Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Therapeutic Effects of Transcranial Alternating Current Stimulation Targeting the Left Dorsolateral Prefrontal Cortex in Patients with Persistent Postural-Perceptual Dizziness: A Preliminary Study

Wenjing Liu

lwjlyxsyx@163.com

Beijing Fengtai You'anmen Hospital

Aihua Liu

Xuanwu Hospital

Qing Liu

Beijing Fengtai You'anmen Hospital

Article

Keywords: persistent postural-perceptual dizziness, transcranial alternating current stimulation, scale assessment, therapeutic effect

Posted Date: November 10th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11237090/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations:
No competing interests reported.

Tables are available in the Supplementary Files section.

Therapeutic Effects of Transcranial Alternating Current Stimulation Targeting the Left Dorsolateral Prefrontal Cortex in Patients with Persistent Postural-Perceptual Dizziness: A Preliminary Study

Wenjing Liu[1], Aihua Liu[2*], Qing Liu[1*]

1 Department of Neurology, Beijing Fengtai You`anmen Hospital, Beijing, China

2 Department of Neurology, Xuanwu Hospital, Capital Medical University, Beijing, China

* These authors contributed equally to this work as corresponding authors

Correspondence:

Aihua Liu, Department of Neurology, Xuanwu Hospital, Capital Medical University, E-mail:liuah818@sina.com

Qing Liu, Department of Neurology, Beijing Fengtai You`anmen Hospital, E-mail:liu18310736860@163.com

Abstract

Background: Persistent postural-perceptual dizziness (PPPD) is a chronic vestibular disorder often refractory to standard pharmacotherapy. Transcranial alternating current stimulation (tACS) offers a non-invasive approach to modulate cortical activity. This prospective study aimed to evaluate the therapeutic potential and safety of multi-session tACS targeting the left dorsolateral prefrontal cortex (DLPFC) in patients with PPPD.

Methods: Ten patients with definite PPPD received a 2-week intervention consisting of 10 Hz, 1.5 mA tACS targeting the left DLPFC. Dizziness handicap, anxiety, and depressive symptoms were evaluated at baseline, immediately post-treatment, and at 1-month follow-up using the Dizziness Handicap Inventory (DHI), Hamilton Anxiety Scale (HAMA), and Beck Depression Inventory (BDI), respectively.

Results: Repeated-measures ANOVA demonstrated significant overall treatment effects across all time points for DHI ($F(2, 18)=30.19$, $p<0.001$), HAMA ($F(2, 18)=12.80$, $p<0.001$), and BDI ($F(2, 18)=6.34$, $p=0.008$). Post-hoc analysis showed immediate post-treatment reductions in DHI ($p=0.038$), with the most pronounced improvements observed across all scales at 1-month follow-up (DHI: $p<0.001$; HAMA: $p=0.003$; BDI: $p=0.010$). Adverse events were mild, transient, and self-limiting, with mild paresthesia being the most frequent (30%).

Conclusion: Multi-session tACS over the left DLPFC significantly alleviated dizziness, anxiety, and depressive symptoms in PPPD patients, with therapeutic benefits sustained at 1-month follow-up. These preliminary findings suggest tACS as a safe, feasible alternative intervention for PPPD.

Keywords: persistent postural-perceptual dizziness; transcranial alternating current stimulation; scale assessment; therapeutic effect

Introduction

Persistent postural-perceptual dizziness (PPPD) is a newly defined chronic vestibular disorder, previously described as phobic postural vertigo(PPV),chronic subjective dizziness(CSD),space motion discomfort (SMD),and visual vertigo(VV)[1]. It is characterized by persistent, non-rotational dizziness and unsteadiness lasting more than three months, which may be exacerbated by upright posture, active or passive movement, and exposure to complex visual environments. The condition can be triggered by acute, episodic, or chronic vestibular syndromes, as well as psychological factors that cause balance-related disturbance including comorbid anxiety or depression[2].

The pathophysiological mechanisms of PPPD remain elusive, though accumulating evidence from related entities such as phobic postural vertigo, chronic subjective dizziness, visual vertigo, and space motion discomfort suggests a multifactorial etiology involving predisposing anxiety traits, heightened sensitivity to acute vestibular events, maladaptive postural control, and aberrant cortical integration of spatial orientation and threat evaluation[3]. Currently, no standardized treatment protocol exists for PPPD. Clinical management primarily relies on pharmacotherapy, notably selective serotonin reuptake inhibitors(SSRIs), psychological interventions, non-invasive brain stimulation, and vestibular rehabilitation. Although SSRIs achieve an effective rate of approximately 73% and concomitantly alleviate anxiety and depressive symptoms, at least one-quarter of patients remain refractory to this approach, underscoring the urgent need for alternative therapeutic strategies. In this context, transcranial alternating current stimulation(tACS) has recently garnered attention as a safe and non-invasive neuromodulatory tool that delivers low-intensity alternating current to the scalp, thereby modulating cortical oscillatory activity and excitability[4].

