

Executive functions as mediator variables between binge eating symptoms and body mass index: A mediation analysis

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Abstract

In recent years, the topic of executive functions has played a significant role in the context of clinical psychology. Maladaptive patterns can impair several aspects of physical and mental health, thus the main goal of the present study is to explore the relationship between executive functions, binge eating symptoms and body mass index. 103 participants showing binge eating symptoms have been involved in the present study, who completed the Binge Eating Screener, the short Hungarian version of the Behavior Rating Inventory of Executive Function - Adult - Self Report scale, and a demographic questionnaire. We conducted an explorative study, since contrary to previous research, we did not only point out the linear relationship between binge eating symptoms and body mass index, but also studied the mediating role of executive functions (cognitive regulation, emotion regulation and behavior regulation) in this relationship. In this model, binge eating symptoms can be defined as predictor variables, while the output variable is the body mass index. Our results show that there is a significant positive correlation between body mass index, binge eating symptoms and certain components of executive functions (cognitive regulation problems and behavior regulation problems). We also found that behavior regulation problems are present as mediators in the relationship between binge eating symptoms and body mass index.

Keywords: binge eating symptoms; body mass index; executive functions; mediation analysis

1. Introduction

Executive functions is a collective term which refers to a complex cognitive construct, including several interrelated skills and cognitive functions, such as mental flexibility, shifting, working memory, inhibitory functions, emotion regulation, self-monitoring, initiating, planning/organizing or task-monitoring (Diamond, 2013; Müller & Kerns, 2015). Executive functions play an important role in implementing planned, goal-oriented behavior, affect social, emotional and intellectual functioning, and organizing mechanisms, and by this, they contribute to the shaping of an adaptive behavioral repertoire. Therefore, executive function deficits or executive dysfunctions can affect behavioral organization negatively. Maladaptive patterns can impair several aspects of physical and mental health, predisposing the person to psychological as well as somatic disorders (Lyons & Zelazo, 2011).

Based on the diagnostic criteria, *binge eating disorder (BED)* can be defined along the following symptoms: recurrent episodes of binge eating characterized by eating significantly larger amounts of food in a relatively short period of time, than what other people would eat in the same time and under the same circumstances. Moreover, the feeling of losing control over eating, eating faster than normal, eating until feeling uncomfortably full, eating large amounts of food even when the person is not hungry, eating alone out of embarrassment, and feelings of disgust, guilt, shame and distress after episodes of binge eating are also typical. Another important diagnostic criteria is the absence of purging mechanisms after episodes of binge eating (American Psychiatric Association, 2013; Iqbal & Rehman, 2020). Several theoretical frameworks explain the development of the disorder, many of them emphasizing its associations with executive function deficits (Manasse et al., 2015).

Set shifting or cognitive flexibility, as a main component of executive functions, enables switching between mental sets in certain situations. This for example ensures that we can change our strategies when facing distress to cope more efficiently. In the case of people affected by binge eating disorder, maladaptive behavior is often induced by specific situations in which they can't use a diverse range of coping mechanisms, thus the malfunctioning of set shifting can be observed (Dingemans et al., 2015; Godfrey et al., 2019).

The role of another crucial component, the working memory has also been identified as being related to eating habits, by contributing to the maintenance of well structured, long-term goals, for example healthy eating habits. Thereby, it provides resistance against short-term goals and behaviors that do not correspond to the long-term, goal-oriented behavior. Proper functioning of this process enables better representation of long-term goals, thus making it easier to focus one's attention on these goals. If problems emerge in this process, being able to differentiate between healthy and unhealthy alternatives becomes much harder, resistance to unhealthy alternatives decreases, and consequently binge eating episodes emerge (Allom & Mullan, 2014; Dohle et al., 2017). The inhibitory control plays an important role in self-regulation, which helps restrain automatic responses. The most common symptoms of binge eating disorder can be identified through self-control problems, and can be traced back to

maladaptive patterns of these functions (Ames et al., 2014). Svaldi et al. (2019) examined the relationship between emotion regulation and symptoms of binge eating. Results show that problems of emotion regulation are associated with unhealthy coping mechanisms, and more frequent appearance of binge eating symptoms, consequently this domain also shows connection with nutritional problems.

