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Prefrontal Cortex Neuromodulation Improve Gait Parameters in Latinx People Living with HIV

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Abstract

Background: Human Immunodeficiency Virus (H.I.V.) infection affects motor and cognitive systems and can lead to impairments in gait and balance. The application of transcranial direct current stimulation (tDCS), particularly to the prefrontal cortex, has shown encouraging results in enhancing cognition and executive functioning in individuals with H.I.V., both in the short and long term. Despite the current research, some experts have suggested that incorporating a task that stimulates higher cognitive centers in conjunction with tDCS may enhance its effects. ***Purpose***: This study aimed to examine the effect of tDCS combined with a tracking task on the prefrontal cortex as a viable treatment for enhancing balance and gait in individuals living with H.I.V. ***Methods***: The study evaluated nine female participants, all living with H.I.V., with an average age of 58.8 ± 4.6. As part of the experiment, each participant's gait was carefully evaluated before and after tDCS treatment to measure any potential changes in their walking patterns accurately. Transcranial Direct Current Stimulation (tDCS) was non-invasively administered to the participants' prefrontal cortex within seven days to investigate its possible effects on brain function. ***Results***: Upon analyzing the data, the results demonstrated significant variations between single and dual tasks in numerous aspects, such as temporospatial, turn, and balance, before transcranial direct current stimulation (tDCS), ultimately shedding light on the potential cognitive difficulties that may arise. Data analysis showed noticeable improvements in various aspects, such as stride length, turn duration, and balance trends, when tDCS was applied. ***Conclusion***: This study's findings suggest that tDCS may improve these parameters. However, it is recommended that treatments be administered over an extended time, which is longer than that observed in this study.

Keywords: Human Immunodeficiency Virus (H.I.V.), Balance, Gait, Neuromodulation, Turn, Sway, Gait Kinematics.

INTRODUCTION

Human Immunodeficiency Virus (H.I.V.) is an autoimmune disorder that targets and eliminates the body's CD4-T lymphocytes, which are crucial for defending against infections. Research suggests that 30-60% of adults with H.I.V. develop HIV-associated neurocognitive disorders (HAND), which can lead to challenges in concentration, memory, planning, organization, and decision-making for individuals. In addition to the effects mentioned above, individuals may experience a decrease in motivation, heightened levels of irritability, feelings of depression, impairment in motor skills, and a decline in coordination and agility. According to previous research, individuals with H.I.V. may undergo alterations in pre-attentive processes, attention, and apathetic behaviors, which are believed to be associated with dopaminergic system dysfunction (Archibald *et al.*, 2004).

As stated in numerous research studies (such as Quiles *et al.*, 2019; Rosario *et al.*, 2020a-b, d Rosario MG, 2020a-b; Rosario *et al.*, 2021a-b, Rosario *et al.*, 2022c-d, Rosario MG, 2022-2023), it has been found that individuals diagnosed with HIV/AIDS, also known as P.L.H.I.V., have shown signs of impaired gait and balance. P.L.H.I.V. may generally exhibit compromised balance, gait, and functional mobility compared with those without the virus, potentially owing to the effects of the virus on their physical health. Based on the above research, there is a significantly increased likelihood of falls and their related complications. In addition, studies have shown that older adults with H.I.V. who experience locomotor impairments, particularly gait speed, have a strong correlation with cognitive decline, suggesting a decrease in processing ability and reaction time (Derry *et al.*, 2020; Berner *et al.*, 2017; Robertson *et al.*, 2006; Paul *et al.*, 2007). The most concerning development is that as time passes, there is a corresponding increase in HIV-related impairments (Rosario *et al*., E, 2021).

