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Comparison of the Effectiveness of Mindfulness-Based Stress Reduction Program with Transcranial Direct Current Stimulation on Stress and Rumination in Adolescents with Cancer

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A B S T R A C T

Objective: Considering the necessity to identify effective interventions to improve stress and rumination in students, the current study aimed to compare the effectiveness of a mindfulness-based stress reduction program with transcranial direct current stimulation (tDCS) on stress and rumination in adolescents with cancer.

Methods and Materials: The research method was a quasi-experimental pre-test and post-test with a control group design. The research population included all adolescents with cancer at Mahak Hospital in Tehran, from which 40 individuals were selected through purposive sampling and randomly assigned to three groups (1- Mindfulness-based stress reduction training; 2- Transcranial direct current stimulation intervention; 3- A combined method of mindfulness-based stress reduction with transcranial direct current stimulation) and one control group. The instruments for data collection included the Lovibond and Lovibond's (1995) Depression, Anxiety, and Stress Scale and the Ruminative Response Scale about an interpersonal upset (2008). For data analysis, one-way analysis of covariance, repeated measures analysis of variance, and the least significant difference post-hoc test were used.

Findings: The results of the covariance analysis along with the post-hoc tests showed that there is no significant difference between the mindfulness-based stress reduction method and tDCS in reducing stress levels ($P>0.05$), and only the difference between these methods compared to the control group was significant ($P<0.05$). In terms of the effectiveness of the interventions under study on stress levels, the combined method was more effective than using each method separately. Regarding the rumination variable, there was no significant difference between the mindfulness-based stress reduction method and the tDCS method in reducing the level of rumination ($P>0.05$), and only the difference of this mindfulness method compared to the control group was significant ($P<0.05$). The

results of the repeated measures analysis of variance along with the post-hoc tests indicated that there were no significant differences between the post-test and follow-up stages for stress and rumination variables (P>0.05); hence, the results were stable.

Conclusion: Based on the results of the current study, counseling and psychology units established in hospitals and oncology clinics need to be more aware of the mental health of adolescents with cancer and should use the combined method of mindfulness-based stress reduction with tDCS to improve stress and rumination in adolescents with cancer.

Keywords: *Mindfulness intervention, Transcranial electrical stimulation, Stress, Rumination, Cancer, Adolescents.*

1. Introduction

Chronic disease refers to conditions that encompass all the potential abilities of an individual, including their psychological capacities. Cancer is one of the common chronic diseases that assigns a significant burden of illness (Gaillard et al., 2015). The diagnosis of cancer can create considerable stress, leading to maladaptive psychological reactions such as anxiety (Götze et al., 2020), depression (Powell et al., 2020), post-traumatic stress (Johnson et al., 2020), and adjustment issues (Tang et al., 2020). Given that this disease affects various age groups (Markaki et al., 2018), the need for attention to it is increasingly felt. In this context, adolescents are among the groups vulnerable to this disease, with an increasing prevalence of the disease among them each year (Furer et al., 2020). In some countries, cancer is the second leading cause of death after cardiovascular diseases and is considered one of the most significant public health problems (Cabanes et al., 2010); however, in Iran, after cardiovascular diseases and accidents, cancer is the third leading cause of death, and its prevalence among children is estimated to be 1.4% (Mohammadzadeh et al., 2022). Between 20 to 40 percent of cancer patients require psychological interventions due to the severe stress and nervous pressures resulting from the illness, especially more so in younger patients, women, and those with severe physical symptoms (Yang et al., 2019).

Review and analysis of scientific evidence demonstrate that cancer is a risk factor for mental health leading to psychological stress (Gaillard et al., 2015; Swartzman et al., 2017). Stress is a state in which biological, psychological, and environmental factors interact. Perceived stress reflects the overall evaluation of the significance and difficulty of environmental and personal challenges. Therefore, both individual and environmental factors are important in the perception of stressors. Situational factors provide the context, while individual factors are the elements that the individual exhibits in response to the situation. The perception of these environmental and individual factors facilitates the assessment of a situation as stressful or non-stressful (Khedri et al., 2022; Sun et al., 2022; Yao et al., 2022). Given the above, the high prevalence of stress in cancer patients is not surprising.

