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Research Paper: Effect of Transcranial Direct Current Stimulation on Dorsolateral Prefrontal Cortex to Reduce the Symptoms of the Obsessive-Compulsive Disorder

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ABSTRACT

Introduction: Obsessive-Compulsive Disorder (OCD) is one of the most common debilitating mental disorders with a prevalence rate of 2% to 3% in the general population. Previous studies have indicated abnormalities in the dorsolateral prefrontal cortex (DLPFC) of OCD patients; thus, we decided to use transcranial Direct Current Stimulation (tDCS) to decline these patients' symptoms.

Methods: A total of 24 patients with OCD participated in this study with the hope of improvement after the application of tDCS. The subjects were randomly assigned to three groups of Sham, Right DLPFC, and Left DLPFC. tDCS was applied for five consecutive days and in each session, patients were subjected to 2 mA current flow for two 15 minutes followed by a 10-minute rest in between (every session lasted for 40 minutes).

Results: Subsequently, the changes in obsessive-compulsive level and cognitive functions were evaluated via Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) and Depression, Anxiety, and Stress Scale 21 (DASS-21) by comparing the results before (pre-test) and after (post-test) tDCS treatment.

Conclusion: Ultimately, the scores of the Yale-Brown scale in the Left DLPFC group showed significant changes after treatment with tDCS (mean difference compared to the sham group: -6.18 and $P \leq 0.05$). Hereupon, this study demonstrated that transcranial direct current stimulation may cause improvements in symptoms of OCD.

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Highlights

- OCD is one of the most common debilitating mental disorders.
- tDCS was applied for enhancing cortical excitability and spontaneous neuronal activity.
- Psychopharmacologic and psychotherapeutic interventions or a combination of them are common treatments for OCD.

Plain Language Summary

OCD is a rather common psychiatric disorder. Psychopharmacologic and psychotherapeutic interventions or a combination of them are common treatments for OCD, thus, rTMS, and tDCS) are mostly suggested for treatment. tDCS is an available method enhancing cortical excitability and spontaneous neuronal activity; thus, it could be effective in improving the symptoms of psychiatric disorders. DLPFC is a promising approach for OCD treatment and we aimed at utilizing that in this study.

1. Introduction

Obsessive-Compulsive Disorder (OCD) is a rather common psychiatric disorder characterized by the presence of obsessions and/or compulsions. OCD is defined as unwanted intrusive and recurrent thoughts, urges, or images (obsessions) and repetitive behaviors or mental acts that the individual feels driven to perform in response to an obsession or according to rules that patients believe must be applied rigidly (compulsions) (D'Urso et al., 2016).

OCD may be associated with both genetic and adventitious factors with a prevalence rate of 2% to 3% in the general population (Brunelin et al., 2018; Meyer, 2013). This disorder also has a prevalence of 1-3% in children and teenagers and 75% of them suffer from other anxiety disorders, such as anxiety, oppositional defiant disorder, attention-deficit/hyperactivity disorder, and Tourette's disorder (Ost et al., 2016).

Symptoms of OCD are intrusive and recurrent thoughts and urge leading to compulsive and repetitive behaviors or mental acts (Brunelin et al., 2018; D'Ursoa et al., 2016). Meyer believed that the emergence of these thoughts depends on religiosity, self-esteem, and personality characteristics (Meyer, 2013). In 30-50% of adults with OCD, the early symptoms would commence in childhood or early adulthood, and if not treated, it may lead to subjective distress as well as a social disability (D'Ursoa et al., 2016; Ost et al., 2016). By the devaluation of life quality, OCD has been ranked as one of the ten most handicapping conditions by the World Health Organization. Studies have revealed that the frustration caused by this disorder leads to high levels of subjective distress, social disability, and suicidal thoughts (Angelakis, Gooding, Tarrier, & Panagioti, 2015; D'Urso et al., 2016).

