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FULL-LENGTH REPORT

Long-term changes on behavioral addictions symptoms among adults with attention deficit hyperactivity disorder treated with methylphenidate

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ABSTRACT

Background: Attention deficit hyperactivity disorder (ADHD) and behavioral addictions (BAs) are highly comorbid but little is known about the effect of anti-ADHD medications on behavioral addiction symptoms. Thus, the aim of this naturalistic prospective study was to investigate the long-term changes on BAs symptoms among methylphenidate-treated adults with a primary diagnosis of ADHD. *Methods:* 37 consecutive adult ADHD outpatients completed a baseline and follow-up assessment of ADHD, mood and BAs symptoms (internet, shopping, food, sex addictions and gambling disorder) after one year of methylphenidate (flexible dose) treatment. *Results:* Internet addiction test scores pre-treatment were significantly higher than post-treatment scores ($p < 0.001$). The same trend was seen for the shopping addiction ($p = 0.022$), food addiction scores ($p = 0.039$) and sex addiction scores ($p = 0.047$). Gambling disorder scores did not differ pre and post treatment since none of the included patients reported significant gambling symptoms at baseline. The rate of ADHD patients with at least one comorbid BA was reduced after methylphenidate treatment (51.4% vs 35.1%). The correlation analyses showed a moderate positive correlation between the changes in sluggish cognitive tempo symptoms, cognitive impulsivity, mood and anxiety symptoms and changes in internet addiction symptoms. *Conclusions:* This is the first study showing that after one-year of treatment with methylphenidate, adult ADHD patients show a significant reduction on internet, food, shopping and sex addiction symptoms. Further controlled studies with larger samples should replicate these preliminary results and elucidate the role of methylphenidate and other moderator factors (such as concomitant psychological treatments or lifestyle habits changes) on BAs improvements.

KEYWORDS

methylphenidate, ADHD, internet addiction, sex addiction, shopping addiction, food addiction

INTRODUCTION

Behavioral addictions (e.g. gambling disorder and internet, sex, shopping, food addiction) are commonly comorbid with attention deficit hyperactivity disorder (ADHD) (Brandt & Fischer, 2019; Grassi, Moradei, & Cecchelli, 2024; Jacob, Haro, & Koyanagi, 2018; Karaca et al., 2017; Retz, Ringling, Retz-Junginger, Vogelgesang, & Rösler, 2016; Theule, Hurl, Cheung, Ward, & Henrikson, 2019; Wang, Yao, Zhou, Liu, & Lv, 2017; Wang, Yin, Wang, King, & Rost, 2024). Also, in a research domain criteria (RDoC) perspective, ADHD and addictions (both substance and non-substance related) share several neurobiological features (e.g. reward dysfunction, inhibitory control network dysfunction) (Cabelguen et al., 2021; Gao et al., 2021; Ko et al., 2023; Koncz et al., 2023; Luijten, Schellekens, Kühn, Machielse, & Sescousse, 2017; Plichta et al., 2014; Werling, Kuzhippallil, Emery, Walitza, & Drechsler, 2022). Several recent international guidelines and consensus studies highly recommend the

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recognition and treatment (both with stimulants medications and psychological interventions) of comorbid ADHD in adults and adolescents with substance use disorders (Brynte et al., 2022; Crunelle et al., 2018; Icick et al., 2020; Ögen et al., 2020). However, little is known about the impact of ADHD medications on behavioral addictions symptoms. Moreover, up to date, pharmacological evidence-based treatments for these conditions are largely lacking and no medications have been approved for these disorders by the principal regulatory organizations. In the current literature, only a few studies on only children and adolescent populations investigated the effectiveness of anti-ADHD medications for behavioral addictions. A study on children showed a beneficial effect of methylphenidate on internet video game play that was correlated to attentional improvement in a sample of ADHD children (Han et al., 2009) and a subsequent study on adolescents with ADHD showed an improvement of internet gaming disorder symptoms with both methylphenidate and atomoxetine (Park, Lee, Sohn, & Han, 2016). Finally, a two-day challenge study on subjects with food addiction did not find a significant effect of methylphenidate on craving and food intake ratings (Davis, Levitan, Kaplan, Kennedy, & Carter, 2014). On the other hand, studies of ADHD patients showed that stimulant medications do not increase the risk of substance use but rather they seem to have a protective effect (Chang et al., 2014; Molina et al., 2023; Quinn et al., 2017).

