Immediate and Sustained Effects of 5-Day Transcranial Direct Current Stimulation of the Motor Cortex in Phantom Limb Pain

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Abstract: The study explored the analgesic effects of transcranial direct current stimulation (tDCS) over the motor cortex on postamputation phantom limb pain (PLP). Eight subjects with unilateral lower or upper limb amputation and chronic PLP were enrolled in a crossover, double-blind, sham-controlled treatment program. For 5 consecutive days, anodal (active or sham) tDCS was applied over the motor cortex for 15 minutes at an intensity of 1.5 mA. The 5-day treatment with active, but not sham, tDCS induced a sustained decrease in background PLP and in the frequency of PLP paroxysms, which lasted for 1 week after the end of treatment. Moreover, on each day of active tDCS, patients reported an immediate PLP relief, along with an increased ability to move their phantom limb. Patients’ immediate responses to sham tDCS, on the contrary, were variable, marked by an increase or decrease of PLP levels from baseline. These results show that a 5-day treatment of motor cortex stimulation with tDCS can induce stable relief from PLP in amputees. Neuromodulation targeting the motor cortex appears to be a promising option for the management of this debilitating neuropathic pain condition, which is often refractory to classic pharmacologic and surgical treatments.  
Perspective: The study describes sustained and immediate effects of motor cortex stimulation by tDCS on postamputation PLP, whose analgesic action seems linked to the motor reactivation of the phantom limb. These results are helpful for the exploitation of tDCS as a therapeutic tool for the management of neuropathic pain.

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Phantom limb pain (PLP), a pain of neuropathic origin, refers to the presence of painful sensations in an absent limb that has been removed by amputation.¹²,¹³ PLP is a common sequela of amputation following trauma or peripheral vascular disease, with an incidence of up to 80%.²⁷ The management of PLP is difficult, with the condition often being refractory to classic pharmacologic and surgical treatments. In recent years, various therapeutic strategies have been proposed, but there is still little evidence-based support for their clinical effectiveness.¹²,³³

Although the etiology and pathophysiological mechanisms of PLP are not yet clearly defined, theoretical and empirical works indicate that brain changes represent a major determinant, proposing maladaptive plasticity as a neural basis of PLP.¹³ In animals, substantial plastic reorganization following deafferentation was shown at multiple loci, from the cortex to the spinal cord.¹²,³⁷,⁴² In humans, emphasis was given to the cortex, with postamputation reorganization of sensory and motor maps closely related to the development of PLP.¹³,⁴⁶ Cortical reorganization also involves changes in cortical excitability. Transcranial magnetic stimulation studies in upper- and lower-limb amputees show that motor threshold and intracortical inhibition
decreases for the muscle proximal to the amputation, suggesting an increased excitability of the corticospinal neurons and a reduction of gamma-aminobutyric acid activity at the cortical level.17,9,10,29,47 Although the relationship between motor excitability and PLP remains unclear,29,34 these cortical excitability shifts were shown to be larger in patients with PLP than in pain-free patients.13,24,29

In light of this evidence, there is considerable interest in determining whether PLP could be alleviated through noninvasive brain stimulation. A large amount of research shows that neurostimulation methods targeting the primary motor cortex (M1) are effective for different types of chronic neuropathic pain when long-term drug therapy is ineffective.39,40 However, few studies have explored these approaches in PLP. Overall, only 2 studies have been conducted with transcranial direct current stimulation (tDCS). The first showed that just a single application of anodal tDCS to M1 induces short-lived (<90 minutes) PLP relief.4 A following single case report suggests that repeated tDCS applications may prolong the analgesic effects of tDCS on PLP.5

With a crossover, double-blind, sham-controlled design, we explored the effect of a 5-day treatment with anodal tDCS of the motor cortex on PLP, with the primary goal of establishing enduring analgesic effects on the intensity of background PLP (ie, pain felt constantly in the phantom limb) and on the frequency of PLP paroxysms (ie, episodes of increased PLP above the background level). We also assessed immediate, day-by-day changes of PLP and nonpainful sensations induced by tDCS, including the patients’ ability to move their phantom limb. Indeed, motor components of the phantom limb seem strictly related to PLP17,38,46 but so far, no previous research on the analgesic effect of motor cortex stimulation by tDCS has searched for a possible concurrent modulation of the motor components of the phantom limb.

Method

Participants

Eight amputees (all right-handed before amputation) were recruited from the inpatient and outpatient populations of the Neurological Rehabilitation Unit of the Hospital “Carlo Poma” of Bozzolo (Italy) and of the Vascular Surgery Unit of the Hospital “Alessandro Manzoni” of Lecco (Italy). Seven of 8 patients suffered from unilateral lower limb amputation, while in 1 patient, the upper limb was amputated. Demographic and clinical data of the patients are reported in Table 1.

