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The Combined Effects of Transcranial Direct Current Stimulation over Left Dorsolateral Prefrontal Cortex with Standardized Exercise for Chronic Back Pain of the Elderly

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ABSTRACT

The aim of this study is to observe the effects of anodal tDCS applied over left prefrontal cortex on the chronic back pain, muscle strength and psychological fear. Thirty-three elderly aged 68 ± 6.27 years with chronic back pain participated. Participants were randomly assigned two group; Experimental group received 2-mA anodal current over left dlPFC with exercise for three days per week during 8 weeks while control group received sham current with exercise during the same period. Pain intensity, functional lift strength and fear-avoidance response of all the participants were evaluated. As a result, there were significant changes in pain intensity, muscle strength and activity-related fear toward the improvement ($P < .05$). In conclusion, the anodal tDCS on left prefrontal cortex would be effective to care the chronic pain of the elderly.

1. Introduction

Chronic back pain is the most common disease in the elderly, and the greater the degree of pain and the longer the period, the greater the limitation of daily life, which has a huge impact on individual quality of life and socioeconomic burden (Jacobs et al., 2006). Many management guidelines have been reported for chronic back pain to prevent and actively treat chronic back pain, and many recommend active and multidisciplinary approaches, including muscular and neurological interventions through exercise and physical therapy (Pillastrini et al., 2012).

At the same time, in the field of brain science, studies have consistently been reported that acute and chronic pain have different brain activity mechanisms in terms of pain perception (Apkarian et al., 2005). In particular, in the case of the elderly, degenerative changes and structural damage not only cause chronic pain, but also cause pain cognitive impairment due to degenerative changes in the brain structure, resulting in longer pain periods and more difficult healing than young adults (Tinnirello et al., 2021).

In this respect, until recently, transcranial direct current stimulation (tDCS) has been proven to be a reliable tool for patients with chronic pain, such as fibromyalgia and spinal cord injury, by non-invasive and safely controlling the excitability of the cerebral cortex. On the other hand, although studies have also been conducted on the effect of tDCS on chronic pain perception, some studies have reported that there is no significant difference between sham and real stimulation (Palm et al., 2013).

In addition, insufficient research has been conducted on the effect of tDCS for the elderly, which is the most common group of chronic pain. In particular, in older adults, degenerative atrophy of the brain due to aging is generally one of the most obvious symptoms in the frontal lobe (Lockhart & DeCarli, 2014), charge of the relationship between chronic pain and cognitive ability above. As the effect of tDCS applied to the frontal lobe on pain perception, the finding could support a new approach to treat chronic pain treatment for the elderly.

Therefore, this study aims to investigate the effect on pain perception and pain-related physical function after applying tDCS over the left dorsal prefrontal lobe during 8 weeks.

2. Methodology

2.1 Participants

It was recruited for senior citizens aged 65 or older who are visiting the S Welfare Center and have chronic back pain, and 33 voluntary participants (ten males and thirteen females) participated in this study. All participants were explained of the purpose and procedure related to the study before the experiment and agreed to participate. The inclusion criteria were those with 1) an intensity of chronic back pain of 3 or higher in visual analogue scale (VAS) and 2) a pain period of 6 months or more, 3) those with no history or surgery related to the brain. If those who were unable to perform tasks in this study due to severe pain, and those who had back surgery or surgery within the last 6 months, they were excluded. On the day before the experiment, all participants had enough sleep and Table 1 shows the demographic characteristics of the 33 elderly participants who participated in this study. The experimental protocol was approved by the Institutional Review Board (KU-IRB-17-126-A-2).

Table 1. Participant demographics

Demographics (n=33) Table	Values
Age (years)	68 ± 6.27
Weight (kg)	70.1 ± 3.26
Height (cm)	168.8 ± 2.30
Hours of sleep the day before experiment	6.12 ± 1.88
Caffeine intake 3 hours ago	None
Drinking alcohol 24 hours ago	None
Average pain for the past week (VAS)	5 ± 2.12
Duration since first onset of pain (month)	101.11 ± 49.84

2.2 Experimental procedure

This study was conducted over a total of eight weeks, with a sham current or a real current of 2mA applied with 50-min exercise program for three days per week. Prior to the experiment, 33 participants were randomly assigned into two groups; 1) experimental group of 17 participants applied the real 2mA current with 50-min exercise program, and 2) the control group of 16 participants applied the sham current with the same exercise program. All participants performed a baseline evaluation two days before the experiment began, followed by the post-evaluation eight weeks later. There was no significant difference in pain intensity between the groups before the experiment started.

