EXECUTIVE FUNCTIONS IN ADOLESCENTS WITH BINGE-EATING DISORDER AND OBESITY

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RUNNING HEAD: EXECUTIVE FUNCTIONS IN ADOLESCENT BED

Abstract

Objective: Binge-eating disorder (BED) in adults is associated with alterations in executive functions (EF) and obesity. Much less is known about these relationships in adolescents, including whether poor EF are associated with eating disorder psychopathology and/or elevated body mass index. The present study examined EF in response to neutral stimuli in youth with BED.

Method: Adolescents with BED and obesity (n=22), individually matched adolescents with obesity (n=22), and normal weight (n=22) completed neuropsychological tests targeting inhibition (Color-Word Interference Test), sustained attention (D2 Concentration Endurance Test), cognitive flexibility (Comprehensive Trail Making Test), and decision-making (Iowa Gambling Task).

Results: Adolescents with BED and obesity displayed significantly poorer inhibitory control compared to normal-weight adolescents. This effect persisted after controlling for the level of secondary education. However, initial differences between adolescents with obesity and normal-weight controls regarding inhibitory control and sustained attention vanished after controlling for education. The three groups did not differ regarding cognitive flexibility and decision-making. Moreover, adolescents with BED and obesity did not perform worse than adolescents with obesity on any of the neuropsychological tests.

Discussion: Overall, our results indicate adolescent BED is associated with only a few alterations in general EF, specifically inhibitory control, and underline BED and educational level as confounding factors in neuropsychological research on obesity. To further delineate EF profiles of adolescents with BED, future research should focus on EF in response to disorder-related stimuli and experimental settings with high ecological validity.

Keywords: binge-eating disorder, obesity, adolescents, executive functions, inhibitory control

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BED, recently established in the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (1), is characterized by recurrent binge-eating episodes, defined as a sense of loss of control over eating an unambiguously large amount of food, that occur without regular use of inappropriate compensatory behaviors. With a median age onset of 12.6 years, BED develops over adolescence with a prevalence rate of 1.6% in youth from the community (2) and up to 25% in treatment-seeking adolescents with overweight and obesity (3, 4). Furthermore, BED in youth is associated with significant eating disorder pathology, general psychopathology and impaired quality of life (2, 5), and longitudinally predicts adverse health outcomes including anxiety disorders, depression, substance use, deliberate self-harm, and obesity in young adulthood (6, 7). Increasing evidence suggests that the feeling of loss of control over eating, irrespective of the episode size, is a salient marker of eating disorder psychopathology in youth (4, 8). This implies that self-regulatory difficulties play an important role in the maintenance of BED.

Self-regulation employs executive functions, a set of higher-level control mechanisms (e.g., inhibition, cognitive flexibility, and decision-making), that enable goal-directed and situationally adjusted behavior (9). EF are highly relevant for the regulation of eating behavior and successfully implementing exercise intentions (10). Preliminary evidence suggests greater EF deficits in adults with BED than in adults with obesity and normal weight (11, 12). This particularly applies to studies using neuropsychological tasks with disorder-related stimuli (i.e., food and body cues) (for review see 13). Findings in adults, however, might not be applicable to adolescents with BED as a recent meta-analysis found evidence for disadvantageous decision-making in adults with eating and weight disorders, but not in youth (14).

For adolescents with BED, investigations on EF are lacking. However, cross-sectional research on EF in adolescents with obesity aged 12-21 years provides a first indication of difficulties with inhibition, cognitive flexibility, sustained attention, and decision-making, when compared to normal-weight controls (15-18). Nevertheless, other studies revealed no relationship between body mass index (BMI) and EF (e.g., cognitive flexibility) in community residing children and adolescents with obesity aged 6-21 years (19, 20). Importantly, cross-sectional and longitudinal evidence indicates that binge eating in youth might play a mediating role on the positive association between BMI and impulsivity as defined by both questionnaire-based assessment and clinical diagnosis of attention-deficit/hyperactivity disorder (21, 22). Altogether, results on EF in adolescents with obesity are mixed. This might be due to the fact that previous comparisons varied highly in their consideration of covariates (e.g., education and IQ estimates) and none of these studies considered comorbidities such as eating disorders including BED. Thus, clarification is needed on whether BED accounts for EF difficulties in individuals with obesity.