Thus, the aim of the present naturalistic prospective study is to investigate the long-term changes of behavioral addictions symptoms, ADHD, mood and anxiety symptoms after one-year of methylphenidate treatment in a sample of adults with a primary diagnosis of ADHD.

METHODS

Participants

All the patients were recruited at the Brain Center Firenze, a specialized clinic for adult ADHD. We enrolled 37 consecutive adult outpatients with a primary diagnosis of ADHD that completed the baseline and one-year follow-up assessment. All the included patients were newly diagnosed as adult ADHD and start a pharmacological treatment with methylphenidate after the first assessment. The ADHD diagnosis was established by one of two psychiatrist expert in the field (GG or CC) and confirmed through the structured clinical interview for adults ADHD, DIVA 5.0 (Hong et al., 2020). All the patients were comprehensively assessed trough a clinical interview and a series of psychometric test (see below) at baseline and after one year of pharmacological treatment with methylphenidate. Twenty seven out of 37 patients (73%) had a lifetime psychiatric comorbidity (35% an anxiety disorder, 32.4% a substance use disorder (cannabis, stimulants, opioids, alcohol), 24% a mood disorder (none of the patient had bipolar disorder), 5.4% obsessive-compulsive disorder, 5.4% an eating disorder (1 patient bulimia nervosa and 1 patient binge eating disorder) and 2.7% an OCD related disorder (excoriation disorder)). All patients were treated with methylphenidate at flexible dose according to clinical response for at least one year. During the one-year period of treatment patients could receive other medications and/or psychotherapy for comorbid conditions and/or behavioral coaching for ADHD symptoms.

Assessment

Clinical assessment. All the patients underwent a clinical interview assessing demographic and clinical characteristics (see Table 1).

ADHD assessment. ADHD symptoms were assessed through the Barkley Adult ADHD Rating Scale-IV (BAARS-IV), a self-report scale, based on the DSM-IV-TR criteria for the diagnosis of ADHD, meant to assess current and childhood ADHD symptoms in adults (Barkley, 2011). The self-report version of current symptoms scale includes 30 items (on a 4-point Likert scale) and 4 subscales (attention, impulsivity, hyperactivity, sluggish cognitive tempo). Each scale of current symptom has three extra questions (assessing functional impairment of ADHD symptoms). The sluggish cognitive tempo (SCT) subscale includes symptoms such as daydreaming, staring, mental fogginess, confusion, hypoactivity, sluggishness, slow movement, lethargy, apathy, and sleepiness (Barkley, 2012).

Impulsivity assessment. Impulsivity traits were assessed using the Barratt Impulsiveness Scale, version 11 (BIS-11). This scale consists of 30 self-descriptive items, with responses in a four-point Likert-type scale

Table 1. Baseline demographic and clinical characteristics of ADHD patients

	ADHD (n = 37)	
Age (years)	28 (33; 24)	
Gender (M:F)	9:28	
Years of Education	16 (18; 13)	
Lifetime Comorbidities	27 (73%)	
Mood disorders	9 (24%)	
Anxiety Disorders	13 (35%)	
Substance Use disorders	12 (32.4%)	
Obsessive-Compulsive Disorder	2 (5.4%)	
Excoriation Disorder	1 (2.7%)	
Eating Disorder	2 (5.4%)	
	Baseline	**One-year follow-up**
Patients taking concurrent medications	11 (29.7%)	11 (29.7%)
SSRI	7 (18.9%)	0 (0%)
SNRI	2 (5.4%)	1 (2.7%)
Anti-Anxiety	2 (5.4%)	9 (24.3%)
Mood stabilizers	0 (0%)	1 (2.7%)

Note: Data are expressed as percentage or median (interquartile range) for all variables. ADHD = Attention-Deficit Hyperactivity Disorder; SSRIs = Selective Serotonin Reuptake Inhibitor; SNRI = Serotonin and Norepinephrine Reuptake Inhibitor.

