Original article

Effects of transcranial direct-current stimulation combined with physical therapy in chronic low back pain treatments: A randomized controlled pilot study

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Background: Chronic low back pain (CLBP) affects 80.0% of the population and reduces their quality of life (QOL). Searching for its most effective treatment has being a challenge in the health-care system. Although studies using transcranial direct current stimulation (tDCS) plus physical therapy (PT) that aim to relieve pain, an optimal intervention method and clinical effectiveness evaluations related to CLBP patient aspects have not been completely investigated.
Objectives: The purpose of this study was to compare treatment effects between a combination of tDCS and PT (combined group) and PT alone (PT group) in pain intensity, gait speed, lumbar range of motion (LROM), QOL in CLBP patients. Besides, we examined the relationships between pain intensity and the remaining variables.
Methods: Twenty CLBP patients participated in this study, randomly divided into PT group and combined group following a 1:1 ratio. Pain intensity, gait speed, LROM, QOL were evaluated before (Pre) and after treatment (Post) as well as a follow-up after 1 week (W1), 2 weeks (W2), 3 weeks (W3), and 4 weeks (W4).
Results: The results showed a significant improvement in pain intensity, gait speed, LROM, QOL in 2 groups, but there were no statistically significant differences between groups for pain intensity, fast speed, lumbar bending the left (LBL), lumbar bending the right (LBR), and QOL. Furthermore, the combined group indicated a correlation: the larger the pain reduction, the larger the gait speed improvement.
Conclusion: A combination between tDCS and PT may be a potentially physiologic method to promote therapeutic efficacy and improve gait speed for CLBP patients.

Keywords: Chronic low back pain, tDCS, physical therapy, pain intensity, gait speed.

Chronic low back pain (CLBP) is low back pain for more than 12 weeks; patients often experience chronic symptoms with intermittent exacerbation [(1)] causing multifactorial disorder, including psychological, physical, social disorders. CLBP is characterized by several functional structures, neurochemical changes in the brain[(2)], and cortical excitability reduction contributed to CLBP.[(3)] Besides, non-pharmacological treatment is highly recommended in CLBP decreases [(4)], in which physical therapy (PT) is a conventional modality in pain reduction, quality of life (QOL) improvement in CLBP patients. [(5 - 7)]

Transcranial direct current stimulation (tDCS) is a non-invasive brain stimulation technique, emerging as a potential tool in treating chronic pain. [(8 - 12)] Motor cortical excitability is increased by anode, and reduced by cathode when tDCS positioned over the primary motor cortex (M1).[(13)] M1 stimulation could release endogenous opioids in brain structures [(14)] and influence brain regions that process pain such as the insula,

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thalamus, periaqueductal grey, etc.[15] In chronic pain studies, M1 is emerging as the most common stimulated region by tDCS.[15] Moreover, tDCS play a priming tool to improve effectiveness of other techniques on CLBP treatment in particular [8-10], and reducing chronic pain in general.[16] Previous studies that combined tDCS with peripheral electrical stimulation [8, 9], exercise [10], postural training [17] achieved superior analgesic effect in CLBP. However, it is unclear whether a concomitant combination of tDCS with PT techniques are more effective in treating CLBP patients.

There has been no study that combines tDCS with PT to examine its efficacy for LROM, gait speed improvement, and correlations between pain reduction and gait speed change in CLBP patients. Thus, the present study aimed to elucidate whether a combination of tDCS with PT results in a better effect than PT alone and whether the pain reduction correlates to gait speed, LROM, and QOL improvement in CLBP treatment.

Materials and methods

Subjects

Participants were recruited via advertisement at the Physical Therapy clinic, Faculty of Associated Medical Science, Khon Kaen University, Khon Kaen, Thailand. Study's procedures were clearly described before the subjects received intervention by the physicians. Inclusion criteria: twenty participants were diagnosed to be CLBP [1]; aged between 20 and 65 years; having an average pain intensity more than 4/10 on VAS score; being right handed; and willing to join this study. Exclusion criteria: neurological diseases or severe psychiatric disorders, pregnancy, having a skull defect or metallic implant in the brain.[10]

Participants signed their informed consent form before receiving the interventions. This study has been approved by the Ethics Committee of Khon Kaen University (Identifier number HE632085).