To date, no standardized treatment protocol has been established for PPPD, and the considerable proportion of patients who remain symptomatic despite existing therapies underscores the pressing need for novel interventions. tACS has emerged as

a promising candidate, offering a safe, non-invasive, and well-tolerated approach with manageable adverse effects and good patient compliance. Nevertheless, the optimal stimulation parameters and long-term efficacy remain to be defined, and the treatment course is relatively protracted, warranting further systematic investigation. Therefore, this prospective study was designed to evaluate the therapeutic effects of a multi-session tACS protocol targeting the left dorsolateral prefrontal cortex in patients with PPPD, with the aim of providing preliminary evidence to inform future clinical practice and research.

Methods

Participants

All participants were recruited from the outpatient and inpatient settings of the Department of Neurology at Xuanwu Hospital, Capital Medical University from September 2022 to September 2023. The diagnosis of PPPD was established in accordance with the clinical diagnostic criteria proposed by the Committee for the Classification of Vestibular Disorders of the Bárány Society[5]. Eligible patients were required to meet all of the following criteria: (1) presence of one or more symptoms including dizziness, unsteadiness, or non-rotatory vertigo on most days for at least 3 months, with symptoms fluctuating in severity over hours without being necessarily continuous throughout the day; (2) exacerbation of symptoms by upright posture, active or passive movement irrespective of direction, and exposure to complex visual environments or moving visual stimuli; (3) onset triggered by acute, episodic, or chronic vestibular syndromes or other medical conditions, with the transition from intermittent to persistent symptoms after resolution of acute triggers or a gradual progressive course in chronic conditions; (4) symptom-induced significant distress or functional disability; and (5) symptoms not better accounted for by another disease. Exclusion criteria comprised primary psychiatric disorders(e.g., major depressive disorder, bipolar disorder, psychotic disorders, neurocognitive disorders, or substance use disorders), conditions increasing fall risk(including arthritis, foot, visual,

cardiovascular, or neurological disorders), use of vestibular suppressants, history of traumatic brain injury or metallic implants, history of epilepsy, and severe systemic or dermatological diseases.

All participants provided written informed consent prior to enrollment, and underwent comprehensive medical history collection, neuropsychological scale assessments, and transcranial alternating current stimulation. Personal information and test results were strictly confidential and accessible only to the individual participants.

Outcome Measures

All participants underwent standardized neuropsychological evaluation as outcome measures administered by trained neurologists, with all scales completed by the participants themselves under the examiner's guidance. The Dizziness Handicap Inventory(DHI), originally developed by Jacobson[6]，was used in its validated Chinese version to grade the severity of dizziness and balance impairment and to assess their impact on daily living[7], with scores categorized as mild(0-30), moderate(31-60), or severe(61-100), and higher scores indicating greater fall risk. Anxiety symptoms were evaluated using the 14-item Hamilton Anxiety Scale(HAMA)[8],employing a 5-point Likert scale(0-4) for each item[9], with total scores interpreted as follows: ⩾29 for severe anxiety, ⩾21 for definite anxiety, ⩾14 for probable anxiety, ⩾7 for possible anxiety, and<7 for no anxiety, following the CCMD-3 diagnostic criteria[10]. Depressive symptoms were assessed with the 21-item Beck Depression Inventory(BDI)[11], which captures three dimensions, including negative affect/suicidality, somatic complaints, and performance difficulties, with each item scored from 0 to 3, and total scores classified as no depression(0-4), mild(5-7), moderate(8-15), or severe(⩾16). Although the HAMA shares some overlapping items with depression scales, it was administered specifically for anxiety severity grading in this cohort[10].

Procedures

All participants received 2 weeks of tACS, followed by a 4-week follow-up assessment period. The tACS intervention was administered by experienced neurologists in accordance with standardized protocols, using a tACS device (model XPNS208-B; Suzhou Xiupunuosi Medical Device Co., Ltd., China) approved for clinical use. During each session, participants were seated comfortably in reclining chairs and instructed to remain relaxed, stay awake, drink water as needed, and minimize verbal communication with the administering neurologist. Stimulation was delivered at an intensity of 1.5 mA (zero-to-peak) with a frequency of 10 Hz, applied through a circular central electrode (diameter 2 cm) placed at FC3 according to the international 10-20 system for electrode placement, and four circular return electrodes (diameter 2 cm each) positioned at FC1, FC5, C3, and F3, targeting the left dorsolateral prefrontal cortex (DLPFC) based on previous research. Each 40-min session comprised a 20-min stimulation block, followed by a 20-min pause, and then another 20-min stimulation block, with ramp-up and ramp-down periods of 15 s each at the beginning and end of stimulation, respectively. The DHI, HAMA, and BDI scores were assessed at three time points: baseline (pre-treatment), immediately post-treatment, and at 1-month follow-up. Adverse events were monitored throughout the entire stimulation course for all participants.

