

Transcranial direct current stimulation in tinnitus rehabilitation: a case report

Estimulação transcraniana por corrente contínua na reabilitação do zumbido: relatos de casos

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ABSTRACT

Tinnitus is an auditory perception without an external sound source. Transcranial direct current stimulation is a promising therapy for modulating the neurobiological substrates associated with this condition. This case report aimed to evaluate whether the discomfort and impact of tinnitus on patients' quality of life change after neuromodulation intervention. Adults with chronic tinnitus were included after otorhinolaryngological evaluation. The cases analyzed derive from a pilot study. The procedures included a speech-language-hearing history, pure-tone audiometry, high-frequency audiometry, pitch and loudness matching, a visual analog scale, and the Tinnitus Handicap Inventory. The intervention consisted of applying a 2-mA current for 20 min for 5 consecutive days, with an anodal electrode in the left temporoparietal area and a cathodal electrode in the right dorsolateral prefrontal cortex. The cases were expressed individually, and the data were analyzed descriptively. Five patients (three women and two men), with a mean age of 45 years, were evaluated. As to audiometry, six ears had normal hearing, while all ears had decreased high-frequency sensitivity. Scale scores decreased after five neuromodulation sessions; the mean score in the pre-therapy group decreased from 5.2 to 4.4 points post-therapy. The total questionnaire score decreased from 36.8 to 33.2 points. The mean loudness decreased from 10.4 to 9.2 dB SL. The results suggest that noninvasive neuromodulation reduced the annoyance and impact of tinnitus on these patients' quality of life.

Keywords: Tinnitus; Transcranial direct current stimulation; Electrical stimulation therapy; Rehabilitation; Hearing; Psychoacoustics

RESUMO

O zumbido é a percepção auditiva sem fonte sonora externa. A estimulação transcraniana por corrente contínua é uma terapia promissora para modular os substratos neurobiológicos associados a essa condição. O objetivo deste relato de casos foi avaliar se há mudança no incômodo e no impacto do zumbido na qualidade de vida dos pacientes após a intervenção com neuromodulação. Foram incluídos pacientes adultos com zumbido crônico, após avaliação otorrinolaringológica. Ressalta-se que os casos analisados derivam de um estudo-piloto. Os procedimentos incluíram anamnese fonoaudiológica, audiometria tonal, audiometria de altas frequências, acufenometria, Escala Visual Analógica (EVA) e *Tinnitus Handicap Inventory* (THI). A intervenção consistiu na aplicação de corrente de 2mA por 20 minutos, durante cinco dias consecutivos, com eletrodo anódico no córtex temporoparietal esquerdo e o eletrodo catódico no córtex pré-frontal dorsolateral direito. Os casos foram descritos individualmente e os dados analisados de forma descritiva. Foram avaliados cinco pacientes (três mulheres e dois homens), com média de idade de 45 anos. Na audiometria, seis orelhas apresentaram audição normal, enquanto todas as orelhas apresentaram diminuição da sensibilidade nas altas frequências. Após cinco sessões de neuromodulação, verificou-se redução nos escores da escala, com diminuição da média do grupo pré-terapia de 5,2 para 4,4 pontos pós-terapia. O escore do questionário total reduziu de 36,8 para 33,2 pontos. A *loudness* apresentou uma diminuição média de 10,4 dBNS para 9,2 dBNS. Os resultados sugerem que a neuromodulação não invasiva reduziu o incômodo e o impacto do zumbido na qualidade de vida desses pacientes.

Palavras-chave: Zumbido; Estimulação transcraniana por corrente contínua; Terapia por estimulação elétrica; Reabilitação; Audição; Psicoacústica

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Introduction

Tinnitus affects more than 740 million people worldwide, with prevalence estimates ranging from 4.1% to 42.7%^(1,2). The prevalence of tinnitus in the population of Rio Grande do Norte, Brazil, was estimated at 50.4% in 2023⁽³⁾.

Tinnitus is the perception of sounds in the absence of external sound stimuli. It is a heterogeneous condition regarding the psychoacoustic characteristics of the symptom, etiology, and associated comorbidities^(1,2,4-6).

It can be caused by a variety of hearing disorders. Most patients with tinnitus have associated hearing loss. Even for those with normal pure-tone audiometry, some hearing dysfunction can be detected through specific tests^(1-4,6,7).

