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Research paper

Transcranial direct current stimulation lessens dual task cost in people with Parkinson's disease

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HIGHLIGHTS

- Dual tasking exacerbates gait dysfunction in people with Parkinson's disease.
- A bi-hemispheric tDCS protocol is feasible in people with Parkinson's disease.
- Cognitive dual task cost after bi-hemispheric tDCS was lessened in people with PD.

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ABSTRACT

Background: Parkinson's disease (PD) progressively impairs motor and cognitive function. Gait dysfunction in PD is exacerbated during dual task gait. Transcranial direct current stimulation (tDCS) may therapeutically benefit motor and cognitive deficits. We examined the effect of a bilateral tDCS protocol on dual task gait in people with PD.

Material and methods: Participants with PD between 50 and 80 years received two sessions of tDCS protocol (1 active, 1 sham) separated by 7 days. tDCS protocols were randomized and blinded to participants. After each tDCS protocol, participants performed single and dual task gait. Single 20-min session of bilateral tDCS (dorsolateral prefrontal cortex; left = anode, right = cathode) at 2 mA and one sham session. Each participant was assessed at baseline for disease severity [Unified Parkinson's Disease Rating Scale (UPDRS)] and executive function [Repeatable Battery for the Assessment of Neuropsychological Status (RBANS)]. Following each tDCS condition (active and sham), participants performed Timed Up and Go (TUG) single and dual task conditions (TUG_{alone}, TUG_{motor}, $TUG_{cognitive}$) and PDQ-39.

Results: Ten participants average age of 68.7 years (±10.2) and average PD duration average 7.9 years (±7.1) were included. The UPDRS ($M = 37$) and RBANS ($M = 13\%$ile) were administered prior to testing. No differences were observed on dependent *t*-test for TUG conditions or PDQ-39. Dual task cost TUG_{motor} was −20.95% ($tDCS_{active}$) versus −22.58% ($tDCS_{sham}$) and $TUG_{cognitive}$ was −25.24% ($tDCS_{active}$) versus −41.85% ($tDCS_{sham}$).

Conclusions: Our bilateral tDCS protocol in people with PD did not significantly improve dual task gait. However, dual task cost following tDCS was lessened, most dramatically in the presence of a cognitive distractor. A larger sample size is warranted to draw further conclusions about our bilateral tDCS approach.

1. Introduction

Parkinson's disease (PD) is a progressive neurological disorder resulting in motor dysfunction and cognitive impairments. Gait dysfunction in PD is characterized by decreased and variable stride length, freezing and postural instability [1]. During dual task gait these impairments are exacerbated in the presence of executive function deficits [1]. That is, gait for people with PD degrades, specifically during motor-cognitive interplay (i.e. dual task conditions). Further, low executive function, attention, and global cognition are associated with altered gait patterns during everyday walking [2]. Consequently, people with PD are nine times more likely to fall than peers with 25% of people with PD

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experiencing a fall-related hip fracture [3]. In order to improve gait in people with PD, both motor and cognitive dysfunction may need to be addressed concurrently.

Emerging evidence suggests brain plasticity may respond to cortical electrical stimulation, pharmacologic modulation, learning dependent practice, or a combination to optimize outcomes for people with neurodegenerative conditions. Current medical management of people with PD focuses on pharmacological therapy and deep brain stimulation (DBS). While both improve motor symptoms, these approaches inadequately address non-motor symptom, particularly cognitive function [4]. Thus, necessity indicates possibility for novel treatment approaches. Transcranial direct current stimulation (tDCS) is a relatively old technique that is being reconsidered as a neurological rehabilitation tool. Use of tDCS in normal individuals has been reported to enhance learning, picture naming, working memory and executive planning [5–8]. The clinical use of tDCS has been reported in the treatment of depression [9], motor recovery [10,11], and recently in PD [12]. Stimulation lasting 15–30 min in these previous studies was reported to be effective. tDCS may have therapeutic potential as it has demonstrated facilitation of motor and cognitive processing separately in healthy people [13] and people with PD [14,15]. Further, a recent study suggested tDCS reduced the associated cost of performing a cognitive task with ambulation in young healthy adults [16]. However, using tDCS to address motor-cognitive interplay concerns in people with PD is yet to be reported. Therefore, our objective was to identify if tDCS reduces dual task cost during gait in people with PD. We utilized a bi-hemispheric tDCS approach. This approach is reported to increase extracellular dopamine levels in the striatum (cathodal tDCS over right PFC) while promoting functional brain network connectivity (anodal tDCS over left PFC) [15] and a dual task gait paradigm [17] to investigate cost associated with motor-cognitive interplay during gait.

