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# Efficiency of Transcranial Direct Current Stimulation (tDCS) in Anorexia Nervosa Treatment- Case Report

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**Abstract**

**Introduction:** Transcranial direct current stimulation (tDCS) is a non-invasive brain stimulation with considerable potential as a treatment for many CNS disorders. Individuals suffering from eating disorders have elevated rates of lifetime depression, anxiety and obsessive-compulsive disorder, also affecting specific brain regions. More studies assess the effect of brain modulation in anorexia nervosa (AN). This study aimed to evaluate the effect, tolerability and safety of tDCS stimulation in the patient with an AN diagnosis.

**Material and method:** The therapy was implemented in an 18-year-old female hospitalized at the I Department of Psychiatry, Psychotherapy and Early Intervention Medical University of Lublin. The simulation was performed twice daily for 25 minutes for two weeks, 20 sessions. To assess a. anthropometric measures, bioelectrical impedance analysis was conducted; b. biological factors fasting venous blood was drawn; c. psychological aspects: Eating Attitudes Test, Rosenberg self-esteem scale, Beck Depression Inventory, Eating Disorder Examination Questionnaire, Body Esteem Scale, Perceived Stress Scale were used.

**Results:** The patient responded well to stimulation - apart from a mild headache. After tDCS sessions, improvement in anthropometric measurements, mood, and body self-esteem was observed. No severe changes in blood parameters were observed after the intervention.

**Conclusions:** Described study case offer preliminary support for achieving meaningful clinical outcomes using transcranial stimulation. However, future clinical studies compared to the placebo group are necessary for proposing a new type of AN therapy.

*Keywords*: transcranial direct stimulation, brain stimulation, anorexia nervosa, eating disorders.

**Streszczenie**

**Wstęp:** Przezczaszkowa stymulacja prądem stałym (tDCS) jest nieinwazyjną stymulacją mózgu o dużym potencjale w leczeniu wielu zaburzeń dotykających ośrodkowy układ nerwowy. Osoby cierpiące na zaburzenia odżywiania mają podwyższone ryzyko rozwoju depresji, zaburzeń lękowych i obsesyjno-kompulsywnych. Coraz więcej badań ocenia wpływ modulacji mózgu na jadłowstręt psychiczny (AN). Badanie miało na celu ocenę wpływu, tolerancji i bezpieczeństwa stymulacji tDCS u pacjentki z rozpoznaniem AN.

**Materiał i metoda:** Terapię wdrożono u 18-letniej kobiety hospitalizowanej w I Klinice Psychiatrii, Psychoterapii i Wczesnej Interwencji Uniwersytetu Medycznego w Lublinie. Symulację przeprowadzano dwa razy dziennie przez 25 minut przez dwa tygodnie, łącznie 20 sesji. Aby ocenić: a. pomiary antropometryczne, przeprowadzono analizę impedancji bioelektrycznej; b. czynniki biologiczne pobrano krew żylną; c. aspekty psychologiczne: wykonano: Kwestionariusz Postaw wobec Jedzenia, Skalę Samooceny Rosenberga, Inwentarz Depresji Becka, Kwestionariusz Badania Zaburzeń Odżywiania, Skalę Oceny Ciała, Skalę Postrzeganego Stresu.

**Wyniki:** Pacjentka dobrze reagowała na stymulację - raportowała wyłącznie lekki ból głowy. Po sesjach tDCS nastąpiła poprawa pomiarów antropometrycznych, nastroju i samooceny ciała. Po zabiegach nie zaobserwowano poważnych zmian w parametrach krwi.

**Wnioski:** Opisany przypadek kliniczny stanowi wstępne wsparcie dla możliwości terapeutycznych stymulacji przezczaszkowej. Do zaproponowania nowego rodzaju terapii AN są konieczne zaślepione randomizowane badania kliniczne.

*Słowa kluczowe*: jadłowstręt psychiczny, zaburzenia odżywiania, stymulacja mózgu, przezczaszkowa stymulacja prądem stałym

## Introduction

Transcranial direct current stimulation (tDCS) is a non-invasive brain stimulation (NIBS) method to modify cortical activities. The intervention is based on using a battery-powered device with connected electrodes: an anode (positive charge) electrode and a cathode (negative charge) electrode. First, evidence of the ability to modify central nervous system (CNS) activity of direct current comes from animal studies more than half a century ago [1]. Brain stimulation developed slowly and was nearly forgotten in the following years. The popularity of NIBS has grown for about 15 years but is still extended [2]. The mechanism of tDCS action is complex and includes shifts in neuronal activity towards depolarization or hyperpolarization. Stimulation modulates spontaneous neuronal network activity without inducing suprathreshold depolarization. Anodal tDCS enhances, and cathodal tDCS decreases cortical activity (3). The CNS stimulation induced prolonged neurochemical changes and indirectly altered connectivity-driven of apart cortical and subcortical areas [3]. Using a tDCS device is safe, portable, easy and simple to apply and implement in outpatient or home conditions and a much cheaper alternative to other neuromodulation methods. tDCS has considerable potential as a treatment for many disorders affecting CNS, including schizophrenia and major depressive disorder, multiple sclerosis, Parkinson's and Alzheimer's diseases [4–7].

