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The Effect of Transcranial Direct Current Stimulation on Self-Esteem and Weight: A Pilot Study on Overweight Individuals

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ABSTRACT

Background: Low self-esteem and overweight are significant factors that can affect mental health and quality of life. Transcranial direct current stimulation (tDCS), as a non-pharmacological method, has the potential to affect physical and psychological health. The present study aimed to investigate the effect of tDCS on self-esteem and weight reduction in overweight individuals.
Methods: This quasi-experimental study was conducted using a pretest-posttest design with a control group. A total of 24 men aged 20 to 40 years from gyms in Mashhad were selected through purposive sampling in 2024 and randomly assigned to experimental and control groups. The study utilized the following tools for data collection: demographic form, Eysenck Self-Esteem Questionnaire, and body mass index (BMI) measurement. Both groups participated in standard physical fitness training; however, the experimental group additionally received anodal tDCS (2 mA, 20 minutes per session, for 10 consecutive sessions). The control group received a sham stimulation protocol. Data were analyzed using one-way ANCOVA in SPSS-21.
Results: The findings indicated a significant difference in self-esteem between the two groups after controlling for the pretest effect ($P = 0.004$, $F = 10.39$). The effect size of tDCS on self-esteem was 33%, suggesting a moderate impact. However, the effect of tDCS on BMI was minimal and did not lead to significant weight reduction.
Conclusion: The results suggest that tDCS, in combination with physical exercise, can have a positive impact on self-esteem in overweight individuals, but does not significantly contribute to weight loss. Further research is recommended to explore long-term effects of this intervention.

Keywords: Transcranial Direct Current Stimulation, Self-Esteem, Body Mass Index, Overweight, Physical Fitness Training

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Introduction

Overweight is an increasingly prevalent public health issue worldwide. Evidence suggests that physical activity can reduce the risks associated with being overweight (Philuek et al., 2025). In this regard, a survey conducted in the United States indicated that the rate of physical inactivity increased from 5.6% in 2003 to 21.2% in 2018. This alarming trend can lead to obesity and cardiovascular diseases (Khamsai et al., 2021; Soontornrungsun et al., 2020; Thanachai et al., 2020). Furthermore, the World Obesity Federation estimated in a 2020 study that approximately 175 million children aged 5 to 19 years worldwide are living with obesity. These data indicate a rising trend in obesity prevalence (Colombo et al., 2025; Johnson et al., 2015). Studies have shown that individuals with excess weight are at a higher risk of developing eating disorders and irregular eating behaviors (Duncan et al., 2017; Nagata et al., 2018). Additionally, the World Health Organization (WHO) has reported that obesity and overweight have tripled over the past 48 years, leading to approximately 2.8 million deaths annually (Ojukwu et al., 2025).

On the other hand, physical activity positively affects self-esteem by encompassing four key domains: motor skills, physical condition, physical fitness, and physical attractiveness (Sonstroem & Morgan, 1989). Body satisfaction is affected by various social factors, including media, society, friends, and family (Lowery et al., 2005). Recent studies have indicated that body dissatisfaction in adolescents is associated with unhealthy weight, with contributing factors such as decreased physical activity, ineffective exercise, and increased computer use (Gillison et al., 2006; Portela-Pino et al., 2024). In fact, athletes engaged in team sports had higher self-esteem compared to those in individual sports and considered their friends as their primary social support. Among various approaches, research has suggested that stimulation of the dorsolateral prefrontal cortex (DLPFC), which enhances control over food cravings, could be an innovative method for treating obesity (Gluck et al., 2017). In recent years, transcranial direct current stimulation (tDCS) has gained considerable attention as a therapeutic approach (Brunoni et al., 2012; Hajloo et al., 2019). This technique involves applying a low-intensity current (≤2 mA) through the scalp (Shiasy et al., 2020). Evidence suggests that DLPFC stimulation via tDCS can reduce appetite, subsequently leading to decreased food consumption (Anderson et al., 2023; Mostafavi et al., 2020).