A novel approach for addressing cognitive deficits in specific populations has emerged as transcranial direct current stimulation (tDCS), which employs a non-invasive electrical current to modulate brain activity by manipulating neuronal membrane potentials. Electrical stimulation modulates the release of neurotransmitters and modifies neural activity. tDCS has numerous cognitive benefits, such as improving verbal problem-solving, working memory, and learning abilities, including computer-based threat detection simulation and object location memory in elderly individuals (Fazeli *et al*., 2017). tDCS has also been demonstrated to induce neuroplasticity by stimulating brain-derived neurotrophic factor (B.D.N.F.), a protein associated with enhanced motor learning and cognitive functioning (Ownby & Acevedo, 2016). The benefits of tDCS vary depending on the brain area being treated. In a study by Pol *et al*., (2021), tDCS stimulated affected areas of the thalamus, resulting in improved freezing gait symptoms, a common issue among individuals with Parkinson's disease. Similarly, Marotta *et al*., (2022) demonstrated the potential of tDCS in significantly enhancing the results of the six-minute walk test and providing short-term benefits for balance in individuals with multiple sclerosis.

The prefrontal cortex, responsible for high-level cognitive functions such as decision-making, planning, and problem-solving, is an area of significant interest. Research has demonstrated that tDCS can alter the function of the prefrontal cortex, resulting in the modification of cognitive abilities. For example, a study by Dockery *et al*., (2011) revealed that tDCS administered to the dorsolateral prefrontal cortex enhances working memory capabilities among healthy individuals. tDCS may increase the excitability of the prefrontal cortex, thereby improving cognitive function. Additionally, this neurostimulator has been the subject of research owing to its potential therapeutic effects in conditions related to prefrontal cortex impairment, such as depression and schizophrenia. As exemplified by a meta-analysis conducted by Kalu *et al*., (2012), tDCS has shown potential for producing antidepressant effects in individuals diagnosed with major depressive disorder, potentially through the modulation of prefrontal cortex activity.

Recent studies have shown that tDCS has excellent potential to enhance cognitive and motor impairments in those living with H.I.V. A study conducted by Jiang *et al*., (2022) revealed that participants with H.I.V. who underwent tDCS demonstrated enhanced preservation errors in the Wisconsin card sorting test, a measure of executive functioning, as well as improved scores in the ratio score of the trail making test, which assesses cognitive impairment. Ownby *et al*., (2021) found tDCS to be effective in improving attention and psychomotor responses, particularly when combined with computer-based cognitive treatment in older adults with HIV-induced HAND. However, further research is necessary to explore the potential impact of tDCS on gait and balance impairments in individuals with H.I.V. Numerous studies have demonstrated the efficacy of tDCS in enhancing cognition and executive functioning, both in the short and long term, as mentioned above. Although the findings are promising, current research on tDCS, prefrontal cortex, and HAND has limitations. To illustrate, the most effective and ideal parameters for tDCS stimulation, including the placement of electrodes, intensity levels, and duration of stimulation, are still being investigated. Furthermore, the potential long-term effects of tDCS on cognitive ability and brain well-being remain uncertain, emphasizing the need for additional investigation in this field. Further research is needed on the impact of tDCS on gait speed, dynamic balance, ability to perform different aspects of gait, balance, and fall risk in the H.I.V. population.

Rosario *et al*., (2022b & 2024) conducted a comprehensive study to analyze the potential impact of transcranial direct current stimulation on gait and balance tasks in individuals living with H.I.V. After completing their research, the authors observed noteworthy enhancements in gait speed and sway after administering five treatments of tDCS. The results of both studies suggest that incorporating a specific activity, such as reaction time or coordination, into tDCS treatment could improve the outcomes. Based on the information above and the research conducted by Rosario *et al*., (2022b & 2024), it is proposed that individuals living with H.I.V. after tDCS treatment and reaction time tasks will experience the following improvements: 1) an increase in gait speed and step/stride length, as well as improved turns during the gait of dual cognitive tasks, and 2) an enhancement of dynamic balance (reduced sway and jerk) measured during a 7-meter flat surface walk. This study sought to identify a practical treatment approach for potential cognitive and physical impairments in people living with H.I.V.

