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Effectiveness of Transcranial Direct Current Stimulation on Cravings in Overweight Individuals

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Quantitative Study

Abstract

Background: Overweight is one of the current problems of people. One of its causes is the craving for food. This study was conducted with the aim to evaluate the effectiveness of transcranial direct current stimulation (tDCS) on craving for food in overweight people.

Methods: The research was a quasi-experimental study with a pretest-posttest design and a control group. The statistical population of the study included all overweight people referred to Aramesh Psychology Center in Tehran, Iran, in 2019. They were selected using a purposeful sampling method and were randomly divided into two groups. The mean and standard deviation of the age of the subjects was 34.27 ± 6.45 years and the mean body mass index (BMI) was 28.12 ± 2.23 kg/m^2. The research instrument was the Food Cravings Questionnaires (FCQs) developed by Cepeda-Benito, Gleaves, Williams, and Erath (2000). Data were analyzed using multivariate analysis of covariance (ANCOVA).

Results: The results showed a significant difference between the tDCS group and control group in terms of mean trait craving ($P \leq 0.001$) and state craving ($P \leq 0.001$) scores.

Conclusion: It seems that tDCS can be used to reduce food cravings in obese people. Theoretical and practical considerations of the research have been presented in the discussion and conclusion sections.

Keywords: Transcranial direct current stimulation; Craving; Overweight

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Introduction

A report released by the World Health Organization (WHO) shows that the prevalence of obesity and overweight between 2011 and 2014 was about 36.5% (Ogden, Carroll, Fryar, & Flegal, 2015). Obesity is a chronic disease that, in addition to causing physical and mental diseases, reduces people's work capacity and ability and makes them vulnerable to most diseases (Nissen & Holm, 2015). In Iran, 28.6% of the population is overweight, 10.8% are obese, and 3.4% suffer from morbid obesity. Unhealthy lifestyle habits play a major role in this public health problem. Thus, it can be stated that the epidemic of obesity requires behavioral and environmental approaches to modify eating behavior and physical activity (Gouda & Prusty, 2014; Yokum, Ng, & Stice, 2011; Sagliano, D'Olimpio, Izzo, & Trojano, 2017). Obesity is not a mental disorder, but it causes widespread anxiety in obese people. Presently, the reaction of communities to obesity is one of the main causes of anxiety. Obesity has a correlation with stress and psychological disturbances (Kristensen & Pedersen, 2015). Contemporary neurological models consider obesity as a brain disorder that involves severe neuronal damage and results in persistent consumption of food despite its negative consequences (Moreno-Lopez, Soriano-Mas, Delgado-Rico, Rio-Valle, & Verdejo-Garcia, 2012). Based on brain imaging, the dorsolateral prefrontal cortex (DLPFC) plays an important role in craving (da Silva et al., 2013; Kulandaivelan, Joshi, Chaturvedi, & Malik, 2018; Andres, Masson, Larigaldie, Bonato, Vandermeeren, & Dormal, 2020). The studies conducted on obesity disorders have also identified changes in prefrontal areas of the brain, especially in the DLPFC and these brain changes are exacerbated by craving and impaired inhibitory control (dos Santos & Granon, 2012; Ray et al., 2019; English, Kitching, Maybery, & Visser, 2018).

Human and animal studies have shown that in transcranial direct current stimulation (tDCS), anodal stimulation increases cortical stimulability, while cathodal stimulation decreases cortical stimulability. The tDCS intervention is used to reduce the symptoms of craving for food and alcohol (Ke et al., 2019; Rooholamini, Soleymani, & Vaghef, 2018; Nitsche & Paulus, 2001). The effectiveness of tDCS on the recovery of drug-dependent patients with food cravings has been investigated in various studies. The results of these studies indicate the effectiveness of this treatment method (Zhang et al., 2019; Cruz, Fong, & Brown, 2018; Hanenberg, Getzmann, & Lewald, 2019).

Studies have identified attentional bias as one of the underlying cognitive factors in craving so that the preference is focused on a specific class of information in such conditions (MacLeod & Mathews, 2012; Moezzi, Ghoshuni, & Amiri., 2020; Ljubisavljevic, Maxood, Bjekic, Oommen, & Nagelkerke, 2016). In a world full of appetizing and tempting images and scenes, encountering food-related clues leads to increased cravings and overeating, since the pleasurable and short-term effects of eating overcome the prediction of the long-term consequences of food consumption such as obesity and health-related problems. There are several treatments available to reduce the harmful effects of obesity. One of the newest therapies used is tDCS (Rohner et al., 2018). In this method, an electric current, although weak, enters the nerve tissue through the skin and skull, and changes the stimulability of the tissue. Common protocols for this procedure are the use of tDCS through 2 electrodes attached to the skin, one of which is the anode and the other is the cathode. An electric current of 1-2 mA is applied for 20 minutes between these 2 electrodes, each

of which usually has a cross-sectional area of 35 square centimeters. The direction of the current is from the anode to the cathode, and according to the direction and intensity of the current, the level of stimulability of the cerebral cortex increases or decreases (Bikson, Name, & Rahman, 2013). Given what was stated above, the present study was conducted to evaluate the effectiveness of tDCS on craving in overweight people.