To our knowledge, no study exists investigating the interplay of BED, obesity and EF in youth. The present study is intended to close this research gap by comparing adolescents with BED and obesity and adolescents with obesity only, and normal-weight controls in their level of general EF, i.e., EF in the context of neutral stimuli, using a series of established neuropsychological tests. We hypothesized that adolescents with BED and obesity and adolescents with obesity only would show greater difficulties in EF (inhibition, sustained attention, cognitive flexibility and decision-making), compared to normal-weight controls without BED. Furthermore, we hypothesized that adolescents with BED and obesity would display greater difficulties in EF than adolescents with obesity only.

METHOD

Participants and Procedure

A total of 22 adolescents with BED and obesity were recruited at enrolment in outpatient cognitive-behavioral therapy for adolescents with BED and tested with a series of neuropsychological tasks prior to the beginning of the therapy (23). Considering the specific manifestation of BED in youth (4), the diagnosis of BED was based on objective (loss of control over eating an unambiguously large amount of food; (1)) and/or subjective binge-eating episodes (loss of control over eating an amount of food that is subjectively, but not objectively large). The BED group included adolescents with a diagnosis of BED according to DSM-IV-TR (24), BED according to DSM-5 (1), or subthreshold BED according to DSM-5 (refer to (23) for more detail). For a subthreshold diagnosis, all DSM-5 criteria had to be met, except for the frequency and/or duration criterion. Of the 22 adolescents with BED, 7 adolescents met the criteria according to DSM-IV-TR (24), 9 adolescents according to DSM-5 (1), and 6 participants were classified as DSM-5 subthreshold.

The two control groups without BED consisted of 22 controls with obesity (OB; BMI > 97th age- and sex-specific percentile) (25, 26) and 22 normal-weight controls (NW; BMI ≤ 90th percentile). Recruitment strategies included school-based screening and Internet-based advertisements (all groups), recruitment in clinical settings (BED and OB groups), and population-based recruitment (BED group). More specifically, the BED (*n* = 19 of 22) and NW (*n* = 20 of 22) groups were mostly recruited via community-based strategies, such as population-based information campaigns for the treatment of BED and school-based screening, respectively, while adolescents of the OB group were primarily recruited via clinical settings, i.e., weight loss programs (*n* = 14 of 22). Adolescents with BED were offered treatment free of charge, while adolescents of the control groups were offered a compensation of 8€/hour for study participation. Adolescents in the BED, OB and NW groups were individually matched for age, sex, and IQ estimate determined by a composite of the vocabulary and matrix reasoning subtest of the Wechsler Intelligence Scales (≤ 15 years: WISC; 27, 28, > 15 years: WAIS-III; 29, 30). Furthermore, BED and OB groups were matched for BMI percentiles.

Inclusion criteria for all groups were 12-20 years of age, normal or corrected-to-normal vision, and sufficient German language skills. Exclusion criteria for all groups included current psychotherapy, weight loss treatment, substance abuse, suicidal ideation, psychotic or bipolar disorder, and current intake of antipsychotic or weight-affecting drugs. Furthermore, adolescents of the control groups were excluded if they had current or lifetime eating disorder diagnoses as well as objective and/or subjective binge-eating episodes. Diagnosis of BED was established by the German version of the Eating Disorder Examination (EDE; 31), and mental comorbidity was determined by the Diagnostic Interview for the Assessment of Mental Disorders in Children and Adolescents (K-DIPS; 32). Height and weight measures were objectively obtained through calibrated instruments. In addition, the socio-economic status determined by the Winkler composite index (33) and the highest level of secondary education (lower = attendance or completion of "Hauptschule", grades 5-9; middle = attendance or completion of "Realschule", grades 5-10; high = attendance or completion of "Gymnasium", grades 5-12) were ascertained.

