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THE EFFECTIVENESS OF TRANSCRANIAL DIRECT-CURRENT STIMULATION (TDCS) ON TEMPTATION CONTROL AND THE CRAVING FOR FOOD IN WOMEN WITH OVERWEIGHT BETWEEN THE AGES OF 30 TO 50 YEARS OLD IN TEHRAN

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Abstract

The aim of this study was to investigate the effectiveness of transcranial direct-current stimulation (tDCS) on the temptation and craving for food in women with overweight aged 30 to 50 years in Tehran. The present study was a trial with a pre-test and post-test design with a control group. The statistical population of the study included all women aged 30 to 50 years who were overweight in Tehran. By targeted sampling, 34 women overweight volunteered to be referred to Mehregan Neurology and Rehabilitation Center for Psychology and Rehabilitation in the winter of 2020. From this sample, 17 people were randomly assigned to the experimental group and 17 to the control group and both experimental groups were first tested. Then, transcranial direct-current stimulation sessions of the brain were performed by tDCS method on the experimental group. After the intervention, both groups were tested. The tools used in this study were the Food Craving Questionnaire-Trait (FCQ-T). The data were analyzed using SPSS-24 software and statistical method of analysis of covariance. The results show that tDCS has reduced the temptation and craving for food in overweight women in their 30^{th} and 50^{th}. Due to the effectiveness of this method in reducing the temptation and craving for food, this method can be used to reduce the craving of obese people and drug usage.

Keywords: Temptation and Craving for Food, Transcranial Direct-Current Stimulation, Overweight

Introduction

The prevalence of obesity has increased in recent years in different countries of the world, including Iran (Moghimi Dehkordi, Safayei, Vahedi, Pourhosseingholi, Pourhosseingholi and Zali, 2012) and due to the association of obesity with various diseases and mortality, efforts to reduce it has become an important issue in the field of health in worldwide level (Ng and Davis, 2013). Despite the etiology, this disorder is highly ambiguous. But it has generally been attributed to an imbalance between energy intake and its consumption and the complex interaction between genes and the environment (Ogden, 2014). On the other hand, there are some factors that cause the weight to return after losing weight; such as the intersection of biological mechanisms such as increased metabolic efficiency, changes in endocrine signaling (e.g., decreased satiety signaling), changes in the neural responsivity of food symptoms (e.g., reward-dependent increases or anticipatory responsivity decreases), and consumption of food (for example, getting used to the pleasurable aspects of food). Thus, bio-stresses thwart weight loss efforts and increase the likelihood of re-gaining weight (Ochner, Barrios, Lee, & Pri-Sunyer, 2013). The World Health Organization (WHO) reports overweight as one of the most common health concerns and has announced its prevalence about 60% of the population (Sénéchal et al., 2011). In Iran, it has been observed that a high percentage of residents of large cities are overweight. It is estimated that 19 million people in the country are overweight (Samiʿi Rad, Ziyaei, Ghanbariyan, Mirmiran, Momenan and Azizi, 2012).

In an effort to understand the determinants of overeating, researchers have increasingly focused on more specific eating structures such as craving for food. Craving can be defined as a physiological or psychological motivational

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state that enhances material-seeking and swallowing behaviors toward food or substances. An influential hypothesis in the research literature of craving for food is that craving arises from the need to compensate for physiological deficiencies (e.g. energy depletion). It seems that the assumption is rooted in the observation that craving is often limited to certain foods and that eating such substances can compensate for nutritional deficiencies. However, the infrastructure of craving for food does not seem to be purely biological. While craving for food may compensate for hemostatic problems. For example, problems can compensate for magnesium levels in women who are menstruating, but different substances can be used to compensate for physiological deficiencies. While there is no craving for them (Baker, Morse and Sherman, 1986; Weingarten and Elston, 1990; Rozin, Levine and Stoes, 1991; Abraham, 1984; quoted from Kachuyi and Ashrafi, 2016). Many researchers underestimate the role of biological effects in the phenomenon of craving and consider psychological processes as the cause of craving (Gendall, Sullivan, Joyce and Bulik, 1997). Nowadays, eating due to the response to external stimuli has become important because of providing the right conditions and environment for obesity. According to existing theories, eating due to an uncontrollable sense and in response to external factors plays an important role in craving. In other words, eating food in such individuals actually acts as a regulator of emotion or stress (Wolz, Fagundo, Treasure, & Aranda, 2015).

