Comparison of the effectiveness of transcranial direct current stimulation (tDCS) and motivational interviewing on self-control, reduction of substance use craving, and psychological distress in men addicted to drugs

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Abstract

Background: The purpose of this research was to compare the effectiveness of transcranial direct current stimulation (tDCS) and motivational interviewing (MI) on self-control, drug craving reduction, and psychological distress in drug-addicted men. **Methods:** The present study is applied in terms of its purpose and quasi-experimental in terms of data collection methodology. The statistical population consisted of drug-addicted clients supported by the Imam Khomeini Relief Foundation of Alborz Province, selected from Rose Clinic and Khaneh Barekat Addiction Treatment Clinic in Mohammadshahr, Alborz, as well as Dr. Fayaz Addiction Treatment Center in Karaj. In the sampling stage, 60 individuals from the aforementioned population were selected using convenience sampling. These individuals were then randomly assigned into four groups of 15. The four groups included: the transcranial direct current stimulation (tDCS) experimental group, the sham treatment group (to control for the placebo effect by placing electrodes without inducing electrical stimulation), the motivational interviewing group, and the control group (receiving no intervention). The research instruments included the Drug Desire Questionnaire (DDQ), the Self-Control Questionnaire, and the standard Psychological Distress Questionnaire. For data analysis, mean and standard deviation were used in the descriptive statistics section, and multivariate analysis of covariance (MANCOVA) was utilized in the inferential statistics section using SPSS software. **Results:** The results showed that transcranial direct current stimulation and motivational interviewing had a significant effect on self-control, craving reduction, and psychological distress in drug-addicted men ($P \leq 0.05$), and the effectiveness of motivational interviewing was significantly greater than that of transcranial direct current stimulation ($P \leq 0.05$). **Conclusion:** Considering the higher effectiveness of motivational interviewing, it is recommended that special training programs be designed and implemented for addiction counselors and treatment specialists so they can utilize motivational interviewing more effectively in the treatment process.

Keywords: Addiction, craving, self-control, psychological distress.

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Introduction

Substance use disorder is a diagnostic term in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) that refers to the recurrent use of drugs causing clinically and functionally significant impairment, including health problems, disability, and failure to meet major responsibilities at work, school, or home (1). Addiction is a chronic, relapsing disease in which drug-seeking continues despite diminished pleasure from drug use and substantial negative consequences for individuals and their families (2). Addiction is a bio-psycho-social and even belief-based (religious) disease characterized by drug-induced neuroadaptation that ultimately affects psychological functioning (changes in thinking, emotions, and behaviors) and social interaction. Focusing on the related thinking, emotions, and behaviors, as well as their neural substrates, provides a more comprehensive and integrated understanding of the nature and course of addiction (3).

On the other hand, craving is one of the various types of substance-related disorders, defined as a strong, sudden, and uncontrollable desire to use the substance in question (4). This phenomenon plays a significant role in the persistence of addiction, relapse after withdrawal, and difficulty in successful treatment. Craving is not only influenced by psychological factors such as anxiety, depression, and stress, but is also affected by environmental conditions, cues associated with previous use, and even social interactions (5). Numerous studies have shown that craving can be exacerbated by the activation of specific neural pathways in the brain, particularly in areas related to reward and memory (6). Therefore, identifying and managing this psychological state is of high importance in the treatment process and the prevention of relapse to use.

At the same time, research indicates that long-term drug use is associated with high levels of neuropsychological deficits, and there is multiple evidence regarding the increased likelihood of developing cognitive impairments with substance use, even after cessation (7). One of the cognitive variables related to substances is self-control, and research evidence has shown that individual differences in self-control can play a role in the treatment outcomes of substance-related disorders. Self-control is an intra-individual conflict between logic and craving, cognition and motivation, and internal planning and action, the outcome of which is the dominance of the first part of each of these pairs over the second part (8). Strengthening the self-control belief system increases an individual's readiness to avoid the temptation to smoke; consequently, success in reducing smoking is reinforced by the belief in self-control ability (9). Thus, individuals with low self-control are at risk of turning to substance use and its resulting problems (10).