METHODS

This study was conducted at the H.I.V. Latino/Hispanic Community Fitness Center in La Perla Precio, San Juan, Puerto Rico. The requirements for participation in this study included providing informed consent for access to medical records, disclosing H.I.V. status, and reporting CD4+ cell counts. This study was approved by the Institutional Review Board (#FY2020-32). Before engaging in the study, all individuals willingly provided and signed informed consent to participate. Before the experimental procedure commenced, researcher members collected detailed demographic data carefully collected from all participants. Before the experimental procedure began, a research member gathered detailed demographic data from all the participants. Demographic characteristics included age, sex, duration of diagnosis, timed 5x sit-to-stand (to evaluate lower limb strength), and the Fukuda test (to exclude vestibular disorders). The distinct attributes of this topic are explicitly delineated and structured in a readily understandable layout, as shown in Table 1.

This study included nine female canvassed and evaluated participants. The average age of these participants was 58.8 ± 4.6 years, and all were living with H.I.V. Each participant completed an interview and reviewed their medical records, which were evaluated using inclusion and exclusion criteria. The inclusion criteria were as follows: 1) age between 25 and 80 years, 2) confirmed diagnosis of H.I.V., 3) CD4 levels above 200 cells/µL, and 4) independent ability to walk without the use of an assistive device. Of the initial pool of candidates, 11 individuals were selected to participate in the screening process, with a diverse representation of three males and eight females.

Gait Protocol: The 7-meter walk gait protocol included pre- and post-gait assessments, during which the participants were instructed to complete two ambulation trials. The first trial involved walking 7 m at a self-selected speed (twice), whereas the second trial involved walking 7 m simultaneously, counting backward from 100 × 3 s (twice). The A.P.D.M. Mobility Lab diligently recorded and measured various spatiotemporal and kinematic parameters for accurate analysis. Sensors were strategically positioned in the chest and lumbar regions to assess mobility of the upper extremities, lower extremities, and trunk.

tDCS protocol: The tDCS steps adhered to the protocol published by Rosario *et al*., (2022), which was executed by utilizing two battery-operated electrical stimulators attached to each participant's forehead with a headband and a pair of 35-cm2 synthetic sponges soaked in saline solution to enhance conductivity. During this intervention, the cathode, which carried a negative charge, was positioned above the supraorbital margin of the left frontal bone. In contrast, the anode, which held a positive charge, was placed over the supraorbital margin of the right frontal bone. The duration of the T.D.C.S. protocol treatment was 20 min, three times per week, for two weeks, with five intervention sessions for each participant. Due to safety considerations, the electrode current was manually raised from 0.5mA to 2.0mA, as the electric currents were directly applied to the skin. To address safety concerns, the participants were directed to disclose any pain or discomfort experienced during their sessions. After each session, the T.D.C.S. electrical stimulator current was automatically decreased to 0 mA. Previous neurocognitive studies have shown the effectiveness of T.D.C.S. electrode timing (20 min), placement (prefrontal cortex), and intensity (1.5-2.0 mA) in individuals diagnosed with stroke (Costa *et al*., 2015), Alzheimer's disease (Boggio PS *et al*., 2009), and H.I.V. (Rosario *et al*., 2022). As a result of careful consideration and evaluation, this specific protocol was ultimately chosen to be implemented in the current study.

As part of the reaction time protocol, the participants were instructed to position themselves in front of five Blaze Pods (https://www.blazepod.com/), each with randomly rotating colors. Their task was to quickly and accurately tap the Blaze Pod, which reactively turned green, for 5 min while receiving tDCS treatment.

Data Analysis

We gathered kinematic data before and after administering five tDCS treatments to obtain comprehensive information. During the study, various gait measurements were collected and analyzed, including cadence (the number of steps taken per minute), gait cycle (the time it takes to complete one whole step), gait speed, support time (determining whether a person's weight is supported by one or both feet), stance time (the length of time one foot remains in contact with the ground), stride time (the time it takes to complete one full stride), swing phase (the part of the gait cycle when the foot is off the ground), and posture. The complete dataset, consisting of multiple pieces of information, was carefully arranged and presented in a comprehensive Excel spreadsheet. As the final stage of our analysis, an MANOVA (analysis of variance) was performed to contrast dynamic gait kinematics before and following the tDCS (transcranial direct current stimulation) intervention. This study's P value of less than or equal to 0.05 was deemed statistically significant.

