Effect of Simultaneous High-definition Transcranial Direct Current Stimulation and Robot-assisted Gait Training on Gait Function in Chronic Stroke Patients

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Research Article

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Abstract

Background

Robot-assisted gait training (RAGT) is used for rehabilitation after stroke, but not all chronic stroke patients achieve satisfactory improvement in physical ability. The purpose of this study was to investigate whether the effects of RAGT on gait and physical function in chronic stroke patients could be enhanced by simultaneously applying high-definition transcranial direct current stimulation (HD-tDCS).

Methods

Twenty-four chronic hemiplegic stroke patients (15 males; mean age 60.5 ± 13.9 years) participated in this study. The subjects were randomly allocated to either the RAGT with real HD-tDCS group (RAGT c rHD-tDCS) or the RAGT with sham HD-tDCS group (RAGT c sHD-tDCS). Each group completed 10 sessions over four consecutive weeks. Gait and physical function were measured by the 10 Meter Walk Test (10MWT), Timed Up and Go (TUG), Functional Ambulation Category (FAC), Functional Reach Test (FRT), Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Fugl-Meyer Assessment (FMA), and the Korean version of the Modified Barthel Index (K-MBI). Assessments were performed before intervention (Pre), immediately after intervention (Post), and at follow-up (F/U) one month after the intervention.

Results

The RAGT c rHD-tDCS group showed statistically significant improvements in 10MWT, TUG, FRT, and BBS at Post and F/U compared to Pre (P<0.05). The RAGT c rHD-tDCS group also improved significantly in the DGI and FMA at Post compared with Pre (P<0.05). The RAGT c sHD-tDCS did not show significant improvement at Post or F/U compared to Pre. Repeated measures analysis of variance revealed significant time × group interactions in the FMA and the K-MBI (P<0.05), indicating that the RAGT c rHD-tDCS group experienced greater improvements in motor and activities of daily living functions compared with the RAGT c sHD-tDCS group.

Conclusion

These results demonstrate that simultaneous application of HD-tDCS during RAGT produces positive effects on gait and physical function in chronic stroke patients. Combining RAGT with HD-tDCS ensured long-term training effects for up to one month. HD-tDCS can be suggested as a complementary tool for
enhancing robotic gait rehabilitation therapy in chronic stroke patients after a larger confirmatory study to verify these effects.

**Trial registration:**

Clinical trials registration information: ClinicalTrials.gov Identifier: NCT04985864 (07/30/2021).

**Background**

Stroke is the second leading cause of death worldwide, and its incidence has increased as the population has aged [1]. Despite a variety of physiotherapeutic options for improving functional outcomes after stroke, more than 30% of stroke survivors cannot walk independently, even in the chronic phase [2]. Gait disorders caused by motor impairments of the lower limbs greatly affect patients’ ability to carry out activities of daily living (ADL) and quality of life [3].

Various approaches to enhancing neuroplasticity are being considered to improve the prospects for physical recovery after stroke. In addition to conventional rehabilitation (i.e., physical, occupational, and speech), several new approaches to enhancing neuroplasticity have emerged over the last two decades, including robot-assisted training, brain stimulation, virtual reality, and cell therapy [4]. However, as these treatments have not always resulted in superior outcomes compared with conventional rehabilitation, novel combination treatments that can better activate neuroplasticity mechanism and enhance therapeutic effects are needed [5].

According to the basics of neuroplasticity and motor learning, by providing intensive, repetitive, and accurate kinematic feedback and symmetrical gait practice, robot-assisted gait training (RAGT) can induce adaptive modification and reorganization of neural connections and networks to maximize recovery and functional outcomes [6]. A recently updated Cochrane revision of 62 trials involving 2,440 participants found that RAGT combined with physiotherapy is most beneficial for patients in the first three months after stroke and in those who are unable to walk [7]. Some studies have shown that Lokomat® improves balance and gait abilities by inducing functional improvements in the lower extremities not only in subacute stroke patients but in chronic stroke patients (more than three months after stroke) as well [8, 9]. Although RAGT has the potential to improve gait ability in stroke patients, not all chronic stroke patients achieve satisfactory recovery [10]. Therefore, it is necessary to investigate additional methods to enhance the advantages of RAGT.