The study was approved by the Ethical Committee at the University of Leipzig Medical Center. Initially, adolescents and their parents (for ages < 18 years) were contacted by phone or e-mail, offered detailed information on the study aims and procedures, and asked for their agreement to participate. After meeting eligibility criteria during telephone screening, adolescents were invited to the laboratory for a detailed diagnostic session. Upon arrival, written informed assent and consent were sought from adolescents < 18 years and their parents, respectively. For participants ≥ 18 years, written informed consent was obtained only from the adolescent. Subsequently, participants were asked to complete a series of neuropsychological tasks in a fixed order for approximately 1 to 1.5 hours.

<< Please insert Table 1 here >>

Neuropsychological Assessment

Color-Word Interference Test. Inhibition was measured using the original paper-and-pencil version of the Stroop Color-Word Interference Test (CWIT; 34). In this test, participants (≥ 10 years) are instructed to perform three trials as quickly and accurately as possible. First, they read aloud color names printed in black ink. Second, participants name the color of a series of colored bars. Third, they name the color of the ink in which a color word is printed rather than reading the word (color-word interference). The dependent variable was determined as completion time in seconds for the color-word interference trial. The internal consistency for this trial was reported as 0.98, convergent and divergent validity were confirmed (34). The CWIT was found to differentiate between clinical groups (e.g., children and adolescents with attention-deficit/hyperactivity disorder) and non-clinical groups in previous studies (35).

D2 Concentration Endurance Test. The D2 Concentration Endurance Test (D2) assesses sustained attention and visual scanning ability of individuals ≥ 9 years (36). This paper-and-pencil task requires participants to detect “d” symbols with two dashes (that may be located either both above, both below, or one above and one below the “d”) among distractors (“d’s” with one, three, or four marks or “p’s” with one or two marks). Participants scan 14 lines of stimuli at 20 seconds maximum duration per line. Two types of errors can occur: omission of target symbols, or striking out distractor symbols. The concentration performance score was determined on the number of correct responses minus errors. Higher scores indicate a better and more stable performance. The D2 test can be considered an internally reliable measure; convergent and divergent validity were confirmed (37). Moreover, clinical (e.g., children and adolescents with behavior problems) and non-clinical groups were differentiated using the D2 in previous studies (38).

Comprehensive Trail Making Test. The Comprehensive Trail Making Test (CTMT; 39), standardized for individuals ≥ 8 years, consists of five visual search and sequencing tasks. The first three trails require the connection of numbers surrounded by distractors in an ascending order. The trails 4 and 5 require alternation in ascending order between numbers in numeric and word forms and between numbers and letters respectively. As dependent variables, the simple sequencing score indicating attention (mean T score of the completion times of first three trails) and the complex sequencing score indicating cognitive flexibility (mean T score of trails 4 and 5) were calculated. High internal consistency was reported for the composite index (mean T score of all five trails; r = .91); convergent and divergent validity were confirmed (39). Furthermore, the composite index has previously been shown to differentiate between clinical and non-clinical groups (40).

Iowa Gambling Task. Decision-making under uncertainty was assessed using the computerized version of the Iowa Gambling Task (41), which has been applied to children and adolescent samples aged ≥ 8 years (42). The task requires participants to select 100 cards from four decks (A, B, C, D). For each selection, participants can either gain or gain-and-lose virtual money. The choice of the decks A and B results in an overall long-term loss (disadvantageous decks), while decks C and D lead to an overall long-term gain (advantageous decks). Net scores were calculated by subtracting the total number of disadvantageous choices from the total number of advantageous choices. IGT performance was derived from a total IGT net score (main outcome) and an IGT learning effect across the net scores of the five consecutive blocks of 20 cards (secondary outcome). According to

Bechara et al. (41), healthy individuals should gradually learn to choose advantageous decks resulting in net scores that develop from initially around zero toward a clearly positive value at the later blocks. Broad evidence supports the use of the IGT to detect decision-making deficits in clinical populations and demonstrates divergent validity (43).