RESULTS

Table 1 provides a detailed breakdown and presentation of the demographic characteristics of the study group. The sample used in this study comprised nine females with an average age of 58.8 ± 4.6. Years According to the data collected, the average age of individuals diagnosed with this condition was 24 years, and the mean CD4 count was 792.3 +/- 156.3.

Table 2a presents the visual representations and numerical comparisons of gait variables, posture, and turns among the various tasks studied before tDCS. The results of the M.A.N.O.V.A. are shown in Table 2a, between single and dual cognitive, pre-tDCS, with the significance level set at $p \leq 0.05$. Gait variables showed significant differences, with cadence, gait speed, and stride length being more affected in the dual task. Among the variables about turning, an important difference was observed between turn duration and velocity in the single and dual-task conditions before tDCS.

Table 2b presents the visual representations and numerical comparisons of gait variables, posture, and turns observed in the different tasks studied after tDCS. The results of the M.A.N.O.V.A. are shown in Table 2b, comparing single and dual cognitive tasks post-tDCS, with a significance level of $p \leq 0.05$. A notable discrepancy (with dual tasks still having an impact) was observed between cadence and gait speed for the gait variables. A significant difference was observed among the turn variables, specifically in the effects of dual tasks on the turn duration post-tDCS.

Table 1: Demographic data of all participants

Characteristics	
Age (years)	M = 58.8 ± 4.6.
Gender	Nine females
Year of Dx (years)	M= 24.1 +/-5.1
Cd4	M= 792.3 +/- 156.3
Resting heart rate (R.H.R.)	73.3 ± 7.7 beats per minute (bpm)
Resting oxygen saturation (SaO_2)	96.5 ± 1.6%

Table 2a: Comparison of Walking Parameters between single and dual tasks. Results of M.A.N.O.V.A. performed comparing tasks. Significance level set at p≤0.05

Motor Component Variables	Single Tasks	Dual Tasks	P-Value
Cadence (steps/min)	117.16 ± 12.600	108.27 ± 11.390	0.05
Gait Speed (m/secs)	1.18 ± 0.202	1.01 ± 0.172	0.005
Stride Length (m)	1.20 ± 0.131	1.11 ± 0.119	0.05
Single limb (secs)	38.46 ± 2.978	37.22 ± 2.735	0.167
Double limb (secs)	23.37 ± 5.842	25.75 ± 5.668	0.191
Stance (% gait cycle)	61.83 ± 3.062	62.96 ± 3.079	0.231
Swing (% gait cycle)	38.18 ± 3.063	37.04 ± 3.079	0.231
A-P Sway Velocity (m/s)	0.43 ± 0.201	0.55 ± 0.438	0.308
M-L Sway Velocity (m/s)	0.31 ± 0.107	0.27 ± 0.112	0.398
Turns-Angle (degrees)	175.58 ± 6.590	173.92 ± 14.888	0.572
Turns-Duration (secs)	2.56 + 0.330	2.82 ± 0.481	0.05
Turn-Velocity (degrees/secs)	170.05 ± 34.907	146.38 ± 28.999	0.05
Turns- # Steps	5.10 ± 0.889	5.77 ± 2.202	0.128
min; minutes, m: meters, secs: seconds, A-P: antero-posterior, M-L: medio-lateral,			

Table 2b: Comparison of Walking Parameters between single and dual tasks post-tdcs. Results of M.A.N.O.V.A. performed comparing tasks. Significance level set at p≤0.05

