Hyperkinetic Disorder, which is slightly different from ADHD and less prevalent, were retrieved from medical records.[14,47,52,53] The Adult ADHD Self-Report rating scale (ASRS v1.1) is extensively used worldwide and composed of two parts: a six-item screener, and 12 more items. Seven studies used the ASRS v1.1 screener[40–43,45,48,50] but only three reported the correct scoring method, which is at least four points on a possible total of six after items are dichotomized.[43,48,50] Other studies used a cut-off on the WURS-25 total score for a retrospective diagnosis of ADHD in childhood,[51] or combined a cut-off on the WURS-25 total score and a correct cut-off on the ASRS v1.1 screener score,[43] or combined a cut-off score on the WURS-k total score and a cut-off score on the ADHD Self Rating scale.[44,46,49]

Item 7: No study mentioned that the diagnosis of ADHD was made differently for subgroups of their samples.
Item 8: Data analysis was deemed appropriate in all the included studies.
Item 9: To complete the response to the fifth item, none of the studies compared the patients who were not included to those who were included.

3.3 | Meta-analysis of adult studies

A meta-analysis of all fourteen studies gives a pooled prevalence rate of 11.29% (95%CI = [5.79, 18.74]) with unacceptable values of $I^2 = 97.31\%$ and $\tau^2 = .13$ (Figure 2). We thus decided to subgroup the studies according to the method used to identify cases.

Five studies used the ASRS 6-item screener with dichotomized items (i.e., weighted),[40–42,48,50] while a sixth study was not included