Methods

The current research was a semi-experimental, single-blind, clinical trial; the experimental and control groups were not aware of the type of intervention. The statistical population of the present study included all overweight people referred to Aramesh Psychology Center in Tehran, Iran, in 2019. It should be noted that the number of participants in each group in an experimental research should be at least 8-12 people (Shafiabadi, 2001); in the present study, each group consisted of 12 people. In total, 24 overweight people were selected as a statistical sample using a purposeful sampling method based on the inclusion and exclusion criteria, and they were randomly assigned to the tDCS group (n = 12) and control group (n = 12). The inclusion criteria included education level of diploma and higher, age of 25-40 years, body mass index (BMI) of 25-29.9 kg/m^2, not taking concomitant medication for other disorders, and uncontrollable tendency to consume at least 1 of the following foods 3 times a week for at least the last month: sweets and nuts, high-fat foods, and fast food. The exclusion criteria included unwillingness to continue the research process and absence from more than 3 treatment sessions. Any metal objects in the head (e.g., implants) or other parts of the body (e.g., heart battery), smoking, drug use, and alcohol consumption were also considered as the exclusion criteria. Moreover, ethical considerations were observed. The ethical principles taken into consideration in the present study were as follows: All individuals received written information about the research and participated in the research voluntarily. Participants were reassured that all their information would be kept confidential and would be used for research purposes only. For privacy reasons, participants' first and last names were not registered.

In the present study, the experimental and control groups were matched by simple random sampling. Before the experimental intervention was implemented in the experimental group, the Food Cravings Questionnaires (FCQs) were completed by overweight people referring to the Royan Clinic in Tehran in the pretest stage. After that, for the subjects of the experimental group, direct current cranial wall stimulation intervention was performed by the researcher who received specialized training in tDCS intervention. No intervention was performed for the control group. The intervention sessions were held 2 days a week at the Aramesh Counseling Center in Tehran. After the interventions, a posttest was taken from the experimental and control groups. Follow-up was performed for both groups 1 month after the posttest. The collected data were then analyzed. Moreover, after the end of the study, the treatment was performed for the control group.

Food Cravings Questionnaires: The FCQs were designed by Cepeda-Benito, Gleaves, Williams, and Erath (2000). The FCQs include the FCQ-Trait (FCQ-T), which examines an individual's mental tendencies to eat, and the FCQ-Status (FCQ-S), which examines the state and intensity of food cravings in a person. Kachooei and Ashrafi (2016) have examined the validity of the Persian version of this questionnaire. It includes questions to examine the axes of thoughts or mental occupation with food

in the patient, emotions before or during food consumption, feeling of guilt after eating, feeling of guilt for surrendering to food cravings, the patient's intention for eating, predicting positive reinforcement in food consumption, and predicting relief from negative states and feelings as a result of eating. The FCQ-S includes 15 questions and the FCQ-T includes 21 questions; the questions are scored on a 6-point Likert scale ranging from never (1) to always (6). A high score in this questionnaire indicates high severity of the disease. In the present study, Cronbach's alpha method was used to determine the reliability of the FCQs and it was 0.85 for the whole questionnaire.

Summary of the tDCS treatment sessions

In this method, a simple tool was used. It included sponge electrodes with an area of 35 square centimeters (7 × 5 cm) that were impregnated with saline and placed on the person's head, and an electric current generating device (Neurosistem 2, serial number 8078-2 MD; Medina Teb Gostar Co, Tehran, Iran). The device worked with a battery and passed a continuous and light electric current through the individual's head. In this study, subjects were treated with tDCS every other day for 5 sessions. Accordingly, the anode electrode (stimulator) was placed on the right dorsolateral posterior region of the cortex (F3) and the cathode electrode (inhibitor) was placed on the right dorsolateral posterior region of the cortex (F4). For artificial stimulation, the electrodes were placed in the same places as the actual stimulation, but the current was cut off after 30 seconds. Therefore, the subject felt the initial itching due to the turning on of the device, but did not receive any current after that. For the experimental group participants, direct current was applied with an intensity of 2 mA for 20 minutes.