One of the most important causes of overeating and obesity is a disturbance in the activity of the brain's dopamine reward circuit (Volkow, Wang, Fowler, Thomasi, & Baler, 2012). Overweight people tend to be more active in the inhale, gastrointestinal tract (anterior insula and frontal operculum) and sensory-motor areas (oral somatosensory regions and parietal operculum) when predicting the intake of delicious food. (Stice, Spoor, Bohon, Veldhuizen and Small, 2008). Thus, one approach to regulate food craving can be described as changing the Dorsolateral Prefrontal Cortex (DLPFC) (Fregni et al., 2008). Recently, brain stimulation interventions have sought to prevent relapse by considering the role of important brain regions involved in craving for food and substances (Goldman et al., 2011; Boggio et al., 2006; Feil et al., 2008). Various studies have shown that the frontal cortex regulates craving and the Dorsolateral Prefrontal Cortex. Direct electrical stimulation of the brain is safe, painless and without side effects (Feil and Zangen, 2010). The tDCS is performed in such a way that a very weak direct electric current (about 1 to 3 mA) is applied to the scalp by the two electrodes on the surface of the cathode and anode, which leads the current flowing from the anode electrode to the cathode electrode. Because direct current polarizes rather than stimulates with discrete impulses, its activity directly fires action potentials in cortical neurons (Sánchez-Kuhn, Pérez-Fernández, Cánovas, Flores, and Sánchez-Santed, 2017). On the other hand, clinical studies by Heeren, Reese, McNally, and Philippot (2013) show that DLPFC is the site of attention control. So manipulating this area can lead to a change in attention control. A non-invasive method such as direct stimulation of the skull using transcranial Direct Current Stimulation (tDCS) is used to regulate and moderate DLPFC activity. In this method, large electrodes are placed on the head that pass a continuous and light electric current through the desired areas. The effectiveness of tDCS depends on the direction of the electric current. Anodal stimulation increases brain activity and arousal, and cathodal stimulation, in turn, decreases activity (Nitsche, Liebetanz, Antal, Lang, Tergau, & Paulus, 2003). In this way, because the brain area related to the craving for food is directly stimulated and on the other hand, the effectiveness of this method in reducing cravings for drugs (Boggio et al., 2006) and food consumption (Goldman et al., 2011) has received increasing attention.

Taherpour, Rostami and Rahimnejad (2019), in a study showed that the combination of mindfulness exercises and electrical stimulation significantly reduced the scores of craving for drug. Forough, Yousefi, Moradi, Rumizadeh and Khairullah (2018), in a study examined a sample of patients with food craving. After the intervention, the mean score of the experimental group in controlling craving was significantly lower than the control group. Khosravian and Soleimani (2015), in another study found that direct extracorporeal electrical stimulation can reduce craving for consumption and increase cognitive self-control in substance abusers. The results of Narimani, Pour Ismaili, Alizadeh Goradel and Molaei (2016) showed that this method is effective in reducing craving and depression in people taking tramadol. The results of Shamalizadeh (2016) study were that direct stimulation of reward orbit and decision making related to the forehead part led to a decrease in craving. Research by Trojek et al. (2016) showed that direct extra-cortical direct electrical stimulation can reduce alcohol consumption in patients. Research by Wietschorke, Lippold, Jacob, Polak, and Hermann (2016) showed that direct extra-cortical electrical stimulation of the prefrontal cortex significantly reduces alcohol craving and their treatment. Batista, Klauss, Fregni, Nietzsche, and Nakamura-Palacios (2015) showed that five daily sessions of tDCS treatment reduced craving in former crack-cocaine users. Dan Uyl, Gladwin, and Weirs (2015) showed in their study that a ten-minute session of tDCS can reduce post-session alcohol craving. In a study of cannabis users, Boggio, Zaghi, Villani, Fecteau, Pascual-Leone, and Fregni (2010) found that tDCS reduced appetite by placing the anode on the posterior cortex of the right forearm and the cathode on the posterior cortex of the left forearm. .

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So far, limited studies have been performed to evaluate the effectiveness of tDCS in controlling and reducing craving for foods in overweight people. These early studies have shown the effectiveness of this method in controlling craving and food temptation. Due to the significant effects of tDCS on the cerebral cortex, this treatment can affect the temptation and craving for food. Therefore, the researcher in the present study sought to determine whether tDCS is effective in temptation and craving for food in overweight women aged 30 to 50 years?