Addicts to alcohol and drugs often have doubts about quitting their addiction. This doubt and feeling of ambivalence cause addicts not to seek treatment quickly or even never to consider their treatment. Another group of addicts comes to the conclusion that they need to be treated, but they give up on this idea very soon and abandon the treatment process. Many also seriously try to change themselves, but after a while, they break their vows and pledges and resume substance use. All of these are problems related to creating "motivation" and maintaining it for quitting addiction (11). It has become apparent that inflexible treatment programs exacerbate this problem, and one of the clear goals of psychosocial treatment should be to increase the client's motivation (12).

Craving is one of the most pressing and persistent topics encountered in the science of addictive disorders. Tiffany and Drobes (1990) defined craving as a term encompassing a wide range of phenomena, including the expectation of the reinforcing effects of drugs and an intense urge for drugs. According to brain imaging, the dorsolateral prefrontal cortex plays an important role in craving, as well as in mood and cognitive disorders (13). Also, based on these studies,

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alterations in the prefrontal regions of the brain, particularly in the dorsolateral prefrontal cortex, have been identified in addictive disorders, and these brain changes associated with drug craving are exacerbated by a strong urge for drugs and impaired inhibitory control (14).

Another therapeutic method used for regulating and modulating the activity of the dorsolateral prefrontal cortex, and consequently reducing substance craving, cognitive deficits, and psychological distress, is transcranial direct current stimulation. A simple device is used in this method, which passes a continuous and mild electrical current through the head using large electrodes placed on the individual's scalp. The effectiveness of this method depends on the direction of the electrical current. Anodal stimulation increases the level of brain activity and excitability, whereas cathodal stimulation, conversely, decreases activity (15). The application of mild amounts of electrical currents to alter brain function has a history of about 200 years. Initial investigations on animal models indicate changes in cerebral cortex activity due to the passage of electrical current in the form of decreased or increased excitability, depending on the conditions of the passed electrical current. These effects remain for a while by changing the rate of protein synthesis and the intracellular levels of cyclic AMP and calcium, but they are mostly reversible and do not cause adverse effects on the function and structure of cells. Transcranial Direct Current Stimulation (tDCS) is the name of one of the brain stimulation techniques introduced in the field of neuropsychology (16). Studies have shown that transcranial direct current stimulation can reduce substance craving by stimulating specific areas of the prefrontal cortex, such as the dorsolateral prefrontal cortex (DLPFC) (17); for example, a systematic review and meta-analysis demonstrated that tDCS significantly reduces craving for substances such as alcohol, nicotine, and illicit drugs (18). Transcranial direct current stimulation, by affecting brain regions associated with executive control, can help improve self-control in individuals with substance use disorders (19). Transcranial direct current stimulation has also been effective in reducing psychological symptoms such as depression and anxiety. The study by Jeong et al. (2024) showed that the use of transcranial direct current stimulation in overweight or obese individuals led to a reduction in food craving and an improvement in scores on psychological factors such as depression and anxiety (20). On the other hand, one of the novel and efficient approaches to psychotherapy is motivational interviewing, which, by emphasizing empathetic dialogue, strengthening intrinsic motivations, and creating readiness for change, has been able to be effective in improving addictive behaviors and enhancing the psychological resilience of individuals. Evidence suggests that this method, by influencing self-monitoring processes (21), reducing internal conflict (22), and increasing self-awareness (23), can help improve self-control and reduce craving, and on the other hand, decrease the individual's emotional burden and psychological stress (24). The study by Jayakumar et al. (۲۰۲۵) also reported that motivational interviewing helps reduce substance use and improve the quality of life of patients by increasing retention in treatment and enhancing overall mental health (25).

Despite scientific and therapeutic advances in the field of addiction, many treatment methods still face problems such as relapse to substance use and side effects. Therefore, new research seeks to introduce and evaluate novel therapeutic methods that can resolve these problems and effectively help improve the psychological and behavioral status of addicts. Transcranial direct current stimulation (tDCS) and motivational interviewing are among the novel and efficient methods that have a high potential for improving addictive behaviors and increasing psychological resilience. Brain stimulation with direct current, by stimulating specific brain areas such as the prefrontal cortex, can improve self-control and inhibit impulses, and reduce substance craving. On the other hand,

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motivational interviewing, by strengthening the individual's intrinsic motivations and reducing resistance to change, can help reduce craving and improve the individual's psychological state. Given the potential effects of each of these methods on self-control, craving reduction, and psychological distress, comparing the effectiveness of these two approaches can help identify more effective and complementary strategies for addiction treatment. Furthermore, the results of this research can be effective in improving treatment protocols and enhancing the quality of life of drug addicts. Thus, the following question arises: "Is there a difference between the effectiveness of treatment through transcranial direct current stimulation and motivational interviewing treatment on self-control, reduction in craving, or psychological distress?"