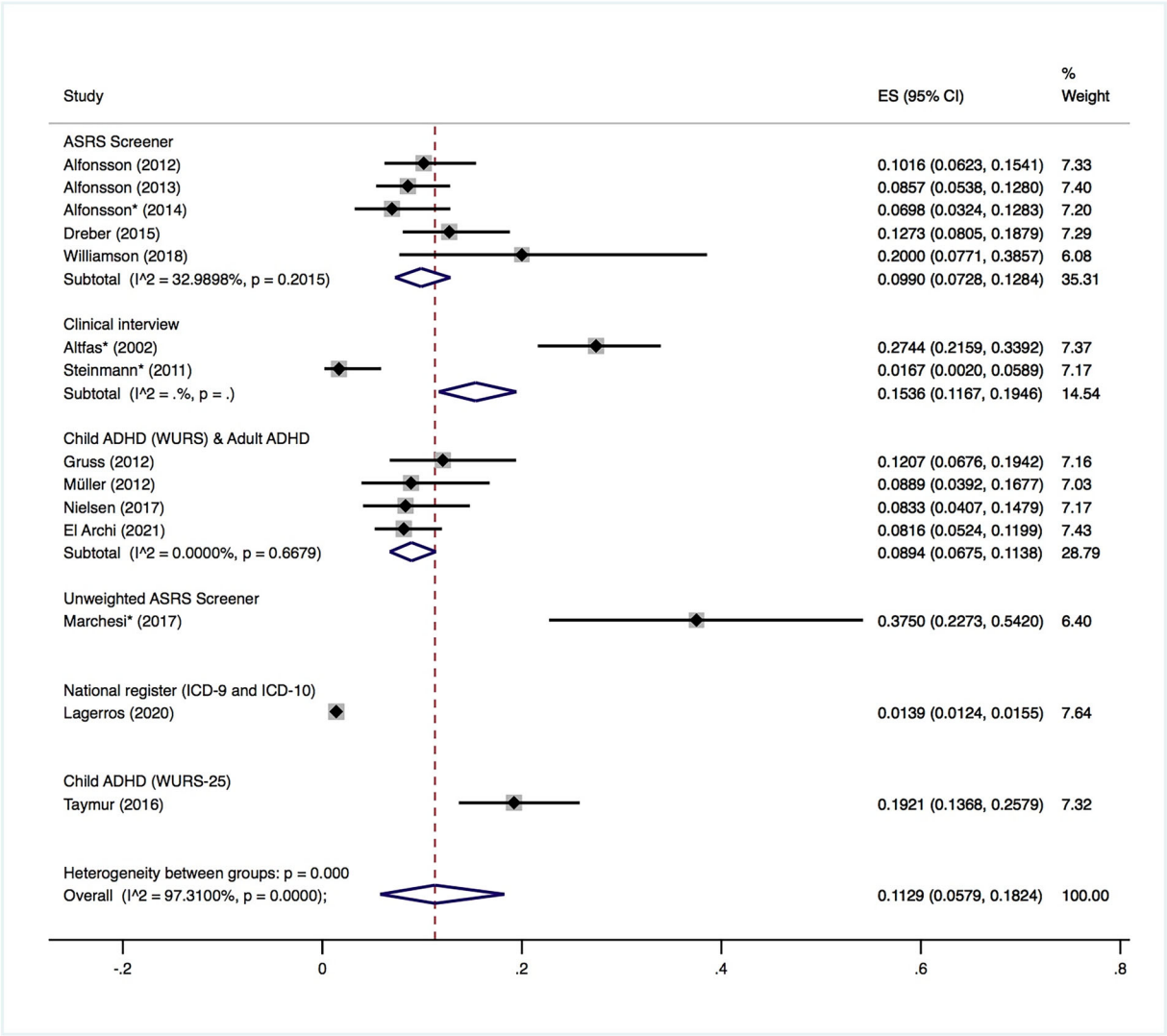

FIGURE 2 Forest plot after a meta-analysis of all 14 studies on adult samples grouped by the case definition method (see text). Studies included in the previous review of the literature are marked with an asterisk 23.

because item scores were not weighted and only one-third of the initial sample returned the questionnaire, resulting in a huge prevalence rate of 37.50%.[45] Heterogeneity is not significant, pooled prevalence rate of 9.90% (Table 3 and Figure 3), and Egger's test for small study bias is not significant (.826, $p < .217$). The set of four studies that most improved heterogeneity reduced the pooled prevalence to 9.55%.

In four studies, a case was defined by combining the score on the WURS-25 or the WURS-k for identifying ADHD in childhood, and the score on the CAARS-S:S Index *T*-score, the ASRS v1.1 screener, or the ADHD Self Rating Scale for identifying ADHD in adulthood. Heterogeneity is not significant, pooled prevalence is 8.94% (Table 4 and Figure 4), and Egger's test for small study bias is not significant (.398, $p < .506$). Omitting one study did not increase heterogeneity.

The diagnosis of ADHD was made during a clinical interview in two studies with a huge difference in prevalence rates.[14,47] The meta-analysis gives a pooled prevalence of 15.36% (95%CI = [11.67, 19.46]) but no measure of heterogeneity could be computed. The last two studies were not included in any meta-analysis. The first only considered the diagnosis of childhood ADHD on the score of the WURS-25[51]; the second was a national register study.[52]

Finally, we did not analyze the country of origin because the most important parameter appeared to be the case definition.

3.4 | Meta-analyses of adolescent studies

The pooled preference of the three studies on adolescents affected by obesity was 28.73% (95%CI = [20.18, 38.10]) with $\chi^2(2) = 5.231$ (NS), $I^2 = 61.763\%$, and $\tau^2 = .018$.[53–55]

4 | DISCUSSION

This systematic review of the literature and meta-analysis of the prevalence of ADHD among candidates for MBS included 14 studies in

TABLE 3 Meta-analysis of studies that used the dichotomized ASRS 6-item screener for case definition.

Author (year)	Prevalence (%) 95CI%	Meta-analysis without that study
Alfonson et al. (2012)	10.16 [6.23, 15.41]	10.04 [6.50, 14.21] $\chi^2(3) = 5.957$ (NS) $I^2 = 49.647\%$ $\tau^2 = .0077$
Alfonson et al. (2013)	8.57 [5.38, 12.80]	10.60 [7.10, 14.65] $\chi^2(3) = 5.116$ (NS) $I^2 = 41.361\%$ $\tau^2 = .0059$
Alfonson et al. (2014)	6.98 [3.24, 12.83]	10.63 [7.69, 13.96] $\chi^2(3) = 4.364$ (NS) $I^2 = 31.253\%$ $\tau^2 = .0032$
Dreber et al. (2015)	12.73 [8.05, 18.79]	9.13 [6.30, 12.38] $\chi^2(3) = 4.346$ (NS) $I^2 = 30.970\%$ $\tau^2 = .0033$
Williamson et al. (2018)	20.00 [7.71, 38.57]	9.55 [7.46, 11.85] $\chi^2(3) = 3.070$ (NS) $I^2 = 2.290\%$ $\tau^2 = .0001$
Meta-analysis ($k = 5$)	9.90 [7.28, 12.84] $\chi^2(4) = 5.969$ (NS) $I^2 = 32.990\%$ $\tau^2 = .0034$	