Motor Component Variables	Single Tasks	Dual Tasks	P-Value
Cadence (steps/min)	116.03+/- 12.807	108.02+/- 12.010	.05
Gait Speed (m/secs)	1.18 +/- .226	1.02+/- .201	.01
Stride Length (m)	1.19 +/- .140	1.10 +/- .132	.318
Single limb (secs)	39.47 +/- 3.083	38.50 +/- 3.158	.318
Double limb (secs)	10.85 +/- 2.882	11.75 +/- 3.048	.344
Stance (% gait cycle)	60.53 +/- 3.083	61.50 +/- 3.160	.331
Swing (% gait cycle)	39.47 +/- 3.083	38.50 +/- 3.158	.331
A-P Sway Velocity (m/s)	.50+/- .551	.36+/- .239	.107
M-L Sway Velocity (m/s)	.33+/- .138	.30 +/- .154	.551
Turns-Angle (degrees)	175.80+/- 6.721	175.80+/- 6.505	.814
Turns-Duration (secs)	2.66+/- .328	2.95+/-.369	.05
Turn-Velocity (degrees/secs)	156.07+/- 35.760	141.07+/- 36.219	.172
Turns- # Steps	4.97+/- .532	5.00 +/- .560	.846
min; minutes, m: meters, secs: seconds, A-P: antero-posterior, M-L: medio-lateral,			

DISCUSSION

This study aimed to determine the effects of a neuromodulator on the motor cortex during gait in individuals with H.I.V., along with the inclusion of tracking and reaction time tasks. In their 2022b and 2024 studies, Rosario *et al.*, examined a population and protocol that closely resembled the current study. The authors proposed incorporating an activity in conjunction with tDCS to augment the efficacy of the intervention. According to the study conducted by Rosario *et al.*, in 2022, we formulated the following hypothesis: Individuals living with H.I.V. who undergo tDCS treatment and perform reaction time tasks will experience an increase in gait speed and step/stride length, as well as an improvement in turns during the gait of dual cognitive tasks. Furthermore, based on the 2024 study, dynamic balance will be enhanced, as evidenced by a reduction in sway and jerk, measured during a 7-meter flat-surface walk.

The present study deconstructed a 7-meter walking task into multiple dynamic elements, including gait parameters such as step and stride length, balance measured by sway, and turns in terms of speed and duration. During single and dual cognitive tasks, measurements were taken before and after tDCS. Researchers observed that specific gait parameters, including stride length, turn duration, and sway, were the primary differentiating factors after tDCS treatment. After consideration, we conclude that our previous assumption was partially correct; therefore, we accept it to a certain extent.

Individuals diagnosed with H.I.V. frequently encounter neurocognitive impairments, referred to as HIV-associated neurocognitive disorders (HAND), which can significantly affect their well-being and daily activities (Rosca *et al*., 2021). It is postulated that cognitive impairments in individuals with H.I.V. are a result of various factors, including the direct impact of the virus on the brain and the adverse effects of antiretroviral therapy (Rosario *et al*., 2020a-c, Hyder & Rosario, 2021). Various studies have examined the potential of tDCS as a pioneering intervention to enhance cognitive function in individuals living with H.I.V. A study conducted by Martin *et al*., (2018) showed that a single session of tDCS over the dorsolateral prefrontal cortex resulted in improved working memory performance in individuals with H.I.V. compared to those who received sham stimulation. These findings indicate that tDCS may regulate neural activity and enhance cognitive outcomes in this group. In addition, a systematic review conducted by Smith *et al*., (2021) emphasized the general safety and feasibility of tDCS in individuals with H.I.V. Smith's study suggests that tDCS has potential as a non-pharmacological approach for addressing cognitive impairments related to H.I.V. This review also underscores the need for further research to elucidate the optimal tDCS parameters and target brain regions to maximize cognitive benefits in individuals living with H.I.V.