Data Analytic Plan

To analyze group differences in neuropsychological test performances, a multivariate analysis of variance (MANOVA) with group (BED, OB, NW) as the independent variable and main test scores (CWIT color-word-interference; D2 concentration performance, CTMT simple sequencing, CTMT complex sequencing, IGT total) as dependent variables was conducted. In case of multivariate significance, ANOVAs per test score were performed with subsequent post-hoc Bonferroni tests. Furthermore, the IGT performance over time was examined by a repeated measures ANOVA with IGT blocks as within-subject factor and group (BED, OB, NW) as between-subject factor. To identify covariates, Kendall's tau correlations and Pearson's correlations were calculated between neuropsychological test scores and sociodemographic (socio-economic status, educational level) or clinical variables (EDE-Q global, DEDQ external eating, BDI sum score, any comorbid mental disorder including dysthymia, major depressive disorder, anxiety disorder, obsessive-compulsive disorder, attention-deficit/hyperactivity disorder, oppositional defiant disorder, and/or conduct disorder). Level of secondary education was the only variable significantly associated with test scores (Kendall's τ ranging from -.28 to .36), while correlations with all other sociodemographic or clinical variables did not reach statistical significance or a medium effect size ($r \geq .3$) (44). Subsequently, ANCOVAs with level of secondary education as covariate were performed and reported if changing significant results obtained in the

ANOVAs. In case of violation of normality and homogeneity of variances, non-parametric tests were conducted and reported if different from parametric test results.

Partial η^2 was used for effect size estimation and interpreted according to Cohen (44) (small effect $0.01 \leq \eta^2 < 0.06$; medium: $0.06 \leq \eta^2 < 0.14$, large: $\eta^2 \geq 0.14$). Between-group differences in post-hoc tests were reported with Cohen's d (small effect $0.2 \leq d < 0.5$; medium: $0.5 \leq d < 0.8$, large: $d \geq 0.8$) (44). A power analysis for MANOVA, global effects, generated in G*Power 3.1.7. (45), achieved an adequate power (0.84) to detect differences in neuropsychological test scores based on the following parameters: Total sample size of N=66, three groups, four main test scores, Pillai trace V=0.234, calculated effect size Cohen's $f^2 = 0.133$ and Type I error rate of .05. Data analyses were conducted with IBM SPSS Statistics 20.0. A two-tailed α level of .05 was applied to all statistical tests.

RESULTS

Group Differences in Socio-demographic and Clinical Characteristics

Groups did not differ on age, sex, IQ estimate, and the adolescent's level of secondary education (all groups), and BMI percentile (BED and OB), respectively (see Table 1). However, the socio-economic status was significantly lower in the OB group than the NW group ($p < .05$). As expected, the BED group had significantly greater eating disorder psychopathology when compared to the OB group based on the external eating scale of the Dutch Eating Behavior Questionnaire (DEBQ; 46), and when compared to the NW group ($p < .05$) based on the global score of the Eating Disorder Examination-Questionnaire (EDE-Q; 47). In addition, the BED group showed higher symptom levels of depression than the OB and NW group, as indicated by the Beck Depression Inventory-II (BDI-II; 48) (both $p < .05$).

Group Differences in Executive Functions

The MANOVA of the main test scores showed a significant between-group difference, (F(10, 118) = 2.124, p = .028, η^2 = 0.15).

Groups differed on color-word-interference (see Table 2 for all ANOVA results). Post-hoc comparisons revealed the BED and the OB groups to perform worse than the NW group (BED-NW: p = .013, d = 1.03 – large effect; OB-NW: p = .024, d = 0.78 – medium effect), while the BED and OB groups did not differ (p = .100, d = 0.06 – small effect). Controlling for level of education, differences between the OB and NW groups vanished (F(2, 62) = 3.233, p = .046, η^2 = 0.09 – medium effect).