Psychopharmacologic and psychotherapeutic interventions or a combination of them are common treatments for OCD; however, they fail to function properly in almost 40% of patients (Brunelin et al., 2018). For that reason, non-pharmacological approaches, such as non-invasive brain stimulation therapies, comprising repetitive Transcranial Magnetic Stimulation (rTMS), and transcranial Direct Current Stimulation (tDCS) are mostly suggested (D'Ursoa et al., 2016; Mondino, Haesebaert, Poulet, Saoud, & Jérôme Brunelin, 2015). tDCS is an available method enhancing cortical excitability and spontaneous neuronal activity under an anode by generating a weak current between anode and cathode. It is suggested that this method enhances cortical excitability and activity by the generation of action potentials; thus, it could be effective in improving the symptoms of psychiatric disorders (Lefaucheur et al., 2017; Stagg, Antal, & Nitsche, 2018) which was first introduced in animal and human experiments in the 1950s, and added to the standard arsenal of methods to alter brain physiology as well as psychological, motor, and behavioral processes and clinical symptoms in neurological and psychiatric diseases about 20 years ago. In contrast to other noninvasive brain stimulation tools, such as transcranial magnetic stimulation, it does not directly induce cerebral activity, but rather alters spontaneous brain activity and excitability by subthreshold modulation of neuronal membranes. Beyond acute effects on brain functions, specific protocols are suited to induce long-lasting alterations of cortical excit-

ability and activity, which share features with long-term potentiation and depression. These neuroplastic processes are important foundations for various cognitive functions such as learning and memory formation and are pathologically altered in numerous neurological and psychiatric diseases. This explains the increasing interest to investigate transcranial direct current stimulation (tDCS and has been suggested to decrease symptoms of OCD (Bation, Poulet, Haesebaert, Saoud, & Brunelin, 2015; Senço et al., 2015).

Imaging studies have manifested abnormalities in the cortico-striato-thalamo-cortical pathways, especially, the Dorsolateral Prefrontal Cortex (DLPFC)-caudate nucleus-thalamus loop in patients with OCD. Also, several pieces of research brought out the clinical effectiveness of stimulating DLPFC in other psychiatric conditions (Brunelin et al., 2018). Accordingly, DLPFC is a promising approach for OCD treatment and we aimed at utilizing that in this study.

2. Methods

In this study, 24 patients, including seven women and 17 men participated, of whom 17 cases were married and 7 cases were single. There were three groups in this study, including the Sham, Right DLPFC (anode in F4 and cathode in FP1 area), and Left DLPFC (anode in F3 and cathode in FP2 area). The subjects were randomly distributed into groups: One woman and five men in the sham group, three women and seven men in the Right DLPFC group, and three women and five men in the Left DLPFC group (Table 1).

All patients were subjected to a 2 mA current flow for 30 minutes with a 10-minute rest in between (the total session period was 40 minutes). This protocol was performed daily for five days. To find a suitable location, an international 10–20 electrode placement system and 5×7 cm^2 electrodes pads were used.

For evaluation of changes in obsessive-compulsive level and cognitive functions, the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) and Depression, Anxiety, and Stress Scale 21 (DASS-21) were used before and after therapy. Data were analyzed by SPSS v. 16. To compare the results of the Y-BOCS and DASS-21, the mean and standard deviation of pre-test and post-test in all groups were examined. Then, the Analysis of Covariance (ANCOVA) was applied to omit the pre-test learning effect. The LSD post-test was used to demonstrate which between-group differences were significant.

3. Results

The severity of OCD cases, who were confirmed with clinical diagnosis, were assessed with the Y-BOCS and their scores were considered as the pre-test scores. These scores were between 12 and 30 (with a mean of 21 and a standard deviation of 4.7), which showed that they suffered from mild to severe OCD. To examine the aspects of emotional disturbance, the DASS-21 was used. Table 2 describes the descriptive data of the sham, left DLPFC, and right DLPFC groups, including the means and standard deviations of both tests in each group.