Transcranial direct current stimulation (tDCS) has been proposed to facilitate the beneficial neuroplasticity effects of post-stroke rehabilitation [11]. tDCS modulates cortical excitability by applying a low-intensity electrical current (e.g., 1–2 mA) to the scalp in the target cortical area to increase (e.g., anodal) or decrease (e.g., cathodal) the cortical excitability of the motor area [12]. Application of tDCS to the primary motor cortex (M1), which controls the movement of upper and lower extremities, increases the activity of the motor cortex to improve motor learning in both healthy individuals and post-stroke
Because tDCS is considered safe and is highly portable, it is easy to use simultaneously with other rehabilitation therapies such as gait training. Intensive upper extremity motor learning in combination with tDCS effectively improves upper extremity motor function after stroke. Although few studies have investigated the efficacy of tDCS in the recovery of lower extremity function after stroke, tDCS has been shown to improve muscle strength in the lower extremities.

One consideration is that tDCS should target the M1 area representing the lower extremities to enhance cortical excitability and affect gait function. This cortical area is located in the medial part of the precentral gyrus deep within the interhemispheric fissure. Targeted application of tDCS to this area is more challenging than targeting the upper limbs. High-definition transcranial direct current stimulation (HD-tDCS) with smaller "high-definition" electrodes has been proposed to improve the focus of the stimulation in the target area. HD-tDCS can reportedly target deeper brain structures than tDCS and can be configured with several channels and multiple small electrodes in a variety of montages to guide current flow. Therefore, it is conceivable that a combination of HD-tDCS and RAGT may effectively stimulate the more deeply located M1 leg area and enhance the effect of combination therapy compared with conventional tDCS in chronic stroke patients.

The purpose of our study was to investigate whether HD-tDCS can enhance the training effect of RAGT on gait and physical function in chronic stroke patients with gait disorder. We hypothesize that combining HD-tDCS with RAGT will significantly enhance gait and physical function in chronic stroke patients compared with RAGT only, and the effect will last until one month after intervention.

**Methods**

**Participants**

This study was a single-center, double-blind, randomized, and prospective study. The subjects were assigned to one of two groups: 1) RAGT with real HD-tDCS (RAGT−rHD-tDCS) or 2) RAGT with sham HD-tDCS (RAGT−sHD-tDCS). Twenty-seven subjects who met the inclusion criteria were enrolled. The inclusion criteria were: 1) chronic phase of stroke (at least three months after stroke onset), 2) aged 19 to 79 years, and 3) a gait disorder with Functional Ambulation Category (FAC) score of 1 to 4. The exclusion criteria were: 1) a history of serious neurological diseases other than stroke (e.g., Parkinson's disease), 2) severe cognitive deficit (a Korean-Mini Mental State Examination (K-MMSE) score ≤ 10), 3) a history of serious mental illness (e.g., schizophrenia, bipolar disorder), 4) a metallic object in the skull, 5) a history of epilepsy, 6) current pregnancy or lactation, 7) an implantable medical device (e.g., pacemaker), and 8) any dermatological problem that prevented attachment of the stimulation electrode. The baseline characteristics of the study subjects are summarized in Table 1. This study protocol and consent form were reviewed and approved by the Korean Food and Drug Administration (No. 1227) and the Institutional Review Board at Samsung Medical Center, Seoul, Republic of Korea (IRB no. 2021-06-131).
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (N = 24)</th>
<th>RAGT − c rHD-tDCS (n = 12)</th>
<th>RAGT − c sHD-tDCS (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60.54 (13.90)</td>
<td>62.58 (11.22)</td>
<td>58.50 (16.41)</td>
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<tr>
<td>Sex (male/female)</td>
<td>15/9</td>
<td>7/5</td>
<td>8/4</td>
</tr>
<tr>
<td>Time since onset (month)</td>
<td>52.50 (45.04)</td>
<td>59.17 (58.92)</td>
<td>45.83 (25.94)</td>
</tr>
<tr>
<td>Affected side (right/left)</td>
<td>15/9</td>
<td>7/5</td>
<td>8/4</td>
</tr>
<tr>
<td>Stroke type (infarction/hemorrhage)</td>
<td>15/9</td>
<td>6/6</td>
<td>9/3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.30 (9.64)</td>
<td>163.83 (8.87)</td>
<td>164.77 (10.72)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.42 (10.74)</td>
<td>67.32 (8.23)</td>
<td>67.52 (13.17)</td>
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<td>BMI (kg/m²)</td>
<td>24.91 (2.91)</td>
<td>25.07 (2.21)</td>
<td>24.74 (3.57)</td>
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<tr>
<td>FAC</td>
<td>3.29 (0.69)</td>
<td>3.50 (0.52)</td>
<td>3.08 (0.79)</td>
</tr>
<tr>
<td>K-MMSE</td>
<td>27.96 (2.46)</td>
<td>27.83 (2.92)</td>
<td>28.08 (2.02)</td>
</tr>
</tbody>
</table>

Continuous values are presented as mean (standard deviation).