In addition, groups differed regarding concentration performance in the D2 Concentration Endurance Test. More precisely, while the BED group did not differ from the OB and NW groups (BED-OB: p = .598, d = 0.41 – small-to-medium effect; BED-NW: p = .462, d = 0.42 – small-to-medium effect), the OB group attained a lower concentration performance score than the NW group (p = .024, d = 0.82 – large effect). However, differences between OB and NW groups disappeared after controlling for level of secondary education (F(2, 62) = 1.353, p = .266, η^2 = 0.04 – small effect).

With regard to simple and complex sequencing in the CTMT, no differences were found between groups. All groups scored close to the T score mean of 50 indicating an average performance.

Regarding the IGT, the groups did not differ on the IGT total score. However, in accordance with hypothesized effects, the NW group obtained a positive IGT total score, while performances of the BED and OB groups resulted in negative IGT total scores. Examining IGT performance regarding a learning effect over time, the results showed a non-significant, but medium-sized main effect of IGT block (F(4, 60) = 1.724, p = .157, η^2 = 0.10) and a non-significant, but medium-sized interaction between block and group (F(8, 120) = 0.896, p = .522, η^2 = 0.06). Descriptively, the overall pattern of performance (learning curves in Figure 1) pointed toward different learning effects, with the NW group non-linearly improving over time, while the BED and OB groups did not reach positive values.

<< Please insert Table 2 and Figure 1 here >>

DISCUSSION

Our findings show selective alterations within general executive functions (EF) in adolescents with BED and obesity and adolescents with obesity only, compared to normal-weight adolescents without BED. As hypothesized, adolescents with BED and obesity and adolescents with obesity only showed more inhibition difficulties, and adolescents with obesity only displayed lower attention endurance scores compared to normal-weight controls. Particularly, the effect in adolescents with BED remained significant in analyses adjusted for education. However, no differences between groups emerged for cognitive flexibility and decision-making. Most strikingly and contrary to expectations, adolescents with BED and obesity did not perform worse than adolescents with obesity only on any of the neuropsychological tests.

In line with our first hypothesis, adolescents with BED and obesity and adolescents with obesity only showed lower outcomes in inhibition than normal-weight controls. First, this finding hints at general inhibitory difficulties in youth with BED and obesity in comparison with the NW group and is consistent with the recent findings of general inhibitory deficits in adults with BED, compared to controls (49, 50). However, no other study compared individuals with BED and obesity and normal-weight controls regarding general inhibition so far. Second, it replicates findings of increased inhibitory difficulties in adolescents with obesity from community and treatment-seeking samples, compared to normal-weight controls (15, 16), but also contradicts experimental evidence for comparable inhibitory capacities of community residing or treatment-seeking adolescents with obesity and normal-weight adolescents (17, 20). Most importantly, the differences in inhibition between youth with BED and obesity and the NW group remained significant after controlling for education, while differences between the OB and NW groups disappeared after taking into account non-significantly lower levels of education in the OB group. This sheds light on the discrepant results on EF in adolescents with obesity (15, 16, 19, 20) and suggests findings of increased inhibitory difficulties in adolescents with obesity might be due to unascertained eating disorder psychopathology and level of education, which underlines the importance of assessing eating disorders and sociodemographic variables in samples with obesity.

Regarding sustained attention, the BED group did not show difficulties compared to the NW group, indicating healthy levels of sustained attention in adolescents with BED and obesity, which corresponds to first evidence from adults with BED compared to a NW group (Kelly et al., 2013). Confirming previous research in adolescents with obesity (17, 18, 20), the OB group, in contrast, attained lower outcomes in sustained attention than the NW group. However, these differences vanished after controlling for level of education. Furthermore, as adolescents with BED were also obese and did not differ from normal-weight controls in sustained attention, obesity was not suggested to account for differences in concentration performance. In addition, the majority of previous studies on sustained attention and inhibitory control only adjusted for either education (20) or intelligence (17, 18), and used heterogeneous measures. Therefore, the comparability of results remains rather limited.