Body Mass Index (BMI) is the most commonly used indicator to categorize a person as underweight, normal weight, overweight, or obese. Body mass index is a function of body weight and body height, and its value shows which of the aforementioned categories the person can be classified into (Sanderson, 2013). Several studies (Goldschmidt et al., 2020; Palavras et al., 2020) proved that there is a significant positive correlation between the severity and frequency of binge eating disorder symptoms and BMI. This means that the more severe one's nutritional problems are, the higher their BMI can be. Positive correlations have been found with executive functions as well, indicating that people with cognitive, emotion or behavior control deficits might use less adaptive coping mechanisms (for example overeating or emotional eating), which can directly manifest in their BMI (Favieri et al., 2019; Solís-Ortiz et al., 2016).

2. Research objectives

Previous research mainly focused on the linear relationship between these constructs. Our aim is to find which aspects of executive functions might have an explanatory role regarding binge eating symptoms and higher BMI. From this perspective, our methodological objective is to test our hypothetical mediation models, where binge eating symptoms are the predictor variable and BMI is the outcome variable. Potential mediator variables are different in each model, representing the different constructs of executive functions, which are the following: cognitive regulation, emotion regulation and behavior regulation. Based on our research results, we aim to draw attention to the effects that the impairment of cognitive, emotional or behavioral executive functions might have on eating patterns, as well as physical and mental health indicators. Our mediation analysis might also play an important role in the shaping of future theoretical models and research questions.

3. Method and procedure

3.1. Participants

To determine the required sample size we performed a power analysis in the G*Power program, where small effect size and medium - power conditions were used for multiple linear regression (Fritz & MacKinnon, 2007). In total, 103 people above the age of 18 participated in our research, who all show binge eating symptoms. More than three - quarters (84.5%) of the participants is woman, and 15.5% are men. The average age of the sample group is 23.29 years (SD = 3.371) with the youngest participant being 18, and the oldest being 35 years old. Nearly a quarter (22.3%) of responders reported following some type diet at the time, while most of them did not. Similarly, the majority (90.3%) of them did not follow any specific nutrition plan at the

time. More than three - quarters (82.5%) of the participants said that they never experienced any type of eating disorder with a clinical diagnosis. The majority (88.3%) of responders did not have any type of eating disorder with a clinical diagnosis at the time, 10.7% reported suffering from binge eating disorder, while one person stated about having bulimia nervosa. Based on the results of self - reporting tools, appearance of binge eating symptoms can be identified in the case of each participant. More than half (52.4%) of participants has normal weight (BMI = 18.5 - 24.99), 38.8% is overweight (BMI = 25 - 29.99), 7.8% has class I (low - risk), class II (moderate - risk) or class III (high - risk) obesity (BMI > 30), and only one person has a body mass index below normal (BMI < 18.5).

3.2. Instruments

Demographic questionnaire

The demographic questionnaire we created consisted of questions regarding gender, age, residence, height (cm), weight (kg), existence of chronic illness, specific diets or nutrition plans, past or present eating disorders and their periods of existence. During data processing, we calculated the BMI of each person from answers regarding their weights and heights.

Behavior Rating Inventory of Executive Functions - Adult Version (short version)

The original self - reporting BRIEF - A questionnaire was developed by Gioia et al. (2000) to measure executive functions. In our study, we used a shorter version of this questionnaire that we adapted to the Transylvanian Hungarian adult population. Our research team has validated this tool previously. The 17 - item questionnaire gives us information about the patterns of executive functions: 6 items measure the dimension of cognitive regulation, 8 items measure the emotion regulation, while 3 items measure behavior regulation problems. The statements can be valued on a Likert-scale from 1 to 3, where 1 means *Never*, 2 means *Sometimes*, and 3 means *Often*. The average value of items belonging to one factor represents the factor score. Higher scores refer to more severe function impairments. In the cognitive regulation factor we can talk about the existence of problems in the case of a score higher than 11. Emotion regulation scale indicates problems above 16 points. In the case of behavior regulation scale, a value above 5 indicates problems. In our study the questionnaire proved to be reliable (Cronbach $\alpha = .890$).

Binge Eating Screener

Herman et al. (2016) developed the questionnaire with the aim of measuring binge eating symptoms. The first part of the questionnaire includes a screening question about whether the person has experienced episodes of excessive overeating during the last 3 months. If someone marked “No”, filling of the questionnaire did not proceed. The tool contains the DSM-5 diagnostic criteria in forms of questions, which can be valued on a Likert-scale from 1 to 4, as follows: 1 - *Never or rarely*, 2 - *Sometimes*, 3 - *Often*, 4 - *Always*. If someone has answered these questions, we can talk about the

existence of binge eating symptoms in each case, only the severity differs. The scores have to be added together, and higher scores can be evaluated as more severe binge eating symptoms. In our study the questionnaire proved to be reliable (Cronbach $\alpha = .710$).