RAGT − c rHD-tDCS, Robot-assisted Gait Training with Real High-definition Transcranial Direct Current Stimulation Group; RAGT − c sHD-tDCS, Robot-assisted Gait Training with Sham High-definition Transcranial Direct Current Stimulation Group; BMI, Body Mass Index; FAC, Functional Ambulation Category; K-MMSE, Korea-Mini Mental State Examination.

*Significant change compared with Pre (P < 0.05), **Significant change compared with Pre (P < 0.01) using Wilcoxon signed rank test.

§Significant change compared with Pre (P < 0.05), §§Significant change compared with Pre (P < 0.01) using Bonferroni’s post hoc analysis in repeated measures analysis of variance.
Experimental protocol

Patient age, sex, height, weight, stroke type, time since onset, FAC, and K-MMSE score were recorded and evaluated to determine whether the subjects met the inclusion criteria. Eligible subjects were randomly assigned to either the RAGT $c$ rHD-tDCS group or RAGT $c$ sHD-tDCS group using a random table. All subjects received 10 sessions in four consecutive weeks (approximately three times a week). The duration of each intervention session was 45 minutes (Fig. 1). The intervention protocol was as follows; 1) subjects wore a cap equipped with HD-tDCS electrodes and a robot device (5 minutes), 2) subjects received real or sham HD-tDCS for 5 minutes without robot training, 3) subjects received RAGT and simultaneous real or sham HD-tDCS for 25 minutes, 4) for the next 5 minutes, subjects received only RAGT without HD-tDCS, and 5) the gait robot and HD-tDCS electrodes were detached (5 minutes). Our protocol was designed to activate the central nervous system through HD-tDCS for 5 minutes before RAGT and provided simultaneous peripheral nervous system stimulation using RAGT for a sufficient period of motor learning without fatigue [27]. This study was double-blind for both evaluators and subjects. All outcome measures were evaluated before the intervention (Pre), immediately after the intervention (Post), and at a follow-up (F/U) visit one month after the intervention.

Robot-assisted gait training

Lokomat® (Hocoma AG, Zurich, Switzerland) is a robotic treadmill training system that uses a harness to support patients while their legs are attached to robotic legs that control the movements of the bilateral hip, knee, and ankle joints to replicate normal gait patterns on a treadmill. Movement of the patient's lower extremities was based on a pre-programmed normal gait pattern and facilitated a bilaterally symmetrical gait pattern as the subjects attempted to walk on the treadmill. This protocol for gait training with Lokomat® offers intensive, task-oriented, repetitive training for gait restoration in stroke patients [28]. During Lokomat® treatment, the body weight support and gait speed were adjusted by an experienced therapist to match each patient's physical function. The speed selected for each subject ranged from 1.4 to 2.0 km/h, and subjects were trained for 30 minutes.

High-definition transcranial direct current stimulation

The HD-tDCS in this study used the YDS-501B® developed by YBrain (YBrain Inc., Pangyo, Republic of Korea), which can accommodate 2 to 16 electrodes (2 cm in diameter), as desired. Using Neurophet tES Lab®, brain stimulation simulation software (Neurophet Inc., Seoul, Republic of Korea) with standard MRI images of the brain, the optimal electrode position to provide the maximum current to the leg motor area in the primary motor area (M1) was selected. The HD-tDCS was applied at 2 mA for 30 minutes to enhance the functional improvement effect of chronic patients [29]. The default settings in the software of the HD-tDCS were six electrodes, maximum current strength of 1 mA per electrode, and a total current strength of 2 mA. According to the 10–20 system, the position and strength of the anode and cathode were set as follows: 1) Anode: $Cz = 1 mA$, $C2 = 0.7 mA$, $C3 = 0.3 mA$, 2) Cathode: $C5 = -1 mA$; $FC5 = -0.5 mA$. 