2.3 Transcranial direct current stimulation (tDCS)

The sham current or a real 2mA current was applied to the left lateral prefrontal lobe F3 according to the international 10-20 EEG system for 15 minutes every time using a cathode electrode (5×5 cm) of tDCS (Y brain Inc., Korea). The sham current used a function built into a device that slowly increased the current to 1.5 mA for the initial 30 seconds and then immediately turned off the current. All participants sat comfortably in chairs during tDCS application and restricted large movements before they conducted 50-min exercise.

2.4 Standardized exercise program

After 15-min tDCS intervention, all participants started to perform the same exercise program protocol for 50 minutes for 3 days per week during 8 weeks. Before the starts of experiments, all participants were instructed how to perform the exercise program in the correct posture by a physical therapist with more than 3 years of clinical experience. Then, all participants performed a standardized group exercise program for 50 minutes two days per week during 4 weeks of the experiment period. Based on the ACSM's guidelines for the elderly, the exercise program was consisted of multi-components, including stretching, balance, aerobic and strengthening exercise. The stretching exercise was used for warm-up and cool-down for each 5 minutes and performed in sitting position. The further detailed description of exercise was shown in Table 2.

Table 2. The components of standardized group exercise program

Training Type	Exercise Title	Program components	Time (min)
Flexibility	Stretching	• Quadriceps stretch • Hamstrings stretch • Calves stretch • Lower back stretch	10
Balance	Tai Chi	• Warrior • Tree pose • Golden rooster	10
Cardiopulmonary & Strengthening	Cardioboxing	• Cross & front punch with slight squat • Hook & Upper-cut with slight squat • Power jogging	20
	Squat	• Arms curl & press with lunge • Arms front & down with narrow squat • Arms up & down with sumo squat	10

2.5 Outcome measurements

2.5.1 Visual analogue scale (VAS)

All participants evaluated the intensity of chronic back pain using VAS. Subjective pain intensity was evaluated for each participant by asking them to choose the level of pain they felt at the time from 0 mm (no pain) to 100 mm (intolerable extreme pain)

2.5.2 Maximum isometric lift strength

A strength evaluation device (Primus RS; BTEco., USA) was used to measure the waist muscle strength of each participant. This device is equipped with a device for carrying out lifting operations, with both feet shoulder-width apart, knees straight, hips bent approximately 45 degrees, elbows fully extended, handles, and 5 seconds of lifting the waist with maximum isometric force. The average was calculated by measuring the maximum isometric lifting force of a total of three times with a rest time of 30 seconds.

2.5.3 Pain-related fear-avoidance response

In this study, among various fear-avoidance evaluation tools, the Tampa scale for kinesiophobia (TSK) questionnaire was used to evaluate fear of pain-induced movement. It consists of four Liked scales per question and can be interpreted by classifying the resulting values into two categories, where activity-related avoidance (TSK-AA) represents the degree of fear-avoidance in everyday activities, while TSK-SA suggests a medically severe fear-avoidance of health.

2.5.4 General perceived effect scale (GPES)

To evaluating the self-perceived intervention satisfaction and feasibility to tDCS usage, all participants were asked “how better their physical status were improved than the previous 8 weeks” at the termination of experiment by using 11-point Likert scale. 0 indicated no feeling for better or worse than the onset of experiment while a score from +1 to +5 indicated the positive effect and a score from -1 to -5 indicated the negative effect.

2.6 Statistical analysis

The Shapiro-wilk test was used to test the normality of the participant demographics, and one-way ANOVA was conducted to verify the interaction effect of the current type and the pre-post period. Bonferroni analysis was used for post-mortem analysis. Independent t-test was used to compare GPES after 8-week experiment between the groups. The significance level was set to α = .05. All statistical analyses used the SPSS statistics (version 20, IBM, USA) program.

3. Results

3.1 Changes in visual analogue scale (VAS)

For pain intensity, one-way ANOVA reported the main effect of evaluation periods, indicating a significant improvement in VAS of pain site between pre- and post-intervention [$F_{(1,32)} = 47.211$; $P < .001$]. Significant interaction was also found between the evaluation periods and current types on VAS [$F_{(1,32)} = 12.487$; $P = .001$].

3.2 Changes in maximum isometric lift strength (MIS)

For muscle strength, the main effect of evaluation periods [$F_{(1,32)} = 34.838$; $P < .001$] and interaction effect between the evaluation periods and current types [$F_{(1,32)} = 12.487$; $P = .011$] were found that indicated a significant improvement in MIS by real tDCS application.

3.3 Changes in pain-related fear-avoidance response

For fear of movement, measured by TSK, there were the main effect of TSK-total [$F_{(1,32)} = 9.141$; $P = 0.005$], TSK-AA [$F_{(1,32)} = 11.297$; $P = 0.002$], TSK-SF [$F_{(1,32)} = 9.941$; $P = 0.004$], indicating that post-intervention decreased significantly the fear of movement. Whereas, interaction effect interaction effect between the evaluation periods and current types was found in two domains of TSK-total [$F_{(1,32)} = 5.571$; $P = 0.025$] and TSK-AA [$F_{(1,32)} = 5.900$; $P = 0.021$] while there was no interaction in TSK-SF subcomponent.

