Brain Mechanisms Associated With Weight Loss, Top-Down Processes A Review Study For Targeting Executive Function In Obesity And Overweight

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Abstract

The purpose of present study was to clarify the links between Executive function and weight-loss. We firstly investigated definition and functions of executive functions and secondly showed studies done in the links. Studies have shown that executive functions can influence on thinking and behaviors, especially, health behaviors. As a result of the preliminary search, the final keywords utilized for the investigation were weight loss, executive functions, obesity and overweight. After that, we found twelve articles and reviewed methods and results of those. The results consisted of three main methods included correlational, experimental methods and ex-post facto studies. In conclusion, present study indicated that executive control as a central control of behavior plays a key role in weight-loss.

Keywords: executive function, weight-loss, overweight, obesity, top-down processes

Introduction

Psychophysical investigation showed that obese people experience normal sweetness and fat but like fat more than non-obese do (1). Obesity and overweight has increased more dramatically in economically developed countries and in urbanized populations and there is a growing global childhood obesity epidemic, with a large variation in secular trends across countries (2). Thus, About 70% of obese adolescents grow up to become obese adults (3). In 1998, The World Health Organization project monitoring of cardiovascular diseases (MONICA) reported Iran as one of the seven countries with the highest prevalence of childhood obesity (3). Over the past decade, there was an increasing in prevalence of weight discrimination by 66% and this percent is comparable to rates of racial discrimination, especially among women (4).

Environmental factors, lifestyle preferences, and cultural environment play pivotal roles in the rising prevalence of obesity worldwide (5, 6). Moreover, there are supporting evidence that excessive sugar intake by soft drink, increased portion size, and steady decline in physical activity have been playing major roles in the rising rates of obesity all around the world (7). Obesity has many health, social, psychological, and economic consequences for the individuals being affected and for the society (8). In addition to social, health, psychological and economic problems associated
with obesity, obesity is associated with many serious diseases such as hypertension, cardiovascular diseases, type 2 diabetes and metabolic syndrome, and tackling obesity means coping with these many diseases. In fact, it can be said that excessive obesity reduces longevity (9). In the US, obesity is a considerable issue if people cannot control it (10). Obese individuals are comfort with discrimination and are highly stigmatized and face multiple forms of prejudice because of their weight (11).

Considering the problems associated with obesity or overweight, some research has been done on how weight can be reduced. Usually, losing weight has been difficult and maintaining the weight-loss is an even greater challenge. Researchers have looked at variables related to weight-loss. For instance, Wang, Phert and Lemon (12) examined longitudinal associations between sources of social support and social undermining for healthy eating and physical activity and weight change. They found that employees, friend and coworker support for healthy eating and family support for physical activity predicted improved weight management. In addition to social support, researchers have shown that psychological aspects such as emotion regulation (13), self-regulation (14), mindfulness (15), executive functions (16), personality traits (17) and self-efficacy (18) are associated with loss weight. Some findings across the lifespan is that obesity is associated with cognitive deficits, especially in executive function, in children, adolescents and adults. However, as illustrated by contradictory studies, the relationship between obesity and cognition is uncertain in the elderly, partly because of inaccuracy of body mass index as a measure of adiposity as body composition changes with aging (19).

Generally, this study is lead to investigate the link between executive function and weight-loss and looking to know how executive function helps lose weight. As we enter the 21st century with greater reliance on technological expertise, life success depends increasingly on the mastery of executive function processes such as goal setting, planning, organizing, prioritizing, memorizing, initiating, shifting, and self-monitoring (20). Executive function is an umbrella term used to describe the processes required for performing deliberate and purposeful activities as well as appropriate social behavior in virtually all daily activity (21). In fact, it refers to a series of cognitive abilities that allow individuals to provide automatic responses to new and complex situations and control their thoughts and behavior (22). Weight-loss maintenance clearly requires executive functioning. First, cognitive control such as the inhibition of automatic responses and approach behavior is highly indicated when, for example, a child needs to resist palatable snacks. Second, adequate memory capacity (‘remembering what I was doing or what I have to do to reach a current goal’) is also seen as a necessary self-regulation ability. It is assumed that enhanced working memory may facilitate planning, monitoring, and self-instruction, which, in turn, can improve impulse control in eating behavior and consequently can help in weight management (23).

The study aimed at clarifying the links between executive function and weight-loss. We firstly investigated definition and functions of executive function and secondly showed studies done in the links.