Research method

The present study was an experimental study with pre-test and post-test with control group, with random replacement of subjects in experimental and control groups. The statistical population of the present study included all overweight women aged 30 to 50 years in Tehran. The sample consisted of 40 overweight women who volunteered to refer to Mehregan Psychiatric and Neurological Rehabilitation Center in the winter of 2019 who were invited to participate in the study and they were examined and matched in terms of demographic variables including age, height, weight, history of obesity and other physical and psychological disorders. The sampling method in the present study was purposeful. Subjects were matched based on age and BMI and were divided into two experimental and control groups of 20 people in each group and both groups were pre-tested. Then, direct electric shock intervention sessions were performed on the experimental group. Direct stimulation of the skull using transcranial direct current stimulation (tDCS), which is a simple tool used in this method, which includes sponge electrodes with an area of 35 cm^2 (7 x 5) that is impregnated with saline and placed on the person's head and the device, which is an electric current generator powered by a 9-volt battery passes a continuous, light current of up to 4 mA through head. For the experimental group, the electrical stimulation intervention was performed five times a week (10 times a month), then the first month once a week (4 times a month), the second month once every two weeks (twice a month); the second month was performed once every two weeks (twice a month) and the third month until the end of the sixth month once a month. The control group did not receive any intervention. After the intervention sessions, post-test was performed on both groups. It should be noted that 3 people in the experimental group were dropped and 3 people were randomly excluded from the control group. The final sample consisted of 34 people (17 people in the experimental group and 17 people in the control group). Inclusion criteria include having a body mass index between 25 and 40, age between 30 and 50 years, not using other treatment methods for obesity such as medication and not having morbid or obese obesity due to physiological (hormonal or metabolic) reasons and exclusion criteria including reluctance to continue attending the study, incomplete completion of the questionnaires and being under psychiatric treatment and having a serious medical condition other than obesity.

Research tools

Demographic Status Questionnaire: This questionnaire contains questions about name, surname, height, weight, history of physical and psychological illness, history of drug use, history of treatments received in the past to reduce food craving designed by the researcher. This form was provided by the staff of the clinic admission department to the referring volunteers and after a brief explanation about the form, they were asked to complete the form. Then, the person referred to the researcher with the completed form and his information was carefully examined in order to have the criteria for entering the project.

Food Craving Questionnaire-Trait (FCQ-T): This questionnaire was designed by Cepeda-Benito, Gleaves, Williams, and Erath (2000) and consists of 39 items and measures the intensity of food craving in a multidimensional level. Answers are scored on a six-point Likert scale from never (1) to always (6). This questionnaire has 5 dimensions: lack of control over eating (lack of control), thoughts or mental occupation with food (thoughts), hedonistic hunger, emotions that may be experienced later or during craving for food or eating (excitement) and guilt over craving or giving in food (sin). The total score of the questionnaire ranges from 39 to 234. In Kachuyei and Ashrafi (2016) research, the apparent and content validity of this scale was confirmed using the opinion of professors and experts and the construct validity was confirmed using factor analysis test. The reliability of the questionnaire was obtained using Cronbach's alpha for all dimensions above 0.65. In the present study, the reliability of this questionnaire was obtained using Cronbach's alpha of 0.77 which indicates the reliability of this tool in the research sample.

Findings

Table 1 shows the mean and standard deviation of the participants' scores in the pre-test and post-test stages.

Table 1. Mean and standard deviation of participants' scores in research variables in pre-test and post-test

Post-test		Pre-test		Group	Variable
Standard deviation	Mean	Standard deviation	Mean		
5/62	30/82	11/89	50	Experimental	**Lack of control**

9/27	47	8	52/47	Control	
6/15	22/17	6/48	35/47	Experimental	**Mental employment**
6/37	32/82	6/10	36/64	Control	
6/89	31/82	8/03	47	Experimental	**Hedonistic Hunger**
6/16	42/17	4/58	49/94	Control	
4/04	11/70	5/50	17/94	Experimental	**Excitement**
3/58	17/11	3/12	19/41	Control	
1/86	12/88	3	8/94	Experimental	**Feeling guilty**
2/71	9/11	3/09	8/70	Control	
17/85	109/41	25/60	159/35	Experimental	**Total**
17/23	148/23	17/23	154/17	Control	

As it can be seen in Table 1, the mean and standard deviation of the total score of craving for food-trait in the pre-test stage were 159.3 and 25.60 in the experimental group and 154.17 and 17.23 in the control group, respectively, and in the post-test stage in the experimental group it was 109.41 and 17.85, respectively, and in the control group it was 148.23 and 17.23, respectively. Kolmogorov-Smirnov test was used to check the normality of the scores, the results of which are shown in Table 2.