Concerning attention, no group differences emerged, which might be attributed to the neutral stimulus material, as, for example, in the context of food stimuli an attentional bias was detected in adolescents with BED (51). Furthermore, consistent with results from an adult sample, adolescents with BED and obesity and normal-weight controls attained comparable levels of cognitive flexibility (52). Moreover, no group differences between adolescents with obesity and normal-weight controls emerged, which is in line with some previous studies in population-based samples (19, 20), but contrasts with the findings of lower cognitive flexibility of adolescents with obesity in other studies with population-based and clinical samples (15, 17). Eventually, executive differences between BED, OB, and NW groups might become more apparent in complex everyday situations, which require self-regulation (53) and in which binge-eating episodes are likely to occur (e.g., 54).

Moreover, with respect to decision-making, adolescents with BED and obesity and normal-weight controls obtained comparable results, expanding heterogeneous findings from adult samples applying the IGT (55, 56). The fact that the OB and NW groups did not differ is in line with the overall result of a recent meta-analysis (14) which did not find disadvantageous decision-making in obese youth, compared to normal-weight controls. However, in accordance with hypothesized effects, the performances of the BED and OB groups in our study resulted in negative test scores suggesting disadvantageous decision-making, while NW group reached a positive test score suggesting advantageous decision-making.

Opposing our hypothesis that adolescents with BED and obesity would display greater EF difficulties than adolescents with obesity only, based on findings in adults with BED (12, 49, 50), both groups achieved comparable results on any neuropsychological task. However, our results are consistent with one previous study using a stop signal task, in which adolescents with obesity only and those with obesity and binge-eating episodes, assessed by a single item of the EDE-Q, did not differ regarding inhibitory difficulties (16). Importantly, our results strengthen this finding by assessing BED with a structured clinical expert interview. However, differences in inhibitory control between individuals with BED and obesity and individuals with obesity only might become more pronounced with increased duration of illness as recent studies with adult samples indicate (49, 50), while for other facets of general EF (e.g., decision-making) individuals with BED and obesity and individuals with obesity only – also at adult age – might not differ (14). Furthermore, the absence of differences could be due to neuropsychological tests using neutral stimuli, as applied in the present study. Greater difficulties in cognitive functioning in adults with BED and obesity, compared to controls with obesity, were predominantly found in studies using disorder-related stimuli (i.e., food and body cues) (13). Furthermore, in our study, only education, but no measure of eating disorder psychopathology exhibited significant correlations with neuropsychological test scores, further suggesting no substantial association between eating disorder psychopathology and general cognitive abilities. In contrast, moderate associations between deficits in behavioral response inhibition and severity of eating disorder psychopathology were found for adults with BED and obesity using food stimuli (50). However, the adults with BED and obesity in that study displayed higher EDE-Q scores than adults with obesity only. Accordingly, the lack of greater group differences in eating disorder psychopathology between the BED and the OB group in our adolescent sample might have influenced the obtained findings in EF. Nevertheless, whether eating disorder psychopathology and disorder-related cognitive abilities are related in adolescents is yet to be determined.

The present study stands out from previous research, by ascertaining BED using a structured clinical expert interview. Another major strength was the well-controlled study design, including adolescents with BED and obesity and both controls with obesity and normal weight, which signalled whether alterations in EF were associated with obesity and/or increased eating disorder psychopathology in BED. Furthermore, the influence of a range of potential covariates (e.g., presence of a comorbid mental disorder) on the test scores was tested by a correlational analysis. The individual matching for age, sex, IQ estimate (all groups), and BMI percentile (BED and OB), and controlling for education, respectively, ruled out effects of sociodemographic and clinical variables on dependent variables.

Among the limitations, first, the comparatively small sample size necessitates careful conclusions. Second, the generalizability of findings may be limited given that we examined a treatment-seeking sample with BED. While treatment-seeking youth might typically show a higher degree of psychopathology than non-treatment seeking youth, they might also possess higher levels of EF, being reflective and organized enough to seek treatment, especially considering that adolescents with BED and obesity with a higher level of secondary education were overrepresented in this study. At the same time, as the majority of adolescents of the OB group were recruited via weight loss programs, the OB control group can be considered as a highly conservative control group.