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mA; CP5 = −0.5 mA. In patients with a left hemisphere lesion, the cathode was placed on the left side to ensure that current flowed to the left side; for patients with a right hemisphere lesion, the cathode was placed symmetrically. The position of the electrodes was the same in both groups, and the stimulation in the sham condition was set to 0 mA intensity (Fig. 2).

**Physical function evaluation**

To measure gait, balance, motor functions, and ADL performance, the 10 Meter Walk Test (10MWT), Timed Up and Go (TUG), FAC, Functional Reach Test (FRT), Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Fugl-Meyer Assessment (FMA), and Korean version of Modified Barthe Index (K-MBI) were performed.

The 10MWT is widely used to determine functional mobility, gait, and vestibular function of stroke patients. The TUG test assesses mobility, balance, gait ability and the risk of a fall in stroke patients and evaluates the ability to maintain balance during gait movements. The FAC is used to assess functional ambulation by determining the amount of assistance required by a subject when walking, regardless of whether aids are used. The FRT assesses a patient's stability and static balance by measuring the maximum distance an individual can reach forward while standing in a fixed position. The BBS and DGI are used to objectively determine a stroke patient's dynamic balance ability to remain safely balanced while performing predetermined tasks. The FMA is designed to assess motor function, sensation, balance, joint range of motion, and joint pain in patients with post-stroke hemiplegia. The K-MBI is used to assess behavior relating to ADL among stroke patients.

**Statistical analysis**

All data were analyzed using SPSS software version 25.0 (IBM Corp., Armonk, N.Y., USA). For all tests, the level of statistical significance was set to 0.05. Baseline characteristics of patients were compared between groups using the independent t-test or Mann-Whitney U test for continuous variables and the chi-square test for categorical variables. To evaluate the effect of interventions, Wilcoxon signed rank test was used to compare outcome measures between time points within groups. In addition, changes between time-points within groups were analyzed using Bonferroni's post hoc analysis of the repeated measures analysis of variance (RM ANOVA). Time × group interactions were examined using RM ANOVA, including RAGT crHD-tDCS and RAGT csHD-tDCS groups and time points (Pre, Post, and F/U).

**Results**

The 27 eligible subjects were randomly assigned using simple randomization to the RAGT crHD-tDCS group or RAGT csHD-tDCS group and received their allocated interventions (Fig. 3). The final analysis included 24 subjects after excluding three subjects who discontinued the intervention for personal reasons: two subjects in the RAGT crHD-tDCS group and one in the RAGT csHD-tDCS group.
Figure 4 illustrates the changes in physical functions at Pre, Post, and F/U in the RAGT rHD-tDCS or RAGT sHD-tDCS groups analyzed using the Wilcoxon signed rank test and Bonferroni’s post hoc analysis of RM ANOVA. Specific values for physical function in the 10MWT, TUG, FAC, FRT, BBS, DGI, FMA – LE, FMA – TOTAL, and K-MBI outcome measures at the Pre, Post, and F/U time points are presented in Supplementary Table 1 and Supplementary Table 2. The FMA results show the lower extremity (FMA – LE) scores and total upper extremity and lower extremity (FMA – TOTAL) scores for the affected side. The groups did not differ in gait or balance function at the Pre, Post, or F/U time point.

Both groups statistically significantly changed from Pre to all other time points in the TUG ($P < 0.05$). The 10MWT, FRT, BBS, and DGI scores changed significantly from the Pre to all other time points in the RAGT rHD-tDCS group ($P < 0.05$). The FMA – LE and FMA – TOTAL scores improved significantly from the Pre to Post time points in the RAGT rHD-tDCS group ($P < 0.05$). The 10MWT and BBS scores in the RAGT sHD-tDCS group changed from Pre to Post ($P < 0.05$).