Materials and Methods

The present study was conducted with the aim of investigating the effectiveness of two psychological interventions on reducing craving, increasing self-control, and reducing psychological distress among drug-addicted clients under the support of the Imam Khomeini Relief Foundation in Alborz province. This study was a quasi-experimental research with a pre-test/post-test design and a control group. This clinical trial was registered with the Iranian Registry of Clinical Trials (IRCT20251110067950N1) on: 2025-11-18. Ethical clearance was obtained from the Research Ethics Committees of Islamic Azad University - Karaj Branch, Iran (IR.IAU.K.REC.1403.072). The statistical population included the aforementioned clients in Rose clinics, Khaneh Barekat in Mahdasht, and Dr. Fayyaz Addiction Treatment Center in Karaj. From this population, 60 individuals were selected using convenient sampling and were randomly assigned to four groups of 15 individuals, including the first experimental group (transcranial direct current stimulation or tDCS), the second experimental group (motivational interviewing), the first control group (sham or fake practice), and the second control group (no intervention). In initial quasi-experimental and interventional studies, a minimum of 12 to 15 individuals per group is sufficient for a preliminary estimation of the effect and to achieve acceptable statistical power (26). Inclusion criteria for the study consisted of a history of drug use for more than 1 year and receiving methadone maintenance therapy. Exclusion criteria from the study included unwillingness to continue participation, occurrence of physical problems, a history of receiving tDCS, the presence of metal prostheses in the head and face, having psychotic disorders, a history of seizures or epilepsy, and heart disease or having a cardiac pacemaker. All participants remained in the research process until the end of the study.

In the pre-test stage, all subjects completed the Drug Craving Questionnaire, Grasmick et al.'s Self-Control Questionnaire, and Kessler's Psychological Distress Questionnaire. The interventions were implemented as follows:

1. **tDCS Group:** This group underwent 10 sessions of transcranial direct current stimulation. The electrodes were placed in the F4 area based on the 10/20 EEG system. Each session lasted 20 minutes, and a current of 2 mA was applied.
2. **Motivational Interviewing Group:** This group participated in 8 weekly 60-minute sessions. The content of the sessions was designed based on the standard motivational interviewing protocol, which included increasing motivation for change, identifying and resolving internal conflicts, and strengthening self-efficacy.
3. **First Control Group:** This group underwent sham or fake practice, in which the electrodes were placed in the same way as the tDCS group, but no electrical current was applied.
4. **Second Control Group:** This group received no intervention.

In the post-test stage, the same questionnaires were completed again by the subjects.

The research instruments included three standard scales. The first instrument is the "Drug

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Craving Questionnaire," designed by Franken et al. (2002) (27). This questionnaire has 14 items that measure three subscales, including "desire and intention for drugs" (items 1 to 5), "craving for use and negative reinforcement" (items 6 to 10), and "pleasure and severity of loss of control" (items 11 to 14). The scoring method is based on a five-point Likert scale (from "strongly disagree" = 1 to "strongly agree" = 5). The range of possible scores for the entire questionnaire is between 14 and 70. A higher score indicates a greater severity of craving. The Cronbach's alpha coefficients for the original version of this instrument have been reported as 0.85 for the total scale and 0.77, 0.80, and 0.75 for its subscales, respectively (27). In the localized version by Mohammadi (2010), Cronbach's alpha coefficients were obtained as 0.82 for the total scale and 0.70, 0.82, and 0.70 for the subscales, respectively (28). Also, in the current sample, internal consistency (Cronbach's alpha) was calculated at 0.87 for the entire questionnaire.