Beyond the application of disorder-related stimuli, future studies are recommended to employ neurophysiological measures (e.g., electroencephalogram) and more challenging performance-based tasks that could provide higher precision to better distinguish between the EF profiles of adolescents with BED and obesity and adolescents with obesity only. In a recent study, Bauer and Manning (57) evaluated novel measures of background electroencephalographic activity during an unusually difficult sustained attention task. They found adolescents with overweight/obesity to exhibit more electroencephalographic frontal beta power and greater intraindividual variability in beta power than normal-weight controls. This suggests frontal beta power to be a marker of EF deficits and, as it was positively correlated with loss of control over eating, to be indicative of problematic eating behavior. Second, performance-based measures should be accompanied by self-report instruments of EF as the two types of measures are considered to account for different aspects of EF (58). Therefore, ratings of everyday situations that require EF (e.g., Behavior Rating Inventory of Executive Function; 59) could elucidate impairments in everyday life. And, third, as first evidence indicated an increase of negative affect to result in a greater increase of behavioral disinhibition in adolescents with loss of control eating compared to adolescents with attention deficit hyperactivity disorder and controls (60), research on the interaction of emotional and executive functions holds illuminating potential.

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Tables

Table 1. Sociodemographic and clinical characteristics of adolescents with BED and obesity and control groups with obesity only and normal weight.

	BED *N* = 22	OB *N* = 22	NW *N* = 22	Test	Effect size
	n (%)	*n* (%)	*n* (%)	χ^2 (2)	*V*
Sex, female	18 (81.80)	18 (81.80)	18 (81.80)	0.000	.00
Level of education, low/middle/high[#]	1/10/11	2/13/7	0/6/16	8.140	.25
	M (SD)	*M (SD)*	*M (SD)*	*F* (2, 63)	partial η^2
Age, years	14.91 (2.22)	14.82 (2.63)	15.23 (2.39)	0.173	0.01
Body mass index, percentile	99.16 (0.57)[a]	98.91 (2.30)[a]	58.91 (24.03)[b]	61.120***	0.66
Socio-economic status, 0-21	12.35 (4.30)[ab]	9.43 (4.40)[b]	13.21 (3.85)[a]	4.525*	0.14
IQ estimate, 1-19	11.71 (2.02)	11.43 (2.17)	11.32 (2.23)	0.189	0.01
BDI global score, 0-63	15.60 (11.00)[a]	4.26 (7.02)[b]	6.84 (11.12)[b]	7.761**	0.20
EDE-Q global score, 0-6	2.73 (1.05)[a]	1.98 (1.14)[ab]	1.29 (1.12)[b]	9.205***	0.23

DEBQ external eating, 1-5	3.17 (0.76)[a]	2.54 (0.75)[b]	2.66 (0.87)[ab]	3.822*	0.11

Note. BDI = Beck Depression Inventory; BED = group with binge-eating disorder and obesity; DEBQ = Dutch Eating Behavior Questionnaire; EDE-Q = Eating Disorder Examination-Questionnaire; IQ = intelligence quotient, estimated by a mean of the standardized scores (according to age norms) of the vocabulary and matrix reasoning subtest of the WISC-IV (Wechsler Intelligence Scales for Children)/ WAIS-III (Wechsler Adult Intelligence Scale); NW = control group with normal weight ; OB = control group with obesity; socio-economic status: index of social class (Winkler, 1998), derived from information on education, income, and current (job) position

[a,b] Different superscripts denote significant group differences in post-hoc comparisons with Bonferroni corrections.

[#] In Germany, secondary school is subdivided in 3 tracks, lower = “Hauptschule” (grades 5-9), middle = “Realschule” (grades 5-10), high = “Gymnasium” (grades 5-12).