Statistical Analysis

All statistical analyses were performed using SPSS 23.0, and figures were generated with GraphPad Prism 8.3.0. Given the unclear overall distribution and the relatively small sample size, normality was assessed using the Shapiro-Wilk test. Demographic data were described as means and standard deviations. To evaluate differences in the three neuropsychological scale scores (DHI, HAMA, and BDI) across the three time points (baseline, immediately post-treatment, and 1-month follow-up), a one-way repeated-measures analysis of variance (ANOVA) was conducted. Mauchly's test of sphericity was performed to verify the homogeneity of

covariance among the three time points. A p-value<0.05 was considered statistically significant for the repeated-measures ANOVA. Additionally, changes in scale scores from baseline to post-treatment and from baseline to 1-month follow-up were compared, with P<0.05 denoting statistical significance. Pearson correlation analysis was applied to examine the relationships between neuropsychological scale scores and clinical variables, including disease duration, age, and duration of each episode, with statistical significance set at P<0.05. In summary, eligible PPPD patients underwent clinical data collection and baseline DHI, HAMA, and BDI assessments, received 2 weeks of tACS intervention, and completed follow-up evaluations with the same scales immediately after treatment and at 1 month post-treatment. Flowchart of the study is shown in Figure 1.

Ethics

The trial received institutional review board approval of Xuanwu Hospital, was performed in accordance with ethical principles originating in the Declaration of Helsinki.

Results

Participants

A total of 10 patients with PPPD were enrolled in this study, comprising 3 males (30%) and 7 females (70%), with a mean age of 56.7±12.5 years (range, 37-69 years). All patients were right-handed. Demographic characteristics are summarized in Table 1. The mean disease duration was 1.8±0.8 years (range, 1-3 years), with an average daily symptom duration of 13.4±4.0 hours (range, 6-18 hours) and a mean of 28± 4.2 days per month with symptom presence. According to the clinical features outlined in the Bárány Society diagnostic criteria for PPPD[5], the most frequent symptom was dizziness, present in all 10 patients (100%), followed by unsteadiness in 8 patients (80%), and non-rotatory vertigo in 6 patients (60%). Analysis of exacerbating factors revealed that active or passive movement was the most common

trigger, reported by 9 patients (90%), while upright posture provoked symptom exacerbation in 3 patients (30%), and exposure to complex visual environments or moving visual stimuli triggered worsening in 2 patients (20%). Among the enrolled patients, 4 (40%) had a concurrent vestibular syndrome, all presenting as benign paroxysmal positional vertigo. All 10 patients met the clinical diagnostic criteria for definite PPPD as defined by the Bárány Society[5]. Detailed clinical data for each patient are presented in Table 2.

Outcome

Repeated-measures ANOVA revealed significant improvements in all three neuropsychological scales across the three time points (baseline, immediately post-treatment, and 1-month follow-up). For the DHI, as presented in Figure 2A, mean scores decreased from 39.9±17.1 at baseline (moderate impairment) to 33.0±15.4 immediately post-treatment (moderate impairment) and further to 22.4±15.6 at 1-month follow-up (mild impairment), with a statistically significant overall effect ($F(2, 18)=30.19$, $p=0.000$). Post-hoc comparisons demonstrated significant reductions from baseline to immediately post-treatment (mean difference 6.6, 95% CI: 0.4-12.9, $p=0.038$), from baseline to 1-month follow-up (mean difference 17.2, 95% CI: 9.9-24.5, $p=0.000$), and from immediately post-treatment to 1-month follow-up (mean difference 10.6, 95% CI: 4.7-16.6, $p=0.002$). For the HAMA, as presented in Figure 2B, mean scores declined from 16.1±6.1 at baseline (definite anxiety) to 12.9±5.1 immediately post-treatment and 9.0±4.5 at 1-month follow-up (both within the possible anxiety range), with a significant overall effect ($F(2, 18)=12.8$, $p=0.000$). Post-hoc analysis showed significant reductions from baseline to 1-month follow-up (mean difference 7.1, 95% CI: 2.7-11.4, $p=0.003$), whereas reductions from baseline to immediately post-treatment (mean difference 3.2, 95% CI: -0.7 to 7.1, $p=0.116$) and from immediately post-treatment to 1-month follow-up (mean difference 3.9, 95% CI: -0.2 to 8.0, $p=0.066$) did not reach statistical significance. Regarding the BDI, as presented in Figure 2C, mean scores decreased from 17.0±13.6 at baseline (severe

depression) to 13.6±10.5 immediately post-treatment and 9.2±8.8 at 1-month follow-up (both moderate depression), with a significant overall effect ($F(2, 18)=6.341$, $p=0.008$). Post-hoc comparisons revealed a significant reduction from baseline to 1-month follow-up (mean difference 7.8, 95% CI: 2.3-13.3, $p=0.010$), but not from baseline to immediately post-treatment (mean difference 3.4, 95% CI: -3.6 to 10.5, $p=0.57$) or from immediately post-treatment to 1-month follow-up (mean difference 4.4, 95% CI: -2.3 to 11.1, $p=0.26$).

In summary, the severity of dizziness, anxiety, and depressive symptoms all demonstrated significant improvement following tACS intervention. The most pronounced improvements were observed at the 1-month follow-up, with significant differences from baseline across all three scales. Notably, the DHI showed a significant reduction immediately post-treatment, indicating early improvement in dizziness symptoms, whereas changes in HAMA and BDI scores at the immediate post-treatment time point did not reach statistical significance. Detailed data are shown in Supplementary Table 1.