(Patton, Stanford, & Barratt, 1995). It measures the total score (range: 30–120) of impulsivity and three factors: Attentional Impulsiveness (AI), Motor Impulsiveness (MI), and Non-planning Impulsiveness (NPI) with higher scores indicating higher impulsivity. BIS-11 was used in its Italian translation (Fossati, Di Ceglie, Acquarini, & Barratt, 2001).

Mood and anxiety symptoms assessment. Mood and anxiety symptoms were assessed using the Symptoms of Depression Questionnaire (SDQ). The SDQ is a 44-item, self-report scale designed to measure the severity of symptoms across several subtypes of depression. The items are rated on a 6-point scale. The SDQ encloses five subscales, investigating the following dimensions: lassitude, mood, cognitive/social functioning (in this study summarized as "mood" subscale); anxiety, agitation, anger and irritability (in this study summarized as "anxiety" subscale); desire to be dead; disruptions in sleep quality; changes in appetite and weight (Pedrelli et al., 2014). For this study, we used the validated Italian version of this scale (Salerno, Burian, & Pallanti, 2017).

Internet addiction. Internet addiction symptoms were assessed using the Internet Addiction Test (IAT), a widely used screening test consisting of 20 questions, all measured on a 5- point Likert scale. The questions are scored from 1 to 5, with a score of 1 for the answer "rarely" and 5 for the answer "always." Summative scores ranging from 20 to 49 are considered "average" online users. Scores ranging from 50 to 79 are considered to be internet users with problematic internet use. Scores ranging from 80 to 100 are considered to be users suffering from severe problems due to their Internet usage. In the results section of this study all subjects scoring above 50 are considered as having internet addiction (Young, 2009).

Gambling disorder. Gambling disorder (GD) symptoms were assessed using The South Oaks Gambling Screen (SOGS), a 20-item questionnaire originally based on DSM-III criteria for pathological gambling and widely used across clinical and epidemiological studies for the screening of gambling behaviors (Lesieur & Blume, 1987). SOGS assess gambling symptoms over the past 6 months and positive responses to 5 or more items result in a designation of "probable pathological gambler". However, recent studies assessing the sensitivity and specificity of the SOGS according to gambling disorder's DSM-5 criteria argued in favor of increasing the cut-off score in order to reduce false positive rates (Goodie et al., 2013). Thus, in this study, we used the suggested cut-off of 8 to classify patients with probable GD according to DMS-5 criteria (Goodie et al., 2013).

Food addiction. Food addiction symptoms were assessed using the Yale Food Addiction Scale (YFAS) version 2.0, a self-report scale designed to reflect the assessment of addictive-like eating behavior based upon the substance-related and addictive disorders (SRADs) diagnostic criteria in the DSM–5. In the YFAS each of the 11 DSM-5 diagnostic criteria for SRADs is considered to be met if one or more of the relevant questions for each criterion meet the threshold. Two different summary scores are reported: a symptom count (0–11) and a diagnosis with severity level (mild, moderate, severe). The symptom count scoring option for the YFAS 2.0 is computed by summing the 11 diagnostic criteria (scores ranging from 0 to 11). Based on the DSM–5 diagnosis for SRADs, mild food addiction is indicated by meeting two to three criteria, moderate food addiction reflects presence of four to five criteria, and severe food addiction is defined as meeting six or more criteria (Gearhardt, Corbin, & Brownell, 2016). In our study patients scoring 3 or more on the YFAS 2.0 were classified as having food addiction.

Sex addiction. Sex addiction symptoms were assessed using the Sex Addiction Screening Test – revised (SAST-R), a 45-itemself-report screener for distinguishing possible cases of sexual addiction. The SAST-R is composed of a 20-item core scale, measuring the general construct of sexual addiction. In addition, the SAST-R contains 4 specific scales measuring vital characteristics of sexual addiction: preoccupation (4 items), loss of control (4 items), relationship disturbance (4 items), affective disturbance (5 items), and an internet scale (6 items) that comprises internet-related sexual activity. Finally, there are 3 scales (6 items) measuring behaviors intended to be more relevant to specific groups—heterosexual men, homosexual men, and women (both hetero- and homosexual). The SAST-R's total score range from 0 to 20 with scores equal or above 6 indicating the presence of significant compulsive sexual behaviors (Carnes, Green, & Carnes, 2010).