On the other hand, due to the adverse outcomes of cancer, rumination also has a high prevalence in adolescents with cancer (Gorini et al., 2018). Rumination is defined as a cognitive pattern that focuses on the causes, meanings, and consequences of emotional states. This cognitive pattern is a maladaptive mental style that is one of the significant predictors of depression. Scientific evidence clearly shows that one of the major indices of depression and anxiety is rumination (Azizi et al., 2023; Carlucci et al., 2018). Individuals who respond to life's dreary experiences with rumination typically experience longer and more severe periods of psychological distress and depressed mood. Studies in the research literature have shown that rumination is one of the predictors of the onset of major depressive episodes and depressive symptoms in both depressed and non-depressed individuals and plays the role of a mediating variable in the impact of other significant risk factors on depression (Dadfarnia et al., 2020; Kovács et al., 2020).

Since cancer leads to psychological problems such as stress and rumination, identifying effective therapeutic approaches to improve these symptoms and outcomes resulting from the disease seems necessary and essential. One of these effective therapeutic approaches is the mindfulness-based stress reduction program. Mindfulness encourages individuals to observe all emotions from a detached perspective. Since the 1970s, mindfulness has been used in therapeutic interventions for common psychological problems such as stress, worry, anxiety, and depression (Abedini & Joibari, 2023; Aini et al., 2021; Allen et al., 2021). The mindfulness-based stress reduction program has shown great efficacy in terms of adaptability and has been beneficial for primary prevention in health or similar sets, achieving the best results in patients with stress symptoms

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and the like (Kumar et al., 2022; Torfiamidpoor et al., 2022). Researchers believe that practicing mindfulness leads to the development of various mindfulness factors such as observation, non-judgment, non-reactivity, and action coupled with awareness. The development of these factors also leads to the improvement of psychological well-being, stress reduction, and psychological symptoms (da Silva et al., 2023).

In recent years, combined approaches have been developed and expanded to achieve effective therapeutic results. In one of these approaches, transcranial direct current stimulation (tDCS) using direct electrical current is integrated with the mindfulness-based stress reduction program, which has been validated in some areas (Aghaziarati et al., 2023). Although the use of these combined therapeutic approaches has not been extensively studied, however, scientific evidence suggests that the selection of these treatments as an integrated approach is based on the results of studies that have examined each of these treatments separately. Altschuler, Rosenbaum, Gordon, Canals, and Avins (2012) investigated the effectiveness of the mindfulness-based stress reduction program in 23 cancer patients. The treatment was administered at least five days a week for three months. The analysis of data from the research sample group showed that this therapeutic program was effective in improving mood and quality of life of the patients under study (Altschuler et al., 2012). Furthermore, the effectiveness of transcranial direct current stimulation (tDCS) using direct electrical current on stress and related factors has been validated (Moslemi et al., 2019). Therefore, the main question of the present research is whether the mindfulness-based stress reduction training and the combined method of stress reduction based on mindfulness along with transcranial direct current stimulation (tDCS) using direct electrical current are effective in reducing stress and rumination in adolescents with cancer?

2. Methods and Materials

2.1. Study Design and Participants

The present study is applied in purpose and quasi-experimental in method, utilizing a pre-test and post-test design with a control group. The population of this study encompassed all adolescents with cancer at Mahak Hospital, Tehran, in the year 2019. Members of the sample group were voluntarily selected from children with cancer at Mahak Hospital. It is recommended that experimental designs include at least 10 participants per group. Considering the research design, a sample size of 40 participants was selected based on inclusion criteria using purposive sampling. The sample members were randomly assigned to three experimental groups and one control group, with 10 individuals in each group. Inclusion and exclusion criteria were also considered for participants' entry into the study. The inclusion criteria included being diagnosed with cancer, age range of 8 to 12 years, and the ability to read and write (for completing research questionnaires). Moreover, suffering from psychiatric disorders, substance dependency, and unwillingness to participate in the research were selected as exclusion criteria. After reviewing the inclusion and exclusion criteria, qualified individuals participated in the study. It is worth noting that among the selected patients who were chosen through purposive sampling, all patients had an equal chance of being placed in either the control or experimental groups; thus, sample group members were randomly assigned to the experimental and control groups. For this purpose, initially, 40 patients willing to participate in the research (voluntary presence) were selected, and then, through a lottery method using a draw bag, the patients' names were drawn randomly to be placed in the experimental and control groups.