Clinical outcome

In the present study, correlations between the DHI, HAMA, and BDI scores at baseline, immediately post-treatment, and 1-month follow-up and clinical characteristics including age, disease duration, and daily symptom duration were examined. A statistically significant correlation was found only between the immediate post-treatment HAMA score and daily symptom duration ($r=-0.636$, $p=0.048$). No other significant correlations were observed. Detailed results are presented in Figure 3.

Safety

Adverse events during and after tACS sessions were recorded, including skin redness and itching at the electrode contact sites, mild discomfort in the surrounding skin areas (primarily described as crawling sensation, tingling, or electric shock-like

sensation), and transient phosphene phenomena. Among the 10 enrolled patients, the most frequently reported adverse event was crawling, tingling, or electric shock-like sensation, occurring in 3 patients (30%). Skin redness and itching were reported in 2 patients (20%), and transient phosphene phenomena were observed in 1 patient (10%). All adverse events resolved spontaneously upon completion of the tACS sessions. Detailed data are presented in Supplementary Table 2.

Discussion

In this exploratory study, we found that tACS over the left DLPFC at 10 Hz and 1.5 mA significantly reduced DHI, HAMA, and BDI scores in PPPD patients, with the most prominent improvements observed at one-month follow-up. The treatment was well-tolerated with only mild transient adverse effects, suggesting that tACS may be a safe and effective non-invasive intervention for PPPD.

Non-invasive brain stimulation (NIBS) techniques have garnered increasing attention in the management of neuropsychiatric and vestibular disorders. Among these, tACS offers a unique advantage by modulating endogenous cortical oscillations through entrainment and resonance, thereby influencing regional and network-level connectivity more effectively than transcranial direct current stimulation (tDCS) in certain contexts[12]. The rationale for tACS is rooted in its capacity to mimic natural electrophysiological rhythms, and recent applications have demonstrated its utility in improving cognitive functions and alleviating symptoms of anxiety and depression[13]. The precise placement of electrodes is critical, as it determines current flow distribution and spatial targeting[14]. In this study, we selected the left DLPFC as the stimulation target, based on prior evidence suggesting that anodal tDCS over this region reduced DHI scores and showed trends toward improvement in HAMD scores, alongside perfusion changes in the right temporal lobe and left hippocampus[15]. These findings imply a potential link between enhanced prefrontal cognitive control over anxiety and reduced vertigo symptoms, supporting the choice of the left DLPFC as a therapeutic node for PPPD.

Regarding stimulation parameters, safety and tolerability were primary considerations. Previous studies have established that current densities below 25 mA/cm² do not cause cerebral tissue damage, and protocols using 2 mA for 20 minutes under 7.0T MRI have shown no adverse thermal effects [4, 16, 17]. Although tACS parameter data are relatively limited, cumulative evidence supports the safety of currents below 4 mA for up to one hour daily. Commonly reported side effects are mild and transient, including skin paresthesia under electrodes and occasional phosphenes, which resolve after stimulation cessation[4]. Based on these safety data and prior tACS protocols, we adopted a stimulation intensity of 1.5 mA and a frequency of 10 Hz, which falls within the effective range for modulating cortical oscillatory activity and has been associated with antidepressant effects in previous trials[18].

The clinical characteristics of our cohort (10 patients, 70% female, mean age ~57 years, mean disease duration 1.8 years) align well with larger multicenter studies, including a Korean cohort of 185 PPPD patients with similar demographics[2]. Precipitating factors were present in all patients, with active or passive movement being the most common trigger (90%), consistent with the 90.8% reported in prior research[2]. However, the proportions of exacerbation by standing posture (30% vs. 87%) and by complex visual environments or moving visual stimuli (20% vs. 52%) were lower in our sample, likely due to the small sample size and individual variability. This discrepancy underscores the need for larger, multicenter studies to better characterize the clinical phenotype of PPPD in the Chinese population.

The central vestibular network intersects extensively with anxiety-related brain circuits, including the prefrontal cortex, amygdala, anterior cingulate cortex, and insula. The DLPFC, as a core region of the central executive network, plays a pivotal role in attention, working memory, and executive functions, and has also been implicated in emotional regulation and anxiety[19, 20]. Stimulation of the DLPFC may enhance visuospatial processing and motor planning, indirectly improving balance and postural stability. Furthermore, accumulating evidence points to DLPFC dysfunction in various psychiatric disorders, and tDCS over this region has shown

therapeutic potential in depression and anxiety, possibly via modulation of functional connectivity, neuronal excitability, and synaptic plasticity[21]. Notably, enhanced connectivity between the DLPFC and the precuneus has been correlated with depressive biomarkers, and the DLPFC may interact with the anterior cingulate and precuneus in cognitive control mechanisms relevant to mood disorders[21]. These neuroanatomical and neurophysiological links provide a strong rationale for targeting the DLPFC in PPPD, a condition frequently comorbid with anxiety and depression[3]. Our findings demonstrate that tACS over the left DLPFC significantly improved DHI, HAMA, and BDI scores post-treatment, with the most pronounced effects observed one month after the intervention. These results contrast with a previous tDCS study in PPPD that reported no significant differences in DHI or symptom scales between active and sham groups[22], suggesting that tACS may offer superior efficacy in this population, potentially through its frequency-specific entrainment effects.