**Function and mechanisms of executive function**

Executive function like other psychological constructs is multidimensional (24). Several theories and concepts about the constitutive skills of executive functions (EF) have been presented with the majority of definitions treating EF as being multidimensional. These concepts, however, includes separate yet related components such as attention control, working memory, cognitive flexibility, containment, strategic planning, impulse control and self-regulation, which support learning, academic achievement, and behavioral competency (25, 26). The prefrontal cortex may control EF, because of its ability to incorporate multiple types of information needed for a task (27). Using factor analysis, they found that cognitive flexibility and fluency, inhibition, and working memory explained 52.7% of the variance of performance on several traditional EF measures.

EF plays a major role in controlling behaviors and thinking (28, 29). Moreover, it has roles in attentional control and frontal lobe functions (30, 31). Hall et al. (32) believed that executive function predicts unique variance in both behaviors, and strongly moderates the association between behavioral intention and behavioral performance. Together behavioral intention and executive function explain more variance in health protective behavior.
Executive function and weight-loss

We conducted a systematic literature review, with eligibility criteria and search strategy created a priori and based on The Cochrane Handbook of Systematic Reviews. The databases searched included PubMed, Google Scholar, and Science Direct. A broad search was conducted using the keywords: weight loss, executive functions, working memory, inhibition, obesity and overweight. As a result of this preliminary search, the final keywords utilized for the investigation were weight loss, executive functions, obesity and overweight. We finally found twelve studies that are directly related to our purposes. The summary of searching stage was illustrated in chart 1 (titles identified1, related keywords and eligible studies). A summary of the studies was illustrated in table 1.

Chart of study selection process

Kemps, Tiggemann and Marshall (33) investigated the impact of weight-loss dieting on the four identified functions of the central executive of working memory: dual-task performance, random generation, task switching and activation of long-term memory. Participants were 32 female current dieters and 32 female non-dieters who completed four well-established cognitive tasks designed to tap each specific function. Participants also completed tasks designed to load on the phonological loop and visuo-spatial sketch pad working memory systems, as well as self-report measures of depressed affect and preoccupying cognitions. Dieters performed more poorly than non-dieters on all central executive measures except random generation. These dieting-related differences were most evident on moderately complex trials, and were partially mediated by preoccupying thoughts about food, weight and body shape, but not by BMI or depressed affect. It was concluded that weight-loss dieting has a relatively global impact on central executive functioning and thus has wide-ranging cognitive consequences.

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1. Executive functions= 2099
2. Working memory= 8810
3. Inhibition= 177032
4. Obesity= 69656
5. Overweight= 13874
6. Weight loss= 12968
Davis et al. (34) in their study tested the effect of aerobic exercise training on executive function in overweight children. Ninety-four sedentary, overweight but otherwise healthy children (mean age = 9.2 years, body mass index? 85th percentile) were randomized to a low-dose (20 min/day exercise), high-dose (40 min/day exercise), or control condition. Exercise sessions met 5 days/week for 15 weeks. The Cognitive Assessment System (CAS), a standardized test of cognitive processes, was administered individually before and following intervention. Analysis of covariance on posttest scores revealed effects on executive function. Group differences emerged for the CAS Planning scale (p = .03). Planning scores for the high-dose group were significantly greater than those of the control group.

Gunstad et al. (35) examined attention and executive function in a cross-section of 408 healthy persons across the adult life span (20-82 years). Bivariate correlation showed that BMI was inversely related to performance on all cognitive tests. After controlling for possible confounding factors, overweight and obese adults (BMI > 25) exhibited poorer executive function test performance than normal weight adults (BMI, 18.5-24.9).

The Lokken, Boeka, Austin, Gunstad & Harmon (36) study sought to examine the cognitive performance of a sample of extremely obese adolescents seeking primary treatment for weight loss. Adolescents were recruited during regularly scheduled medical appointments at a children's center for weight management associated with a major children's hospital in the Southeast United States. A computerized battery of cognitive tests was administered to obese adolescents and the number of them were 25 with body mass index >99th percentile. The finding of their study revealed that obese adolescents exhibited deficits in many cognitive domains, including impairment in attention and executive functions.

Walther, Birdsill, Glisky & Ryan (37) study examined the association between body mass index (BMI), regional volume differences in gray and white matter measured by magnetic resonance imaging (MRI), and cognitive functioning in older females. Participants included 95 community-dwelling older females (ages 52–92 years) who underwent extensive neuropsychological testing and high-resolution MRI scanning. Optimized voxel-based morphometry techniques were employed to determine the correlation between BMI and regional gray and white matter volumes. x, obese women performed poorer on tests of executive functioning. Smaller gray matter volume in the left orbitofrontal region was associated with lower executive functioning. Additionally, despite the lack of significant group differences in memory and visuomotor speed, gray and white matter volumes predicted performance on these measures.