Table 2. Results of Kolmogorov-Smirnov test for research variable in pre-test and post-test stage

Post-test craving for food-trait	**Pre-test craving for food-trait**	**Results**	
0/11	0/07	**positive difference**	**Absolute value of the proportions difference**
-0/07	-0/09	**Negative difference**	
0/11	0/09	**Kolmogorov-Smirnov Statistics**	
0/200	0/200	**Significance level**	

Levin test was used to evaluate the homogeneity of variance of variables. Table 3 shows the results of the Mbox tests and the homogeneity of Levin variance between the dependent variables of the study.

Table 3. Results of Mbox test and Levin test to equal the error variance of dependent variables in experimental and control groups

p	F	df2	df1	Mbox	**dependent variable**
0/974	0/01	32	1	1/42F= 0/128P=	**Lack of control**
0/297	1/12	32	1		**Mental employment**
0/608	0/26	32	1		**Hedonistic Hunger**
0/423	0/65	32	1		**Excitement**
0/684	0/16	32	1		**Feeling guilty**

The results in Table 3 show that Levin test is not significant in the absence of control, mental occupation, hedonistic hunger, excitement and guilt. Thus, the variance of post-test error of the experimental and control groups is not significance in lack of control, mental occupation, hedonistic hunger, excitement and guilt sense. Therefore, the variance of post-test error of the experimental and control groups is not significantly different in lack of control, mental occupation, hedonistic hunger, excitement and guilt. And the assumption of homogeneity of variances is confirmed. Also, Mbox test was performed to investigate the condition of matrix-covariance homogeneity, which this condition has been observed due to its lack of significance in this study ($p \geq 0.128$, $F = 1.42$). To investigate the effect of experimental intervention, multivariate and univariate analysis of covariance on post-test scores of the groups was performed by controlling the pre-test of dependent variables. Table 4 shows the results of multivariate analysis of covariance on post-test scores by controlling pre-test variables of research dependent variables.

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Table 4. Results of multivariate analysis of covariance for comparing post-test scores of research variable in experimental and control groups

)p(	df Error	df Hypothesis	F ratio	Value	Test
0/001	23	5	20/20	0/81	**Pillai's Trace**
0/001	23	5	20/20	0/18	**Wilk's Lambda**
0/001	23	5	20/20	4/39	**Hotelling's Trace**
0/001	23	5	20/20	4/39	**Roy's Largest Root**

The contents of Table 5 show that there is a significant difference between the experimental and control groups in terms of at least one dependent variable. Table 6 shows the results of univariate analysis of covariance on post-test scores with pre-test control of research-related variables (lack of control, mental occupation, hedonistic hunger, excitement and guilt).

Table 6. Results of univariate analysis of covariance for comparing the post-test scores of research dependent variables in experimental and control groups

Test power	Trace size	p	F	Mean squares	df	Total squares	Dependent variable
1	0/59	0/001	39/62	1960/21	1	1960/21	**Lack of control**
1	0/68	0/001	59/54	769/48	1	769/48	**Mental employment**
1	0/57	0/001	37/10	994/14	1	994/14	**hedonistic hunger**
0/97	0/38	0/001	16/63	183/32	1	183/32	**Excitement**
1	0/55	0/001	33/74	119/64	1	119/64	**Feeling guilty**

The results in Table 6 show that univariate analysis of covariance are significant for lack of control (F = 39.62 and P = 0.001), mental employment (F = 59.54 and P = 0.001), hedonistic hunger (F = 37.10 and P = 0.001). Excitement (F = 16.63 and P = 0.001) and feel guilty (F = 33.74 and P = 0.001). Therefore, the research hypothesis is confirmed.