3.3. Procedure

After consenting to participate in the study, participants completed the online surveys: first the demographic questionnaire, then the short version of the BRIEF - A (short version) questionnaire, and finally the Binge Eating Screener. Filling the questionnaires took approximately 15 minutes. Data processing was conducted with the IBM SPSS 20 statistical software package, and the PROCESS application to examine the mediation models.

3.4. Design and data analysis

Our study follows a correlational, cross - sectional design. Initially, we examined correlation between executive functions, binge eating symptoms and body mass index. Then we created mediation models, where binge eating symptoms were the predictor variable, and BMI was the output variable in each case, while the mediator variables were the different constructs of executive functions. To be able to measure the indirect effect in our mediation models, we used the bootstrap method, following the recommendations of Hayes (2013). Our study can be defined as exploratory.

4. Results

In the cognitive regulation factor the lowest score earned by a participant was 6, while the highest was 17 ($M = 11.281$, $SD = 2.554$). Regarding emotion regulation, the lowest and highest scores were 8 and 24 respectively ($M = 17.097$, $SD = 4.150$). In the behavior regulation dimension the lowest acquired score was 3, and the highest was 9 ($M = 5.514$, $SD = 1.770$). Each participant reported experiencing binge eating symptoms, from the mildest at 5 points to the most severe at 16 points ($M = 10.466$, $SD = 2.554$) on the Binge Eating Screener. In our sample population, the lowest BMI was 14.68, and the highest BMI was 38.50 ($M = 22.390$, $SD = 3.665$). Table 1 contains the Skewness and Kurtosis indices, based on which we can conclude that the examined variables follow the rules of normal distribution.

Table 1: Descriptive statistics

Variable	<i>N</i>	<i>M</i>	<i>SD</i>	<i>S</i>	<i>K</i>
Cognitive regulation	103	11.281	2.554	.174	-.901
Emotion regulation	103	17.097	4.150	-.024	-.808
Behavior regulation	103	5.514	1.770	.294	-.894

BEDS	103	10.466	2.554	.040	-.880
BMI	103	22.390	3.665	1.096	1.772

Notes. BEDS = Binge Eating Disorder Symptoms, BMI = Body Mass Index, S = Skewness, K = Kurtosis

Results presented in Table 2 show that there is a tight correlation between BMI and binge eating symptoms ($r = 0.454$, $p < 0.01$). Furthermore, BMI shows significant correlation with cognitive regulation ($r = 0.347$, $p < 0.01$), and behavior regulation ($r = 0.223$, $p = 0.024$). Emotion regulation and BMI are not correlated ($r = -0.08$, $p = 0.932$). Similarly, binge eating symptoms are significantly correlated with both cognitive regulation ($r = 0.365$, $p < 0.01$), and behavior regulation ($r = 0.333$, $p < 0.01$). Finally, emotion regulation does not show correlation with binge eating symptoms either ($r = 0.152$, $p = 0.125$).

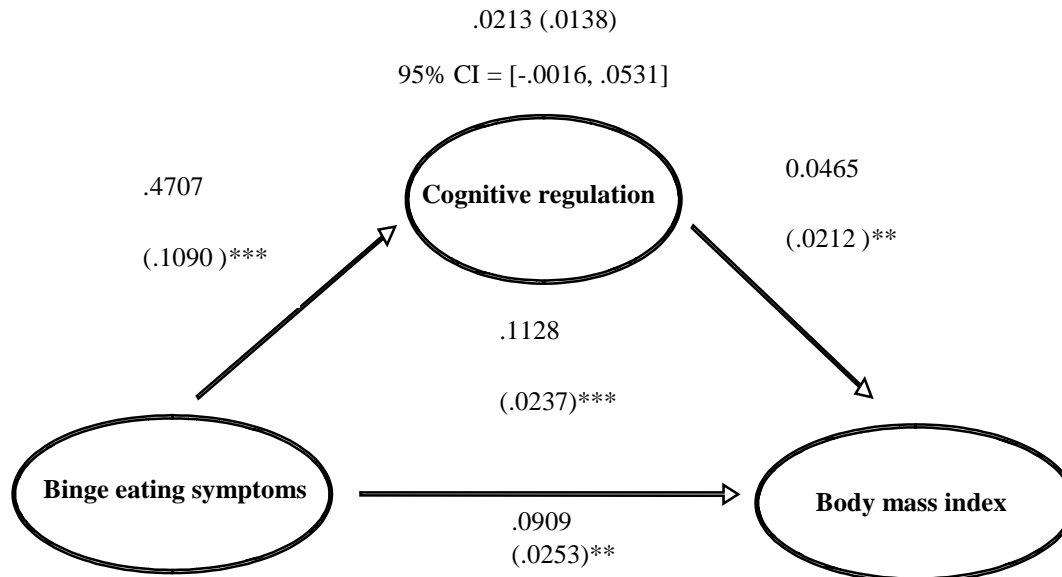
Table 2: Correlations between executive functions, binge eating symptoms and BMI