Shopping addiction. Shopping addiction symptoms were assessed using the Bergen Shopping Addiction Scale (BSAS), a self-report screening scale consisting of 28 questions covering seven addiction criteria (salience, mood modification, conflict, tolerance, withdrawal, relapse, and problems) (Andreassen et al., 2015). The questions are scored from 1 to 5, from *Strongly disagree* (1) to *Strongly agree* (5). The total score can range from 28 to 140. This scale is still lacking of well-established cut-off score for the diagnosis of shopping addiction. Therefore, according to what suggested by the authors who developed the scale, score above the 50% of the maximum score were considered as indicative of the presence of a probable shopping addiction (according to our ADHD sample we chose 70 as the cut-off score).

Statistical analysis

Normality of all variables was evaluated using the Shapiro–Wilk test. Normally distributed variables were BAARS-IV total and both hyperactivity and sluggish cognitive tempo subscale scores, SDQ total and mood and anxiety subscales scores, internet addiction test scores, BIS-11 total and BIS-11 subscales scores, pre-treatment and post-treatment differences on both IAT and BSAS scales. All the other variables were non-normally distributed. Since most of the examined variables were not normally distributed, non-parametric

tests were used. Cronbach's alpha was used to test the internal consistency for self-report measures (BAARS-IV, BIS-11, SDQ, BSAS, SAST, YFAS). Cronbach's alpha revealed from questionable to good internal consistency for self-report measures (BAARS-IV: $\alpha = 0.83$ Good; BIS-11: $\alpha = 0.65$; SDQ: $\alpha = 0.76$ Acceptable; BSAS: $\alpha = 0.80$ Good; SAST: $\alpha = 0.77$ Acceptable; YFAS: $\alpha = 0.76$ Acceptable). Wilcoxon signed rank test was used to compare continuous pre-treatment and post-treatment clinical scales scores (IAT, SOGS, BSAS, SAST-R, YFAS, BAARS-IV and SDQ total scores and subscales), while McNemar test was used for categorical variables (percentage of subjects with a comorbid behavioral addiction pre- and post-treatment). For McNemar test uncorrected p-value was used since SPSS applies an unnecessarily conservative correction to the McNemar test (Newcombe et al., 1998). Spearman's correlation coefficient was calculated to evaluate the correlation between the difference of pre-treatment and post-treatment on the behavioral addiction scores with methylphenidate dose, concurrent pharmacological or psychological treatment, demographic characteristics and the difference of pre-treatment and post-treatment on mood, ADHD and impulsivity scales (BAARS-IV, SDQ and BIS-11 total and subscales scores). Finally, we examined the contribution of ADHD, mood and impulsivity symptoms to the change in behavioral addiction symptoms after treatment (calculated subtracting post-treatment score to pre-treatment score on each BAs scale; therefore, positive values indicate a decrease of symptoms, negative values an increase of symptoms and a score of 0 no changes).

In the linear regression models 95% confidence intervals (CI) and variance inflation factor (VIF) values to inspect multicollinearity were used. Values were acceptable, with VIF scores of less than 2.1 for all models. In addition, scatter plot and quantile chart were used to value homoscedasticity of residuals and normality of residuals respectively. The stepwise method selection was used to select predictors into the model. Level of significance was set at $p = 0.05$. All analyses were carried out using the Statistical Package for the Social Sciences v25 (SPSS, 2017).

Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. The study was approved by the Florence's Institutional Review Board (protocol number #18762). All subjects were informed about the study and all provided informed consent.

RESULTS

At baseline no patients were under anti-ADHD medications, 11 out of 37 patients were under pharmacological treatments (7 under SSRIs, 2 under SNRIs, 2 under anti-anxiety medications). At one-year follow-up 11 patients were under concomitant methylphenidate and other medications (9 patients were under pregabalin and 1 patient under duloxetine for their anxiety symptoms, 1 patient were under lithium for his affective instability) (see Table 1). During the one-year treatment period 22 out of 37 patients undergone a psychological treatment (18 patients a cognitive behavioral therapy and 4 patients a behavioral coaching for ADHD).