Study design

This was a randomized controlled trial, pilot study. Twenty CLBP subjects were randomly divided into two groups following a 1:1 ratio. The first group was PT group or control group; the subjects received hot packs, ultrasound, mobilization, and educational back exercise. The second group was combined group; the subjects received tDCS, hot packs, ultrasound, mobilization, and educational back exercise. All techniques were conducted 3 sessions/week for 4 weeks continuously. The subjects were assessed their pain intensity, gait speed, LROM, QOL at Pre, Post, and follow-up at W1, W2, W3,W4 after finishing the intervention (Figure 1).

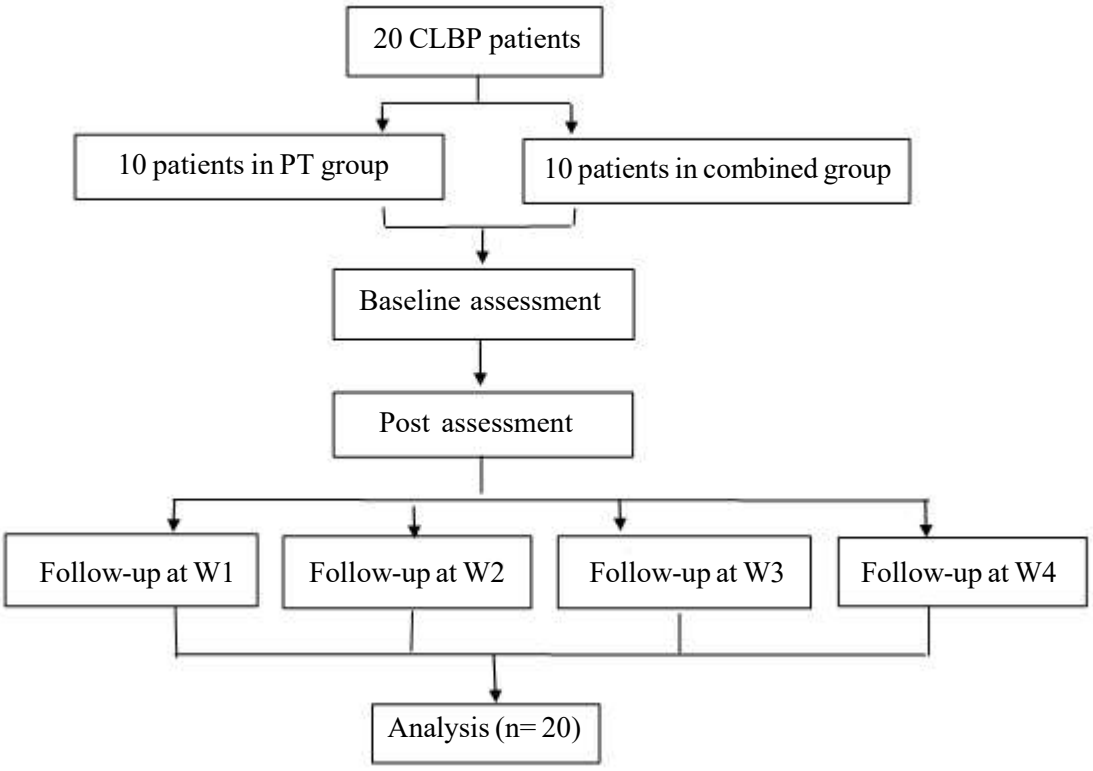

Figure 1. Overview of the study methodology.

Transcranial direct current stimulation

The tDCS applied via a pair of 0.9% NaCl – soaked surface sponge electrodes (35 cm^2) and delivered through a battery-driven power supply (Soterix Medical, Model 1224-B, New York, NY, USA). An anode was positioned on M1; contralateral pain backside, approximately C3 or C4 in the 10-20 electroencephalogram (EEG) system. A cathode was placed on a contralateral supraorbital region, 2 mA in 20 min. The first and the last 30s were gradually ramped up, ram down to avoid any sudden increase or decrease of the current. [17]

Physical therapy

A hot pack was positioned on the low back region for 15 minutes, and continuous ultrasound with 3 MHz frequency and 1.5 W/cm^2 intensity over the paravertebral low back region for 10 minutes. Mobilization: unilateral technique 3 time/set for 5 min. Educational back exercise: patients were guided to perform back extension and flexion by a physiotherapist.