There is no accepted consensus on the pathophysiology of tinnitus, due to its etiological heterogeneity^(1,4-6). However, it is believed that tinnitus is associated with cochlear changes that generate disordered spontaneous activity in the cochlea, caused by a change in the functioning of the outer hair cells or by an increase in the endocochlear potential^(1,2,4,6).

There is dysfunctional activity in the central component of tinnitus related to the processes involved in homeostatic plasticity responsible for cortical hyperactivity after hearing loss. The reorganization of the central tonotopic map triggers tinnitus by increasing the synchrony of discharges between neurons. The reduction in sensory input hyperpolarizes neurons in the thalamus, generating an increase in thalamic and cortical action potentials. This process is maintained by the corticothalamic pathway and activation of the reticular nucleus, which sends inhibitory stimuli to specific thalamic nuclei^(2,6,8,9).

The degree of discomfort caused by tinnitus can vary from mild to severe, negatively impacting the patient's quality of life, interfering with their ability to concentrate, perceive sounds, and sleep, which can lead to social isolation, irritability, emotional distress, insomnia, and stress^(2,5,7,10).

There are still not enough evidence-based multidisciplinary clinical practice guidelines to ensure an optimal treatment protocol^(5,8,11,12). Over 60 therapeutic resources are available in the literature, making it possible to reduce the discomfort and harm of symptoms, seeking habituation and decreased sensation of intensity (loudness)⁽⁵⁾.

The therapeutic resources for managing tinnitus include correction of hearing loss, sound therapy, cognitive-behavioral therapy, medications, diet, physiotherapy, and neuromodulation^(1,4-6).

Transcranial direct current stimulation (tDCS) is a non-invasive method of neuromodulation that involves the application of low-intensity current (0.5 to 2.0 mA), using electrodes fixed to the patient's scalp, and promotes selective modulation of excitability or inhibition of cortical activation^(2,5,8,9,11).

The spatial distribution of the electric field generated by neuromodulation can be affected by current intensity, stimulation polarity, and neuronal positioning. The effect of the electric field on neuronal excitation or inhibition depends primarily on the direction of their axons and somatic dendritic axis in relation to the electric field. Thus, the two electrodes modulate, facilitating or inhibiting the activity of brain areas, depending on the positioning of neuronal bodies in the gyri and sulci⁽⁹⁾.

The application of tDCS to the right dorsolateral prefrontal cortex (DLPFC) and the left temporoparietal area (LTA) is effective in reducing the intensity and impact of tinnitus by increasing cortical excitability in the temporal areas of individuals with

persistent tinnitus perception. The frontal and prefrontal regions are believed to be part of the neural network related to tinnitus perception and interaction with the limbic system (amygdala, anterior cingulate cortex, and insula). These regions comprise the central network responsible for the cognitive-emotional aspects of tinnitus pathophysiology^(2,8,9,13).

Given the high prevalence of individuals with tinnitus and its negative impact on quality of life, this study is pertinent to address the efficacy of tDCS as a therapeutic strategy for tinnitus. This case report aimed to evaluate whether the discomfort and impact of chronic tinnitus on patients' quality of life change after tDCS neuromodulation intervention.

CLINICAL CASE PRESENTATION

This case report was approved by the Research Ethics Committee of the Onofre Lopes University Hospital, Federal University of Rio Grande do Norte, Brazil, (CEP/HUOL/UFRN) under approval number 5,622,441. All participants signed an informed consent form consenting to the performance and dissemination of the research.

The patients included in this case report were recruited from a pilot study, which served as the basis for a randomized clinical trial.

After an otorhinolaryngological consultation, the HUOL outpatient clinic referred patients aged over 18 years, complaining of chronic tinnitus and more than 3 points in the visual analog scale (VAS).

Participants underwent the following evaluation procedures at the UFRN Speech-Language-Hearing Teaching Clinic: medical history survey, pure-tone audiometry (PTA), high-frequency audiometry (HFA), pitch and loudness matching, VAS, and the Tinnitus Handicap Inventory (THI).

Audiological examinations were performed in a soundproof booth using an Interacoustics® Clinical Audiometer AC40, measuring the perception of tinnitus frequency (pitch) and intensity (loudness) with an adapted protocol⁽⁷⁾.