To statically control the influence of pre-test, the ANCOVA was applied (Table 3), which showed at least one significant difference between groups. Therefore, the LSD post hoc test was done. A significant difference was observed between the left DLPFC and sham groups in the Y-BOCS scores (Table 4). No significant differences were observed in the DASS-21 scores between groups.

4. Discussion

Studies have shown that stimulating DLPFC has some beneficial effects in psychiatric conditions with an abnormality in this area (Brunelin et al., 2018). We aimed to reduce the clinical symptoms of OCD and attempted to employ a tDCS as a non-invasive method in two regions of left DLPFC and right DLPFC.

In this study, OCD patients experienced a protocol of tDCS treatment (2 mA current flow for 15 minutes with 10 minutes of rest in between for five days), and their depression, anxiety, stress level, and OCD symptoms were assessed using DASS-21 and Y-BOCS. Participants in both groups of Left and Right DLPFC showed no significant difference in scores of the DASS-21. Although

Table 1. Demographic data of the patients

Vriables	Sham Group	Right DLPFC Group	Left DLPFC Group	Total
Men	5	7	5	17
Women	1	3	3	7

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Table 2. Descriptive data of the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) and Depression, Anxiety, and Stress Scale 21 (DASS-21)in all groups

Test	Mean±SD	
	Pre-test	Post-test
Yale-Brown (Sham)	18.88±4.390	17.00±7.783
DASS-21 (Sham)	29.75±10.209	24.62±14.071
Yale-Brown (Left DLPFC)	21.50±4.660	0.38±0.744
DASS-21 (Left DLPFC)	30.50±15.137	25.87±13.206
Yale-Brown (Right DLPFC)	22.62±4.809	15.50±6.761
DASS-21 (Right DLPFC)	20.87±14.980	14.25±13.551

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Table 3. Analysis of Covariance (ANCOVA) results

Test	Sum of Squares	Average Squares	Degrees of Freedom	F	P
Modified model	714.41	238.13	3	19.25	0.0001
Covariate variable	700.07	700.07	1	59.59	0.0001
Independent variable	68.06	136.13	2	5.50	0.012
Error	12.37	12.37			

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our results showed no significant difference in the right DLPFC, another study on five patients using a different protocol for 15 days, demonstrated significant improvements (Dinna et al., 2016). One of the reasons for the absence of a significant improvement can be the high variation in scores that increases the standard deviation. This problem can be solved by increasing the number of cases in all groups. Also, a longer period of treatment may result in more satisfying results. One promising point, which strengthens these ideas is that there was no significant difference in pre-test and post-test scores of the sham group, as well. We observed a significant improvement in the Y-BOCS scores in the left DLPFC. This shows that this protocol has some positive effects on decreasing the difficulties caused by OCD.

Several studies have employed tDCS to reduce problems caused by OCD with different protocols and considering different areas of the brain (Bation, Mondino, Le Camus, Saoud, & Brunelin, 2019; Bation et al., 2016; Brunelin et al., 2018; D'Ursoa et al., 2016; Goradel, Pouresmali, Mowlaie, & Movahed, 2016; Meyer, 2013; Mondino et al., 2015; Najafi et al., 2017; Palm et al., 2017; Senço et al., 2015). Improvements following the

Table 4. The results of the LSD Post Hoc Test

Variables	Average Difference	P
Left DLPFC	-3.155	0.09
Sham	-6.18*	0.003
Right DLPFC	3.155	0.09
Sham	-3.02	0.11

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treatment with tDCS in different areas suggest that there is not only one specific area affected by OCD, but also it seems that OCD involves more complex and extended neurological pathways.

5. Conclusion

Applying tDCS as a non-invasive method in the left DLPFC area is effective for decreasing the difficulties of OCD.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed about the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information. They were free to leave the study whenever they wished, and if desired, the research results would be available to them.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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