2. Material and methods

2.1. Participants

We recruited a sample of convenience of ten participants who fulfilled the UK Brain Bank criteria for idiopathic PD between ages 40–80 years old. Each participant provided informed consent approved by the Texas Woman's University Institutional Review Board. Following consent, participants were scored at baseline on the Hoehn and Yahr scale [18] and United Parkinson's Disease Rating Scale (UPDRS) [19] for disease severity. We tested executive function capacity at baseline using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) [20]. Quality of life was assessed by the Parkinson's Disease Questionnaire – 39 (PDQ-39) [21] after each tDCS session. Participants in this study were tested during "ON" times where the positive effect of the medication is evident.

2.2. Procedure

Each participant received two sessions of tDCS protocol (1 $tDCS_{active}$, 1 $tDCS_{sham}$) separated by 7 ± 2 days. tDCS protocols were randomized and blinded to participants. In order to apply our tDCS protocol, saline soaked electrode sponges were placed directly on the scalp over the hair with the anodal electrode over the left dorsolateral prefrontal cortex and the cathodal electrode right dorsolateral prefrontal cortex. We used the 10–20 International System to determine electrode placement. A constant electrical current of 2 mA lasing 20 min was used for $tDCS_{active}$ sessions. A 30 s electrical current ramp at tDCS session onset and termination was employed for participant comfort. For the sham condition, an electrical current of 1 mA initiated the first 30 s of the session to control for potential sensation bias. Afterward, no electric current passed through the electrodes. Participants were seated without a concurrent activity during the tDCS protocol for sham and active conditions. Following each tDCS protocol, participants performed a single and dual task gait activity.

2.3. Outcome measures

Motor-cognitive interplay during gait was assessed in single and dual-task scenarios by the Timed Up-n-Go (TUG) under three conditions: TUG_{alone}, TUG_{manual} and $TUG_{cognitive}$ [22]. The TUG_{alone} is a single attention task where the participant was required to stand up at a normal safe pace, walk 3 m, turn 180°, walk back, and sit down. During the TUG_{manual}, the participant carried a full cup of water throughout the task. During the $TUG_{cognitive}$, the participant counted aloud backwards by three from a randomly selected number between 50–100 during the task. Additionally, the participants were asked to count aloud backwards by three as a cognitive alone task to serve as comparison to $TUG_{cognitive}$. The time required to complete each task was recorded. Number of calculations was also recorded during the $TUG_{cognitive}$ and cognitive alone tasks. One practice trial of the TUG_{alone} was allowed to familiarize the participant with the task. All three TUG tasks were performed following the tDCS protocol under the supervision of one of the investigators and were randomized. The PDQ-39 was administered following each tDCS session.

2.4. Data analysis

Descriptive statistics were used to analyze participant characteristics of disease severity and executive function. Dependent T-tests were used to compare between group (tDCS active vs. sham) differences on single and dual task TUG conditions as well as quality of life. To assess the impact of adding a secondary task to gait we calculated dual task cost with the following formula: (dual task time – single task time) / (single task time) [23]. We analyzed the relationship of motor and cognitive function with dual task cost using Pearson product-moment correlation coefficient.

3. Results

All ten participants (8 male and 2 female) completed our study. Baseline testing and observation of participants revealed a median Hoehn and Yahr stage of 2, indicating mild midline or bilateral symptoms without impairment of balance [24], and a mean UPDRS total score of 37.00 (motor sub-score = 24.30). Cut-off scores for mild disability in the motor subsection of the UPDRS is <33 [25], indicating our participants displayed mild motor impairments. Correspondingly, only five of our ten participants reported falling within the previous year (n = 2, 1 fall; n = 2, >1 fall; n = 1, >1 fall day). Executive function results on the RBANS showed a mean total scaled score of 82.90 placing our participants in the 13th percentile on average for their age-matched peers. See Table 1 for participant characteristics.

We compared between group differences on single and dual task TUG conditions with dependent *t*-tests. Though the time required to complete single and dual task TUG conditions after $tDCS_{active}$ was less than $tDCS_{sham}$, there were no significant differences between groups (TUG_{alone}, $p = 0.40$; TUG_{motor}, $p = 0.39$; $TUG_{cognitive}$, $p = 0.10$). Additionally, there were no differences in quality of life scores (PDQ-39) between tDCS protocols ($p = 0.48$). Table 2 details the group comparisons.

Calculating dual task cost for time to complete the TUG_{motor} and $TUG_{cognitive}$ and number of correct calculations during the $TUG_{cognitive}$ revealed a lower dual task cost for each condition