Limitations

Several limitations should be acknowledged. First, the sample size was small (n=10) due to the low diagnosis rate and limited patient awareness of PPPD, which may have contributed to the discrepancy between certain clinical characteristics in our cohort and those reported in larger studies[15]. Also, the sample size analysis was not performed when design the study. Multicenter studies with larger samples are warranted to validate our findings. Second, this was an observational study without a sham control group like previous study[23], precluding definitive conclusions about efficacy. Although a sham-controlled design was initially considered, it was not feasible given the limited number of eligible outpatients. Future randomized sham-controlled trials are needed. Third, we relied solely on psychometric scales (DHI, HAMA, BDI) for outcome assessment and did not incorporate neuroimaging or cognitive evaluations. Subsequent studies should include objective measures such as functional MRI, cerebral perfusion, or cognitive scales (e.g., Mini-mental state

examination (MMSE)、Montreal cognitive assessment (MoCA) to further elucidate the neural mechanisms and cognitive effects of tACS in PPPD.

Conclusion

This study demonstrates that tACS over the left DLPFC significantly improves dizziness, anxiety, and depressive symptoms in PPPD patients, with the most pronounced effects observed at one-month follow-up. The intervention was well-tolerated with minimal adverse effects. These findings support tACS as a safe and effective therapeutic option for PPPD and suggest that the DLPFC may be involved in the pathophysiological mechanisms of PPPD, warranting further investigation as a potential neuromodulatory target.

References

1. Balough, B. J. Expanding the Differential Diagnosis of Chronic Dizziness. Yearbook of Otolaryngology-Head and Neck Surgery 2008;2008:34-35.
2. Park JH, Nguyen TT, Kim SH, et al. Clinical characteristics of persistent postural-perceptual dizziness and its visual subtype in Korean patients: A multicenter cross-sectional study. Brain and Behavior 2024;14.
3. Crisan H, Courtis ND, Courtis AD. Persistent Postural-Perceptual Dizziness (PPPD): A systematic review of 10 years' progress in diagnosis and treatment. 2016.
4. Tavakoli AV, Kyongsik Y. Transcranial Alternating Current Stimulation (tACS) Mechanisms and Protocols. Frontiers in Cellular Neuroscience 2017;11:214.
5. Staab JP, Eckhardt-Henn A, Horii A, et al. Diagnostic criteria for persistent postural-perceptual dizziness (PPPD): Consensus document of the committee for the Classification of Vestibular Disorders of the Bárány Society. Journal of Vestibular Research 2017;27:191-208.
6. Jacobson G. The development of the dizziness handicap inventory. Arch Otolaryngol Head Neck Surg 1990;116.
7. Poon DMY, Chow LCK, Hui Y, Au DKK, Leung MCP. Translation of the dizziness handicap inventory into Chinese, validation of it, and evaluation of the quality of life of patients with chronic dizziness. Annals of Otology, Rhinology & Laryngology 2004;113:1006-1011.
8. Hamilton M. Hamilton anxiety scale. 1959.
9. Chinese Medical Association Psychiatric Branch. *Chinese classification of mental disorders* (CCMD-3). 3rd ed. Jinan: Shandong Science and Technology Press; 2001..
10. Tung V, Thong N, Mai N, et al. Diagnostic Value in Screening Severe Depression of the Hamilton Depression Rating Scale, Hamilton Anxiety Rating Scale, Beck Depression Inventory Scale, and Zung's Self-Rating Anxiety Scale Among Patients with Recurrent Depression Disorder. Acta informatica medica : AIM : journal of the