More and more studies assess the effect of brain modulation in diseases affecting eating behaviour traits, such as anorexia nervosa (AN). Food consumption leads to the activation of the specific region of the brain, and many studies have implicated the reward circuit that regulates food intake as abnormal in early AN diagnosis [8]. Long-lasting malnutrition leads to many brain abnormalities. The prolonged starvation may aggravate abnormal food behaviours and lead to psychiatric symptoms, including emotional and cognitive deficits [8].

The important aspects of the pathogenesis are the changes in neurotransmission, including serotonin (5-HT), corticotropin-releasing hormone (CRH), and dopamine (DA) pathways. 5-HT dysregulation contributes to the dysphoric mood and mediates a lack of pleasure from food-related experiences. In AN, elevated CRH has anorexigenic effects - loss of appetite and stimulation of cortisol secretion (a catabolic hormone responsible for increasing the availability of fuel substrates) [9]. The DA system changes in ED lead to impaired visual discrimination learning, decision-making and executive control problems [10]. Reports of neuroimaging assessment confirm abnormally metabolic resting rates, including reduced or increased cerebral activity depending on specific brain regions. The changes in metabolism may be accounted for by many core symptoms of AN (such as disturbed satiety, the construct of body image) and declined cognitive performance. Patients have reduced brain and ventricular volume during the acute phase of illness. The brain morphology changes contribute to malnourishment and are reversible with recovery [10].

Individuals suffering from ED have elevated rates of lifetime depression, anxiety and obsessive-compulsive disorder also affecting specific brain regions [10]. The evidence-based treatment of AN is still limited, and therapeutic options are concerned mainly with weight restoration. The mortality of AN is the highest of all psychiatric disorders and, according to data from meta-analysis, is estimated at 5.1 deaths per 1000 person-years [11]. Studies indicate recovery rates of 25% to 70%, indicating the need for relapse prevention and new treatment methods [12]. To date, few studies reported the effect of tDCS on AN treatment response, and the results were inconclusive [13]. The promising research results concerning other psychiatric conditions suggest a potential favourable impact on AN outcomes, including core symptoms and coexisting disruptions. The aim of the study is to present the effect, tolerability and safety of tDCS stimulation in the patient with AN diagnosis.

## Study case and description

An 18-year old female, hospitalized due to AN. The patient has been suffering from ED since the age of 12. The symptoms worsened in July 2021, she refused to eat meals and was exercising excessively. The patient was referred for the first time, for outpatient treatment in September the same year. Treatment did not bring much effect and eventually, starving, in December 2021, she was admitted to the youth ward of a psychiatric clinic. The patient was hospitalized with a body weight of 43 kg and a height of 180 cm (BMI = 13.2 kg/m2). The treatment included nutritional rehabilitation, pharmacotherapy (sertraline 200 mg per day), cognitive behavioral therapy and family therapy. The tDCS stimulations started in February 2022, when the body weight reached 47.5 kg (BMI = 14.7 kg/m2) and vital signs have stabilized. It is also important

that simulations started almost two months after the sertraline was introduced so that the effects of the drug did not distort the examination of therapy results.

During the physical examination prior to inclusion in the project, the patient reported low self-esteem and lack of motivation to fight the disease. After agreeing to participate in a research project using tDCS stimulation, the patient was comprehensively examined - blood tests, body composition analysis, electroencephalography (EEG) and questionnaires to assess mental state were performed. The tools used to assess the effect of stimulation are presented in Table 1.

The patient was treated with tDCS according to the protocol developed by Strumila et al. in2019 [20]. Briefly,