The second instrument is the "Self-Control Questionnaire" by Grasmick et al. (1993) (29). This questionnaire includes 24 items comprising six subscales: "impulsivity" (items 1, 4, 9, 16), "preference for simple tasks" (items 2, 7, 11, 22), "risk-seeking" (items 3, 8, 14, 23), "preference for physical activities" (items 5, 10, 15, 24), "self-centeredness" (items 6, 12, 18, 21), and "mood instability" (items 13, 17, 19, 20). The scoring method is performed on a five-point Likert scale from "strongly disagree" = 1 to "strongly agree" = 5. The total score range of the questionnaire is between 24 and 120, and a higher score indicates greater self-control. The Cronbach's alpha coefficient of the original version of this instrument is 0.90 (29), and in the study by Sarmad et al. (2012), it was reported as above 0.70 for the Persian version. In the present study, the Cronbach's alpha coefficient for the total scale was 0.89 (30).

The third instrument is the "Kessler Psychological Distress Questionnaire" designed by Kessler et al. (2002) (31). This questionnaire has 10 items covering three subscales: "educational presence" (items 1 to 3), "social presence" (items 4 to 7), and "cognitive presence" (items 8 to 10). The scoring method is on a five-point scale from "none of the time" = 1 to "all of the time" = 5. The range of scores varies from 10 to 50, and a higher score indicates a higher level of psychological distress. In the original version, the Cronbach's alpha coefficient was reported as 0.92 (31), and in the localized version by Yaghoubi (2015), a value of 0.70 was obtained (32). In the present sample, the Cronbach's alpha coefficient of the questionnaire was calculated to be 0.81.

For data analysis, descriptive statistics (mean and standard deviation) and inferential statistics, including the Analysis of Covariance (ANCOVA) test, were used to compare the groups. Furthermore, to check the assumptions of covariance analysis, the Shapiro-Wilk test for normal distribution of data, Levene's test for homogeneity of variances, and the test for homogeneity of regression slopes were performed. All analyses were conducted using SPSS software version 24.

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Findings

Table 1. Frequency distribution and mean of the demographic characteristics of participants by group

Variable	Categories	tDCS Group (15 participants)	Sham Group (15 participants)	Motivational Interviewing Group (15 participants)	Control Group (15 participants)	Total (60 participants)
Age (years)	Mean ± standard deviation	34.5 ± 4.2	35.1 ± 5.0	33.8 ± 4.7	35.4 ± 4.1	34.7 ± 4.5
Marital status	Single	6 (40%)	5 (33%)	7 (46%)	5 (33%)	23 (38%)
	Married / divorced	9 (60%)	10 (67%)	8 (53%)	10 (67%)	37 (62%)
Educational level	Below diploma	4 (26%)	5 (33%)	3 (20%)	6 (40%)	18 (30%)
	Diploma	7 (46%)	6 (40%)	8 (53%)	7 (46%)	28 (46%)
	University education	4 (26%)	4 (26%)	4 (26%)	2 (13%)	14 (23%)
Employment status	Employed	8 (53%)	7 (46%)	9 (60%)	8 (53%)	32 (53%)
	Unemployed	7 (46%)	8 (53%)	6 (40%)	7 (46%)	28 (46%)

The mean and standard deviation of the variables in the control and experimental groups are shown in Table 2.

Table 2. Mean and standard deviation of the research variables in the control and experimental groups

Variables	Statistics	tDCS Group Pre-test	tDCS Group Post-test	Sham Group Pre-test	Sham Group Post-test	Motivational Interviewing Group Pre-test	Motivational Interviewing Group Post-test	Control Group Pre-test	Control Group Post-test
Craving	Mean	40.64	54.07	40.63	61.13	64.13	45.40	63.60	64.07
	Standard deviation	4.15	1.87	5.30	4.91	4.24	3.50	5.02	4.86
Self-control	Mean	83.07	99.73	78.60	91.40	81.27	111.33	80.87	79.87
	Standard deviation	5.14	4.87	6.44	4.13	3.78	10.80	4.05	7.92
Psychological distress	Mean	27.60	20.87	28.60	25.13	28.07	17.87	28.40	28.13
	Standard deviation	2.38	2.44	1.50	2.80	1.28	1.35	1.54	1.06