Bonferroni’s post hoc analysis revealed that the 10MWT, TUG, FRT, and BBS scores of the RAGT rHD-tDCS group changed significantly from Pre to all other time points ($P < 0.05$), whereas the RAGT sHD-tDCS group did not show significant improvements from Pre to any other time point. The DGI, FMA – LE, and FMA – TOTAL scores improved significantly from the Pre to Post time points in the RAGT rHD-tDCS group only ($P < 0.05$). In addition, significant time × group interactions were found in FMA – TOTAL with the RAGT rHD-tDCS group, which demonstrated greater improvements compared with the RAGT sHD-tDCS group ($P < 0.05$). The RM ANOVA revealed significant time × group interactions in the K-MBI ($P < 0.05$), indicating that the RAGT rHD-tDCS group experienced greater improvement compared with the RAGT sHD-tDCS group across time points.

**Discussion**

The purpose of this study was to investigate whether simultaneous application of HD-tDCS could enhance the training effect of RAGT in chronic stroke patients. The findings suggest that adding real HD-tDCS to RAGT has several key advantages in gait, balance, motor function, and ADL performance over RAGT with sham HD-tDCS. Furthermore, the improvements in gait and balance function in the RAGT rHD-tDCS group were maintained for at least one month after intervention. ADL performance and motor function showed significant time × group interactions.
In stroke patients with gait disorders, the ability to control gait, balance, and motor functions is reduced by hemiparetic abnormalities with asymmetry, increased stride variability, and muscle weakness [30]. Rehabilitation treatment to improve physical function is important because decline of these functions increases the risk of falls during walking among stroke patients, leading to low quality of life [31]. Subacute stroke patients and those who are not able to walk independently may be more likely to benefit from the RAGT intervention [7]. However, evidence for the effect of RAGT in chronic stroke patients is insufficient [32]. Choi et al. (2022) reported improvements in functional gait and balance ability in chronic stroke patients who received RAGT with body weight support five times a week for six weeks [33]. We found significant improvements in gait and balance function (10MWT, TUG, and BBS) in both groups after intervention three times a week for four weeks. The increase in gait and balance function in both groups after the intervention may be due to advantages of RAGT in that a larger number of steps can be practiced per session [34], symmetrical gait can be facilitated [35], and paretic leg step length symmetry is fostered [28].

Although there are few studies using HD-tDCS with RAGT, a clinical improvement in chronic stroke patients was reported in two of three studies that compared real stimulation (anodal on M1) and sham stimulation (supraorbital stimulation) applied with RAGT. Danzl et al. (2013) reported a significant improvement in FAC scores after RAGT with real tDCS intervention compared to those before intervention [36]. Seo et al. (2017) found statistical improvements in the FAC and 6-Minute Walk Test in the real tDCS group at one month F/U after intervention only [37]. Additionally, previous studies investigating the effects of tDCS with RAGT on gait, balance, and motor abilities in subacute and chronic stroke patients found overall improvements in TUG and FAC after intervention, although no significant effects were found in 10MWT, BBS, 6MWT, or FMA – LE [38]. In contrast to previous studies, our results after Bonferroni correction showed significant improvements in gait, balance, and motor functions (10MWT, FRT, BBS, DGI, FMA – LE, and FMA – TOTAL) as well as TUG after intervention with real HD-tDCS in chronic stroke patients. It is thought that combined application of HD-tDCS could help to facilitate cortical excitability of the M1 leg area; therefore, it could enhance the training effect of RAGT to increase its consistency in chronic stroke patients [39].

Stroke affects not only gait, balance, and motor functions but also the ability to perform ADL. Consistent with previous findings, this study found significant time × group interactions in ADL performance and motor function in the RAGT + cHD-tDCS group compared with the RAGT + cSHD-tDCS group, which leads us to conclude that the combination of HD-tDCS and RAGT has beneficial effects on motor and ADL function [40, 41]. These results suggest that combining RAGT with HD-tDCS facilitates changes in neuroplasticity that promote physical function recovery and increases cortical activity to enhance subsequently spontaneous activities such as ADL [42].

Furthermore, tDCS has a long-term positive effect on function through learning processes in stroke patients. A study comparing the effects of tDCS and HD-tDCS applied over the M1 on motor learning in a group of children found that both tDCS and HD-tDCS maintained improved motor learning effects not
only after training but after six weeks of F/U [43]. The results of a previous study of applying tDCS to RAGT showed that improved gait endurance was maintained for up to one month in chronic stroke patients [37]. In our study, combining HD-tDCS with RAGT maintained the improved gait and balance function after the intervention until the F/U time point, different from a previous study that used tDCS. Therefore, the combination of RAGT and HD-tDCS was confirmed to have long-term effects even on gait and balance function in chronic stroke patients.