The protocol followed the guidelines of the Declaration of Helsinki and was approved by the local ethical committee of each hospital. Each patient gave informed consent before participating in the study. Inclusion criteria were as follows: 1) age 18 to 90 years, 2) normal score (>24) at the Mini-Mental State Examination,15 3) limb amputation at least 2 months before study enrollment, 4) stable presence of PLP for at least 2 months, and 5) written informed consent. Exclusion criteria were as follows: 1) coexistence of major neurologic, neuropsychological, and psychiatric diseases; 2) being actively enrolled in a separate study targeting pain relief; and 3) any contraindication to noninvasive brain stimulation.46

Before the experiment, each patient underwent a detailed interview about phantom sensations in order to assess 1) the features of phantom limb sensations; 2) the features of PLP; 3) presence of voluntary or involuntary phantom movements or of immobilized phantom postures; and 4) any other subjective descriptions of the qualities of the deafferentation pain. Patients were encouraged to describe exhaustively the quality of any subjective sensation they perceived in their phantom limb.

Additionally, the Groningen Questionnaire Problems after Amputation27 was used to assess the following: time, side, level, and reason of amputation; duration of pain experienced before amputation; frequency of phantom sensation, phantom pain, and stump pain; amount of trouble and suffering experienced as a consequence of these sensations; type of phantom sensations; and medical treatment received for phantom pain and/or stump pain and self-medication (see Table 1).

**tDCS Treatment Protocol**

In a crossover, double-blind, sham-controlled design, the amputees underwent 2 weeks of treatment with tDCS comprising 1 week of active tDCS (5 days, Monday to Friday) and 1 week of sham (5 days, Monday to Friday) tDCS, counterbalanced across participants. Therefore, 4 of the 8 patients received active tDCS in the first week of treatment followed by a week with sham tDCS, and the remaining 50% of patients received the 2 stimulations in the opposite order (week 1, sham tDCS; week 2, active tDCS). Patients continued their usual drug intake during the treatment (see Table 1).

tDCS was delivered with a battery-driven constant current stimulator (BrainStim, E.M.S. s.r.l., Bologna, Italy; http://brainstim.it) using a pair of surface saline-soaked sponge electrodes placed on the patient’s scalp. The anodal electrode was placed over C3 or C4 (according to the 10-20 electroencephalograph system for electrode placement) in order to stimulate M1 contralateral to the amputation, with the cathode electrode over the contralateral supraorbital area. This choice was guided by 2 main considerations: First, massive sensorimotor cortical reorganization occurs in the cerebral hemisphere contralateral to the amputation,9,13,46 and, second, in order to produce analgesic effects, brain stimulation should be applied to the motor cortex contralateral to the side of pain.29 Moreover, in the treatment of chronic pain, motor cortex stimulation with repetitive transcranial magnetic stimulation (rTMS) may be more effective when the stimulation site is adjacent to the cortical representation of the painful zone, rather than within the painful zone itself.31 However, the low spatial resolution and diffuse current spread of tDCS does not allow focal stimulation of the hand (or leg) area in M1 as rTMS does; indeed, analgesic effects were induced by stimulating with tDCS the M1 relative to the upper limb even for sublesional pain in the lower limbs.15
The electrodes (35 cm²) were firmly attached by elastic bands, and an electroconductive gel was applied under the electrodes before the montage, in order to reduce contact impedance. During active tDCS, a constant current of 1.5 mA was applied for 15 minutes, with a ramping period of 10 seconds both at the beginning and at the end of the stimulation (ie, fade-in and fade-out phases, respectively). The current density (.043 mA/cm²) was maintained below the safety limits.16,43 The choice of the stimulation parameters was based on previous positive effects obtained in PLP3,4 but also considered the difficulty in maintaining blinding when using a higher intensity stimulation (eg, 2 mA) in a crossover design.39 Sham tDCS was applied with the same parameters and electrode montage as active tDCS, but the current lasted only for 30 seconds.18 The sham and active modes of the tDCS device were activated through the use of codes that were set and then saved by the principal investigator (N.B.), who did not participate in data collection. Using these codes, the device was activated by the blinded experimenter, and the intensity (1.5 mA) and duration (15 minutes) of tDCS were displayed independently from the type of stimulation (real vs sham). This method has been shown to be reliable for keeping both the experimenter and the participant blinded to sham and real tDCS,18 and it is commonly used in clinical investigations.3-6,16