To adhere to ethical standards in the current research, efforts were made to obtain adolescents' consent to participate in the study and they were assured that all obtained information would be kept confidential. Those who wished to be informed about their psychological status were provided only with their own scores. The control group was assured that, if they wished, they would receive an 8-session mindfulness-based stress reduction program after the completion of the research. Additionally, adolescents were free to withdraw from the research at any time.

The research questionnaires were distributed before and after the implementation of the mindfulness-based stress reduction program and transcranial direct current stimulation (tDCS) in both the experimental and control groups. In this method, after participants were voluntarily and randomly assigned to the experimental and control groups, questionnaires were distributed among participants of all four groups at the pre-test stage before implementing the therapeutic method. The research was conducted at Raz Psychological and Counseling Services Center. The pre-test was conducted in the first session when participants came to the Raz Psychological Services Center for an introduction and explanation of the research process. In the first session, grouping of the eligible and selected individuals was done,

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and members were divided into four groups of ten. The research process and the overall objective of this study were explained to the participants and their parents.

After the therapeutic sessions, questionnaires were again distributed to all members of the experimental group to assess the variables at the post-test stage. It is important to note that the follow-up assessment was conducted one month after the post-test phase through sending an online link of the questionnaire to parents. The follow-up questionnaires were uploaded to Google Forms and the link was sent to the parents' WhatsApp groups, requesting that the adolescents respond to the questionnaires.

2.2. Measures

2.2.1. Stress

To assess the stress of adolescents with cancer, the Lovibond and Lovibond's (1995) Depression, Anxiety, and Stress Scale was used. This questionnaire consists of 21 questions in the areas of depression (7 questions), anxiety (7 questions), and stress (7 questions), which is a shortened version of the DASS-42. In this study, questions from the stress subscale were used. This scale was first presented by Lovibond and Lovibond in 1995 and tested in a large sample. The questionnaire items are designed on a Likert scale and have options of none, some, moderate, and a lot. The lowest score for each question is zero and the highest score is 3. The final score for each of the depression, anxiety, and stress subscales is obtained through the sum of scores of the respective questions. The validity and reliability of this questionnaire were examined in Iran by Samani and Jokar (2007), who reported test-retest reliability for the depression, anxiety, and stress subscales as 0.80, 0.76, and 0.77, respectively, and Cronbach's alpha for each of the subscales as 0.81, 0.74, and 0.78, respectively (Zamani-Alavijeh, 2023).

2.2.2. Rumination

To measure the level of rumination in adolescents with cancer, the Rumination Response Scale about an Interpersonal Upset (2008) was used. This scale was created by Nolen-Hoeksema et al. in 2008 and was first translated and adapted by Mammadari and Shirinkar (2014). The scale consists of 22 statements measuring rumination over the past week regarding a specific interpersonal upset reported by the subject. The response scale for the items ranges from strongly agree (5 points) to strongly disagree (one point). Nolen-Hoeksema and colleagues (2008) reported an internal consistency of 0.90 and an overall correlation between 0.51 and 0.85 for this questionnaire. In Iranian studies, Cronbach's alpha for the questionnaire was 0.87, and the overall correlation ranged between 0.46 and 0.84 (Ramezani et al., 2023).

2.3. Interventions

2.3.1. tDCS

Since there was one tDCS device at the center, the intervention schedule for each participant in the tDCS group was defined in such a way as to avoid interference with other members, and a schedule of 10 sessions was announced for each individual. Then, therapeutic sessions in the mindfulness-based stress reduction program were conducted in groups, while transcranial direct current stimulation (tDCS) sessions were conducted individually among members of the experimental group; however, individuals in the control group did not receive any treatment. tDCS treatment is a non-invasive method where a weak direct current (1 to 4 milliamperes) is applied to the scalp, causing long-term changes in brain cortex polarity through depolarization and hyperpolarization of neurons and affecting neurotransmitters. The stimulation in this intervention was applied with a current intensity of 2 milliamperes for 20 minutes through two anode and cathode electrodes in sizes of 5x7 on the left posterior prefrontal cortex (F3) and right posterior prefrontal cortex (F4). There were 10 therapeutic sessions, each lasting approximately 20 minutes. The time interval between sessions was 48 hours, and the intervention lasted a total of 30 days. It is worth mentioning that due to existing sensitivities, in the implementation of the tDCS intervention, a student assistant was present and supervised the process. The sessions were conducted by a trained neuroscientist at the Raz Psychological and Counseling Services Center.