Maayan, Hoogendoorn, Sweat & Convit (38) in their study examined the relationship between obesity, executive function, disinhibition, and brain volumes in relatively healthy youth. Participants included 54 obese and 37 lean adolescents. Participants received a cognitive battery, questionnaires of eating behaviors, and magnetic resonance imaging (MRI). Neuropsychological assessments included tasks targeting frontal lobe function. Eating behaviors were determined using the Three Factor Eating Questionnaire (TFEQ), and structural MRIs were performed on a 1.5 T Siemens Avanto MRI System (Siemens, Erlangen, Germany) to determine brain GM volumes. Obese participants had significantly higher ratings of disinhibition on the TFEQ, lower performance on the cognitive tests, and lower orbitofrontal cortex (OFC) volume. Disinhibition significantly correlated with BMI, Stroop color-word score, and OFC volume.

Staiano, Abraham and Calvert (39) in their study examined the role of competitive versus cooperative exergaming play on short-term changes in executive function skills, following a 10-week exergaming training intervention. Fifty-four low-income overweight and obese African American adolescents were randomly assigned to a competitive exergaming condition, a cooperative exergaming condition, or a no-play control group. Youths in the competitive exergaming condition improved in executive function skills more than did those in the cooperative exergaming condition and the no-play control group. Weight loss during the intervention was also significantly positively correlated with improved executive function skills.

Cortese, Comencini, Vincenzi, Speranza and Angriman (40) did a research titled Attention-deficit/hyperactivity disorder and impairment in executive functions: a barrier to weight loss in individuals with obesity? They discussed
the evidence showing that ADHD and/or deficits in executive functions are a barrier to a successful weight control in individuals enrolled in weight loss programs. Impairing symptoms of ADHD or deficits in executive functions may foster dysregulated eating behaviors, such as binge eating, emotionally-induced eating or eating in the absence of hunger, which, in turn, may contribute to unsuccessful weight loss. ADHD-related behaviors or neurocognitive impairment may also hamper a regular and structured physical activity.

Fitzpatrick, Gilbert & Serpell (41) in their review aimed at systematically investigating the evidence suggesting that obese individuals demonstrate impaired performance on behavioral tasks examining executive functioning abilities. A systematic review of literature was carried out by searching five separate databases (PsycINFO, MEDLINE, EMBASE, CINAHL and PubMed) and a hand search of relevant journals. Twenty-one empirical papers were identified from the search criteria and the results were considered in relation to different executive functioning domains. There is little consistency of results both within and across different domains of executive functioning. The review suggests that obese individuals show difficulties with decision-making, planning and problem-solving when compared to healthy weight controls, with fewer difficulties reported on tasks examining verbal fluency and learning and memory.

Verbeken, Braet, Goossens and Van der Oord (23) investigated the impact of EF training with game-elements on weight-loss maintenance among obese children. Forty-four children (aged 8–14 years) who were in the final months of a 10-months inpatient treatment program in a medical pediatric center were randomized to either the 6 week EF-training condition or to a care as usual only control group. The EF-training consisted of a 25-session training of inhibition and working memory. Treatment outcomes were child performances on cognitive tasks of inhibition and working memory and childcare worker ratings on EF-symptoms as well as weight loss maintenance after leaving the clinic. Children in the EF-training condition showed significantly more improvement than the children in the care as usual only group on the working memory task as well as on the childcare worker reports of working memory and meta-cognition. They were also more capable to maintain their weight loss until 8 weeks post-training.

The Manasse et al. (42) study sought to examine executive function (EF) in overweight individuals with and without loss-of-control (LOC) eating. Eighty overweight and obese individuals entering a behavioral weight loss trial with (n = 18) and without (n = 62) LOC eating were administered a clinical interview and neuropsychological battery designed to assess self-regulatory control, planning, delayed discounting and working memory. Results indicate that overweight individuals with LOC eating display relative deficits in EF compared with overweight individuals without LOC eating. Planning and self-regulatory control deficits in particular may contribute to dysregulated eating patterns, increasing susceptibility to LOC episodes.