In this regard, Mostafavi et al. (2020) indicated that tDCS significantly reduces food craving and energy intake, particularly when targeting the DLPFC. Multisession bilateral stimulation with a current intensity of 2 mA is recommended for optimal results. Moreover, in a meta-analysis, Liu et al. (Liu et al., 2024) examined whether real tDCS applied during physical exercise could enhance muscle strength compared to sham tDCS. Their findings revealed that cortical excitability increased in both real and sham stimulation groups; however, in the real tDCS group, lower limb muscular strength and explosive power were significantly improved. Tabasi et al. (2024) also investigated the effects of Omega-3 combined with DLPFC stimulation via tDCS on depression and obesity. Their findings indicated that neither Omega-3 nor tDCS alone had a significant impact on executive functions, depression, food cravings, or weight in experimental groups compared to the control group. However, the interaction of these two factors led to improvements in executive functions and a reduction in food cravings, making it an effective strategy for weight management.

Given the above considerations, obesity and overweight are not only global health concerns, but also have profound psychological impacts, including reduced self-esteem and increased social anxiety. Since self-esteem plays a crucial role in health-related behaviors, identifying innovative strategies to improve it in overweight individuals is essential. In recent years, tDCS has emerged as a non-invasive method for modulating cortical

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activity, with evidence suggesting its effectiveness in regulating appetite and eating behaviors. However, few studies have explored the impact of this technique on self-esteem and weight reduction. Therefore, the present study aimed to provide new insights into the use of tDCS as a complementary intervention for enhancing both psychological and physical health in overweight individuals.

Methods

The present study was a quasi-experimental research with a pretest-posttest design involving an experimental and a control group. In terms of purpose, it was considered an applied study. The statistical population included all men aged 20 to 40 who had recently started exercising in bodybuilding gyms in Mashhad in 2024.

After obtaining approval from the University of Tehran and receiving an ethics code from the Ethics Committee of the Institute of Physical Education and Sports Sciences, the study was implemented. To recruit participants, researchers visited two sports centers in Mashhad and conducted sampling based on the study criteria. Due to accessible geographical conditions, cooperative management, time and financial constraints, as well as the similarity in services and sports equipment, two gyms in Mashhad (Smart Gym and Dr Amin Zahedi Progym) were selected. The sample size was determined using the G-Power software (effect size $f = 0.30$, $\alpha = 0.05$, power = 0.80, number of groups = 2, number of covariates = 1), and a total of 24 eligible participants were selected through purposive sampling. The selected individuals were then randomly assigned to either the experimental or control group. The inclusion criteria were being male, not having engaged in physical exercise in the past two years, training in a gym for less than one month, having a body mass index (BMI) above 25, and scoring 10 or lower on the Eysenck Self-Esteem Questionnaire. The exclusion criteria included unwillingness to continue participation, sustaining an injury during the study (to the extent that continuing the intervention would be harmful), and having a history of seizures.

Following group allocation, an orientation session was held for the participants, explaining the research procedure, objectives, and the importance of their participation. Participants also received detailed information about the intervention process and expectations. At the end of this session, a pretest was administered to assess the study variables for all participants. Subsequently, all participants in both groups (intervention and control) followed a standardized physical fitness training program, consisting of three 60-minute sessions per week. These training sessions included:

- Warm-up (20 minutes): Aerobic exercises and dynamic stretching
- Main exercises (35 minutes): Bodyweight exercises, barbell, and dumbbell training
- Cool-down (5 minutes): Static stretching exercises

In addition to these training sessions, the intervention group underwent anodal tDCS. The stimulation was applied at an intensity of 2 mA for 20 minutes over 10 consecutive sessions. Electrodes were positioned according to the"10-20 EEG system", with the anode (positive electrode) placed over F3 and the cathode (negative electrode) over Fp2. Conversely, the control group received a sham stimulation protocol. In this method, participants initially received a 2 mA current for 15 seconds, but after this period, no current was applied, even though the device remained on and the electrode pads were placed on their heads. This approach was designed to create an experience similar to the intervention group and control for potential placebo effects. At the end of the 10-session intervention, all participants completed the posttest questionnaires to evaluate the effects of the intervention on the studied variables.

Data Collection Instruments: The data collection instruments used in this study included a consent form and demographic questionnaire, the Eysenck Self-Esteem Questionnaire, Body BMI measurement, and the Neurostim-2 tDCS.

Consent Form and Demographic Information:

At the beginning of the study, participants completed a consent form along with a researcher-designed demographic questionnaire. This questionnaire collected descriptive and demographic information such as educational level, sports history, age, height, and weight.