This study has some limitations. First, as it was an exploratory clinical trial with a small number of patients, and further studies using a larger stroke population are needed to validate the results. Second, lesion sites such as cortical and subcortical lesions and stroke types were not considered when recruiting study subjects (Supplementary Table 3). The effect of HD-tDCS can be influenced by lesion location and size. Analysis of different effects according to stroke type or lesion location will provide further guidance about more effective methods of combining HD-tDCS and RAGT.

**Conclusions**

These results demonstrated that simultaneous application of HD-tDCS during RAGT resulted in a positive effect on gait and physical function of chronic stroke patients more than RAGT alone. Combining RAGT with HD-tDCS ensured long-term training effects for up to one month. We conclude that HD-tDCS can be a complementary tool for enhancing robotic gait rehabilitation therapy in chronic stroke patients after a larger confirmatory study to verify these effects.

**Abbreviations**

ADL
Activities of Daily Living
RAGT
Robot-assisted Gait Training
HD-tDCS
High-definition Transcranial Direct Current Stimulation
K-MMSE
Korean-Mini Mental State Examination
Pre
Before the Intervention
Post
After the Intervention
F/U
Follow-up
10MWT
10 Meter Walk Test
TUG
Declarations

Ethics approval and consent to participate

All participants recruited through Samsung Medical Center provided informed consent before participating in the present study. This study protocol was approved by the ethics committee of the Samsung Medical Center Institutional Review Board.

Consent for publication

Not applicable

Availability of data and material

The datasets supporting the conclusions of this article are included in the manuscript.

Competing interests

The authors declare that they have no competing interests to disclose.

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ICT), Korea, under the ICT Creative Consilience program (IITP-2021-2020-0-01821) supervised by the IITP (Institute for Information & Communications Technology Planning & Evaluation).

**Authors’ contributions**

EMK contributed to the data collecting, data analysis, and drafting of the manuscript. JSL and GHL contributed to the experimental design, data analysis, data interpretation, and revision of the manuscript. YHK contributed to the experimental design, data interpretation, and critical revision of manuscript and final approval. All authors have read and approved the final manuscript.

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We would like to thank all participants who consented to participate in the study.

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**References**


**Figures**

![Intervention protocol](image)

**Figure 1**

Intervention protocol
Figure 2

Electrode montage for high-definition transcranial direct current stimulation. (A) The position and intensity of the anode (Cz = 1 mA; C2 = 0.7 mA; C3 = 0.3 mA) and cathode (C5 = −1 mA; FC5 = −0.5 mA; CP5 = −0.5 mA) in patients with a left hemisphere lesion. For patients with a right hemisphere lesion, electrodes were placed symmetrically. (B) Electrodes placed according to the selected montage on a patient with a left hemisphere lesion.

Figure 3

Study flow diagram.

RAGT ċ rHD-tDCS, Robot-assisted Gait Training with Real High-definition Transcranial Direct Current Stimulation Group; RAGT ċ sHD-tDCS, Robot-assisted Gait Training with Sham High-definition Transcranial Direct Current Stimulation Group.
Figure 4

Effect of robot-assisted gait training with high-definition transcranial direct current stimulation on gait and physical function.

RAGT rHD-tDCS, Robot-assisted Gait Training with Real High-definition Transcranial Direct Current Stimulation Group; RAGT shD-tDCS, Robot-assisted Gait Training with Sham High-definition
Transcranial Direct Current Stimulation Group; 10MWT; 10 Meter Walk Test; TUG, Timed Up and Go; FRT, Functional Reach Test; BBS, Berg Balance Scale; DGI, Dynamic Gait Index; FMA, Fugl-Meyer Assessment; LE, Lower Extremity; K-MBI, Korean Version of the Modified Barthel Index; Pre, Pre-intervention; Post, Post-intervention; F/U, 1 Month Follow-up; RM ANOVA, Repeated Measures Analysis of Variance.

*Significant change compared with Pre ($P < 0.05$), **Significant change compared with Pre ($P < 0.01$) using Wilcoxon signed rank test.

§Significant change compared with Pre ($P < 0.05$), §§Significant change compared with Pre ($P < 0.01$) using Bonferroni’s post hoc analysis in repeated measures analysis of variance.

**Supplementary Files**

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