*Table 1. The tools used to assess the effect of stimulation*

| Used tool | Short Description |
|---|---|
| Symptoms of eating disorders and applied eating patterns | |
| Eating Attitudes Test (EAT-26) Part A | One of the most widely used standardized screening measures for ED. The EAT-26 forms three subscales: dieting, bulimia & food preoccupation and oral control [14]. The test consists of parts A and B, where the second part (B) includes 4 behavioural questions related to compensatory behaviour. These are not scored questions.<br><br>Interpretation of the results of part A: score 20 or above indicates high level of concern about eating behaviors |
| Eating Disorder Examination Questionnaire (EDE-Q) | Diagnostic interview, which has been modified to reflect current DSM-5 diagnoses. The EDE-Q is the questionnaire considered the 'gold standard' measure of ED psychopathology [17].<br>Higher scores indicate greater levels of symptomatology. |
| Body image | |
| Body Esteem Scale | A 28-item multidimensional measure of body esteem rating sexual attractiveness, weight concern, physical condition. Respondents rate specific body parts and functions using a five-point Likert scale. The higher the score, the higher the self-esteem is [18]. |
| Rosenberg self-esteem scale | A 10-item self-report measure of global self-esteem. It consists of 10 statements related to overall feelings of self-worth or self-acceptance. The items are answered on a four-point scale ranging from strongly agree to strongly disagree. The scale uses a 0-30 scale where a score below 15 may indicate problematic low self-esteem [15]. |
| Depressive symptoms/ Stress response | |
| Beck Depression Inventory (BDI) | The BDI is a 21-item self-report inventory designed to assess the presence and severity of depressive symptoms. The scale evaluates key symptoms of depression, including pessimism, sense of failure, self-dissatisfaction, guilt, punishment, crying, irritability, social withdrawal, indecisiveness, body image change, insomnia, fatigability, loss of appetite, and weight loss. Each item is rated on a 4-point type scale ranging from 0 to 3, in severity over the past two weeks. Scores from 0 through 9 indicate no or minimal depression, scores from 10 through 18 indicate mild to moderate depression, scores from 19 through 29 indicate moderate to severe depression and scores from 30 through 63 indicate severe depression [16]. |
| The Perceived Stress Scale (PSS-10) | A 10-item questionnaire widely used to assess stress levels in young people and adults aged 12 and above. It evaluates the degree to which an individual has perceived life as unpredictable, uncontrollable and overloading over the previous month. Higher scores indicate higher levels of perceived stress [19]. |

stimulation was performed twice a day for 25 minutes for two weeks, 20 sessions. Originally, 30 sessions were scheduled, but the patient left the hospital on request earlier. The anode was located on the left dorsolateral

cortex prefrontal (F3), while the cathode was on the right (F4). Soterix 1x1 tDCS mini-CT LTE (model 1601-LTE, Soterix Medical, New York, NY, available from Elmiko Medical, Poland) was used for therapy. The stimulation effect was enhanced by activities conducted during the session - reading books, solving crosswords or discussions with team members. The patient responded well to stimulation - apart from a mild headache, stimulation had no side effects. Research team members had doubts about the irritation of the delicate skin due to the disease, but luckily no irritation occurred. Only slight reddening of the skin was present for some time after stimulation.

To assess the effect of tDCS, questionnaires listed above in Table 1. were used. The patient had critical thoughts towards her body and was not eager to introduce diet changes or rehabilitation of body weight. On the EAT-26 scale, she received 58 points and above 22 points in EDE-Q, indicating a severe eating disorders problem. On the self-esteem scales, the results were low and indicated undervaluation. The levels of perceived stress and depressive symptoms were high. Changes in body weight were observed throughout hospitalization, as shown in Table 2. The patient gained 2.42 kg of body weight while receiving tDCS stimulation.

After the completion of the tDCS stimulation cycle, a slight improvement in the parameters was observed in the reported symptoms. Interestingly, two weeks after the completion of stimulation, the improvement progressed. The observed results are presented in Table 3. Moreover, during each of the three meetings with the research team members, the patient was asked (in the questionnaire) about an ideal subjective weight. At the first meeting, it was 38 kg, immediately after the end of stimulation 49 kg, and after 2 weeks of follow up it was already 43 kg. Blood biochemical parameters examined before and after the therapy indicate that the stimulation had no adverse effect on laboratory tests (see Table 4.). The slight improvement could have been caused by the improved nutrition of the body, but we are not able to say whether the tDCS was directly related to this.

*Table 2. Changes in body weight during hospitalization*

| Week | Body mass [kg] | Week | Body mass [kg] | Stimulation |
|---|---|---|---|---|
| 1 | 43 | 8 | 46.32 | |
| 2 | 42.24 | 9 | 46.60 | |
| 3 | 43.76 | 10 | 46.80 | |
| 4 | 44.04 | 11 | 47.5 | Beginning |
| 5 | 44.64 | 12 | 49.34 | |
| 6 | 44.96 | 13 | 49.92 | Termination |
| 7 | 45.58 | | | |

*Table 3. Changes in examined factors during tDCS stimulation*

| Scale | Entry of the stimulation | End of the stimulation sessions | Improvement/ no improvement | Follow up after 2 weeks | Improvement/ no improvement |
|---|---|---|---|---|---|
| Eating Attitudes Test (EAT-26), part A | 58 | 42 | improvement | 36 | improvement |
| Rosenberg self-esteem scale | 6 | 7 | improvement | 10 | improvement |
| Beck Depression Inventory (BDI) | 34 | 22 | improvement | 21 | improvement |
| Eating Disorder Examination Questionnaire (EDE-Q) | 22.3 | NA | NA | 20 | improvement |
| Body Esteem Scale | 69 | NA | NA | 77 | improvement |
| The Perceived Stress Scale (PSS-10) | 34 | 29 | improvement | NA | NA |