Society for Medical Informatics of Bosnia & Herzegovina : casopis Drustva za medicinsku informatiku BiH 2023;31:249-253.
11. Richter P, HSEERLEIN A, Kick H, Biczo P. PSYCHOMETRIC PROPERTIES OF THE BECK DEPRESSION INVENTORY: Past, Present and Future of Psychiatry:(In 2 Volumes), 2014.
12.Elyamany, O., et al., Transcranial alternating current stimulation (tACS): from basic mechanisms towards first applications in psychiatry. European Archives of Psychiatry and Clinical Neuroscience, 2020. 271(1): p. 135-156.
13. Merton, P., Stimulation of the cerebral cortex in the intact human subject. Neture, 1980. 285.
14. Wang H, Wang K, Xue Q, et al. Transcranial alternating current stimulation for treating depression: a randomized controlled trial. Brain 2022;145:83-91.
15. Yagi C, Morita Y, Yamagishi T, et al. Changes in functional connectivity among vestibulo-visuo-somatosensory and spatial cognitive cortical areas in persistent postural-perceptual dizziness: resting-state fMRI studies before and after visual stimulation. Frontiers in Neurology 2023;14.
16. Mihály V, Takeuchi Y, Brinyiczki K, et al. Direct effects of transcranial electric stimulation on brain circuits in rats and humans. Nature Communications 2018;9:483.
17. Schwab BC, Misselhorn J, Engel AK. Modulation of large-scale cortical coupling by transcranial alternating current stimulation. 2018.
18. Alexander ML, Alagapan S, Lugo CE, et al. Double-blind, randomized pilot clinical trial targeting alpha oscillations with transcranial alternating current stimulation (tACS) for the treatment of major depressive disorder (MDD). Translational Psychiatry 2019;9.
19. White L, Makhoul W, Teferi M, Sheline Y, Balderston N. The role of dlPFC laterality in the expression and regulation of anxiety. Neuropharmacology 2023;224:109355.
20. Struckmann W, Bodén R, Gingnell M, Fällmar D, Persson J. Modulation of dorsolateral prefrontal cortex functional connectivity after intermittent theta-burst

stimulation in depression: Combining findings from fNIRS and fMRI. NeuroImage Clinical 2022;34:103028.
21. Branco LC, Fregni F. Home-Based Transcranial Direct Current Stimulation (tDCS) to Prevent and Treat Symptoms Related to Stress: A Potential Tool to Remediate the Behavioral Consequences of the COVID-19 Isolation Measures? Frontiers in Integrative Neuroscience 2020.
22. Im JJ, Na S, Kang S, et al. A Randomized, Double-Blind, Sham-Controlled Trial of Transcranial Direct Current Stimulation for the Treatment of Persistent Postural-Perceptual Dizziness (PPPD). Frontiers in Neurology 2022;13.
23. Palm U, Kirsch V, Kübler H, et al. Transcranial direct current stimulation (tDCS) for treatment of phobic postural vertigo: an open label pilot study. European Archives of Psychiatry and Clinical Neuroscience 2018;269:269-272.

List of Abbreviations

Persistent postural-perceptual dizziness, PPPD; phobic postural vertigo, PPV; chronic subjective dizziness, CSD; space motion discomfort, SMD; visual vertigo, VV; selective serotonin reuptake inhibitors, SSRIs; transcranial alternating current stimulation, tACS; dorsolateral prefrontal cortex, DLPFC; Dizziness Handicap Inventory, DHI; Hamilton Anxiety Scale, HAMA; Beck Depression Inventory, BDI; analysis of variance, ANOVA; Mini-mental state examination, MMSE; Montreal cognitive assessment, MoCA;

Funding

This study is self-funded

Declaration of Interest

The author declare no compete interests.

Acknowledgement

We would like to thank the doctors and nurses for their support during the study, and all the patients and their families for participating in this trial.

Authors' Contribution

Wenjing Liu contributed to the study design, data acquisition, analysis and interpretation of data and draft the manuscript. Aihua Liu contributed to the concept, design of the study, data acquisition, revise and approve the final version of the article. Qing Liu contributed to the study design, interpretation of data, revise the manuscript and approve the final version of article.

Ethics Approval declaration and Consent to Participate

This prospective study was approved by the Institutional Review Board of Xuanwu Hospital. Protocols were conducted in accordance with the relevant guidelines and regulations for the use of human subjects in research as set by the Chinese government. All participants provided written informed consent prior to enrollment.

Consent for Publication

All authors have reviewed the final manuscript and consented to pubulished the paper.