Eysenck Self-Esteem Questionnaire: The Eysenck Self-Esteem Questionnaire (Eysenck, 1976; cited in Biabangard, 1994) consists of 30 items with response options of "Yes," "No," or "?", where "?" scored as 0.5 points. "Yes" or "No" responses are scored as 1 point depending on the item: "Yes" is scored for items 1, 2, 5, 9, 10, 11, 16, 22, 23, 29, 30, while "No" is scored for items 3, 4, 6, 7, 8, 12–21, 24–28. The total score ranges from 0 (minimum) to 30 (maximum), with higher scores indicating higher self-esteem levels. This scoring system ensures clarity and consistency in quantifying participants' self-esteem based on their responses. Regarding the construct validity of this test among students at Shahid Chamran University, a Cronbach's alpha of 0.74 was reported for male students and 0.79 for female students. Additionally, concurrent validity with Ahvaz Self-Esteem Scale was r = 0.79 for females and r = 0.74 for males, both significant at p< 0.001. These results confirm the satisfactory psychometric properties of the instrument (Soleymani, 2022).

BMI Measurement: In this study, BMI was used as an indicator of obesity. BMI was calculated using the following formula: BMI= $Weight\ (kg) / Height\ (m)^2$

A BMI value within 20-25 is considered normal, whereas values below 20 indicate underweight, above 25 indicate overweight, and above 30 indicate obesity (Soleymani, 2022).

Neurostim-2 tDCS Device: The Neurostim-2 device, developed by MedinaTeb Research and Development Group, was introduced to the market in 2015 as Iran's first industrially manufactured tDCS system. This device has undergone extensive safety and clinical testing and is certified under BS EN 60601-1:2014 standards. The device has demonstrated high reliability in controlled laboratory settings and met international medical device safety standards. Previous studies utilizing tDCS have shown significant test-retest reliability (ICC = 0.85–0.92) when applied under standardized protocols (Nitsche et al., 2008).

Data analysis

In this study, data were analyzed using SPSS version 21 through measures of central tendency and dispersion, as well as the creation of tables and charts. Initially, the Kolmogorov-Smirnov test was conducted to assess the normality of the data distribution. Given the normal distribution of the study variables and the homogeneity of variances, one-way analysis of covariance (ANCOVA) was applied for between-group comparisons. The significance level in this study was set at $\alpha = 0.05$.

Results

The mean and standard deviation of the participants' age in the present study were 26.32 ± 6.78. The pre-groups were similar in terms of age and socioeconomic status. Figure 1 shows mean scores of BMI and self-esteem in both pre-test and post-test conditions for research groups.

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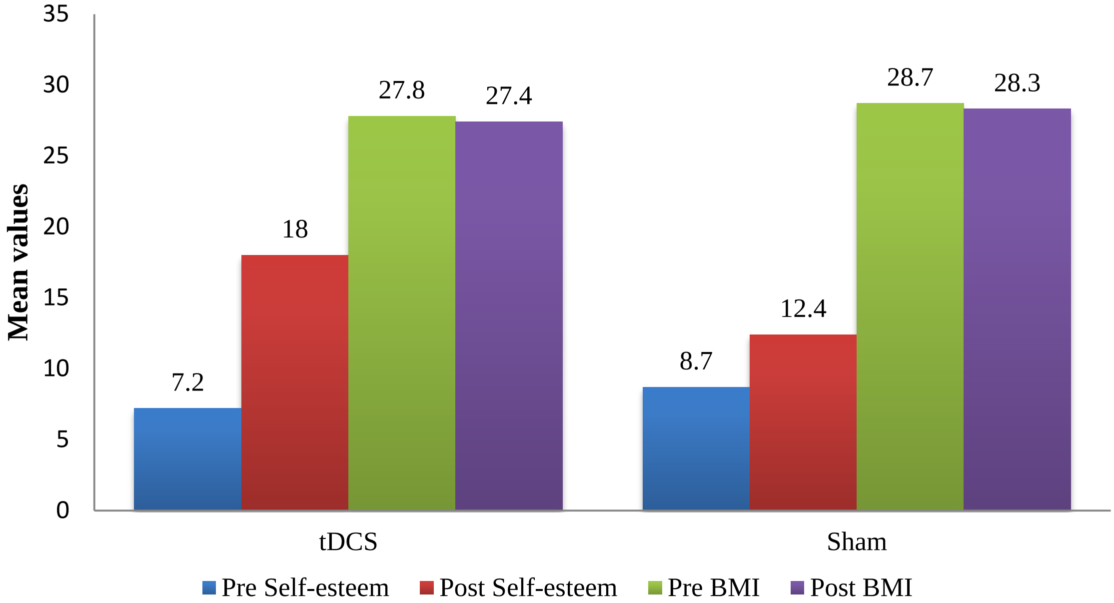