Variable	Cognitive regulation	Emotion regulation	Behavior regulation	BMI	BEDS
Cognitive regulation	–				
Emotion regulation	.475**	–			
Behavior regulation	.251*	.360**	–		
BMI	.347**	-.008	.223*	–	
BEDS	.365**	.152	.333**	.454**	–

Notes. * $p < 0.05$, ** $p < 0.01$, BEDS = Binge Eating Disorder Symptoms, BMI = Body Mass Index

To carry out the mediation analysis we initially performed 10000 bootstrap method. We created two mediation models, in both of which binge eating symptoms are the predictor variable, and BMI is the outcome variable. Cognitive regulation and behavior regulation stand as the two potential mediator variables of the two models. Emotion regulation showed no correlation with binge eating symptoms and body mass index, thus this construct was not further investigated.

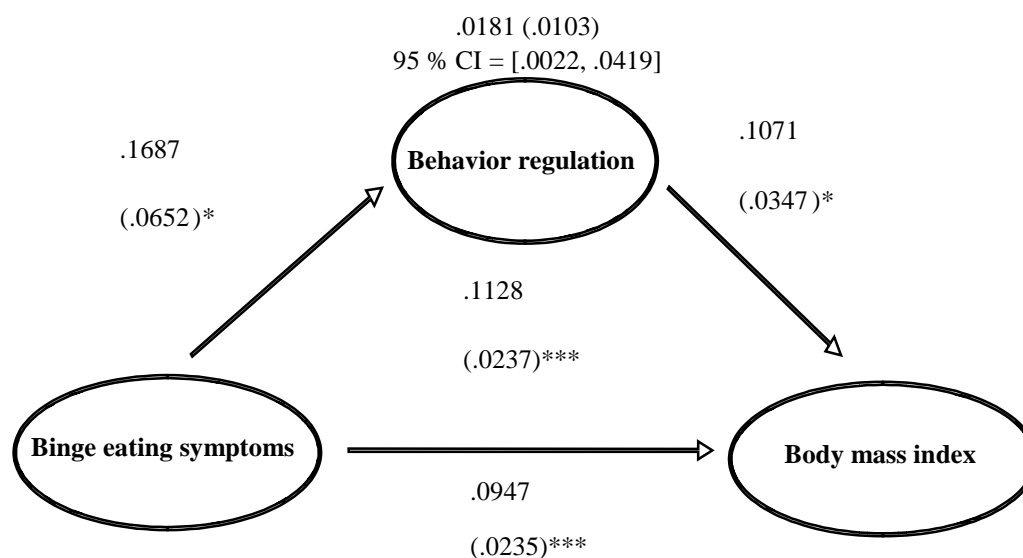
Figure 1: Cognitive regulation as mediator between binge eating symptoms and BMI



Notes. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on Figure 1 we can say that participants who experience increased binge eating symptoms also have more severe cognitive regulation problems ($a = .470$, $SE = .109$, $p < .001$), and besides more severe cognitive regulation problems are related to higher BMI ($b = .046$, $SE = .021$, $p = .030$). Responders who showed increased binge eating symptoms had higher BMI ($c' = .090$, $SE = .025$, $p = .0005$). Based on the analysis we can conclude that the effect of the mediator variable is not statistically significant. We can only interpret mediation if in the case of indirect effect 0 does not fall within the confidence interval (Hayes, 2013). In the case of the indirect effect ($ab = .021$, $SE = .013$) the confidence interval (95% CI = from $-.001$ to $.053$) includes the 0 value, and for this reason cognitive regulation cannot be interpreted as a mediator variable in the relationship between binge eating symptoms and BMI.