The results of this test showed that the significance levels of the Shapiro–Wilk test for all variables were greater than 0.05; therefore, the distribution of the data related to the pre-test and post-test of craving, self-control, and psychological distress was normal, and the use of parametric statistical tests was permissible. The results showed that the relationship between the pre-test and post-test of craving, self-control, and psychological distress was linear and positive. Levene's test also showed that the homogeneity of variances was established and that there was no significant difference between the error variances of the groups (significance levels greater than 0.05). Moreover, the results of the test of homogeneity of regression slopes indicated that there was no significant interaction between group and the pre-tests ($P > 0.05$); therefore, the assumption of parallel slopes was met. Accordingly, the necessary conditions for performing analysis of covariance in this study were fully satisfied.

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Table 3. Results of the covariance test for comparing the control and experimental groups based on the post-test score while controlling for pre-test scores of craving

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level	Eta Coefficient
Corrected model	3229.010	4	807.252	57.562	0.001	0.807
Intercept	402.359	1	402.359	28.691	0.001	0.343
Craving pre-test	117.877	1	117.877	8.405	0.005	0.133
Group	3176.520	3	1058.840	75.502	0.001	0.805
Error	771.323	55	14.024			
Total	193282.000	60				

The analysis of covariance in Table 3 showed that the F value related to the covariate was 8.405, which was statistically significant ($P \leq 0.05$). On the other hand, the F value related to group was also 75.502 and was statistically significant ($P \leq 0.05$); that is, after removing the effect of the pre-test, there was a significant difference between the mean scores of the four groups in the post-test. Therefore, the null hypothesis stating that there is no significant difference between the mean scores of the four groups in the post-test after eliminating the possible effect of the pre-test is rejected. Therefore, transcranial direct current stimulation and motivational interviewing have a significant effect on reducing craving in men addicted to narcotic drugs.

Table 4. Results of the covariance test for comparing the control and experimental groups based on the post-test score while controlling for pre-test scores

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level	Eta Coefficient
Corrected model	13905.858	4	3476.465	81.547	0.001	0.856
Intercept	1194.948	1	1194.948	28.030	0.001	0.338
Self-control pre-test	108.875	1	108.875	2.554	0.016	0.144
Group	13479.181	3	4493.060	105.393	0.001	0.852
Error	234.725	55	42.631			
Total	593471.000	60				

The analysis of covariance in Table 4 showed that the F value related to the covariate was 2.554, which was statistically significant ($P \leq 0.05$). On the other hand, the F value related to group was also 105.393 and was statistically significant ($P \leq 0.05$); that is, after removing the effect of the pre-test, there was a significant difference between the mean scores of the four groups in the post-test. Therefore, the null hypothesis stating that there is no significant difference between the mean scores of the four groups in the post-test after eliminating the possible effect of the pre-test is rejected. Therefore, transcranial direct current stimulation and motivational interviewing have a significant effect on self-control in men addicted to narcotic drugs.

Table 5. Results of the covariance test for comparing the control and experimental groups based on the post-test score while controlling for pre-test scores

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level	Eta Coefficient
Corrected model	941.187	4	235.297	58.608	0.001	0.810
Intercept	204.720	1	204.720	50.992	0.001	0.481
Psychological distress pre-test	14.120	1	14.120	3.517	0.046	0.160
Group	940.728	3	313.576	78.105	0.001	0.810
Error	220.813	55	4.015			
Total	32902.000	60				

The analysis of covariance in Table 5 showed that the F value related to the covariate was 3.517, which was statistically significant ($P \leq 0.05$). On the other hand, the F value related to group was also 78.105 and was statistically significant ($P \leq 0.05$); that is, after removing the effect of the pre-test, there was a significant difference between the mean scores of the four groups in the post-test. Therefore, the null hypothesis stating that there is no significant difference between the mean scores of the four groups in the post-

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test after eliminating the possible effect of the pre-test is rejected. Therefore, transcranial direct current stimulation and motivational interviewing have a significant effect on psychological distress in men addicted to narcotic drugs.