Chart 1. Comparison of Self-esteem and BMI before and after intervention

According to Figure 1, it appears that self-esteem increased in both groups after one month (in post-test phase), while BMI did not significantly decrease in either tDCS or Sham groups. The parametric assumptions of data were then examined. Results of the Kolmogorov-Smirnov test for normality showed no significant difference between the distribution of BMI and self-esteem scores across the two groups (experimental and control) ($P > 0.05$). This indicates that data did not exhibit substantial dispersion and followed a normal distribution. Furthermore, Levene's test values for BMI and self-esteem scores were not significant ($P > 0.05$). Therefore, the variance of scores for both experimental and control groups regarding primary variables of the study was homogenous. As a result, the assumption of using Analysis of Covariance (ANCOVA) in data was confirmed.

Table 1 shows the results of ANCOVA, indicating that after controlling for pre-test variable, with $F_{(1, 21)}= 10.39$ and $P= 0.004$, there was a significant difference in the adjusted mean self-esteem scores of participants based on group membership (experimental and control). The effect size of tDCS on self-esteem was 33%. Therefore, with 99% confidenceit can be stated that tDCS significantly improved self-esteem in overweight individuals, and the effect of the treatment was moderate.

Table 1 also reveals that after controlling for the pre-test variable, with $F_{(1, 21)} = 0.13$ and $P= 0.72$, no significant difference was found in the adjusted mean BMI scores between groups based on group membership (experimental and control). The effect of tDCS on BMI was negligible. Therefore, with 99% confidenceit can be stated that tDCS did not improve BMI in overweight individuals (Table 1).

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Table 1. ANCOVA results for effects of tDCS on self-esteem and BMI

Variables	Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Self-esteem	Intercept	305.88	1	305.88			
	Group	172.89	1	172.89	18.39	*0.0001	0.47
	Error	349.27	21	16.63	10.39	*0.004	0.33
BMI	Intercept	0.10	1	0.10			
	Group	0.05	1	0.05	0.27	0.61	0.01
	Error	7.43	21	0.35	0.13	0.72	0.006

* Computed using alpha = 0.01

Discussion

The present study aimed to examine tDCS effects on self-esteem and weight reduction inoverweight individuals. Findings revealed that tDCS-based intervention led to a statistically significant improvement in participants' self-esteem, with a moderate effect size. This result is clinically relevant, indicating that brain stimulation can be utilized as an adjunctive approach for enhancing psychological indicators such as self-esteem in at-risk populations, including overweight individuals. These findings align with those reported by Ghanbari and Asgari (2020), who demonstrated the effectiveness of tDCS combined with cognitive-behavioral therapy in reducing attentional bias toward food in overweight individuals. Their study suggested that brain stimulation can modulate cognitive-emotional tendencies related to overeating, which may, in turn, contribute to improvements in psychological outcomes such as self-esteem. The consistency between the current findings and prior evidence highlights the potential role of tDCS in promoting cognitive and emotional self-regulation in this population.Moreover, results are indirectly consistent with findings of Harris and Orth (2020) who analyzed data from over 68,000 participants and concluded that self-esteem and social relationships are reciprocally linked and remain stable throughout developmental stages. Therefore, it can be inferred that interventions aimed at enhancing self-esteem via neuromodulation might not only affect self-concept but also have broader social and interpersonal implications. Such insights open new avenues for designing integrative psychotherapeutic interventions that incorporate neuromodulation technologies.