Outcome measurements

After the subjects adhered and signed the informed consent form, personal data such as age, gender, pain duration, pain intensity, gait speed, LROM, QOL were collected.

Pain intensity was assessed by the visual analog scale (VAS). VAS is based on a linear scale 100 mm long, with the captions " no pain at all " on the far left and "mostly painful" on the far right.[10, 17] The LROM referred to the number of degrees of motion of lumbar flexion, lumbar extension, LBL, and LBR, measured by goniometers. Normal speed and fast speed were assessed by a 4-meter walk test. QOL was evaluated by the World Health Organization Quality of Life, that translated into the Thai language. An experienced physiotherapist conducted all measurements, who was not related in data analysis.

Statistical analysis

All statistical analyses were conducted on SPSS (version 25.0). Descriptive statistics were applied to explain baseline assessment (means ± standard deviations). Age and gender were analyzed by Chi-square test. Normal distribution data were evaluated by the Shapiro-Wilk's test. Mann Whitney U, unpaired sample *t* - test compared between groups at baseline and after treatment. The Friedman, one way repeated analysis of variance (ANOVA) test compared within group following time. If they have significance, Wilcoxon U, Bonferroni test were used. The Spearman test was used to detect correlations between pain intensity and other variables. Statistical significance was set as $P < 0.05$ for all analyses.

Results

Twenty volunteers (10 males, 10 females) completed this study. The general characteristic in both groups are demonstrated in Table 1.

Table 1. Demographic and baseline data (mean ± standard deviation).

Variables	Combined group (n = 10)	PT group (n = 10)	*P* - value
Age (year)	50.1 ± 6.5	45.3 ± 10.1	0.43
Gender (male/female)	6/4	4/6	0.18
Pain duration (months)	> 6 months	> 6 months	
VAS	7.8 ± 0.9	7.4 ± 1.5	0.74
Normal speed (m/s)	0.7 ± 0.2	0.5 ± 0.1	0.06
Fast speed (m/s)	0.9 ± 0.3	0.8 ± 0.3	0.06
Lumbar extension (degree)	11.5 ± 6.0	17.5 ± 7.5	0.08
Lumbar flexion (degree)	48.6 ± 22.9	54.7 ± 27.1	0.85
Lumbar bending the left (degree)	12.9 ± 4.6	13.0 ± 2.6	0.85
Lumbar bending the right (degree)	12.8 ± 5.3	13.2 ± 2.8	0.68
Quality of life (score)	84.8 ± 7.9	88.1 ± 10.9	0.45

Pain intensity: there was no statistically significant difference in pain intensity between groups all times. There were statistically significant decreases in pain intensity in both groups ($P < 0.001$). Statistically significant decreases in pain intensity were showed at post treatment (post) ($P = 0.004$, *$P = 0.004$), *W1* ($P = 0.007$, $P = 0.005$), *W2* ($P = 0.007$, $P = 0.008$), *W3* ($P = 0.007$, $P = 0.007$), W4 ($P = 0.009$, $P = 0.007$) in PT group, combined group compared with pretreatment (pre), respectively, (Figure 2A).

Fast speed: there was no statistically significant difference in fast speed between groups all times. There were significant differences in fast speed among times in the PT group ($P = 0.019$) and the combined group ($P < 0.0001$). In PT group: there was a statistically significant increase in fast speed at Post ($P = 0.047$) compared with Pre. In combined group: there was a statistically significant increase in fast speed at Post ($P = 0.012$) compared with Pre; however, there were a statistically significant decrease in fast speed at W1 ($P = 0.047$), W2 ($P = 0.013$) compared with Pre, (Figure 2B).

Normal speed: there were a statistically significantly higher normal speed increase in the combined group than the PT group at Post ($P = 0.011$). One-way repeated ANOVA showed statistically significantly differences in normal speed in PT group over time ($P = 0.007$), but not for the combined group. There was statistically significant increase in normal speed at Post ($P = 0.009$) compared with Pre in the PT group, (Figure 2C).