Conclusion

The aim of this study was to investigate the effectiveness of transcranial stimulation of the brain on the temptation and craving for food in overweight women aged 30 to 50 years in Tehran. The results of testing this hypothesis with the results of research by Taherpour et al. (2019), Forough et al. (2018), Khosravian and Soleimani (2018), Narimani et al. (2015), Shamalizadeh (2016), Trojak et al. (2016) Et al. (2016), Batista et al. (2015), Dan Yeville et al. (2015) and Boggio et al. (2010) are consistent. A logical conclusion about some form of treatment for craving for certain foods is that manipulating brain activity can lead to a return to balance in the desired brain cycles and lead to significant behavioral improvements. Some studies have shown a substantial reduction in craving for food through electrical stimulation-based interventions in some areas of the brain aimed at increasing the activity of the dorsolateral prefrontal cortex (Fregni et al., 2008). Explaining this finding, it can be said that since studies have shown that the anterior cingulate, nucleus amygdalæ, insular cortex, and lateral dorsal and forehead cortices are consistent with craving and are in fact one of the most important areas involved in predicting symptom dependence and drug planning or the consumption of food and drug is extracranial stimulation. Moderation of activity in this area (left and right lateral dorsal forearm) with the help of transcranial electrical stimulation method reduces craving. The main evidence points are due to sharing of mechanisms of food craving and drug addiction. Drug craving and addiction are likely to be affected by endogenous opioids, serotonin and dopamine in the brain in similar ways (Pelchat, 2009). Based on this, it is possible that direct electrical stimulation from the skull at the level of neuronal activity, by applying a slight direct current to the head, causes an immediate change in the frequencies and electrical waves of the brain by changing the release of serotonin and dopamine. Positive stimulation depolarizes local neurons. This means that by changing their voltage by 5 to 10 microvolts, the neurons bring these regions from the potential state with a voltage of 65 microvolts to 55 microvolts. As a result, neurons need less input through their dendrites to begin activity. The negative electrode also slightly hyperpolarizes the neurons, and as a result, the neurons need more inputs to start activity (Zilabi Sandegani, 2016). Transcranial stimulation in various studies has been identified as modifier of perception and knowledge and behavioral performance. What exactly is going on in the brain during extracranial stimulation has remained unclear. However, experiments on animals, humans, and even evidence recorded directly from the neurons of the tested cases provide a general explanation. The anode (negative

pole) is where the electrons enter the brain. The cathode (positive pole) is where electricity leaves the brain. Therefore, when electrons accumulate to enter the exciter electrode, a negative charge is created below the exciter cathode. A smaller cathode can deliver a more concentrated load to the desired area of the brain, and this is when it has accumulated more load at the exit door. Thus, the size of the affected area of the brain can be shaped or controlled by changing the size of the cathodal electrode or by changing the size or location of the anodal electrode (Jackson et al., 2016). Boggio et al. (2010) concluded that tDCS reduces craving by placing the anode on the right DLPFC and the cathode on the left DLPFC. Continued consumption causes nervous adaptation and reduced sensitivity. These adaptations eventually lead to the phenomenon of tolerance as well as craving during the abstinence period. In terms of mechanism of action, it is assumed that tDCS is effective by affecting the dopaminergic pathway and improving patients' cognitive function. The use of tDCS in the DLPFC region reduces risky behavior and arousal and can improve tolerance toward craving. tDCS can increase response inhibition (Stramaccia et al., 2015). Hogeveen et al. (2016) showed that tDCS can increase response inhibition, both in high quality and routine. tDCS can also reduce risk-taking behavior (Facto et al., 2007).

One of the limitations of this study is the lack of sufficient and reliable information from the subjects, which in some cases causes the non-cooperation of eligible subjects. It was observed that some of the subjects experienced stress and anxiety during the performance, which prevented the subject from focusing enough attention on the intervention and testing process. The present study was performed on women aged 30 to 50 years. Therefore, the results of this study are not generalizable to men and people outside this age range. He pointed out the lack of instrumentation to measure craving level, such as the saliva level. It is suggested that the research be conducted with a larger number of subjects in both groups of men and women. Increase the number of intervention sessions and present it as a scheduled intervention protocol over a period of time. It is suggested that future researchers examine the electrical stimulation of the brain on craving for a variety of foods such as fat and glucose separately. Considering the bio-psycho-social model, it is suggested that in addition to the new biologic therapies of which the present study is an example, individual psychotherapy and group therapy be used. According to the results of this study, which showed that direct electrical stimulation from the skull temporarily reduces food craving, it is suggested that this treatment with more sessions along with other psychiatric and pharmacological treatments be used for obese patients or people with craving.

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