The DLPFC, targeted by tDCS, regulates emotions, self-evaluation, and cognitive control, enhancing positive self-concept and reducing negative thoughts in overweight individuals. tDCS mitigates cognitive biases and improves emotional regulation, response inhibition, and attention, addressing maladaptive behaviors like overeating. By reducing self-criticism and strengthening self-regulation, tDCS fosters improved self-esteem in this population. From a behavioral perspective, tDCS may reinforce neuronal pathways associated with successful healthy behaviors, such as controlled eating or increased physical activity, by encoding them as rewarding experiences. This reinforcement strengthens the link between effort, success, and self-worth, fostering a cycle of improved self-esteem. The effects of tDCS on self-esteem result from a complex interplay of biological, cognitive, and behavioral factors. Thus, brain stimulation can be integrated into psychotherapeutic approaches for overweight individuals, supporting both neurobiological reorganization and positive psychological development.

Other findings of this study showed that despite the application of tDCS interventions, no significant changes were observed in BMI among participants. This result is consistent with some previous research that has questioned the direct effect of tDCS on weight reduction or physiological markers such as BMI. For instance, the study by Baianoet et al. (2014) found no significant difference between real and sham tDCS in reducing food cravings in overweight individuals. Similarly, the results of Beaumontet et al. (2021)indicated that tDCS did not exert a specific effect on food cravings, hunger, or eating behavior—factors that are essential prerequisites for observable changes in BMI.

Weight loss is a complex process affected by neural, cognitive, behavioral, metabolic, and environmental factors, making neuromodulation like tDCS insufficient on its own to induce significant BMI changes. While tDCS may enhance cognitive control and reduce cravings, it must be combined with dietary, physical activity, and habit modification strategies for meaningful outcomes. Lack of BMI change in this study could also result from the short intervention duration, as sustained weight reduction typically requires 8–12 weeks of comprehensive interventions. Moreover, uncontrolled lifestyle variables and over-reliance on neuromodulation likely limited the results. Therefore, integrating tDCS with longer-term, multifaceted approaches are essential for achieving substantial weight loss effects.

Nevertheless, several studies (Afzali et al., 2021) have reported that tDCS may significantly affect cognitive variables related to eating behavior (e.g., food craving, attentional bias, and urges). These findings suggest that while tDCS may lay the cognitive and emotional groundwork for behavioral change, its translation into physiological outcomes like weight loss requires sustained intervention, multimodal approaches, and long-term follow-up. Overall, the body of evidence indicates that in clinical interventions targeting weight loss, tDCS is most effective when used as an adjunct to behavioral, nutritional, and physical strategies. Future interventions should consider designing multidimensional and integrative approaches to maximize the therapeutic potential of neuromodulation in obesity treatment.

Strengths of the current study include the quasi-experimental design with a control group, randomized allocation, and the use of non-invasive tDCS alongside physical training, which provided a scientific framework for examining the simultaneous effects of physiological and psychological interventions. The use of ANCOVA to control for pretest scores increased the accuracy of statistical analysis. However, the study faced limitations, such as a relatively small sample size, restriction of participants to physically active men, and short duration of the intervention, which may limit the generalizability of the findings. Moreover, lack of long-term follow-up precludes conclusions regarding the sustainability of the observed effects.

Conclusion

Based on the findings of this study, it can be concluded that tDCS, when combined with physical exercise, can significantly enhance self-esteem in individuals with overweight. This effect highlights high potential of non-invasive neuromodulation interventions in improving psychological indices. However, the absence of a significant change in BMI suggests that tDCS alone is insufficient for weight reduction and must be integrated with behavioral, nutritional, and psychological components. These findings may inform the design of multi-level intervention programs aimed at promoting both mental and physical health in overweight populations. Future research is recommended to include more diverse samples, longer intervention durations, and extended follow-up assessments to evaluate the sustainability of intervention effects.

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Conflict of interest

The researchers declared no conflict of interest.

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Ethical considerations

All ethical considerations have been observed.

Code of ethics

IR.SSRC.SPH.REC.1402.202

Authors' Contributions

A.S.M. conceived the idea presented in this paper. P.S. developed the theory and performed the calculations. H.G.Z. and M.G.N. validated the analytical methods. H.I.G and M.H.S. were involved in the investigation of [a specific aspect] and supervised the findings of this study. All authors discussed the results and contributed to the final manuscript.

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