Lumbar flexion: Mann–Whitney test showed statistically significantly higher lumbar flexion in PT group than combined group at Post ($P = 0.015$), W1 ($P < 0.001$) and W2 ($P = 0.029$). Statistically significant differences in lumbar flexion improvement in the two groups were showed (PT group, $P = 0.001$; combined group, $P = 0.002$). In PT group: there were statistically significant increases in lumbar flexion at Post ($P = 0.012$), W1 ($P = 0.017$) compared with Pre. In combined group, there were statistically significant increases in lumbar flexion at Post ($P = 0.008$), W3 ($P = 0.013$), W4 ($P = 0.017$) compared with Pre, (Figure 2D).

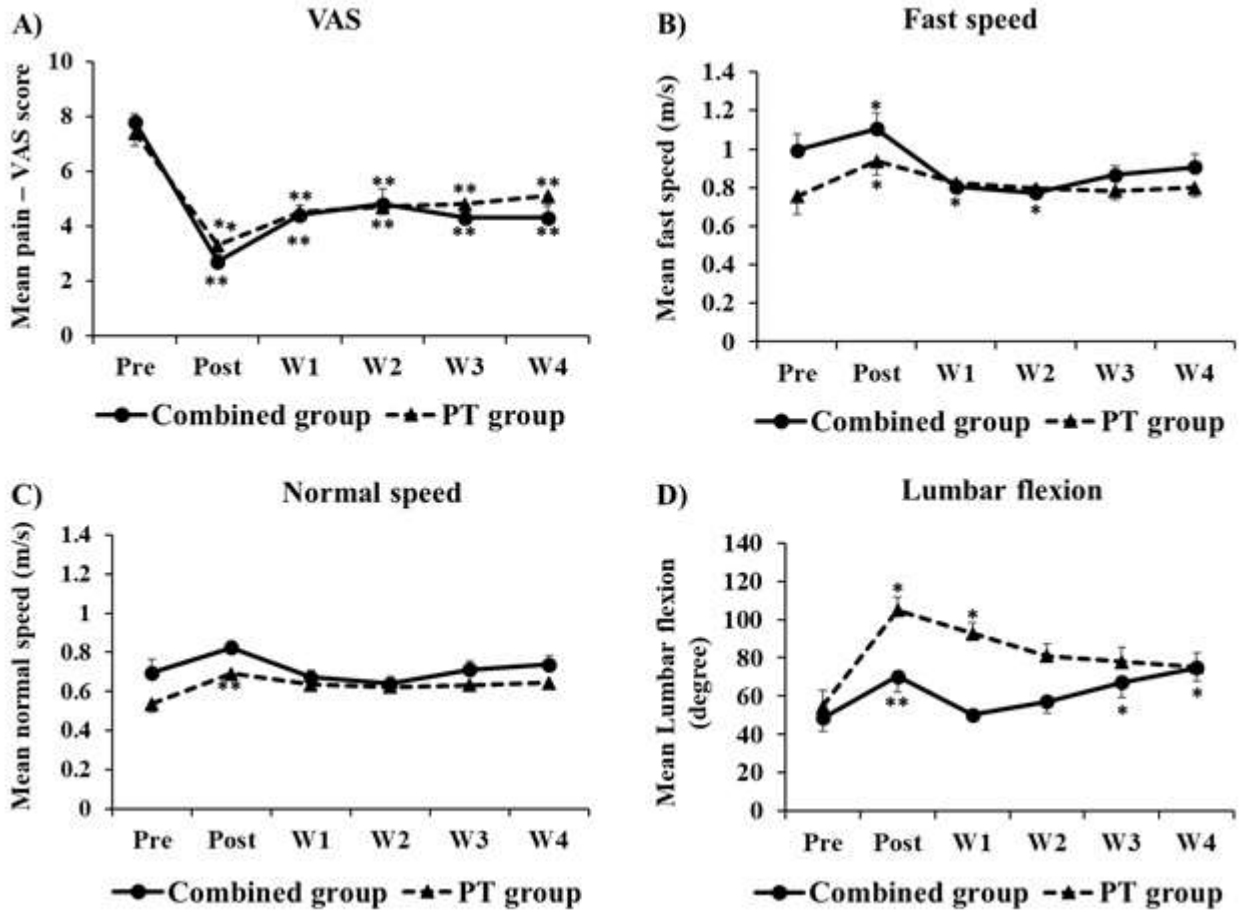

Figure 2. Mean and standard error of: **(A)** pain intensity; **(B)** fast speed; **(C)** normal speed; **(D)** lumbar flexion in the two groups over time, * $P < 0.05$, ** $P < 0.01$