Data Availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Figure Legend

Figure 1 Study Flowchart

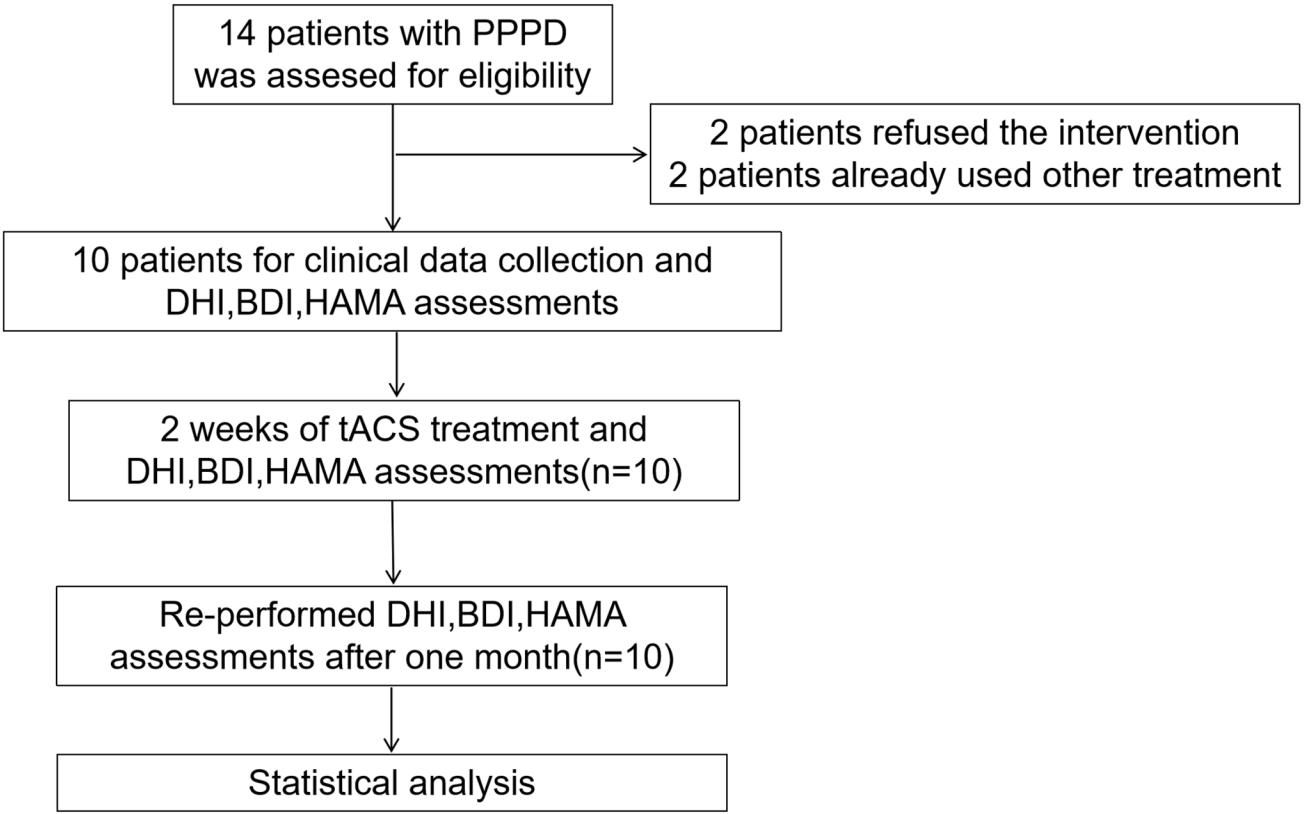
Figure 2 The Mean Reductions of the Outcome Scale Scores from Baseline to Weeks 2 in the Active tACS and One Month Follow-up after tACS

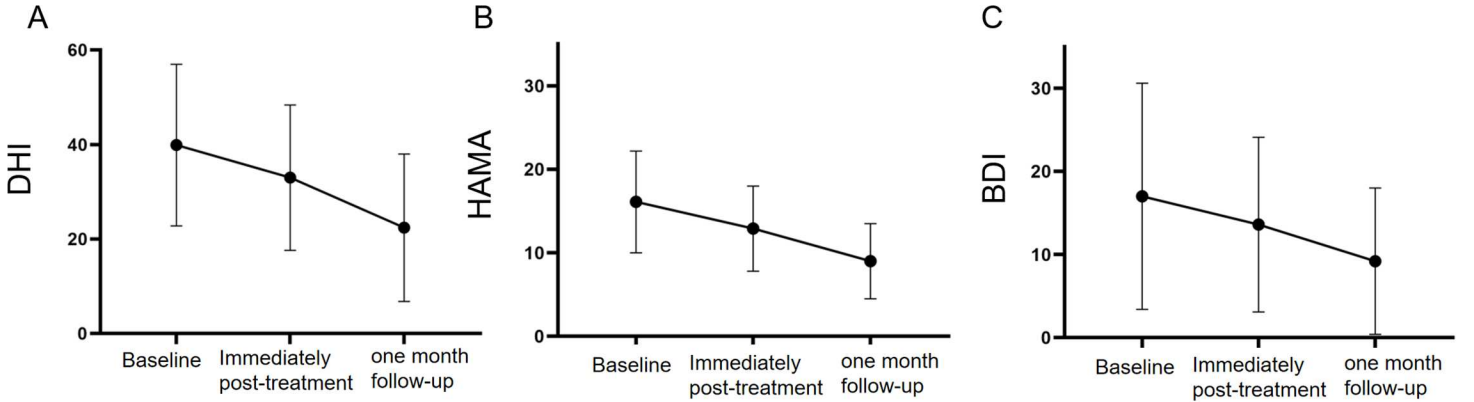
Figure 2A The Mean Reductions of the Dizziness Handicap Inventory (DHI) Score from Baseline to Weeks 2 in the Active tACS and One Month Follow-up after tACS
Note: DHI scores grade the severity of dizziness and balance impairment and to assess their impact on daily living, with scores categorized as mild(0-30), moderate(31-60), or severe(61-100), and higher scores indicating greater fall risk