Figure 2: Behavior regulation as the mediator between binge eating symptoms and BMI



Notes. * $p < 0.05$, *** $p < 0.001$

Based on Figure 2 we can say that responders who experience increased binge eating symptoms also have more severe behavior regulation problems ($a = .168$, $SE = .065$, $p < .05$), and besides, more severe behavior regulation problems are related to higher BMI ($b = .107$, $SE = .034$, $p = .002$). Participants who showed increased binge eating symptoms had higher BMI ($c' = .094$, $SE = .023$, $p = .0001$). Based on the results, behavior regulation problems are present in the relationship between binge eating symptoms and BMI as a mediator variable, as we can interpret the indirect effect as statistically significant. In terms of indirect effect ($ab = .018$, $SE = .010$) 0 does not fall within the confidence interval (95% CI = from .002 to .041), thus our mediation model proved to be acceptable. Increased binge eating symptoms are correlated with higher BMI, which is a relationship directly affected by behavior regulation problems ($c = .112$, $SE = .023$, $p < .001$).

5. Conclusions and discussion

To summarize, our results show significant positive correlation between binge eating symptoms and BMI, which relationship can manifest in the following way: people who experience increased binge eating episodes will have higher body mass index, as opposed to people who experience either less severe or less frequent binge eating symptoms.

Based on the results of our study we can also see that more severe problems of the executive functions are correlated with higher BMI. By this, we have partially

verified results acquired by Goldschmidt et al. (2020) who found that a decrease in executive functions correlates with higher body mass index. In our study, this could not be proven in the case of emotion regulation, presumably because emotion regulation problems can mobilize a wide variety of coping strategies in individuals. Affective factors such as this can manifest in a wide range of patterns, only one of which is eating problems. Contrary to this, in the case of cognitive deficits, underdeveloped inhibitory functions can have a more direct, and global effect on the individual's behavioral repertoire. From a practical point of view, our results show that individuals who have increased problems with behavior regulation (for example with the inhibitory control or self - monitoring) or cognitive regulation (with cognitive flexibility or working memory), report having higher BMI, as opposed to individuals who don't experience such severe problems in these domains. This result is not only true in the context of BMI. Cognitive and behavior regulation problems show a high degree of correlation with binge eating symptoms. Therefore, individuals who have disadvantages in these domains are less likely to be able to suppress or delay their urges, and they succumb more easily to immediate pleasure rather than long - term preferences or goals. For this reason, it is harder for them to show resistance against excessive eating, which also facilitates more frequent binge eating symptoms. Consequently, we can say that our results are in alignment with findings of Ames et al. (2014) who also proved the relationship between inhibitory control functions and binge eating symptoms. Moreover, our conclusions match the results of a study conducted by Dingemans et al. (2015) in which they referred to positive correlation between cognitive regulation problems and binge eating symptoms.

Our mediation analysis shows that behavior regulation deficits directly affect the relationship between binge eating symptoms and BMI. Hence, we can say that individuals with lower performing self - monitoring and inhibitory control functions are more vulnerable to developing binge eating symptoms and weight problems. Our results indicate a direction for future psychological interventions, which focus on reducing binge eating symptoms and regulating body weight. Data shows that from the domain of executive functions, behavior regulation problems have the highest contribution to binge eating episodes, thus to the deterioration of physical health. For this reason, trainings that focus on the improvement of self - monitoring and inhibitory control should be included in the psychological work to protect mental and physical health.

6. Limitations and future directions

The main limitations of our study lies in the use of a self - reporting questionnaire to measure executive functions. In the future, it would be recommended to use other measuring tools, and psychometric tests to gather more specific data. Another option for improvement is the examinations of a specific clinical sample, where each participant has a clinical diagnosis of binge eating disorder, thus our results can be more accurate. It may also be recommended to involve more individuals who

are in the overweight or obese category based on their BMI, so that research results can be more extensible.