Abbreviation: ADHD, attention-deficit with hyperactivity disorder.

adults ($N = 24{,}455$, median = 147) and three in adolescents ($N = 299$, median = 84). We found that ADHD is overrepresented in the studied population compared to the general population, but the pooled prevalence in adults was half smaller than the value of 20.9% reported in a previous review of five studies that focused on BMI change after MBS ($N = 492$).[27] We further extend the results of a systematic review focused on obesity and ADHD, but excluded candidates or patients who had undergone MBS.[15]

4.1 | Studies in adults

The meta-analysis of the 14 studies in adults was so heterogeneous that we had to group the studies according to their method of case definition, and, consequently, had to drop five of them. One did not use the standard rating algorithm of the 18-item ASRS v1.1, which probably inflated the prevalence rate to an impressive 37.50%.[45] In a second study, the diagnosis of ADHD in adults was simply not made and replaced by the total score of the WURS-25 which lists a set of symptoms often reported by adults with ADHD in childhood.[51] A third study was a national register study where ICD-9 or ICD-10 codes for Hyperkinetic Disorder (HKD) were counted.[52] The algorithm for diagnosing HKD differs from that for ADHD although the eighteen items are identical. The diagnosis of HKD has been replaced by the diagnosis of ADHD in the ICD-11. The resulting prevalence rate of HKD is significantly lower than that of ADHD as defined in the DSM-IV, a large systematic review and a meta-regression analysis study showed.[3] In a fourth study, a psychiatrist diagnosed patients "using semi-structured interviews over one or more visits" according to DSM-IV criteria without naming it. He diagnosed 27.44% of patients

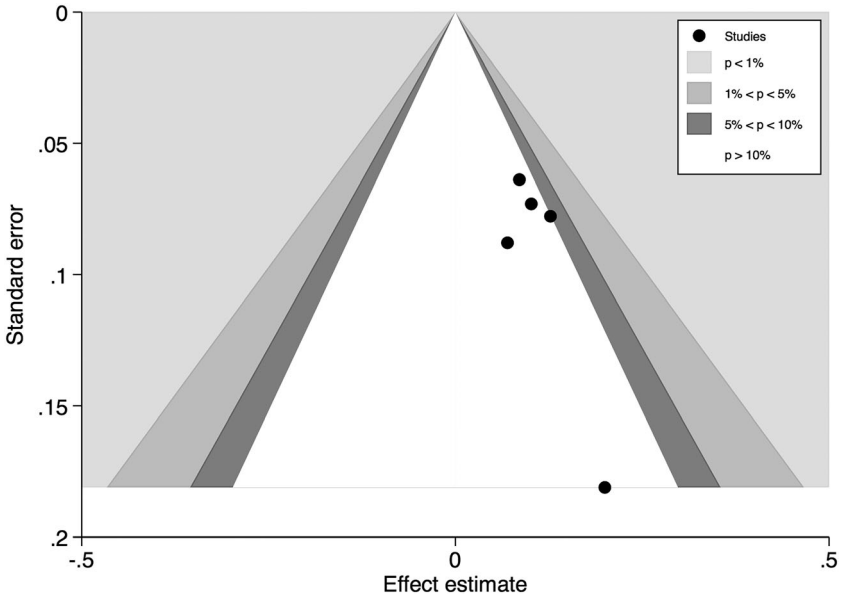

FIGURE 3 Funnel plot after meta-analysis of five studies on adult samples that used the ASRS V1.1 6-item screener to define a case.

with ADHD but surprisingly all of the inattentive predominant subtype.[14] This is totally unexpected and hardly explicable. In a fifth study, a licensed psychologist diagnosed patients, presumably according to DSM-IV criteria although that was not mentioned, and a prevalence of 1.67% was computed.[47] Therefore, the pooled prevalence for these two studies is likely to be unreliable. Age was similar between studies ($t[333] = .450$, NS), but there were fewer men, and BMI mean value was lower in the former compared to the latter study: 10.23% vs. 17.50% and 36.20 ± 8.20 vs. 50.03 ± 7.51. The prevalence of persistent ADHD is known to decrease by advancing age[56] and may be one reason for partly explaining this huge difference.