Table 1. Summary of the most relevant studies investigating relationship between executive function and weight-loss

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Methods</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kemps, Tiggemann and Marshall (33)</td>
<td>2005</td>
<td>64 female</td>
<td>Correlation study</td>
<td>Weight-loss dieting had a relatively global impact on central executive functioning</td>
</tr>
<tr>
<td>Davis et al. (34)</td>
<td>2007</td>
<td>94 children</td>
<td>Experimental method</td>
<td>Effect of aerobic exercise training on executive function in overweight children</td>
</tr>
<tr>
<td>Gunstad et al. (35)</td>
<td>2007</td>
<td>408 healthy persons</td>
<td>Correlation study</td>
<td>Poorer executive function test performance of overweight and obese adults than normal weight adults</td>
</tr>
<tr>
<td>Lokken, Boeka, Austin, Gunstad &amp; Harmon (36)</td>
<td>2009</td>
<td>25 adolescents</td>
<td>Ex-post facto study</td>
<td>Many cognitive domains, including impairment in attention and executive functions deficits of obese adolescents</td>
</tr>
</tbody>
</table>
### Discussion

The purpose of study was to review the links between executive functions and weight-loss. 11 researches were found to be consistent with this study. Generally, we divided studies in three groups; first, correlational studies that have been done using regression and correlation analyses. Second, ex-post facto studies that investigated executive functions in obese. Third, studies have been done using experimental methods. Correlational studies have shown that there are relationships between executive functions and overweight. Moreover, ex-post facto studies have shown that overweight and obese adults (BMI > 25) exhibit poorer executive function test performance than normal weight adults. Experimental studies have also shown that executive functions training can significantly improve overweight. In terms of tools, studies used variety tools in order to examine executive functions such as visuo-spatial sketch pad working memory systems, the cognitive assessment system (CAS), standardized test of cognitive processes, computerized

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Sample Description</th>
<th>Study Type</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walther, Birdsell, Glisky &amp; Ryan (37)</td>
<td>2010</td>
<td>95 community-dwelling older females</td>
<td>Correlation study</td>
<td>Poorer performance of obese women compared to normal weight women on tests of executive functioning</td>
</tr>
<tr>
<td>Maayan, Hoogendoorn, Sweat &amp; Convit (38)</td>
<td>2011</td>
<td>54 obese and 37 lean adolescents</td>
<td>Correlation study</td>
<td>Significantly higher ratings of disinhibition on the TFEQ, lower performance on the cognitive tests, and lower orbitofrontal cortex (OFC) volume of obese participants</td>
</tr>
<tr>
<td>Staiano, Abraham and Calvert (39)</td>
<td>2012</td>
<td>55 low-income overweight and obese African American adolescents</td>
<td>Experimental study</td>
<td>Youths in the competitive exergaming condition improved in executive function skills more than did those in the cooperative exergaming condition and the no-play control group</td>
</tr>
<tr>
<td>Cortese, Comencini, Vincenzi, Speranza and Angriman (40)</td>
<td>2013</td>
<td>7 articles</td>
<td>Review</td>
<td>Symptoms of ADHD disorder or executive function impairment may lead to nutritional behaviors such as eating or drinking due to hunger, which in turn results in unsuccessful weight loss.</td>
</tr>
<tr>
<td>Fitzpatrick, Gilbert &amp; Serpell (41)</td>
<td>2013</td>
<td>21 empirical papers</td>
<td>Systematic review</td>
<td>difficulties with decision-making, planning and problem-solving among obese individuals compared to healthy weight controls</td>
</tr>
<tr>
<td>Verbeken, Braet, Goossens and Van der Oord (23)</td>
<td>2013</td>
<td>44 obese children</td>
<td>Experimental study</td>
<td>Children in the EF-training condition showed significantly more improvement than the children in the care as usual only group on the working memory task as well as on the childcare worker reports of working memory and meta-cognition</td>
</tr>
<tr>
<td>Manasse et al. (42)</td>
<td>2014</td>
<td>80 overweight and obese individuals</td>
<td>Experimental study</td>
<td>overweight individuals with LOC eating display relative deficits in EF compared with overweight individuals without LOC eating</td>
</tr>
</tbody>
</table>
battery of cognitive tests, high-resolution MRI scanning, inhibition and working memory tasks. In fact, studies illustrated behavioral and neuropsychological results.

Executive functions refer to a family of top-down mental processes needed when you have to concentrate and pay attention, when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible (26). There are key executive functions such as inhibition, working memory and cognitive flexibility (43, 20). For example, inhibitory control of attention enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli (20); it may influence on weight-loss. It seems that increasing inhibitory control can increase selective attention to calories. Researches have shown that people with overweight problems have deficits in inhibition for selecting calories (44, 45). Therefore, EF may play a major role for predicting weight-loss.

Though researches have been done in order to examine the links between EF and weight-loss, it needs to use neuroimaging techniques for clarifying regions are involved in people with overweight and also it should be examined EEG devise so that it can clarify frequency bands may be cooperated with executive functions in people with overweight. To sum up, present study indicated that executive control as a central control of behavior plays a key role in weight-loss.

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