In order to examine more precisely the pairwise differences between the experimental and control groups in the variables of craving, self-control, and psychological distress, a post hoc test (pairwise comparison) was used. This test enables us to determine which groups differ significantly from one another and in which variables a greater therapeutic effect has been observed.

Table 6. Results of the post hoc test for comparison between all groups

Variable	Group Comparison	Mean Difference	Significance Level (Sig)	Significance Result
Craving	Brain stimulation – sham	-7.06	0.043	Significant
	Brain stimulation – motivational interviewing	8.67	0.001	Significant
	Brain stimulation – control	-10.00	0.001	Significant
	Sham – motivational interviewing	15.73	0.001	Significant
	Sham – control	-2.94	0.370	Not significant
	Motivational interviewing – control	-18.67	0.001	Significant
Self-control	Brain stimulation – sham	8.33	0.017	Significant
	Brain stimulation – motivational interviewing	-21.60	0.001	Significant
	Brain stimulation – control	19.86	0.001	Significant
	Sham – motivational interviewing	-29.93	0.001	Significant
	Sham – control	11.53	0.005	Significant
	Motivational interviewing – control	41.46	0.001	Significant
Psychological distress	Brain stimulation – sham	-4.26	0.041	Significant
	Brain stimulation – motivational interviewing	3.00	0.070	Not significant
	Brain stimulation – control	-7.26	0.001	Significant
	Sham – motivational interviewing	7.26	0.001	Significant
	Sham – control	-3.00	0.088	Not significant
	Motivational interviewing – control	-10.26	0.001	Significant

As observed in the above table, in all variables, motivational interviewing (MI) had a greater effect than brain stimulation (tDCS), sham treatment, and the control group:

- In the variable of craving, the mean difference between motivational interviewing and control (-18.67) indicates the greatest reduction in craving.
- In the variable of self-control, the mean difference between motivational interviewing and the control group (41.46) indicates the highest level of increase in self-control among the groups.
- In the variable of psychological distress, motivational interviewing also produced the greatest reduction in the level of psychological distress, with a mean difference of (-10.26).

These results show that motivational interviewing acted more effectively than the other interventions (brain stimulation and sham) in improving the psychological components of individuals addicted to substances. Therefore, the use of motivational interviewing can be a more desirable strategy for reducing craving, increasing self-control, and improving patients' mental health.

Discussion

The aim of this study was to compare the effectiveness of transcranial direct current stimulation and motivational interviewing on self-control, reduction of craving, and psychological distress in men addicted to narcotic drugs. The results of the study showed that transcranial direct current stimulation and motivational interviewing have a significant effect on psychological distress in men addicted to narcotic drugs; however, comparison of the means showed that motivational interviewing has a greater effect on craving. Regarding transcranial direct current stimulation, the obtained results are consistent with the results

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of Gairola et al. (2024), Salemi et al. (2024), and Liu et al. (2023) (12, 33, 34). Liu et al. (2023), in another study on 35 men addicted to heroin, showed that transcranial direct current stimulation over the left posterior parietal cortex significantly reduces symptoms of anxiety and stress compared with the control group (12).

At the same time, Vollstädt et al. (2025), in one of the most recent studies entitled "Modification of inhibitory control and craving through transcranial direct current stimulation as an add-on treatment for substance use disorder," showed that a combination of tDCS and self-control and emotion regulation training leads to a reduction in addiction relapse and craving for opioids (35). Fischell et al. (2020), in a study entitled "Transcranial direct current stimulation applied over the dorsal and ventral prefrontal cortex in smokers alters cognitive circuits involved in nicotine withdrawal syndrome," positively evaluated the effect of tDCS on reducing psychological distress (36). The study by Trojak et al. (2016) showed that transcranial direct electrical stimulation is capable of reducing alcohol use in patients with alcohol disorder (37). Den Uyl et al. (2015), in a study entitled "Transcranial direct current stimulation, implicit alcohol association and craving," as well as Klauss et al. (2014), in a study entitled "A randomized controlled trial of targeted modulation of the prefrontal cortex with tDCS in patients with alcohol dependence," found a positive effect of transcranial stimulation therapy in reducing the level of alcohol craving (38, 39). Also, regarding cocaine craving, Batista et al. (2015), in a study entitled "A trial of targeted modulation of the prefrontal cortex with bilateral tDCS in patients with crack–cocaine dependence," showed that transcranial electrical stimulation plays a very valuable role in reducing the level of craving and dependence on cocaine–crack (40). Feeser et al. (2014), in a study entitled "Transcranial direct current stimulation enhances cognitive control during emotion regulation," positively evaluated the effect of transcranial electrical stimulation, and tDCS can be effective in reducing psychological distress and regulating emotions (41). In this regard, it can be said that transcranial direct alternating current stimulation is a non-invasive brain stimulation method that uses weak electrical current to modulate activity in specific brain regions (42). Transcranial direct alternating current stimulation has increasingly been investigated as a potential treatment for a wide range of neurological and psychiatric disorders, including substance abuse. Side effects are usually mild and transient and include headache, tingling, and itching at the stimulation site (43).