The VAS subjectively assessed tinnitus discomfort in terms of annoyance, based on a graphic-visual scale ranging from 0 to 10 cm, where 0 corresponds to no perception of tinnitus and 10 to intense annoyance^(4,6,7,13).

THI is a validated questionnaire to assess the consequences of tinnitus, consisting of 25 questions divided into three subscales (functional, emotional, and catastrophic). The degree of impact can be interpreted according to the score as slight (0 to 16), mild (18 to 36), moderate (38 to 56), severe (58 to 76), or catastrophic (78 to 100)^(4,6,7,9).

The Microstim NKL Foco model was used for neuromodulation sessions, which were held in a quiet room with comfortable chairs and a private space to ensure patient comfort. The therapist was fully trained and certified in non-invasive neuromodulation techniques by the Center for Assistance and Research in Neuromodulation (NAPeN Network).

The electrodes were wrapped in sponges (5 × 7 cm) soaked in sodium chloride solution (0.9% NaCl) and were positioned on the scalp (fixed with elastic bands), following the International 10-20 System of Electroencephalography^(2,8,9,11,13). The tDCS sessions were adapted from the published protocol⁽¹³⁾ and were held over 5 consecutive days, totaling five sessions. The volunteers received stimulation at 2 mA for 20 min.

The cathodic electrode was positioned in the right DLPFC (F4) and the anodic electrode in the LTA (CP5).

At the first consultation, patients signed an informed consent form and underwent a medical history survey, VAS, THI, and hearing tests. Then, they participated in five tDCS neuromodulation sessions, with the VAS administered before and after each cortical stimulation session. They were reevaluated with THI and hearing tests at the final consultation, held 1 week after the end of neuromodulation.

The cases were described individually, and the data were analyzed descriptively using SPSS 29.0 software. The analysis calculated measures of central tendency (mean and median) and variability (standard deviation, minimum, and maximum) of quantitative variables, and absolute frequency of qualitative variables.

The sample consisted of five patients with chronic tinnitus, as described below.

Subject 1 (S1)

AMS, a 66-year-old retired woman, reported a sudden onset of tinnitus in her left ear over 3 years before. The tinnitus was a whistling, intense, continuous sound, worsened in noisy situations. It interfered with her emotional balance, speech perception, and communication skills. She had abnormal hearing thresholds in high frequencies in her right ear and moderate sensorineural hearing loss in her left ear. Suspected diagnosis: Ménière's syndrome.

Subject 2 (S2)

BRMN, a 36-year-old female psychologist. She reported a sudden onset of tinnitus in her left ear over 13 years before. The tinnitus was a whistling, intense, continuous sound, worsened

in noisy situations, stress, and silence, interfering with emotional balance, sleep, attention, concentration, reading, and speech perception. Hearing thresholds were within normal limits bilaterally. Suspected diagnosis: Ménière's syndrome.

Subject 3 (S3)

FSS, a 56-year-old female nurse assistant, reported a sudden, hissing-like tinnitus in her left ear, which had been present for over 3 years. It had been occurring continuously and with varying intensity, worsening in stressful situations and silence. The symptom interfered with her emotional balance and sleep. Hearing thresholds were within normal limits, bilaterally. Suspected diagnosis: traumatic brain injury.

Subject 4 (S4)

PHBM, a 40-year-old male civil servant. He reported a sudden tinnitus onset in his left ear over 3 years before. It was a mild, continuous whistle, aggravated by stressful and quiet situations. The symptom interfered with emotional balance, reading, and sleep. Hearing thresholds were within normal limits, bilaterally. Suspected diagnosis: Somatosensory tinnitus.

Subject 5 (S5)

RESF, a 37-year-old male civil servant. He reported a gradual onset of bilateral tinnitus since adolescence. It was a whistling, intense, continuous sound, worsened in quiet and noisy situations, interfering with emotional balance, attention, concentration, reading, and sleep. He had abnormal hearing thresholds in high frequencies, bilaterally. Suspected diagnosis: Idiopathic bilateral hearing loss.

The main evaluation findings are shown in Table 1, characterizing the participants' outcome measures and the descriptive analysis of the group's values.