References

- Allom, V., Mullan, B. and Hagger, M. (2015). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review*, 10(2), pp. 168 - 186. doi:10.1080/17437199.2015.1051078
- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. Fifth ed. Washington, DC: American Psychiatric Publishing.
- Ames, S. L., Kisbu - Sakarya, Y., Reynolds, K., Boyle, S., Cappelli, C., Cox, M. G., Dust, M., Grenard, G. L., Machinon, D. P. and Stacy, A. W. (2014). Inhibitory control effects in adolescent binge eating and consumption of sugar - sweetened beverages and snacks. *Appetite*, 81, pp. 180 - 192. doi:10.1016/j.appet.2014.06.013
- Diamond, A. (2013). Executive function. *Annual Review of Psychology*, 64, pp. 135 - 168. doi:10.1146/annurev-psych-113011-143750
- Dingemans, A. E., Visser, H., Paul, L. and Furth, E. F. (2015). Set - shifting abilities, mood and loss of control over eating in binge eating disorder: An experimental study. *Psychiatry Research*, 230, pp. 242 - 248. doi:10.1016/j.psychres.2015.09.001
- Dohle, S., Diel, K. and Hofmann, W. (2017). Executive functions and the self - regulation of eating behavior: A review. *Appetite*, pp. 1 - 19. doi:10.1016/j.appet.2017.05.041.
- Favieri, F., Forte, G. and Casagrande, M. (2019). The Executive Functions in Overweight and Obesity: A Systematic Review of Neuropsychological Cross - Sectional and Longitudinal Studies. *Frontiers in Psychology*, pp. 1 - 27. doi:10.3389/fpsyg.2019.02126
- Fritz, M. S. and MacKinnon, D. P. (2007). Required Sample Size to Detect the Mediated Effect. *Psychological Science*, 18(3), pp. 233 - 239. doi:10.1111/j.1467-9280.2007.01882.x
- Gioia, G., Isquith, P., Guy, S. and Kenworthy, L. (2000). *Behavioral Rating Inventory of Executive Function: Professional manual*. Psychological Assessment Resources.
- Godfrey, K., M., Butryn, M., Forman, E. M. and Martinez, M. (2019). Depressive symptoms, psychological flexibility, and binge eating in individuals seeking behavioral weight loss treatment. *Journal of Contextual Behavioral Science*, 14, pp. 50 - 54. doi:10.1016/j.jcbs.2019.09.005

- Goldschmidt, A. B., Hipwell, A. E., Stepp, S. D., McTigue, K. M., and Keenan, K. (2020). Weight Gain, Executive Functioning, and Eating Behaviors Among Girls. *Pediatrics*, 136(4), pp. 856 - 863. doi:10.1542/peds.2015-0622
- Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis. A regression-based approach*. Second ed. New York, US: The Guilford Press.
- Herman, B. K., Deal, L. S., DiBenedetti, D. B., Nelson, L., Fehnel, S. E. and Brown, T. M. (2016). Development of the 7 - Item Binge - Eating Disorder Screener (BEDS - 7). *The Primary Care Companion for CNS Disorders*, 18(2). doi:10.4088/PCC.15m01896
- Iqbal, A. and Rehman, A. (2020). Binge Eating Disorder. [Online]. Available: <https://www.ncbi.nlm.nih.gov/books/NBK551700/>
- Lyons, K. E. and Zelazo, P. D. (2011). Monitoring, metacognition and executive function: Elucidating the role of self - reflection in the development of self - regulation. *Advances in Child Development and Behavior*, 40, pp. 379 - 412. doi:10.1016/B978-0-12-386491-8.00010-4
- Manasse, S., M., Forman, E. M., Ruocco, A. C., Butryn, M. L., Juarascio, A. S. and Fitzpatrick, K. K. (2015). Do executive functioning deficits underpin binge eating disorder? A comparison of overweight women with and without binge eating pathology. *International Journal of Eating Disorders*, 48(6), pp. 677 - 683. doi:10.1002/eat.22383
- Müller, U. and Kerns, K. (2015). The development of executive function. In L. S. Liben, U. Müller and R. M. Lerner (Eds.), *Handbook of child psychology and developmental science: Cognitive processes*. Wiley, pp. 571 - 623.
- Palavras, M. A., Hay, P., Mannan, H., da Luz, F. Q., Sainsbury, A., Touyz, S. W. and Claudino, A. (2020). Integrated weight loss and cognitive behavioural therapy (CBT) for the treatment of recurrent binge eating and high body mass index: a randomized controlled trial. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, 26, pp. 249 - 262. doi:10.1007/s40519-020-00846-2
- Sanderson, C. A. (2013). *Health Psychology*. Second ed. Hoboken, NJ: Wiley.
- Solís - Ortiz, A., Gutierrez-Muñoz, M. L., Morado - Crespo, L., Trejo - Bahena, S. A., & Kala, L. (2016). Executive Functions Correlated with Body Mass Index in Overweight Middle - Aged Women. *Psychology*, 7(3), pp. 410 - 417. doi:10.4236/psych.2016.73043
- Svaldi, J., Werle, D., Naumann, E., Eichler, E., & Berking, M. (2019). Prospective associations of negative mood and emotion regulation in the occurrence of binge eating in binge eating disorder. *Journal of Psychiatric Research*, 115, pp. 61 - 68. doi:10.1016/j.jpsychires.2019.05.005