Lumbar extension: Mann–Whitney test showed a statistically significantly higher lumbar extension in PT group than combined group at Post ($P = 0.004$), W1 ($P = 0.003$), and W2 ($P = 0.035$). There were statistically significant differences in lumbar extension in the two groups (PT group, $P = 0.025$; combined group, $P < 0.001$). In PT group: there were statistically significant increases in lumbar extension at Post ($P = 0.017$), W1 ($P = 0.024$), W2 ($P = 0.015$) compared with Pre. In combined group, there were statistically significant increases in lumbar extension at Post ($P = 0.005$), W1 ($P = 0.017$), W2 ($P = 0.008$), W3 ($P = 0.005$), W4 ($P = 0.005$) compared with Pre, (Figure 3A).

Lumbar bending the right: there was no statistically significant difference in LBR between the groups at all times. Statistically significant differences in LBR were showed in 2 groups (PT group, $P = 0.001$; combined group, $P = 0.007$). There were statistically significant increases in LBR at Post ($P = 0.007$, $P = 0.005$), W1 ($P = 0.016$, $P = 0.016$), W2 ($P = 0.016$, $P = 0.016$), W3 ($P = 0.026$, $P = 0.035$) in PT group, combined group compared with Pre, respectively, (Figure 3B).

Lumbar bending the left: there was no statistically significant difference in LBL between the two groups at all times. Statistically significant differences in LBL were observed in the two groups at all times (PT group, $P = 0.002$; combined group, $P = 0.003$). In PT group: there were statistically significant increases in LBL at Post ($P = 0.007$), W1 ($P = 0.016$), W2 ($P = 0.01$), W3 ($P = 0.026$) compared with Pre. In combined group, there were statistically significant increases in LBL at Post ($P = 0.008$), W1 ($P = 0.028$), W2 ($P = 0.042$), W3 ($P = 0.035$), W4 ($P = 0.035$) compared with Pre, (Figure 3C).

Quality of life: there was no statistically significant difference in QOL between groups all times. One-way repeated ANOVA showed statistically significantly differences in 2 groups over time (PT group, $P < 0.001$; combined group, $P < 0.001$). In PT group: there were statistically significant improvement in QOL at Post ($P = 0.003$), W1 ($P = 0.043$). In combined group: there were statistically significantly improvement in QOL at Post ($P < 0.001$), W1 ($P < 0.001$), W2 ($P = 0.001$), W3 ($P < 0.001$), W4 ($P = 0.001$). (Figure 3D).