To analyze the data in this study, descriptive statistical methods such as frequency, percentage, mean, and standard deviation, and inferential statistics such as univariate analysis of covariance (ANCOVA) and Bonferroni post hoc test were used. Furthermore, SPSS software (version 24; IBM Corp., Armonk, NY, USA) was used to analyze the research data. The significance level in this study was considered at $\alpha = 0.05$.

Results

Mean ± standard deviation of the age of the experimental and control group was 38.6 ± 8.9 and 37.8 ± 6.2 years, respectively. There was no significant difference between the two groups in terms of age ($P > 0.05$). Table 1 shows the mean and standard deviation of craving in the subjects of the experimental and control groups.

After data were collected and coded in the software, they were analyzed. Pretest and posttest scores of food craving for the experimental and control groups were first provided. Descriptive indices, including mean and standard deviations of food craving scores are presented in table 1.

Table 1. Mean and standard deviation of craving in the experimental and control groups

		Groups	N	Mean	SD
FCQ-S	Pretest	tDCS group	12	50.500	3.966
		Control group	12	56.083	5.534
FCQ-S	Posttest	tDCS group	12	36.667	11.452
		Control group	12	54.000	4.767
FCQ-T	Pretest	tDCS group	12	70.917	5.143
		Control group	12	74.833	7.964
FCQ-T	Posttest	tDCS group	12	51.083	14.286
		Control group	12	72.333	4.677

Table 1 shows that the control group's mean pretest and posttest FCQ-S scores were not significant. The mean pretest score was 56.083 ± 5.534, while the mean posttest score was 54.00 ± 4.767. However, the mean posttest FCQ-S score of the experimental group decreased compared to the pretest score of this group, reducing to 36.667 ± 3.966 from 50.500 ± 11.452.

Moreover, the mean pretest score of the control group was 74.833 ± 7.964, while the mean posttest score was 72.332 ± 4.677. However, as stated, the mean posttest FCQ-S score of the experimental group declined compared to the pretest, dropping to 51.083 ± 5.134 from 70.917 ± 14.286.

To examine the research question, ANCOVA was used, and the assumptions were first tested, and the results were later provided. One of the assumptions of the parametric analyses was the normality of the research variable scores. Moreover, Kolmogorov–Smirnov test was used to measure the normality distribution. The results of this test suggested that the variables were normally distributed ($P > 0.05$).

Homogeneity of regression slopes assumption: This assumption requires an equal relationship between the covariate and dependent variables for each group. This assumption is examined by comparing the regression line slopes in the two groups and calculating the F values and their significance. Because the F value for the different regression line slopes of pretest and posttest scores of the research variables between the two groups was 0.05, the regression line slope of these scores between the two groups was not significant, and the homogeneity of the regression slopes assumption was met.

Levene's test was used to determine the homogeneity of variances which yielded no significant difference in the scores variance of the dimensions of FCQs. This is because the significance level of the F value, in this case, was higher than 0.05 ($P < 0.05$), thus confirming the homogeneity of the variance assumption.

Covariance matrix assumption with Box's M value was 3.74. examined for the multivariate analysis of the dimensions of the FCQs, as Box's statistic amounted to 3.74. The F value obtained for this statistic was 0.73, and the significance level of the F value calculated was greater than 0.001 ($P > 0.001$). Thus, the homogeneity of the covariance matrix assumption was met.

ANCOVA was used to examine the research question: Does tDCS training significantly reduce FCQ dimensions among overweight people? The results are given in table 2.

As multivariate ANCOVA assumptions were confirmed, Wilks' lambda value had to be examined, the results of which are given in table 2.

Table 3 shows that the F value obtained from Wilks' lambda is 6.833, where the significance level is less than 0.05 ($P = 0.001$). Therefore, the mean combined scores of food craving dimensions differ significantly between the control and experimental groups. Subsequently, ANCOVA was carried out to understand which of the two dependent variables (FCQ-S and FCQ-T) had significantly changed (Table 3).