The average methylphenidate final dose of completers was relatively low ranging from 10 to 40 mg with a mean of 32.16 (±8.2) mg/day. Methylphenidate treatment was well tolerated and none of the patients report clinically significant side effects during the one-year period of treatment. Only two patients showed increased anxiety when increasing the dose up to 60 mg and therefore their dose was tapered down to 40 mg.

The Wilcoxon signed ranked test showed that internet addiction test scores pre-treatment were significantly higher than post-treatment scores (median 44 (54; 32.5) and 34 (48; 25) respectively) ($Z = 89.5$; $p < 0.001$; $d = 0.53$ suggesting a moderate effect size). The same trend was seen for the shopping addiction scores (pre-treatment median 46 (60; 33.5) and post-treatment median 36 (52.5; 31.5), $Z = 175.5$; $p = 0.022$; $d = 0.32$ suggesting a small-moderate effect size). Despite the low baseline scores, a significant pre-post treatment reduction was observed for both food addiction scores (pre-treatment median 1 (2; 0) and post-treatment median 1 (2; 0), $Z = 71$; $p = 0.039$) and sex addiction scores (pre-treatment median 2 (3.75; 0) and post-treatment median 1 (2; 0), $Z = 52.5$; $p = 0.047$). Gambling disorder scores did not differ pre and post treatment since none of the included patients reported significant gambling symptoms at baseline (see Table 2 and Fig. 1).

The rate of ADHD patients with at least one comorbid behavioral addiction decrease after methylphenidate treatment (51.4% vs 35.1%, χ^2 (1) = 3.00, $p = 0.083$). Specifically, the rate of subjects with comorbid internet addiction decreased from 29.7% to 18.9% (χ^2 (1) = 2.66, $p = 0.102$, OR = 0.55, the rate of food addiction decreased from 18.9% to 13.5% (χ^2 (1) = 0.50, $p = 0.479$, OR = 0.67), the rate of sex addiction 5.4%–0% (χ^2 (1) = 2.00, $p = 0.157$, OR = 0, while the rate of shopping addiction remained stable (13.5%, χ^2 (1) = 0.00, $p = 1.00$, OR = 1) and that of gambling disorder did not change since none of the patients had GD at baseline (see Table 2).

The correlation analyses showed a moderate positive correlation between the changes in sluggish cognitive tempo subscale scores as well as in BIS-11 attentional subscales and changes in internet addiction scale scores only (r(35) = 350, $p = 0.034$ and r(35) = 0.339, $p = 0.040$ respectively). Also, we found a moderate positive correlation between SDQ total scores and SDQ mood and anxiety subscales scores changes and internet addiction scale scores (r(35) = 0.337, $p = 0.041$; r(35) = 0.350, $p = 0.034$; r(35) = 0.361, $p = 0.028$). Correlation analyses did not show a significant correlation between demographic characteristics (age and gender), methylphenidate doses, other medications and psychological treatments and behavioral addiction scores reductions (see Table A1 in Appendix).

Table 2. Behavioral addictions, ADHD, impulsivity and mood/anxiety symptoms changes pre and post methylphenidate treatment