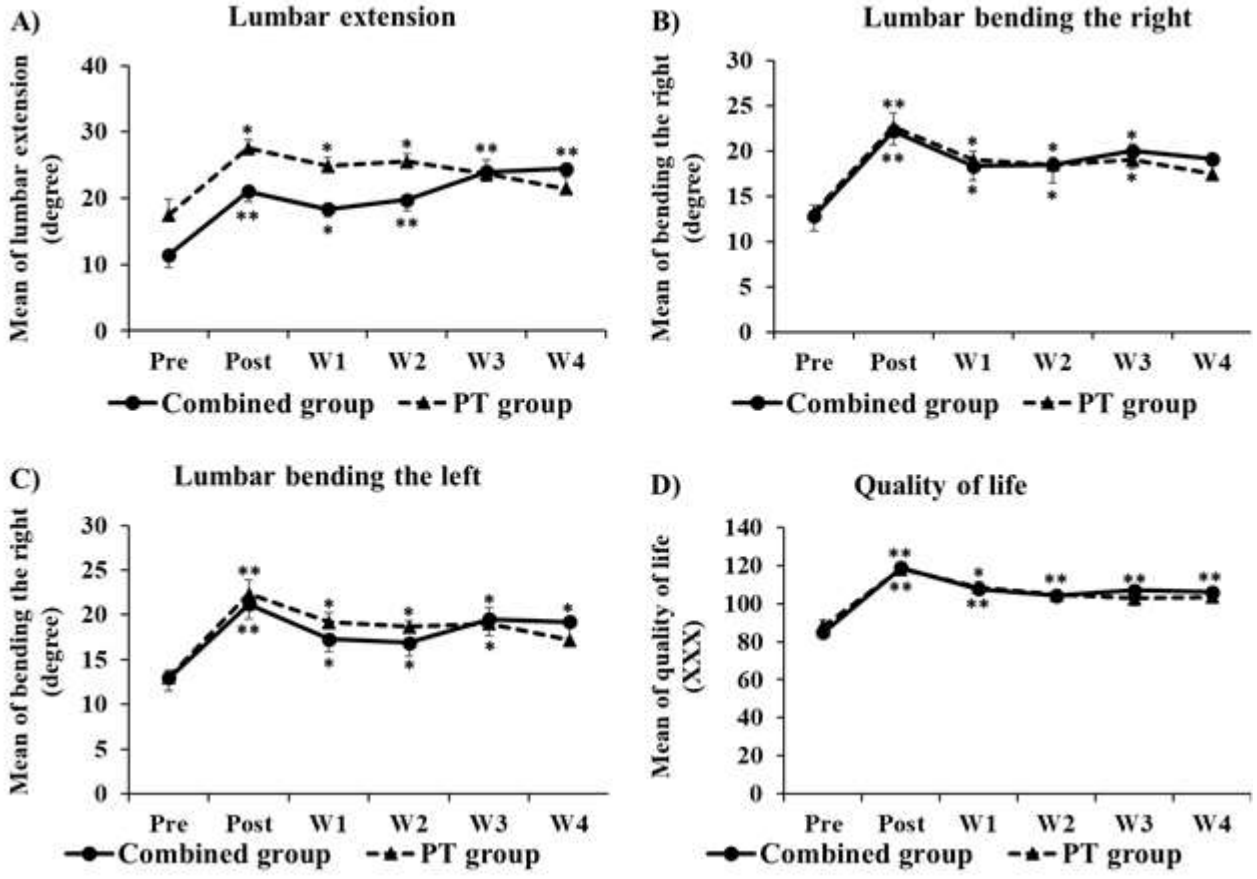

Figure 3. Mean and standard error of: **(A)** lumbar extension; **(B)** lumbar bending the right; **(C)** lumbar bending the left; **(D)** quality of life in the two groups over time, * $P < 0.05$, ** $P < 0.01$

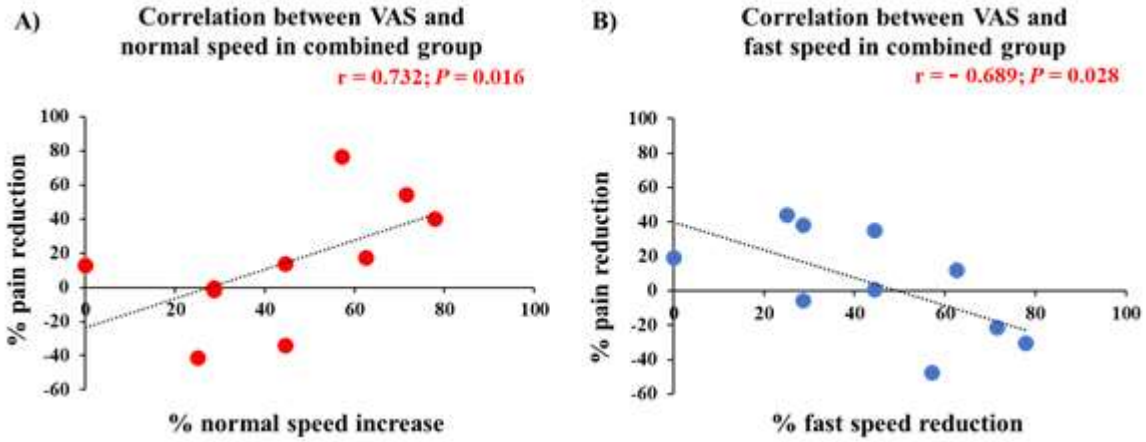

Figure 4. Correlations between the percentage of pain reduction and the percentage of gait speed change at W4 in combined group. **(A)** normal speed; **(B)** fast speed.

Correlations between pain intensity and other variables: in combined group, there was a statistically significant correlation between pain reduction and gait speed changes at W4, but not for other variables. A statistically significant positive correlation between the percentage of pain reduction and the percentage of normal speed increase ($r = 0.732$, $P = 0.016$). A statistically significant negative correlation between the percentage of pain reduction and the percentage of fast speed reduction ($r = -0.689$, $P = 0.028$). In PT group: our finding did not detect any statistically significant correlation between pain reduction and other variables, (Figure 4).