A meta-analysis was performed on the five studies that used the ASRS six-item screener to define cases: the pooled prevalence rate was 9.90% ($N = 756$), with non-significant heterogeneity and Egger's test for bias. However, the scoring method for that shortened part of the ASRS v1.1 is likely to overestimate the prevalence of ADHD. A two-stage scoring method gave a more realistic estimate of the prevalence in a random sample of adults from the general population: 11.27% vs. 2.99%.[5]

A second meta-analysis was performed on the last four studies included in the review. Their authors combined the WURS-k (or the WURS-25) to screen for ADHD in childhood with a measure of actual ADHD (i.e., CAARS-S:S Index *T*-score, the ASRS v1.1 screener, or the ADHD Self Rating Scale). The German studies used a cut-off score of 30 on the WURS-k to retrospectively identify ADHD in childhood. This is a comfortable value since a cut-off of 24 showed very good properties in a convenience sample of 105 adults, but the cut-off rose to 36 when DSM-5 criteria were applied.[57] When combined with the WURS-25, the ASRS v1.1 screener offered an improved screening in 317 patients with borderline personality disorder.[58] However, specificity and sensibility were far lower than for the two-stage scoring of the ASRS v1.1 in a convenience sample of 105 adults.[59] In this analysis, heterogeneity and Egger's test for bias were not significant, and the pooled prevalence was 8.94% ($N = 608$).

To summarize, our systematic review and meta-analyses resulted in two comparable estimates of the prevalence rate of ADHD in adult candidates for MBS. A previous review of the literature reported a mean prevalence of 20.94%[27] and included four studies from our selection,[14,40,45,47] while we did not retain one of theirs,[60] that reported on patients who had undergone MBS and where assessed during follow-up.

TABLE 4 Meta-analysis of studies that defined a case by combining of the WURS (either WURS-k or WURS-25) for child ADHD and another instrument (either CAARS-S:S, ASRS v1.1 screener, or the ADHD-Self Rating Scale) for adult ADHD.

Author (year)	Prevalence (%) 95CI%	Meta-analysis without that study
Gruss et al. (2012)	12.07 [6.76, 19.42]	8.26 [5.94, 10.91] $\chi^2(2) = .092$ (NS) $I^2 = 0.000\%$ $\tau^2 = .0000$
Müller et al. (2012)	8.89 [3.92, 16.77]	8.97 [6.62, 11.63] $\chi^2(2) = 1.562$ (NS) $I^2 = 0.000\%$ $\tau^2 = .0000$
Nielsen et al. (2017)	8.33 [4.07, 14.79]	9.09 [6.65, 11.86] $\chi^2(2) = 1.500$ (NS) $I^2 = 0.000\%$ $\tau^2 = .0000$
El Archi et al. (2021)	8.16 [5.24, 11,99]	9.75 [6.70, 13.28] $\chi^2(2) = .963$ (NS) $I^2 = 0.000\%$ $\tau^2 = .0000$
Meta-analysis ($k = 4$)	8.94 [6.75, 11.38] $\chi^2(3) = 1.563$ (NS) $I^2 = 0.000\%$ $\tau^2 = .0000$	

Abbreviations: ADHD, attention-deficit with hyperactivity disorder; WURS, Wender Utah Rating Scale.

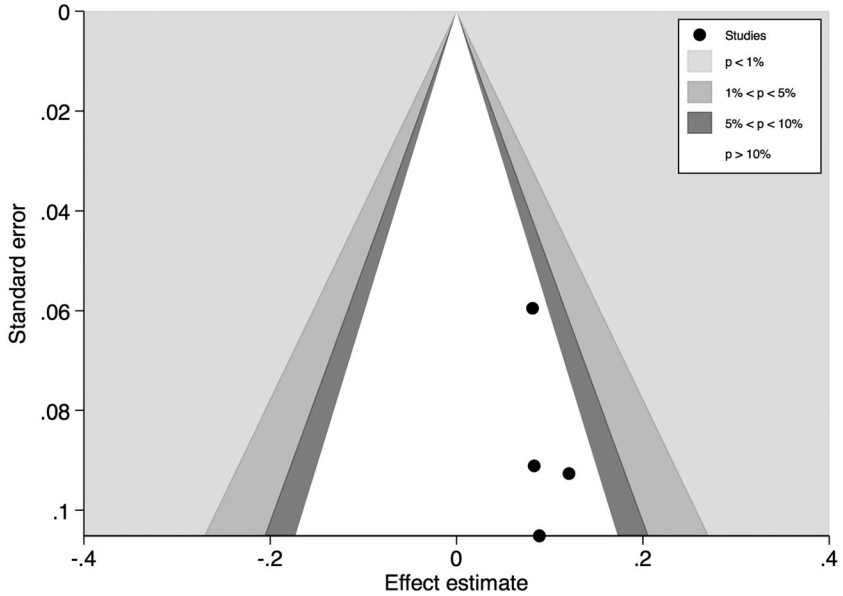

FIGURE 4 Funnel plot after meta-analysis of four studies on adult samples that assessed ADHD in childhood and in adulthood to define a case. ADHD, attention-deficit with hyperactivity disorder.