Table 1. Descriptive characterization of outcome measures in the study sample before and after the intervention

Descriptive analysis by individual						
Patient	Loudness		VAS		Total THI	
	Before tDCS	After tDCS	Before tDCS	After tDCS	Before tDCS	After tDCS
S1	16 dB SL	18 dB SL	5.4	4.4	28 points	22 points
S2	5 dB SL	6 dB SL	3.4	2.2	36 points	36 points
S3	5 dB SL	5 dB SL	6.4	6	48 points	44 points
S4	11dB SL	7 dB SL	3.6	2.6	22 points	16 points
S5	15 dB SL	10 dB SL	7	7	50 points	48 points
Descriptive analysis by group						
Variable	Time point	Mean	SD	Minimum	Maximum	Median
Age	Before	45.00	13.342	34	64	38.00
VAS	Before	5.160	1.621	3.4	7.0	5.40
	After	4.432	2.077	2.2	7.0	4.40
Functional THI	Before	14.40	6.542	4	20	18.00
	After	10.00	7.211	0	18	8.00
Emotional THI	Before	14.00	3.742	8	18	14.00
	After	14.00	6.782	4	22	14.00
Catastrophic THI	Before	8.40	5.177	2	14	10.00
	After	9.20	4.147	4	14	10.00
Total THI	Before	36.80	12.21	22	50	36.00
	After	33.20	13.828	16	48	36.00
Loudness	Before	10.40	5.273	5	16	11.00
	After	9.20	5.263	5	18	7.00

Subtitle: tDCS = transcranial direct current stimulation; VAS = visual analog scale; THI = Tinnitus Handicap Inventory; dB SL = decibels sensation level; VAS = visual analog scale; SD = standard deviation

The VAS was measured before and after each neuromodulation session, while pitch and loudness matching, HFA, and THI assessments were performed at the beginning and end of the intervention protocol.

Regarding the location of the tinnitus, four patients (S1, S2, S3, and S4) complained of unilateral tinnitus (left ear), and one patient (S5) complained of bilateral tinnitus.

As for PTA results, three patients (S2, S3, and S4) had hearing thresholds within the normal range in both ears, one patient (S1) had normal hearing in the right ear and moderate hearing loss in the left ear (the same ear as the tinnitus), and one patient (S5) had abnormal hearing thresholds only in high frequencies, bilaterally.

The patients had decreased sensitivity in HFA hearing thresholds, with the following group medians: 9000 Hz (35 dB); 10000 Hz (45 dB); 11200 Hz (57.5 dB); 12500 Hz (65 dB); 14000 Hz (60 dB); 16000 Hz (50 dB). In the pitch and loudness

matching, one patient (S1) identified 750 Hz, and four patients (S2, S3, S4, and S5) identified 8000 Hz as the frequency (pitch) that most closely resembled their tinnitus.

Regarding the sensation of intensity (loudness), two patients had a significant decrease of 4 dB SL (S4) and 5 dB SL (S5); two patients had a slight increase of 1 dB SL (S2) and 2 dB SL (S1), and one case maintained the value (S3) (Table 1). The group's means were 10.40 dB SL before therapy and 9.20 dB SL after it.

VAS values decreased in four patients (S1, S2, S3, and S4), while one patient (S5) remained stable after neuromodulation (Figure 1). The group's mean decreased from 5.2 before therapy to 4.4 points after it.

Finally, total THI scores decreased in four patients (S1, S3, S4, and S5), whereas one case (S2) remained stable after neuromodulation (Figure 2). The group's mean total THI decreased from 36.8 points before therapy to 33.2 points after it.