	Pre-treatment	Post-treatment	Z/χ^2	d/OR	*p*
Internet Addiction Test (IAT)					
Symptoms scores	44 (32.5; 54)	34 (25; 48)	89.5	0.53	<0.001
Comorbidity prevalence	29.7%	18.9%	2.66	0.55	0.102
Bergen Shopping Addiction Scale (BSAS)					
Symptoms scores	46 (33.5; 60)	36 (31.5; 52.5)	175.5	0.53	0.022
Comorbidity prevalence	13.5%	13.5%	0.00	1	1.00
Yale Food Addiction Scale 2.0 (YFAS)					
Symptoms scores	1 (0; 2)	1 (0; 2)	71	0.52	0.039
Comorbidity prevalence	18.9%	13.5%	0.50	0.67	0.479
Sex Addiction Screening Test – Revised (SAST-R)					
Symptoms scores	2 (0; 3.75)	1 (0; 2)	52.5	0.32	0.047
Comorbidity prevalence	5.4%	0%	2.0	1	0.157
The South Oaks Gambling Screen (SOGS)	0 (0; 0)	0 (0; 0)	0	–	0.157
ADHD symptoms (BAARS-IV Total)	50 (41.5; 56)	37 (28.5; 44)	48.5	1.1	<0.001
Inattention (BAARS-IV)	27 (23; 31)	19 (15; 23)	23	0.18	<0.001
Hyperactivity (BAARS-IV)	12 (9; 13)	9 (7; 11)	172	0.49	0.011
Impulsivity (BAARS-IV)	11 (8; 14)	9 (7; 12)	148	1.8	0.017
Sluggish Cognitive Time (BAARS-IV)	24 (20.5; 29)	20 (15.5; 24.5)	90.5	1.02	0.001
Impulsiveness (BIS-11 Total)	71 (65; 75.5)	67 (62; 71.5)	129.5	0.43	0.004
Attention (BIS-11)	22 (19; 24.5)	21 (18; 23)	1,654	0.50	0.037
Motor (BIS-11)	23 (20.5; 27.5)	22 (18; 26)	169	0.40	0.045
Non Planning (BIS-11)	24 (22; 26.5)	25 (22.5; 26.5)	239	0.02	0.893
SDQ Total	130 (117; 151)	112 (96; 129)	129.5	0.77	0.001
Mood (SDQ)	56 (49.5; 62)	44 (38; 51)	84.5	0.60	<0.001
Anxiety (SDQ)	40 (37; 49.5)	37 (30; 47)	216.5	0.44	0.067
Suicidal Ideation (SDQ)	16 (19.5; 14)	13 (12; 16)	171	0.51	0.018
Sleep Quality (SDQ)	7 (6; 9.5)	7 (6; 8)	180.5	0.17	0.605
Appetite and Weight (SDQ)	10 (8; 11)	10 (8.5; 11)	218.5	0.19	0.721

Note. Data are expressed as median (interquartile range) for all variables. ADHD = Attention-Deficit Hyperactivity Disorder; BAARS-IV = Barkley Adult ADHD Rating Scale-IV; BIS-11 = Barratt Impulsiveness Scale, version 11; SDQ = Symptoms of Depression Questionnaire.

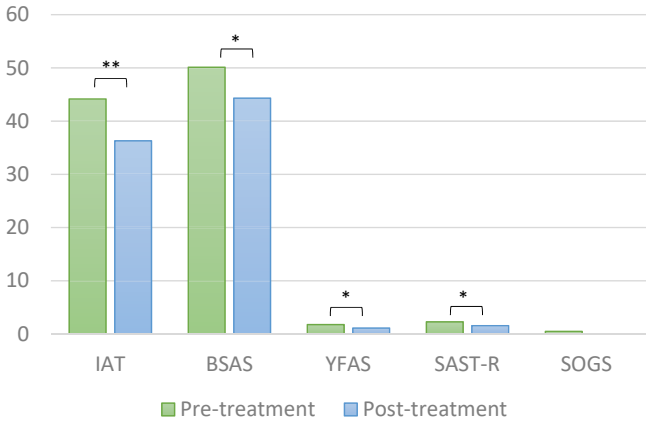

Fig. 1. Pre-treatment and post-treatment behavioral addiction scores changes

Note. Data are expressed as mean for all variables. IAT = Internet Addiction Test; BSAS = Bergen Shopping Addiction Scale; YFAS = Yale Food Addiction Scale; SAST-R = Sex Addiction Screening Test – Revised; SOGS = South Oaks Gambling Screen.