A structured interview is a gold standard for diagnosing ADHD,[6] but it is highly demanding on resources. Screening for ADHD with self-rated questionnaires has proven its feasibility and reliability providing that a stringent algorithm is used.[5,59] As we mentioned above, combining the ASRS with one of the versions of the WURS is not likely to improve the screening, especially if a two-stage rating algorithm is used. At the end of the day, the two estimates are close and we may conclude that ADHD is likely to be 5 times more frequent in adult candidates for MBS.

4.2 | Studies in adolescents

We identified and selected only three studies using different methodologies, which is insufficient to obtain any reliable estimate of the prevalence of ADHD in adolescents seeking MBS. Males represented half of the sample in one study[53] but a quarter in the other two. Age range was not reported in one study,[53] whereas another included participants aged from 10 to 25 years old.[54] Unsurprisingly, the heterogeneity was high ($I^2 = 61.763\%$, and $\tau^2 = .018$) and the pooled prevalence of 28.73% is certainly overestimated.

4.3 | Individual study and review limitations

Study design, patients sampling, and case definition were not consistent between studies, resulting in high heterogeneity, which may decrease the confidence in the results. The methodological quality of studies published in 2016 and 2017 in the field of MBS was rated highly unsatisfactory in a very recent systematic review and meta-analyses.[61] We also found that the quality of studies in our review was moderate to low, as assessed by the JBI checklist. The sample size was insufficient in most studies, and the representativeness of the participants was not thoughtfully assessed. Some studies analyzed adolescents and adults, altogether, and separate analyses for males and females were not reported. We did not observe language or duplication bias, and subgrouping the studies in adults with regard of the method for case definition resulted in two homogeneous groups of four and five studies with comparable estimates of pooled prevalence. Although funnel plots showed an asymmetric repartition of studies in both cases suggesting some bias, Egger's tests were not significant.

4.4 | Recommendations for future studies

Based on the results of this study, we may suggest several recommendations for future studies:

- Foster multicentric studies to damper systematic variability.
- Include at least 160 participants in each study, if the predicted prevalence rate is 10%, but at least 340 if the predicted prevalence rate is 5%.
- Include as many men as women, because ADHD is far more frequent in boys in childhood while candidates for MBS are more likely to be adult women. This recommendation is even more important for adolescent samples.
- Analyze adolescents and adults separately when the age range includes 18 years.
- An undisputed definition of an ADHD case is the prerequisite for conducting informative studies about the outcomes of MBS. Clinical interviews shall be preferred to screening. Failing that, researchers should use the same standard and validated screening questionnaire. The 18-item ASRS v1.1 allows a two-stage scoring that has similar specificity and sensitivity of the six-item screener but does not inflate the prevalence rate. The new ASRS-5 six-item screener has not yet been used. The two instruments are not mutually exclusive and may be used in the same booklet of questionnaires, just as we did for the WURS-25 and the WURS-k.
- Provide a more detailed description of the participants, including mean age and age range, sex ratio, occupation, marital status, socio-economic status, mean BMI, and BMI range. Subgroups may carry significant information, and it would be possible to perform meta-regression analyses.
- Provide more information about the pattern of psychiatric and non-psychiatric background because ADHD is known to happen with several comorbidities, which may help better understand the underlying causes of obesity in these patients.

5 | CONCLUSION

ADHD is a neurodevelopmental disorder associated with many psychiatric and somatic comorbid conditions, including overweight and obesity. All these three are public health concerns, and their co-existence in the same individual reduces both quality of life and life expectancy. Since ADHD is believed to have some negative impact on weight loss after MBS, it is mandatory to assess candidates for this condition. Our systematic review and meta-analyses suggest that about 9% of adult candidates may be concerned, which is far from being negligible. Large multicentric studies with higher quality are needed in both adolescents and adults before undergoing MBS to confirm a higher prevalence rate of ADHD in these populations and better assess the outcomes after surgery in these patients.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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