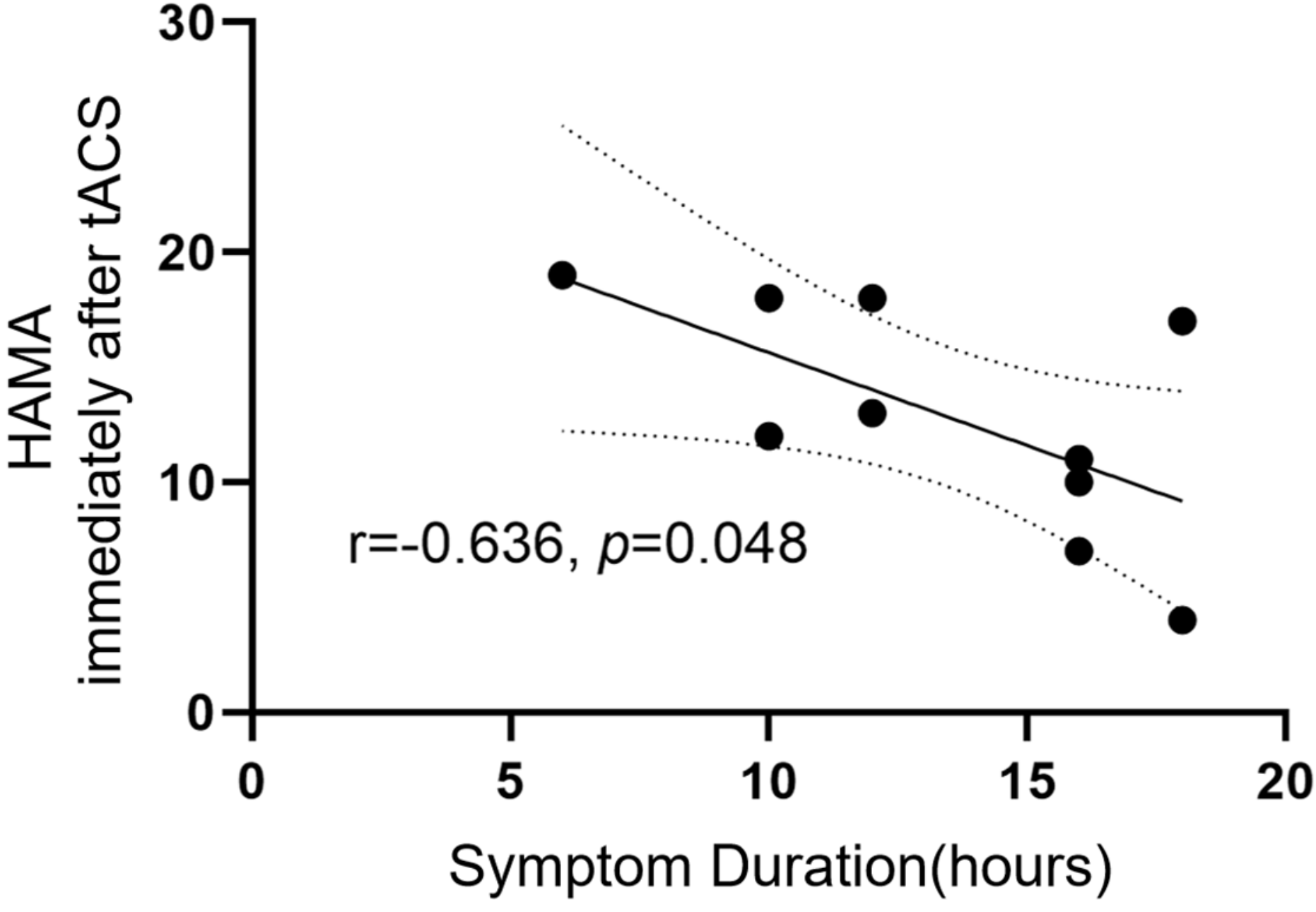
Figure 2B The Mean Reductions of the Hamilton Anxiety Scale (HAMA) Score from Baseline to Weeks 2 in the Active tACS and One Month Follow-up after tACS
Note: HAMA scores assess the anxiety symptoms, with total scores interpreted as follows: ⩾29 for severe anxiety, ⩾21 for definite anxiety, ⩾14 for probable anxiety, ⩾7 for possible anxiety, and<7 for no anxiety.

Figure 2C The Mean Reductions of the Beck Depression Inventory (BDI) Score from Baseline to Weeks 2 in the Active tACS and One Month Follow-up after tACS
Note: BDI scores assess the depression symptoms and total scores classified as no depression(0-4), mild(5-7), moderate(8-15), or severe(⩾16).

Figure 3 Relationship between Symptom Duration and HAMA immediately after tACS


14 patients with PPPD was assesed for eligibility
2 patients refused the intervention
2 patients already used other treatment
10 patients for clinical data collection and DHI,BDI,HAMA assessments
2 weeks of tACS treatment and DHI,BDI,HAMA assessments(n=10)
Re-performed DHI,BDI,HAMA assessments after one month(n=10)
Statistical analysis


A
DHI
60
40
20
0
Baseline
Immediately post-treatment
one month follow-up
B
HAMA
30
20
10
0
Baseline
Immediately post-treatment
one month follow-up
C
BDI
30
20
10
0
Baseline
Immediately post-treatment
one month follow-up


HAMA
immediately after tACS
30
20
10
0
r=-0.636, p=0.048
0
5
10
15
20
Symptom Duration(hours)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table.docx
- SupplementaryTables.docx