*Table 4. Changes in blood parameters*

| Variable | Entry the stimulation | End of the stimulation sessions |
|---|---|---|
| TSH [uU/ml] | 0.7 | 0.813 |
| FT4 [pmol/l] | 12.56 | 13.99 |
| FT3 [pmol/l] | 3.49 | 3.37 |
| Calcium [mmol/l] | 2.470 | 2.390 |
| Inorganic phosphates [mmol/l] | 1.33 | 1.35 |
| Total magnesium [mmol/l] | 0.950 | 0.940 |
| Ferritin [ug/l] | 95.43 | 120.30 |
| Body weight [kg] | 47.5 | 49.4 |

*Table 5. Changes in anthropometric measures during intervention*

| Timeframe | TBW | TBW % | ECF | ECF % | ICF | ICF % | FM | FM % | FFM | FFM % | BMI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry of the stimulation | 27.41 | 57.71 | 12.55 | 45.79 | 14.86 | 54.21 | 10.05 | 21.16 | 37.45 | 78.84 | 14.66 |
| End of the stimulation sessions | 28.89 | 58.36 | 13.13 | 45.46 | 15.75 | 54.54 | 10.03 | 20.27 | 39.47 | 79.73 | 15.28 |
| 2 weeks after last tDCS | 27.55 | 56.22 | 12.50 | 45.37 | 15.05 | 54.63 | 11.37 | 23.20 | 37.63 | 76.80 | 15.12 |

*TBW – total body water; ECF – extracellular fluids; ICF – intracellular fluids; FM – fat mass; FFM – fat free mass; BMI – body mass index*

**Discussion**

The aim of the study was to assess the safety and effect of tDCS stimulation on psychological, biological factors in patient suffering for AN. According to obtained results, tDCS stimulation may be a safe method in AN therapy. After two weeks of stimulation, improvement in anthropometric measurement, some blood parameters (e.g. ferritin), symptoms of depression and stress and self-body image were observed. It should be noted that psycho- and pharmacotherapy were conducted simultaneously and may affect outcomes. Current evidence-based interventions show limited efficacy in the treatment of ED, leading to the growing interest in other approaches. The systematic review indicates not enough promising evidence of brain stimulation in AN to implement them in clinical practice [13]. Some reports indicate none, while other improvements in BMI after tDCS [21].

Brain stimulation indirectly affects body mass by changes in the activity of brain regions and psychological effects, and BMI should be only one or more indicators of tDCS efficacy. Studies conducted by Constazo confirm better results of tDCS compared to family psychotherapy (BMI). Nevertheless, the authors assessed interventions' long-term (6 months) effect. It has been shown that tDCS reduced the severity of mood symptoms observed in AN [22]. Depression could lead to deterioration of appetite, more significant criticism, and self-body esteem, making the treatment of ED more difficult. The meta-analysis confirmed the substantial superiority of tDCS compared to sham in treating patients with diagnosed major depressive disorders [23]. These results suggest that tDCS may have another direct mechanism of action linked to improving incorrect food behaviour. The patient examined by us did not report any severe adverse effects. More studies confirm the safety and tolerability of brain stimulation [21]. Most reports of problems after stimulation were: itching, burning sensation and headache. Nevertheless, the available evidence of the effectiveness of tDCS in AN treatment is obscure [20]. Most of the studies were conducted in small groups, and assessed outcomes vary from experiment to experiment [21].

This study contributes to the limited knowledge around the effects of tDCS stimulation in the patient with AN diagnosis. Our patient demonstrated a positive response to the new treatment model. During the study, anthropometric measures slightly increased, which can be observed mainly in the changes of the BMI (see Table 5.). However, as previously mentioned, we are not able to say whether the weight gain was due to the therapy or the motivation to leave the hospital. Instead, we believe that the improvement in all the tests used directly confirms the beneficial effects of the stimulation. This case study's results are limited by the short intervention period and the fact that only one patient was treated. Additionally, further investigation is needed to see if other patients

show similar improvements, although the report of this case is promising. Especially since, no side effects were observed, measured or reported by participants or staff.

These findings offer preliminary support for achieving meaningful clinical outcomes using tDCS. Future studies of this method that include larger samples, longer follow-up periods, and comparison to placebo group, could be crucial for finding a new AN therapy.

## Conflict of interest

The authors have declared no conflict of interest.

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