Table 2. Multivariate test results on posttest scores of the Food Cravings Questionnaires by controlling the pretest scores

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Observed Power[b]
Pillai's trace	0.418	6.833[a]	2.000	19.000	0.006	0.418	0.872
Wilks' lambda	0.582	6.833[a]	2.000	19.000	0.006	0.418	0.872
Hotelling's trace	0.719	6.833[a]	2.000	19.000	0.006	0.418	0.872
Roy's largest root	0.719	6.833[a]	2.000	19.000	0.006	0.418	0.872

Table 3. Analysis of covariance results on posttest scores of the Food Cravings Questionnaires by controlling pretest scores

Dependent variable		Sum of Squares	df	Mean Square	F	P.	Partial Eta Squared
FCQ-S posttest	Contrast	1003.999	1	1003.999	12.169	0.002	0.378
	Error	1650.068	20	82.503			
FCQ-T posttest	Contrast	1606.151	1	1606.151	13.518	0.001	0.403
	Error	2376.255	20	118.813			

Table 3 shows that for the FCQ-S dimensions, the F value is 12.169, and the significance level is lower than 0.05 (F = 12.169; P = 0.002). Thus, the mean FCQ-S score differed significantly between the control and experimental groups. Generally speaking, tDCS was found to reduce FCQ-S of overweight people, as the Eta squared was 37%. For FCQ-T, the F value was 13.518, and the significance level was less than 0.05 (F = 12.169; P = 0.002). Therefore, the mean FCQ-T score differed significantly between the control and experimental groups. Thus, it was found that tDCS caused FCQ-T to decrease, with 40% Eta squared.

Discussion

The present study was conducted with the aim to determine the effectiveness of tDCS on attentional bias in overweight people. The results indicated that tDCS treatment has been effective on cravings (trait craving and trait craving). This finding is consistent with the results of a study by Brunoni et al. (2013) on the effectiveness of tDCS on reducing depression and a study by Chatroudi (2018) on the effect of tDCS on reducing pain.

In explaining this result, it can be stated that tDCS treatment has high impact on cognition and behavior. The dorsolateral prefrontal area is associated with executive actions in the brain, and craving is one of the dimensions of executive actions. Therefore, electrical stimulation of this area of the brain is used to improve many cognitive and emotional processes and controls, including attention, and reduces behavior. It seems that transcranial stimulation of the brain using the tDCS method can cause changes in the simultaneous activity of nerve cells without a direct change in the action potential during the stimulation time. Experimental studies have shown that electrical stimulation activates the neural pathways of white matter (Brunoni et al., 2013). The relatively extensive brain stimulation by tDCS is an important advantage both in terms of the physiopathological effects that occur primarily at the network level and in terms of the many beneficial effects it produces (Rohner et al., 2018). In this regard, it can be stated that centralized stimulation plays a major role in reducing cravings among overweight people. However, transcranial stimulation of the brain using tDCS can cause this stimulation in the frontal lobe and ultimately improve craving (Chatroudi, 2018).

Nitsche and Paulus (2001) suggested that the effects of a 13-minute tDCS session could last for 90 minutes after stimulation. Fregni et al. (2008) demonstrated that DLPFC simulation using an anode (left) and cathode (right) reduced food cravings. Goldman et al. (2011) suggested that a 20-minute tDCS therapy session on the forehead cortex of healthy people could temporarily reduce food cravings, but increase the (expressed) ability of resistance against food cravings. Kekic et al. (2014) found similar results among overweight women.

In their clinical study, Heeren, De, Koster, and Philippot (2013) found that DLPFC controls attention. Thus, manipulating this area can change how attention is

controlled, as it is one of the major problems of overweight and obese people. Overweight people are distracted with the slightest sign of food, which causes them to overeat. Each method that can improve attention and inhibition in the forehead cortex will also reduce food cravings, thereby reducing weight.

One of the limitations of the present study was the unfamiliarity of many individuals and specialists with this uncommon cranial wall stimulation treatment and as a result the lack of public approval for this type of treatment. Another limitation was the short duration of the study. The limited statistical population of people referring to Royan Clinic in Tehran limits the generalizability of the results of this study to other groups. It is suggested that in future research, the subjects of the control and experimental groups be matched in terms of age, intelligence, and pretest scores. Other psychological variables associated with overweight in individuals should also be treated with cranial wall stimulation. It is recommended that follow-up be performed in future studies to more accurately calculate the duration of treatment. It is suggested that larger samples be used in future research in order to increase the generalizability of the findings. Moreover, more extensive studies are recommended by increasing the number of treatment sessions in this area. Planners and administrators of psychological service centers are advised to use cranial wall stimulation therapies to improve psychological characteristics. Researchers are advised to investigate the effectiveness of cranial wall stimulation therapies on psychological characteristics such as mental health, anxiety, stubbornness, and obsession.

Conclusion

Based on the findings of this study, it can be stated that the treatment of direct current stimulation through the skull was effective on cravings. Therefore, treatment of direct stimulation through the skull can be used as a therapeutic or educational method for the improvement of the condition of overweight people.

Conflict of Interests

Authors have no conflict of interests.

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