Following these analyses, a linear regression analysis with IAT score pre-post-treatment changes as outcome only and ADHD symptoms pre-post-treatment changes (BAARS-IV sluggish cognitive tempo), impulsivity (BIS-11 attentional subscale), depression and anxiety symptoms pre-post-treatment changes (SDQ mood and anxiety subscales) as predictors were calculated. This analysis found only anxiety (SDQ anxiety subscale) as significant predictor (R^2 = 0.12; β = 0.316; t = 3.496; [95%CI: 2.745, 20.351]; p = 0.038). In the present model, residual normality was met, instead, homoscedasticity was not. Then a second linear regression analyses with behavioral addiction score pre-post-treatment changes as outcome, pre-treatment ADHD symptoms (BAARS-IV sluggish cognitive tempo), impulsivity (BIS-11 attentional subscale), depression and anxiety symptoms (SDQ mood and anxiety subscales) as predictors were included. In this model, no variables were included.

DISCUSSION AND CONCLUSIONS

This is the first study showing the long-term changes on behavioral addiction symptoms in a sample of adults with a primary diagnosis of ADHD treated with a stimulant medication (methylphenidate). Our study showed that after one-year of treatment with methylphenidate ADHD patients showed a significant reduction on internet, food, shopping

and sex addiction symptoms. The number of patients showing gambling symptoms were too low at baseline to detect a possible effect of methylphenidate. The rate of ADHD patients with comorbid behavioral addictions dropped from 51.4% to 35.1% after-treatment. Finally, the improvement in internet addiction symptoms was moderately correlated with the improvement in attention (specifically the sluggish cognitive tempo subscale), cognitive impulsivity, mood and anxiety symptoms, while concomitant treatments with psychotherapy, coaching or other medications were not correlated with behavioral addictions improvement.

The results of this study seem to be in line with the most recent literature confirming the safety and even suggesting a protective effect of anti-ADHD medications on substance use disorder for both child/adolescents and adults with ADHD. Indeed, a recent large longitudinal study showed that stimulant treatment is not associated with increased or decreased risk for later substances use for adolescents and young adults with childhood ADHD and previous studies from large samples and epidemiological registers showed a long-term protective effect of stimulants on substance abuse in ADHD subjects (Chang et al., 2014; Molina et al., 2023; Quinn et al., 2017). All together these data seem to stress the importance of considering firstly a proper pharmacological treatment of ADHD even in front of patients with an addiction comorbidity. In line with this perspective, our study suggests a possible moderator effect of ADHD symptoms improvement (especially inattention and cognitive impulsivity), mood and anxiety symptoms improvement on subsequent improvements in behavioral addiction symptoms, suggesting again the importance of treating core ADHD symptoms to observe an improvement in addiction symptoms. These latest observations are further supported by several studies and meta-analyses showing a strong association between attentional problems and internet addiction and high rates of comorbidity between behavioral addictions and mood and anxiety disorders (Wang et al., 2017). Also, several recent studies consistently reported an association between core aspects of ADHD (such as impulsivity and emotional dysregulation) and problematic use of the internet (e.g. gaming disorder) (Cabelguen et al., 2021; Ko et al., 2023).

Several limitations are worth mentioning. First of all, the naturalistic nature of our study did not allow us to completely exclude the putative moderator effects of other factors such psychological treatments and/or lifestyle habits changes (even if the correlation analyses did not show a link between psychological treatments and/or other medications and BAs symptoms improvement). Therefore, the lack of a control group did not allow any firm conclusions on the direct effect of methylphenidate and its putative mechanism of actions on behavioral addictions in ADHD patients.

The estimate of the prevalence of behavioral addictions in the ADHD sample was not based on a clinical diagnosis but was based on the IAT, BSAS, SAST-R, SOGS and YFAS scale scores. Using a self-report tools such as those just mentioned could potentially imply an over diagnosis (excessive self-estimation of behavioral addictions) as well as an under diagnosis (e.g. patients with low insight in their addictive behaviors). However, our results showed an estimated prevalence of behavioral addictions substantially in line with current literature on lifetime substance use disorders in ADHD populations. Finally, the BIS-11 scale has been criticized as a reliable measure of subjective impulsivity and alternative models has been suggested (Kapitány-Fövény et al., 2020). Another limitation is represented by the small sample size. In fact, the small number of subjects potentially limited the possibility of identifying clinical differences between ADHD subjects with and without behavioral addictions across the follow-up and to detect any effect on gambling disorder. Also, since the sample cover a specific ADHD population (adults with high mean level of education), the results are not generalizable to a broader ADHD population.