2.3.2. Mindfulness-Based Stress Reduction Program

The mindfulness-based stress reduction program consists of 8 sessions of 90 minutes each (two sessions per week) based on the model by Kabat-Zinn (2003). It is worth mentioning that the group sessions of this intervention for the group receiving the mindfulness-based stress reduction program and the combined group were held at the Raz Psychological and Counseling Services Center. The management and conducting of the sessions were the

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responsibility of the student. This program aims to 1) provide an opportunity to test and develop an understanding of individual responses to stress and a means to modulate it, 2) allow the group to play an active role in their treatment process, 3) teach choices for self-care that enhance their feelings of competence and control, 4) increase the sense of well-being and integrity during mindfulness and meditation practices, and 5) provide a safe and supportive group environment where members can disclose their cancer experiences. The details of the mindfulness-based stress reduction program sessions are presented in Table 1.

Table 1

Content of Sessions Based on the Mindfulness-Based Stress Reduction Program

Session	Content
First	Introduction and conceptualization of the problem, information about the mindfulness-based stress reduction method and its role in health and well-being with research evidence. Discussion on the timing and duration of sessions and continuation of the program.
Second	Training in body relaxation: A brief review of the previous session followed by explanations about body relaxation, tension and muscle relaxation, how to sit for body relaxation, and which muscles should undergo relaxation.
Third	Similar to the previous session, body relaxation for muscles but in 9 groups of muscles performed with eyes closed. It is noted that after performing body relaxation for each muscle group, participants should open their eyes for 2 minutes to prevent falling asleep.
Fourth	After a brief review of the previous session, training focused on breath awareness was provided. Introduction to mindfulness of breathing techniques such as inhalation and exhalation with calmness, saying calming words during breathing without thinking of anything else, and observing breathing with closed eyes.
Fifth	After a brief review of the previous session, body scanning technique training was provided in the fifth session. At the end of this session, homework was assigned to practice the technique of awareness of the sense of taste at least once during eating and, if necessary, practice it with family members.
Sixth	After a brief review of the previous session, mindfulness of thoughts was taught. First stage: focusing attention on the mind without thinking about anything else, by focusing on a mental point or a cross mark. Second stage: inducing a negative thought about oneself through the instructor (30 minutes). Third stage: introducing a positive thought about oneself through the instructor (30 minutes).
Seventh	Full mindfulness was the focus of this session, and after a brief review of previous sessions and repetition of each for 20 to 30 minutes, it was taught. Like in previous sessions, a rest period of 2 to 5 minutes was considered between each phase. At the end of this session, participants were asked to perform the deep breathing technique before sleep for 20 minutes and the technique of awareness of the sense of taste through eating for 20 minutes as homework.
Eighth	This session provided a summary of the topics discussed in previous sessions and concluded by asking participants to apply the mindfulness training techniques in their daily lives to aid in their health improvement.

2.4. Data analysis

For data analysis derived from the information collection tools, SPSS.v21 software was used. To describe demographic information and research variables, central tendency and dispersion indices such as (mean and standard deviation) were used. To determine the effectiveness of the interventions, one-way analysis of covariance, repeated measures analysis of variance, and the least significant difference post-hoc test were used. Before conducting the tests, assumptions of parametric tests such as the Shapiro-Wilk normality test, Levene's test, Box's M test, and the homogeneity of regression slopes were examined.