Transcranial direct alternating current stimulation, by applying weak electrical current through electrodes placed on the scalp, causes changes in neuronal excitability. This stimulation can lead to changes in brain activity and improvement in the function of areas related to emotion regulation and stress control. Among the target regions in tDCS, the dorsolateral prefrontal cortex can be mentioned, which plays an important role in emotion regulation and executive control (33). This method, by modulating the activity of different brain regions related to emotion regulation and reducing the excitability of the nervous system, can help improve psychological states. Transcranial stimulation can also be used as a complementary treatment for other substance abuse treatments, such as cognitive behavioral therapy (44). At the same time, tDCS, by reducing psychological distress, can help improve self-efficacy and increase the quality of life of these individuals. These improvements can lead to a reduction in the tendency to return to substance use (45). Overall, the results of studies show that transcranial direct current stimulation can significantly reduce psychological distress in men addicted to narcotic drugs. This reduction in distress can play an important role in improving the treatment and rehabilitation process of these individuals.

The results of the present study showed that motivational interviewing has a significant effect on psychological distress in men addicted to narcotic drugs. In this regard, numerous studies

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have shown that motivational interviewing can reduce psychological distress in men addicted to narcotic drugs. For example, a meta-analysis of 12 randomized controlled studies showed that motivational interviewing reduces symptoms of depression and anxiety (46). Another study on 80 men addicted to methamphetamine showed that motivational interviewing significantly reduces symptoms of depression, anxiety, and stress compared with the control group (47). Forman et al. (2023) found that motivational interviewing helps individuals increase their motivation for change through exploring ambivalence and strengthening commitment to reducing alcohol use (48). Ingesson et al. (2023), in a study entitled "Patients' experience of receiving motivational enhancement therapy in a specialized addiction treatment center in Sweden," stated that many patients reported that motivational interviewing helped them find greater motivation to change their addictive behaviors (49). The techniques used in motivational interviewing made them feel that they could have greater control over their lives. Many patients reported that the positive effects of motivational interviewing continued even after the end of the treatment sessions. These effects included improvement in family and social relationships and increased life satisfaction.

In explaining the obtained result, it can be said that motivational interviewing is a counseling approach designed to increase individuals' intrinsic motivation to change unhealthy behaviors. There are several mechanisms that may explain the effectiveness of motivational interviewing in reducing psychological distress. Motivational interviewing helps individuals become aware of their abilities to cope with addiction and the psychological problems associated with it (50). Increased self-efficacy can lead to a reduction in negative feelings and psychological distress (49). Therapists in motivational interviewing, by creating a supportive and empathetic atmosphere, help patients feel less lonely and helpless. This emotional support can help reduce stress and anxiety (51). Motivational interviewing encourages individuals to focus on their personal values and goals and to find practical ways to achieve these goals. This approach can help improve individuals' outlook on life and reduce psychological distress (52). Overall, the results of the study show that motivational interviewing can effectively reduce psychological distress in men addicted to narcotic drugs. These findings highlight the importance of using motivational interviewing as a complementary method in addiction treatment programs.