Discussion

This study aims to compare the effects of combination tDCS with PT, and PT alone on CLBP treatments. The combined group observed a significantly higher normal speed increase than PT group immediately finishing interventions. However, other variables such as pain intensity, fast speed, LBL, LBR, and QOL improved to the same level between groups. On the other hand, PT group indicated a greater lumbar extension and flexion improvement than combined group. Finally, our results demonstrated a significant correlation between pain reduction and gait speed change in combined group.

There has been no consensus on boosted effects of tDCS when combined with another modality in reducing pain for chronic pain. Previous studies demonstrated that tDCS enhanced effect in treatment [8-12], while other studies did not detect tDCS strengthened effect when it merged with additional therapeutics. [18, 19] In this study, we predicted a pain relief in combined group would be greater, but it was equivalent to PT group. We assume that PT may not promote activation in the same neural regions and not likely to induce action potentials, while tDCS applied over M1 to change neuronal membrane threshold, cortical excitability. Thus, it is possible that the combination tDCS and PT did not create a synergistic effect in reducing pain. Neural areas affected by tDCS, and that affected by another modality must be the same region to enhance an impact together.[10] Besides, how to combine to achieve the best effect is critical. The studies [10-12] indicated that an enhanced effect of tDCS when combined with another modality by using tDCS sessions continually. In our study, we used nonconsecutive tDCS sessions; this may be a reason why the combination of tDCS and PT did not show an enhanced effect on the treatment. Thus, it is possible that using continuous tDCS sessions is a good strategy to strengthen the treatment effects in chronic pain. Further study should investigate whether tDCS combined with PT daily will produce a more dominant effect in CLBP treatment.

Our results observed a significantly higher normal speed increase in combined group compared with PT group, but not for the fast speed. This is the first study that combined tDCS and PT in improving CLBP gait speed. Thus, this finding might be a great significance in CLBP treatment strategy because most clinical treatments only concentrate on reducing pain, although patients gait patterns are different, compared with the healthy.[20] On the other hand, balance and postural control during dynamic stances play an important role in gait speed control [20, 21], fast speed requires more coordination and balance than normal speed. In

addition, the cerebellum fulfills an important role in balance control. [22 - 24] Inhibition of the cerebellum (CBI) is an indicator of the connection between M1 and the cerebellum, measured by transcranial magnetic stimulation (TMS).[25, 26] Furthermore, increase or decrease connectivity between the cerebellum and M1, depending on the polarity of applied tDCS over the cerebellum.[27] We hypothesize that the fast speed has triggered the cerebellum's inhibition on M1, reducing the combined effect of tDCS in proving fast speed. However, this effect needs to investigate by TMS the next time.

The present study showed a correlation between pain reduction and the gait speed changes in CLBP patients in combined group. A previous study [28] assessed spatiotemporal gait speed parameters in chronic mechanical low back pain (CMLBP) patients, indicated that CMLBP patients had the higher the pain intensity, the slower the gait speed, and vice versa. Besides, gait speed has been dominated by several brain regions such as the thalamus, insula, prefrontal areas, etc [29]; tDCS of M1 could affect brain regions, that impacting gait speed.[30] Thus, our idea is tDCS effect leads to a correlation between pain reduction and gait speed changes of CLBP patients in combined group.

Homeostatic plasticity refers to the capacity stabilizing the properties of the neuronal circuit. [31] Using tDCS in long-duration might create a homeostatic effect in the motor cortex. [8, 31] According to the homeostasis rule, enhancing motor cortex excitability could reduce the motor learning paradigm.[32] In our study, patients were guided to perform lumbar flexion and extension exercises. Thus, tDCS effect may reduce lumbar flexion, extension performance in the combined group compared with PT group.

This study had limitations such as small sample size; M1 determination was based on 10 - 20 EEG; there was no tool to retest the position (such as TMS); our study lacked tDCS group; this group is possible to present tDCS role in the intervention effect clearly.

Conclusion

tDCS showed its enhanced effect in improving gait speed; the larger the pain reduction, the better the gait speed improvement when tDCS combined PT on CLBP treatment.

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Conflict of interest

The authors hereby declare no conflict of interest.

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