3. Findings and Results

In this study, there were 40 adolescent participants with cancer from Mahak Hospital, Tehran. The mean ± standard deviation for participants in the first experimental group (10.30 ± 1.33), the second experimental group (9.90 ± 1.19), the third experimental group (10.40 ± 1.26), and the control group (10.20 ± 1.31) were calculated. Results from the analysis of variance indicated that there was no significant difference between the groups in terms of the age variable ($F = 0.285$, $P = 0.836$). Therefore, it can be stated that the four groups in this study are age-matched. Overall, 42.5% (17 participants) were female and 57.5% (23 participants) were male. A Chi-square test was used to compare the groups in terms of the distribution of participants' gender. Results showed that there was no significant difference between the four groups regarding the distribution of the gender variable; hence, the groups are matched in terms of gender ($\chi2 = 0.180$, $P = 0.672$). The majority of participants in this study had leukemia (35%, equivalent to 14 participants) and lymphoma (35%, equivalent to 14 participants). Since the type of cancer could potentially influence the variables under study, placement of individuals in the groups was equal. The results of the Chi-square test also indicate that there is no significant difference between the groups in this regard ($\chi2 = 0.180$, $P = 0.672$). The mean and standard deviation of the research variables are presented in Table 2.

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Table 2

Mean and Standard Deviation of Stress and Rumination at Three Stages: Pre-test, Post-test, and Follow-up

Variable	Group	Pre-test		Post-test		Follow-up	
		M	SD	M	SD	M	SD
Stress	Mindfulness	10.15	1.91	12.20	1.69	12.25	1.83
	tDCS	14.70	1.83	12.90	1.29	12.01	1.41
	Combined	16.10	1.20	10.80	2.20	10.78	2.33
	Control	15.60	1.51	15.33	1.80	15.01	1.58
Rumination	Mindfulness	76.30	3.33	74.30	2.26	74.75	2.31
	tDCS	75.60	3.53	74.20	3.49	74.29	3.14
	Combined	77.40	3.02	73.50	2.76	73.89	2.61
	Control	75.80	2.44	76.01	2.35	76.20	3.19

To compare the effectiveness of interventions on stress and rumination, one-way analysis of covariance was used, and to examine the stability of the results, repeated measures analysis of variance was utilized. The use of these parametric tests requires the fulfillment of assumptions that were examined before inferential analysis.

For this purpose, the Kolmogorov-Smirnov test findings indicated that the data from the experimental and control groups on the variables of stress and rumination in pre-test and post-test stages do not differ significantly from a normal distribution, and the data distribution is normal ($P > 0.05$). Also, the Levene's test for examining the assumption of equality of error variances showed that the assumption of equality of error variances for the research variables is met ($P > 0.05$). The results of the Box's M test, as another assumption for the analysis of covariance, show that the covariance matrices of the dependent variables across all levels of the independent variable (groups) are homogeneous or equal ($P = 0.495$; M Box = 9.372; $F = 0.933$). Furthermore, the interaction between the covariate and independent variable in both experimental and control groups was not significant ($P > 0.01$), indicating that the assumption of homogeneity of regression slopes is also met. Therefore, with the parametric test assumptions being met, the use of one-way analysis of covariance and repeated measures analysis of variance is permissible.

Table 3

Results of Analysis of Variance and Post-Hoc Test to Compare The Effectiveness of Interventions

Variable	MS	F	Sig.	Group 1	Group 2	M.D	S.E	Sig.
Stress	38.620	14.514	0.000	Mindfulness	tDCS	-0.895	0.735	0.323
					Combined	1.805	0.783	0.028
					Control	-3.174	0.766	0.000
				tDCS	tDCS	0.895	0.735	0.232
					Combined	2.699	0.795	0.002
					Control	-2.279	0.770	0.006
				Combined	tDCS	-1.805	0.783	0.028
					Combined	-2.699	0.795	0.002
					Control	-4.978	0.770	0.000
Rumination	21.730	9.096	0.000	Mindfulness	tDCS	-0.550	0.696	0.435
					Combined	1.907	0.742	0.015
					Control	-1.859	0.726	0.015
				tDCS	tDCS	0.550	0.696	0.435
					Combined	2.457	0.753	0.003
					Control	-1.309	0.730	0.082
				Combined	tDCS	-1.907	0.742	0.015
					Combined	-2.457	0.753	0.003
					Control	-3.766	0.730	0.000

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In Table 3, the results show that there is no significant difference between the mindfulness-based stress reduction method and the tDCS method in reducing stress levels (P > 0.05), and only the difference between these methods compared to the control group is significant (P < 0.05). In terms of the effectiveness of the interventions under study on stress levels, the combined method is more effective than using each method separately. Regarding the rumination variable, there was no significant difference between the mindfulness-based stress reduction method and the tDCS method in reducing the level of rumination (P > 0.05), and only the difference of this mindfulness method compared to the control group was significant (P < 0.05).