**Measurement of the Treatment Effects**

**Immediate tDCS Effects**

During the 2 weeks of tDCS treatment, patients were asked to rate their current pain state on a 10-cm visual analog scale (VAS) immediately before and immediately after each daily tDCS application. VAS scores were used to assess 1) PLP intensity at the moment of assessment (0 = absent, 10 = the worst possible PLP), 2) nonpainful phantom limb sensation (0 = absence of phantom sensation, 10 = the most vivid and intense phantom sensation possible), and 3) phantom limb movement (0 = immobile phantom limb, 10 = phantom limb easily moved); this last VAS rating was only included in the evaluation starting from the third patient treated. The order of the VAS ratings was randomized across each evaluation session. VAS was administered by an experimenter (V.S.) blinded to the tDCS condition (active vs sham).

**Sustained tDCS Effects**

Participants completed a daily diary in which they made 3 separate VAS ratings, assessing 1) PLP background intensity (ie, pain felt in the phantom limb constantly or most of the day: 0 = absent, 10 = the worst possible PLP), 2) frequency of PLP paroxysms (ie, when PLP clearly increases above the background level: 0 = never during the day, 10 = very frequent), and 3) stump pain intensity (0 = absent, 10 = the worst possible PLP). These measurements were obtained during the week prior to the treatment (baseline), during the first week and the second week of the treatment, and during the first week after the end of the intervention.
Phantom Limb Pain Relief by tDCS

(follow-up). For each week, patients were required to complete the diary every day, from Monday to Sunday.

**Beck Depression Inventory (BDI)**

Depressive symptoms were assessed with the BDI, a 21-question multiple-choice self-report inventory. The BDI was administered on the first day of treatment, prior to the first tDCS session, and at the end of the second week of treatment, after the last tDCS session.

**Questionnaire for tDCS Side Effects**

At each tDCS session, participants completed a 9-item questionnaire to evaluate the potential adverse effects of tDCS. The items were as follows: 1) headache, 2) neck pain, 3) scalp pain, 4) scalp burn, 5) prickle, 6) reddened skin, 7) drowsiness, 8) difficulty concentrating, and 9) mood changes. For every item, participants rated the intensity of their sensations using a 4-point scale (from 0 = absent to 3 = strong, total score = 0–27). Moreover, for each reported discomfort, they also rated its relation to tDCS on a 5-point scale (0 = unrelated to tDCS to 4 = absolutely due to tDCS, total score = 0–36). In this study, patients never reported adverse tDCS effects. Occasionally, slight discomfort was reported during both active and sham tDCS (mean total score: active tDCS = 3.22 vs sham tDCS = 2.74, t7 = 1.09, P = .31), which was judged equally to be due to active tDCS and sham tDCS (mean total score: active tDCS = 2.50, sham tDCS = 2, t7 = 1, P = .35), hence suggesting that patients were unable to differentiate the 2 stimulations.

**Data Analysis**

For each VAS rating used to assess the immediate tDCS effects, the change induced by sham or active tDCS at each daily session was computed as a percentage as follows:

\[
\left( \frac{\text{Pre-tDCS VAS} - \text{Post-tDCS VAS}}{\text{Pre-tDCS VAS}} \right) \times 100\%
\]

Negative values indicate a reduction of the VAS score after tDCS. These data were then analyzed via repeated measures analysis of variance (ANOVA), 1 for each VAS, with 2 within-subject factors: tDCS week (sham tDCS, active tDCS) and day (1–5). Similarly, the sustained effects of tDCS were computed for each VAS rating of the diary as follows:

\[
\left( \frac{\text{Baseline VAS} - \text{Posttreatment VAS}}{\text{Baseline VAS}} \right) \times 100\%
\]

The baseline VAS was the average VAS score for the week preceding the treatment, whereas the posttreatment VAS was the average VAS score for each of the other weeks, namely, the week of sham tDCS, the week of active tDCS, and the follow-up week. Again, negative values indicate a reduction of the VAS score in the posttreatment VAS.

These average VAS scores were then analyzed via 1-way ANOVAs, with the within-subject factor week (week of sham tDCS, week of active tDCS, week of follow-up). Additionally, we assessed whether differences in the sustained effects induced by active and sham tDCS could be ascribed to the order of the tDCS weeks of treatment, with possible carryover or ceiling effects driven by those patients who received sham tDCS after active tDCS. To address this issue, for the sustained effects, VAS scores were further analyzed via a mixed ANOVA, with the within-subject factor week (week of sham tDCS, week of active tDCS) and the between-subjects factor order (patients receiving active tDCS in the first week of treatment vs patients receiving active tDCS in the second week).