Gait-Stride Length

Rosario (2023) noted that dual tasks could change cadence, gait speed, stride length, and single-limb support in HIV-infected individuals with H.I.V. who experience dual cognitive demands. The current study suggests that tDCS neurostimulation and reaction-tracking activity may improve specific motor cognitive impairments in this group. The observation of similar stride lengths demonstrated the validity of this statement and turn durations after the treatment above. By our research, Pol *et al*., (2021) reported a notable enhancement in stride length, step length, and step width in individuals with Parkinson's disease (P.D.). Like the current study, multiple studies have reported implementing an identical treatment approach of tDCS placement on the prefrontal cortex at an intensity of 1 mA or two mA for five consecutive days. Research on tDCS and its effects on stride length is ongoing; however, promising results have been reported in various populations. tDCS is a potential tool for improving gait performance and mobility by modulating the neural activity in key brain regions.

Research conducted by Smith *et al*., in 2018 delved into the impact of tDCS on gait parameters among individuals diagnosed with Parkinson's disease. The researchers discovered that applying anodal tDCS over the motor cortex caused a significant increase in stride length compared with sham stimulation. This location implies that tDCS could benefit gait performance by enhancing motor cortical excitability and influencing neural activity in the motor cortex and related brain areas. In a comprehensive meta-analysis conducted by Jones and his team of researchers in 2020, the potential impacts of tDCS on motor abilities were meticulously explored in individuals without any preexisting health conditions. The analysis revealed a consistent improvement in gait parameters, including stride length, following tDCS targeting the motor cortex. These findings prove that tDCS can influence gait characteristics and improve walking ability. In a parallel study, Rosario *et al*., also examined the impact of tDCS on individuals living with H.I.V. and their gait patterns in 2022, mirroring the focus of the current study. Based on the results gathered, it can be determined that there was a noticeable and noteworthy enhancement in both gait speed and H.I.V. dementia score, indicating the effectiveness and success of the treatment. The primary distinction between the two studies is that the present study revealed a variation in stride length, while gait speed remained unchanged. Future studies should investigate the potential benefits of tDCS on gait parameters using more challenging walking tasks, such as ramps or steps, to elicit significant gait issues and identify major changes with tDCS treatment.

Balance

The results indicate that various components of balance, such as sway, require a distinct approach, potentially involving an extended treatment period or the inclusion of additional locations for tDCS electrodes. Based on research, it has been observed that individuals living with H.I.V. often face issues with maintaining balance and coordination (Rosario *et al*., 2024). Studies have shown that tDCS can effectively impact balance and motor control in individuals with neurological disorders such as H.I.V. (Rosario *et al*., 2024). Rosario *et al*., (2024) also observed a decrease in sway and an improvement in standing balance concerning its adjunct components. Hence, the authors concluded that tDCS could serve as a feasible treatment option for individuals with H.I.V. infection who experience postural challenges. In response to these research outcomes, a study by Mello *et al*., (2019) showed that tDCS at the cerebellum improved balance abilities in individuals diagnosed with Parkinson's. A meta-analysis by Kim *et al*., (2021) found that tDCS interventions targeting the motor cortex led to noteworthy enhancements in balance and gait measures in individuals with stroke. The evidence above suggests that tDCS has the potential to enhance balance ability through its impact on the brain regions involved in motor control.

Turns

The third result demonstrated changes in turn speed following the active neuromodulation treatment. Gait abnormalities are prevalent in a variety of neurological disorders, including those living with H.I.V., significantly affecting the quality of life and increasing the likelihood of falls (Rosario, 2023). tDCS can enhance turning performance and mitigate gait deficits in individuals with these conditions through modulation of cortical excitability. Similar to our results, Mirelman *et al*., (2016) examined the effects of tDCS on turning performance in individuals diagnosed with Parkinson's. The researchers discovered that anodal tDCS over the primary motor cortex yielded significant improvements in turning velocity, step length, and gait symmetry compared with sham stimulation. These improvements facilitated cortical excitability and motor planning processes, enhancing coordination and efficiency in the turning tasks.