Table 4

Results of Analysis of Variance and Post-Hoc Test to Examine The Stability of the Effects of Interventions

Variable	MS	F	Sig.	Stage 1	Stage 2	M.D	S.E	Sig.
Stress				Pre-test	Post-test	3.714	0.904	0.001
					Follow-up	3.714	0.904	0.001
	96.571	16.868	0.001	Post-test	Pre-test	-3.714	0.904	0.001
					Follow-up	0.000	0.000	NK[1]
Rumination				Pre-test	Post-test	2.286	0.707	0.007
					Follow-up	2.071	0.699	0.011
	30.036	8.782	0.011	Post-test	Pre-test	-2.286	0.707	0.007
					Follow-up	-0.214	0.155	0.189

To examine the stability of the effectiveness of the intervention methods in reducing stress and rumination, repeated measures analysis of variance was used. The calculated significance level for the F value in Wilks' lambda test is less than the predetermined alpha value (α = 0.05), which suggests that the interaction effect of time on the group is significant. In other words, there is a significant difference between groups in measurements taken over time. The results of the repeated measures analysis of variance (Table 4) for the interaction of time effect on the independent variable indicated that there are no significant differences between post-test and follow-up stages for the variables of stress and rumination (P > 0.05); therefore, the results were stable.

4. Discussion and Conclusion

This study aimed to compare the effectiveness of a mindfulness-based stress reduction program with transcranial direct current stimulation (tDCS) on stress and rumination in adolescents with cancer. The results related to the comparison of effectiveness showed that the combined method of stress reduction based on mindfulness along with tDCS has greater effectiveness than using each method separately in improving stress and rumination in adolescents with cancer. Moreover, the tDCS method alone was not able to have a significant impact on reducing rumination. In the research literature, no study was found that concurrently assessed the effectiveness of a mindfulness-based stress reduction program along with transcranial direct current stimulation (tDCS) in reducing stress and rumination; however, studies on the effectiveness of the mindfulness-based stress reduction program (Ahmadi & Valizadeh, 2021; Altschuler et al., 2012; Campbell et al., 2012; Carmody & Baer, 2008; Dehghani et al., 2022; Eifert et al., 2009; Flugel Colle et al., 2010; Goldin et al., 2012; Habibi, 2019; Jafari & Shahabi, 2017; Keng et al., 2011; Kumar et al., 2022; Lenze et al., 2014; McCallion, 2017; Mir Rajaee et al., 2017; Rahmani, 2020; Sabouri & Mansouri, 2022; Smith et al., 2015; Sofyan et al., 2023; Sun et al., 2021; Torfiamidpoor et al., 2022) and transcranial direct current stimulation (Aghaziarati et al., 2023; Brunoni et al., 2012; De Raedt et al., 2017; DosSantos et al., 2012; Ferrucci & Priori, 2014; Fregni et al., 2018; Fregni et al., 2008; Jacobson et al., 2012; Keshvari et al., 2017; Moslemi et al., 2019; Narimani et al., 2017; Nitsche et al., 2012; Quartarone et al., 2004; Vafaye Sisakht & Ramezani, 2017) have validated their effectiveness in improving stress and rumination separately. Additionally, no study was found that had investigated the effectiveness of these two types of interventions together.

In explaining this finding, it is possible to refer to the advantage of using the beneficial features of both interventions. There are basic clinical theories for tDCS that can consider it as an alternative treatment to

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pharmacotherapy, for example, in patients with low drug tolerance or those who are required to use medications that interact with each other (Aghaziarati et al., 2023; Fregni et al., 2018). Considering the problems that adolescents with cancer face, they inevitably need to consume various medications to alleviate cancer symptoms, and concurrent use of psychiatric drugs may cause various side effects for these individuals. Therefore, the use of alternative methods such as tDCS to improve psychiatric problems and as a complementary method for psychotherapy can be very beneficial.