In conclusion, after one-year of treatment with methylphenidate, adult ADHD patients show a significant reduction on internet, food, shopping and sex addiction symptoms. Further prospective studies with controlled designs and larger samples should replicate these preliminary results and elucidate the role of moderator factors (such as concomitant psychological treatments or lifestyle habits changes) on the observed improvements on behavioral addiction symptoms and the mechanisms of action of methylphenidate on these symptoms.

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Authors' contribution: GG: study concept and design, analysis and interpretation of data, final manuscript drafting. CM: statistical analysis, data collection and managing. CC: study supervision and final manuscript drafting.

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Appendix

Table A1. Spearman's correlation analysis between IAT and BIS-11, BAARS-IV and SDQ score pre-post-treatment changes

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. IAT	7.86	11.31	–																		
2. BIS-11 Total	3.16	6.21	0.13	–																	
3. BIS-11 Inattention	1.81	5.50	0.34*	0.70**	–																
4. BIS-11 Motor	1.08	3.39	0.15	0.36*	0.14	–															
5. BIS-11 Non Planning	0.05	5.07	−0.34*	0.34*	−0.15	−0.27	–														
6. BAARS-IV Total	10.81	11.33	0.27	0.42**	0.39*	0.39*	−0.14	–													
7. BAARS-IV Inattention	6.86	6.20	0.26	0.13	0.26	0.32	−0.31	0.83**	–												
8. BAARS-IV Hyperactivity	1.65	3.43	0.12	0.48**	0.29	0.20	0.13	0.75**	0.48**	–											
9. BAARS-IV Impulsivity	1.35	6.76	0.13	0.59**	0.48**	0.36*	−0.03	0.57**	0.26	0.51**	–										
10. BAARS-IV SCT	4.08	6.68	0.35*	0.29	0.52**	−0.13	−0.09	0.45**	0.42**	0.42**	0.43**	–									
11. SDQ Total	18.21	30.39	0.35*	−0.14	0.08	−0.08	−0.17	0.04	0.13	−0.08	−0.11	0.32	–								
12. SDQ Mood	11.46	15.01	0.34*	−0.18	0.04	−0.09	−0.22	−0.02	0.08	−0.12	−0.17	0.22	0.88**	–							
13. SDQ Anxiety	4.16	12.24	0.36*	−0.09	0.12	−0.11	−0.19	0.03	0.08	−0.01	−0.11	0.28	0.66**	0.90**	–						
14. SDQ Suicidal Ideation	2.30	5.06	0.11	−0.36*	−0.21	−0.13	−0.11	−0.07	0.06	−0.29	−0.27	0.05	0.66**	0.79**	0.69**	–					
15. SDQ Sleep	0.35	2.81	0.08	−0.07	0.06	−0.04	0.03	0.16	0.15	0.08	−0.13	0.04	0.44**	0.50**	0.40*	0.35*	–				
16. SDQ App/ Weight	−0.32	2.80	−0.26	0.37*	0.19	0.35*	0.04	−0.07	−0.11	−0.11	0.02	−0.22	−0.15	−0.09	−0.14	−0.12	0.17	–			
17. Age	30.16	8.53	−0.23	−0.01	−0.06	0.12	−0.13	0.04	0.05	0.10	0.14	−0.15	−0.32	−0.13	−0.01	−0.13	0.08	0.20	–		
18. Years Education	15.51	2.48	0.17	0.12	0.19	0.09	−0.24	0.20	0.21	0.27	0.03	0.04	−0.23	−0.10	−0.01	−0.12	0.14	0.06	0.47**	–	
19. MPX Dose	32.16	8.21	−0.11	−0.10	−0.30	−0.01	0.03	−0.01	−0.23	0.09	−0.01	−0.30	−0.04	−0.12	−0.17	−0.17	−0.10	−0.19	−0.12	−0.28	–

Note. $^{*}p < 0.05$. $^{**}p < 0.001$. IAT = Internet Addiction Test; BAARS-IV = Barkley Adult ADHD Rating Scale-IV; BIS-11 = Barratt Impulsiveness Scale, version 11; SDQ = Symptoms of Depression Questionnaire.