Through the directed stimulation of cortical regions involved in motor control, tDCS can potentially augment neural plasticity, motor learning, and gait coordination, ultimately resulting in improved mobility and decreased risk of falling, according to Reis *et al*., (2018) findings. Dong *et al*., (2021) conducted a systematic review and meta-analysis to examine the effect of tDCS on balance and gait in individuals with stroke. After implementing tDCS, researchers found that stroke patients improved their gait and decreased the risk of falling (Dong *et al*., 2021). It is worth noting that, despite the focus of this study on stroke patients, it is interesting to note that both stroke patients and P.L.H.I.V. (people living with H.I.V.) exhibit similar cortical presentations. These similarities suggest a potential overlap in neurological effects between these two patient groups. As an illustration, people who have experienced a stroke exhibit reduced cortical excitability due to nervous system lesions, resulting in impaired motor planning during gait and locomotion, similar to P.L.H.I.V. (Dong *et al*., 2021).

Additionally, a meta-analysis conducted by Reis *et al*., (2018) examined the impact of tDCS on gait and balance in stroke patients. The analysis demonstrated that the combination of tDCS and physical therapy led to significant improvements in gait speed, balance control, and turning abilities compared to physical therapy alone. This study illuminated the potential of tDCS as an additional intervention to improve motor recovery and functional outcomes after stroke.

Similarly, numerous researchers have observed that the motor cortex can be stimulated directly through tDCS to improve the functioning of the muscles in the lower limbs. According to research such as Kaski *et al*., (2012), it has been proven that this particular stimulation directly correlated to improved motor adaptability, heightened strength in the quadriceps muscles, and an increase in activation amplitude of the anterior tibialis, ultimately leading to enhanced fine motor control specifically at the ankle. In this context, the control mechanism pertains to the capacity of tDCS electrical current to depolarize membrane potentials in individuals, as discussed in the 2021 study conducted by Dong *et al*., In a comparable fashion to the effects of stroke and P.L.H.I.V., tDCS has been proven by Workman *et al*., (2019) to improve gait parameters in individuals struggling with multiple sclerosis (Workman *et al*., 2019). Although it is acknowledged that the motor cortex plays a role in the improvement following tDCS (Rosario *et al*., 2022b), it is essential to consider other potential factors that could account for the observed results, which should be further explored by prospective researchers in the field of tDCS.

CONCLUSION

The quantity of tDCS research continues to flourish as the literature consistently supports its efficacy in individuals with mild cognitive impairment. tDCS has shown considerable enhancements in multiple domains of motor cognitive function across various populations, including stroke, Parkinson's disease, and H.I.V. These improvements include increased processing speed, task planning, selective attention, and memory in older adults with mild motor cognitive impairments, as demonstrated in studies by Gonzalez *et al*., (2017), Rosario *et al*., (2022b), and others. However, before the current investigation, limited research was available on the utilization of tDCS in individuals with H.I.V. It is imperative to develop a new approach to enhance motor cognitive components in individuals with H.I.V., as the virus can damage both the immune and nervous systems. tDCS has shown great potential in improving balance and motor function owing to its unique ability to modulate brain activity.

Additional research is needed to fully understand the mechanisms of action and potential applications of tDCS as ongoing studies investigate its effects. Although tDCS has demonstrated potential as a safe and effective method for modulating brain function, additional research is mandated to optimize stimulation parameters, establish long-term effects, and investigate its potential in conjunction with other treatments. Nonetheless, tDCS is a captivating field in neuroscience studies with the potential to influence diverse aspects of brain function and mental well-being. tDCS is a promising tool for enhancing gait performance and overall mobility through modulation of neural activity in critical brain regions. Additional research is necessary to 1. Investigate the most influential parameters of tDCS stimulation for improving stride length, 2. Ascertain its potential as a rehabilitative intervention in clinical settings, and 3. Examine balance in different populations to optimize stimulation parameters for optimal efficacy.

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Consent to participate: The participant gave signed consent for this study

Authors' Contributions:
M.R. conceived and designed the study as the P.I.. Data collection was completed by D.W. and M.R. All drafts of the manuscript development include all author's contributions.

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