On the other hand, a common component of stress and rumination is significant psychological tension, and understanding the physiological-biological and psychological bases of this component is very effective in treatment. Since mindfulness applies moment-to-moment bodily feedback and teaches individuals to become aware of their feelings, bodily states, and breathing, it also educates people to consider their mental and inner psychological factors, which exacerbate psychological tension, as a collection of transient thoughts and emotions; thus, through mindfulness practices, the individual prevents focused attention on physiological and psychological factors that exacerbate tension (Parsons et al., 2017).

Furthermore, mindfulness, by encouraging individuals to repeatedly practice focused attention on neutral stimuli and mindful awareness of the body and mind, helps anxious individuals to disengage from preoccupations with threatening thoughts and stress about performance and shifts their mind out of automatic gear. In other words, these techniques, by increasing the individual's awareness of present-moment experiences and redirecting attention to cognitive systems and more efficient information processing, result in reduced stress and physiological tension in the individual (Sun et al., 2021; Torfiamidpoor et al., 2022). Therefore, integrating the positive aspects of both transcranial direct current stimulation and the mindfulness-based stress reduction program can lead to improvements in stress and rumination and, in general, the well-being of adolescents with cancer, and this integration will be beneficial like combining pharmacotherapy and psychological interventions.

The results of the repeated measures analysis of variance for the interaction effect of time on the independent variable showed that there are no significant differences between post-test and follow-up stages for the variables of stress and rumination; hence, it can be said the results were stable. Consistent with these findings, Jafari and Shahabi (2017) also found that the effectiveness of the mindfulness-based stress reduction program on overt and covert anxiety and the quality of life of women with obesity was stable in the follow-up stage (Jafari & Shahabi, 2017). In terms of the durability of the results of transcranial direct current stimulation (tDCS), the study by Shiozawa and colleagues (2014) showed that transcranial direct current stimulation (tDCS) has a lasting effect in improving generalized anxiety disorder in the follow-up stage (Shiozawa et al., 2014).

In explaining the sustainability of the impact of transcranial direct current stimulation (tDCS), it can be stated that this effect results from interventions in areas such as the anterior prefrontal and anterior cingulate cortex, which play a role in emotional instability. Studies in humans and animals have shown that stimulating the prefrontal areas with mild electric current, by activating opioid pain receptors involved in persistent anxiety problems, leads to an increase in dopaminergic activity or changes in glutamatergic neurotransmission and leaves a lasting impact on brain neurochemistry (DosSantos et al., 2012). These lasting effects play a significant role in the sustainability of intervention results.

In explaining the sustainability of the effects of mindfulness, it can be stated that mindfulness and mindfulness skills help adolescents with cancer to gain insight and awareness about their automatic patterns of thoughts, emotions, sensations, and anxiety-provoking behaviors, and then they can skillfully choose beneficial targeted responses that lead to sustainable learning in responding to stress-inducing stimuli (De Raedt et al., 2017). Since one of the concerns of psychologists and counselors is the sustainability of the therapeutic effects of psychological interventions, the findings of the current study can somewhat alleviate this concern.

5. Limitations & Suggestions

Among the limitations of the current study are the lack of control over confounding variables affecting the dependent variables such as the progression of the disease and the lack of motivation in adolescents with cancer. The findings of the current study are limited to adolescents with cancer, and caution should be exercised in generalizing the results to other adolescents with chronic diseases. Based on the results of the present study, counseling and psychology units in hospitals and oncology clinics need to be more aware of the mental health of adolescents with cancer and, considering the findings of this study, use the combined method of stress

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reduction based on mindfulness along with tDCS to improve stress and rumination in adolescents with cancer. Since chronic diseases like cancer significantly affect the psychological health of patients, comprehensive and all-encompassing attention to physical and psychological health in the care protocols and programs for these patients seems necessary and essential. In the framework of the findings of the present study, one of the recommendations is to add psychological interventions including the mindfulness-based stress reduction program and tDCS method to improve stress and rumination in adolescents with cancer.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors contributed equally.

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