At the same time, based on the obtained results, the effectiveness of motivational interviewing is greater than that of transcranial direct current stimulation. The effectiveness of motivational interviewing is greater than that of transcranial direct current stimulation. In explaining this result, it can be said that motivational interviewing pays attention to the psychological, emotional, and motivational aspects of patients and therefore can have more lasting and deeper effects. Motivational interviewing, by creating a supportive and empathetic atmosphere, helps reduce psychological distress and increase patients' self-confidence. Motivational interviewing, by increasing patients' self-efficacy, helps them feel greater control over their behaviors and cope more effectively with challenges related to addiction.

Conclusion

The present study was conducted with the aim of comparing the effectiveness of two interventional methods, transcranial direct current stimulation and motivational interviewing, on self-control, reduction of craving, and psychological distress in men addicted to narcotic drugs. The findings of the study showed that both interventional methods are effective and significant in reducing psychological distress in the target population; however, comparison of the means indicates that motivational interviewing has a greater effect on reducing craving. In explaining this finding, it can be said that transcranial stimulation, as a non-invasive neural method, by modulating the activity

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of brain regions related to emotion regulation and cognitive control (such as the dorsolateral prefrontal cortex), can help reduce symptoms of anxiety, depression, and stress and improve psychological distress. On the other hand, motivational interviewing, as a psychological counseling approach, by creating an empathetic and supportive atmosphere, increasing self-efficacy, strengthening intrinsic motivation for behavior change, and focusing on personal values and goals, addresses deeper dimensions of the psychological and behavioral problems of the addicted individual. The relative superiority of motivational interviewing over transcranial stimulation in reducing craving can be attributed to the more comprehensive and more psychological nature of this method, which helps the individual gain a greater sense of control over his life, improve his family and social relationships, and increase life satisfaction. Overall, both interventional methods have considerable clinical value and can be used separately or in combination in addiction treatment and rehabilitation programs; however, considering the deeper and more lasting effectiveness of motivational interviewing on craving, the priority of this method in clinical interventions is recommended.

Limitations of the Study

Although an effort was made to select the research sample from among clients supported by the Imam Khomeini Relief Committee of Alborz Province, the convenience sampling method, instead of random and probability methods, may limit the generalizability of the findings. In addition, all participants were selected from Alborz Province and only from three specific treatment centers (Rose Clinic, Khaneh Barakat Clinic in Mohammadshahr, and Dr. Fayaz Center in Karaj); therefore, the findings of the study are not automatically generalizable to the entire population of individuals addicted to narcotic drugs throughout the country or even to other provinces. The specific cultural, economic, and social characteristics of Alborz Province may have influenced the results.

Moreover, the present study was conducted exclusively on men addicted to narcotic drugs, and no women were included in the sample. This issue poses a serious challenge to the generalization of the results to the population of addicted women, because physiological, neural, and psychological responses to therapeutic interventions in women may differ from those in men. Therefore, the findings of this study cannot be directly generalized to addicted women.

The present study generally examined the effectiveness of interventions on "men addicted to narcotic drugs," without making a precise distinction between types of narcotic drugs (such as heroin, opium, methamphetamine, crack, etc.). This is while the neural and psychological effects of each of these substances are different, and the response to therapeutic interventions may also be influenced by the type of substance used. The lack of differentiation based on the type of substance used is considered one of the serious limitations of this study.

Research Suggestions

Overall, the results of this study show that both transcranial direct current stimulation and motivational interviewing are effective in improving self-control, reducing craving, and reducing psychological distress in men addicted to narcotic drugs; however, motivational interviewing generally has greater effectiveness. These findings highlight the importance of using comprehensive and multidimensional approaches in addiction treatment. Nevertheless, considering the higher effectiveness of motivational interviewing, it is suggested that special training programs be designed and implemented for counselors and addiction treatment specialists so that they can use motivational interviewing more effectively in the treatment process. At the same time, considering that transcranial direct current stimulation also has

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positive effects, it is suggested that this method be used as a therapeutic supplement alongside motivational interviewing in order to achieve greater improvement in patients. Future research should examine the long-term effects of both therapeutic methods. Examining the durability of the results of motivational interviewing and transcranial direct current stimulation and evaluating their effects over longer time periods can help provide a better understanding of the stability of the effects of these methods.

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Ethical consideration

Ethical considerations in terms of honesty and integrity in texts and sources have been observed.

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Conflict of interest

None.

Authors' contributions

All authors contributed equally to the preparation of this article.

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