**p* < .05; ***p* < .01; ****p* < .001

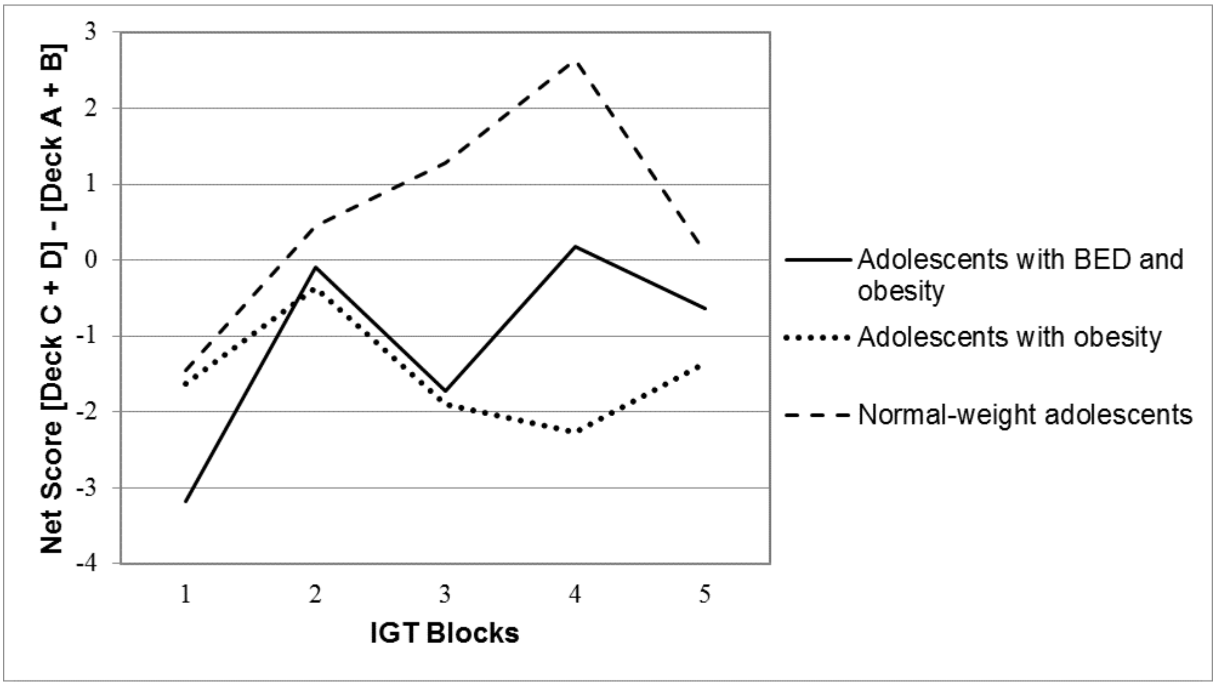
Table 2. Results of neuropsychological assessment: Means (*M*), standard deviations (*SD*), and group differences in executive functioning

		BED (*N* = 22)	OB (*N* = 22)	NW (*N* = 22)	ANOVA		
		M (*SD*)	*M* (*SD*)	*M* (*SD*)	$F(2, 63)$	*p*	partial η^2
CWIT	color-word interference	92.55 (17.58)[a]	91.17 (25.09)[a]	74.17 (18.11)[b]	5.464	.006	0.15
D2	concentration performance	158.73 (29.68)[ab]	147.50 (24.83)[a]	171.77 (32.46)[b]	3.755	.029	0.11
CTMT	simple sequencing	48.14 (11.02)	46.80 (8.38)	48.54 (11.54)	0.169	.845	0.01
	complex sequencing	46.11 (8.32)	49.82 (9.14)	51.14 (10.95)	1.642	.202	0.01
IGT	total	-5.45 (31.72)	-7.54 (25.18)	3.00 (26.00)	0.888	.416	0.03

Note. BED = group with binge-eating disorder and obesity; CTMT = Comprehensive Trail Making Test; CWIT = Color Word Interference Test (Stroop); D2 = Concentration Endurance Test; IGT = Iowa Gambling Task; NW = control group with normal weight; OB = control group with obesity

[a, b] Different superscripts denote significant group differences in post-hoc comparisons with Bonferroni corrections.

Figure 1. Iowa Gambling Task (IGT) learning effect across five consecutive blocks in adolescents with BED and obesity, adolescents with obesity, and normal-weight adolescents.



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