3.4 General perceived effect scale (GPES)

There was no significant difference in GPES by independent t-test between the experimental and control group.

Table 3. Results of independent variables after 8-week intervention in each group

Variables	Experimental group		Control group		P-value
	Baseline	8-week	Baseline	8-week	Interaction
VAS	5.65 (1.99)	2.53 (1.62)	5.81 (1.42)	4.81 (1.47)	.001**
MIS	75.86 (4.88)	109.83 (29.96)	74.13 (16.82)	86.72 (15.93)	.011*
TSK-total	23.94 (4.36)	19.88 (6.63)	21.62 (7.41)	21.12 (6.56)	.025*
TSK-AA	22.47 (4.14)	18.58 (5.07)	19.37 (5.88)	18.75 (5.48)	.021*
TSK-SF	16.82 (2.12)	15.82 (2.35)	13.75 (1.98)	12.93 (2.46)	.746
GPES	N/A	2.58 (1.58)	N/A	1.58 (1.93)	.990

Values are Mean (SD); GPES: Global perceived effect scales; MIS: Maximal isometric strength; TSK: Tampa Scale for Kinesiophobia; VAS: Visual analogue scale

Statistical analysis for pain intensity, functional strength, fear of movement and quality of life was performed by one-way repeated ANOVA; post-hoc analysis was performed using Bonferroni correction; Whereas, Statistical analysis for intervention satisfaction was performed by independent t-test

* P < .05; ** P < .001

4. Discussion

This study observed the effect of anode tDCS on pain-related clinical indicators such as chronic pain level, physical functional performance ability, and pain-related fear-avoidance psychology in the elderly when applied for a short period of time to the left ventral frontal lobe. As a result of the research, a significant improvement was found in the group, which was not found when the sham current was applied for 10 days when the positive current was applied to all variables.

First, the results of this study were consistent with the results of various previous studies on the effect of tDCS on chronic pain after application to the left frontal lobe (Pinto et al., 2018). According to Antal et al. (Antal et al., 2010), the application of an anode tDCS current to the primary motor cortex on the opposite side of the foot with symptoms in 10 elderly people complaining of chronic plantar fasciitis for 20 minutes significantly improved pain level and functional movement from week 1. In addition, the relationship between increased excitability of the primary motor cortex and chronic pain relief is attributed to the influence of the primary motor cortex's excitability leading to increased excitability of the prefrontal cortex, resulting in a wide range of pain perception.

A significant increase in the maximum isometric lifting force shown in this study can also be interpreted as a secondary result due to the improvement of pain recognition above. In other words, the reduction in back pain would lead to the improvement in a functional muscle strength, as reported in a number of previous studies, rather than the control of the cerebral cortex due to tDCS itself (Lee et al., 1995).

In addition, this study showed a significant improvement in pain-avoidance responses associated with daily activity, consistent with previous studies showing that psychological atrophy of functional movement with pain improvement, self-efficacy, muscle strength increase, and psychological impairment improved with tDCS application to dorsal prefrontal lobe (Altmaier et al., 1993; Wolkenstein & Plewnia, 2013). Lastly, the reason why TSK-SA and GPES did not have significant results is that musculoskeletal pain complained of participants was not a medically serious disease but a disease that caused a little discomfort in daily activities.

This study has some limitations to generalize the results. First, lifestyle of all participants could not be controlled technically. Second, the experimental period was somewhat short that it was difficult to identify the effect continuity of tDCS. Therefore, it is suggested that large-scale and long-term intervention to find out the additional feasibility of tDCS studies will continue to be needed in the future with reference to the results of this study, suggesting the merits of tDCS as one of the management methods to improve chronic pain in the elderly in the community.

5. Conclusion

This study measured pain intensity, maximum lift, and fear-avoidance after applying a sham or real current tDCS to the left frontal lobe for three days a week during 8 weeks in the elderly with chronic back pain, and all three variables showed significant improvements in the sham current application period. In conclusion, this study proved the possibility that the short-term continuous application of the left dorsal prefrontal lobe of the anode tDCS could be effective in improving pain recognition and physical function, and further research is needed on the tDCS effect according to long-term application.

Conflict of interest statement

We hereby confirm that the manuscript has no any actual or potential conflict of interest with any parties, including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence or be perceived to influence.

We confirm that the paper has not been published previously, it is not under consideration for publication elsewhere, and the manuscript is not being simultaneously submitted elsewhere.

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