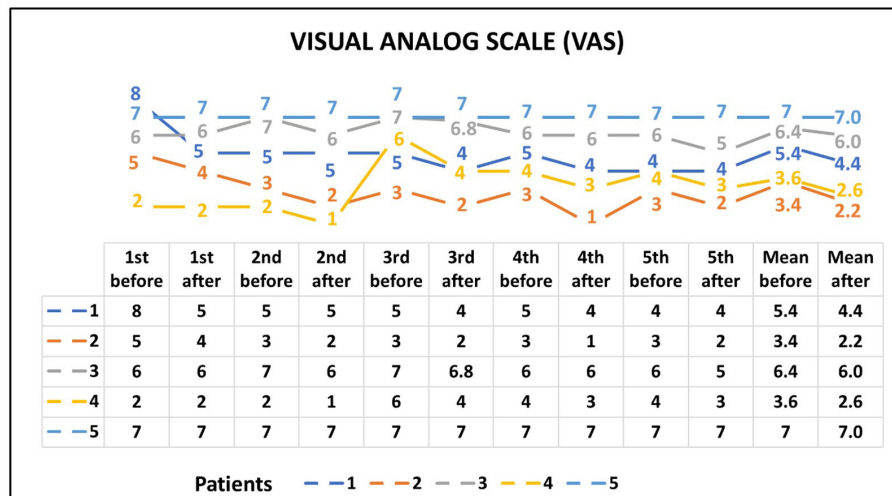


Figure 1. Characterization of reported visual analog scale results before and after neuromodulation sessions
Subtitle: VAS = visual analog scale

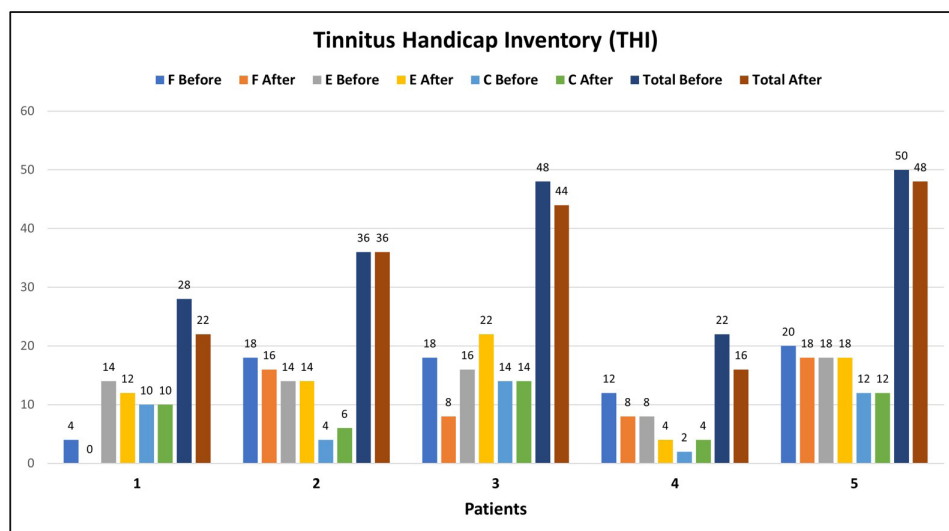


Figure 2. Characterization of the total and subscale scores in the Tinnitus Handicap Inventory by patients before and after transcranial direct current stimulation
Subtitle: F = functional; E = emotional; C = catastrophic

Discussion

This study hypothesized that patients with tinnitus undergoing rehabilitation with tDCS could have their symptoms improved. The results showed that the mean annoyance score (VAS) and the impact on quality of life (THI) decreased after tDCS.

Tinnitus is a symptom with the potential to negatively impact an individual's quality of life, causing functional limitations and suffering^(1,4,9,11,13). All patients reported that tinnitus interfered with their emotional balance, which could worsen anxiety and depression.

Decreased sensitivity in high frequencies (HFA) may characterize an early sign of changes in the function of the outer hair cells of the cochlear basal region and trigger tinnitus even in patients with PTA hearing thresholds within the normal range (250 to 8000 kHz)⁽¹²⁾. Four patients in this study (S1, S2, S4, and S5) had worse high-frequency hearing thresholds in the ear with tinnitus.

It's worth noting that the auditory integrity of tinnitus patients can influence cortical stimulation results. Patients with hearing thresholds close to normal have the best results⁽¹²⁾. Patients with severe hearing loss require longer sessions and higher current intensity to achieve therapeutic effects, due to greater neuroplastic changes⁽¹¹⁾. However, this finding could not be observed in the present sample, since only one patient (S1) had moderate hearing loss (tinnitus in the left ear), with decreased VAS and THI scores after treatment.

Loudness results varied among the five patients, as it increased in some and decreased in others. Characterizing tinnitus is knowingly complex because it is a subjective symptom with subjective measurement, which can influence the degree of discomfort on the day of the exam^(4,6,7,14). The intervention may not have influenced the perception of tinnitus intensity.

This result is consistent with the literature, which indicates that loudness can be influenced by multiple factors, including the integrity of the auditory pathway and individual adaptation to tinnitus^(1,4,6). Previous studies have also reported mixed results regarding the effectiveness of tDCS in modulating tinnitus intensity, highlighting the need for further investigation to better understand the mechanisms underlying this perception^(2,8-10,12,13).

The characterization of tinnitus discomfort using the VAS verified a reduction in the scores of patients S1, S2, S3, and S4, suggestive of an improvement in symptom discomfort after neuromodulation, compatible with the literature^(2,8,9,11,13).

Likewise, the total THI scores of patients S1, S3, S4, and S5 decreased, indicating that tDCS could reduce the impairment caused by tinnitus in the patient's quality of life, especially in their daily functions, confirming findings from other studies^(2,8-11,13).

The functional subscale had the greatest reduction in the total score. This subscale investigates the discomfort caused by tinnitus in mental, social, occupational, and physical functions^(6,8,13,14). Patients reported significant improvements in their functional capacity after neuromodulation, reflected in activities such as concentration, auditory perception, attention, sleep, and reading. These results reinforce the relevance of tDCS as a promising therapeutic approach in the management of tinnitus, in line with the literature^(2,8-11,13).

The results demonstrated that tDCS had a significant positive effect on reducing tinnitus perception, as evidenced

by the decrease in VAS and THI scores. These suggest that the intervention effectively improved patients' quality of life, reducing the discomfort and impact of tinnitus.

Considering the pathophysiology of tinnitus, it is believed that the frontal and prefrontal regions connect with structures of the limbic system, such as the amygdala, anterior cingulate cortex, and insula, thus constituting part of the central map that influences the cognitive-emotional aspects of tinnitus^(8,10,11,13). Thus, tinnitus often leads to emotional distress due to the neural connections between the brain regions responsible for its perception and the affective aspects associated with the limbic system^(4,6,8,9,11).

Therefore, these aspects should be part of the patient's assessment, since the severity of the condition can be influenced or aggravated by factors such as psychological, cognitive, and personality traits, more than by the sensory aspect⁽¹¹⁾.

This impairment was observed in the patients through the scores on the emotional (S2, S3, and S5) and catastrophic (S1, S2, S3, S4, and S5) subscales, which did not decrease even after tDCS, unlike the functional subscale. It is suggested that the psychological/psychiatric consequences of tinnitus, such as anxiety, depression, and panic, which compromise the performance of daily activities, require individualized and specialized counseling, combined with neuromodulation. A multidisciplinary approach that integrates neuromodulation with psychological support is essential in the management of tinnitus.

Applying tDCS over the LTA stimulates cortical and subcortical regions such as Brodmann areas 41 and 42 (primary auditory cortex), Brodmann areas 21 and 22 (associative auditory cortex), and the limbic system (hippocampus and amygdala). Thus, stimulating these regions may decrease tinnitus perception^(8-10,12). Revalidating the findings of this case report, the literature reports that anodal current administered over the LTA has a greater potential to suppress tinnitus and reduce its discomfort^(2,5,8).

The results reiterate the findings in the literature, which state that anodal tDCS administered over the LTA decreased the perception of tinnitus annoyance (VAS) and severity (THI)^(8,10,11,13). It is important to note that validated techniques were used to measure results, which demonstrated a reduction in the impact and discomfort caused by tinnitus in the study cases.

The results of this study motivate further research to produce robust evidence regarding the benefit of tDCS for tinnitus rehabilitation, applicable in clinical practice, so that speech therapist can offer their patients an innovative and promising tinnitus management protocol.

FINAL COMMENTS

Tinnitus discomfort and impact decreased in the study cases after five tDCS sessions, especially in daily activities such as concentration, auditory perception, and sleep, verified respectively with the VAS and THI.

The variation in loudness results suggests that more neuromodulation sessions may be necessary to achieve more effective therapeutic results in reducing tinnitus intensity.

The findings of this case report demonstrate the benefits of tDCS in the five study cases and encourage future research to reinforce evidence on neuromodulation effectiveness in tinnitus treatment, helping to improve the quality of life of patients.

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