In every ANOVA, the partial eta-squared (\( \eta^2_p \)), which measures the proportion of total variance attributable to a main factor or to an interaction, was calculated, and the Bonferroni test was used for multiple post hoc comparisons, with a level of significance set at \( \alpha = .05 \).

Finally, changes in BDI scores before and after the treatment were assessed with paired t-tests. The data were statistically analyzed using Statistica software for Windows (release 6.0; StatSoft, Tulsa, OK).

**Results**

As assessed in the baseline period, all patients included in the study experienced background pain (average score of 5.6 on VAS, range = 2–8.4), with pain paroxysms of 6.4 on average (range = .3–10); stump was overall negligible (average score on VAS = .3, range = 0–1), and therefore these data were not considered for analysis. On average, patients showed only mild depression (mean BDI score = 14, range = 3–25) at baseline.

**Immediate tDCS Effects**

With respect to PLP intensity, the repeated measures ANOVA showed a significant effect of the tDCS week (\( F_{1,7} = 6.64, P = .04, \eta^2_p = .49 \)), showing a significant difference between sham tDCS (−9%) and active tDCS (−28%, P = .04). The main effect of day (\( F_{4,28} = .83, P = .5, \eta^2_p = .11 \)) and the tDCS Week × Day interaction (\( F_{4,28} = 1.32, P = .3, \eta^2_p = .16 \)) did not reach significance.

With respect to nonpainful phantom limb sensations, no significant effects emerged from the repeated measures ANOVA: tDCS week (\( F_{1,7} = 2.01, P = .2, \eta^2_p = .22 \)), day (\( F_{4,28} = .89, P = .5, \eta^2_p = .12 \)) and the tDCS Week × Day interaction (\( F_{4,28} = .59, P = .7, \eta^2_p = .01 \)). Finally, the analysis of the phantom limb movement showed a significant effect of the tDCS week (\( F_{1,5} = 6.62, P = .05, \eta^2_p = .57 \)), showing a significant difference between sham tDCS (−9%) and active tDCS (28%, P = .04). The main effects of day (\( F_{4,20} = .17, P = .9, \eta^2_p = .03 \)) and the tDCS Week × Day interaction (\( F_{4,20} = 2.58, P = .07, \eta^2_p = .24 \)) were not significant (see Fig 1).

Pearson correlation was used to test the association between the immediate PLP relief and the increased movement of the phantom limb. A significant negative correlation was found (\( r = −.95, P = .003 \)), indicating that the greater the increased movement of the phantom limb, the greater the PLP relief (Fig 2). Moreover, correlation analysis did not show any association
between the average daily responses to active tDCS and to sham tDCS, with respect to both PLP intensity (r = .24, P = .6) and phantom limb movement (r = −.08, P = .9).

**Sustained tDCS Effects**

With respect to the PLP background intensity, the significant effect of week in the ANOVA (F2,14 = 5.45, P = .02, η2 = .44) revealed the PLP relief during the week of active tDCS (−42%, P = .04) and during the follow-up week (−41%, P = .04), with no difference between these 2 conditions (P = .9), as compared to the sham tDCS week (−17%). With respect to the frequency of PLP paroxysms, the main effect of week (F2,14 = 10.12, P = .002, η2 = .59) showed a significant reduction during the week of active tDCS (−33%, P = .03) and during the follow-up week (−44%, P = .01), with no difference between these 2 conditions (P = .6), as compared to the change in PLP in the sham tDCS week (−9%) (Fig 3).

There was no association between the immediate PLP relief after each stimulation of the active tDCS week (ie, daily immediate effect) and the sustained effect, namely, the improvement of the PLP background intensity (r = .29, P = .5) and PLP paroxysms (r = −.14, P = .8) at the 1-week follow-up. Also, changes in the PLP background intensity (r = −.18, P = .7) and paroxysms (r = .31, P = .5) occurring in the week of sham tDCS were not associated with those occurring in the week of active tDCS.

The order of active and sham tDCS in the 2 weeks of treatment did not affect the results: When comparing the sustained tDCS effects in patients who received active tDCS in the first week of treatment with those in patients who received active tDCS in the second week, the main effect of order and the Order × Week interaction failed to reach significance in every analysis, whereas the main effect of week was still significant: PLP background intensity, order (F1,6 = .001, P = .9), week (F2,12 = 5.09, P = .02), Order × Week (F2,12 = .62, P = .5); frequency of PLP paroxysms, order (F1,6 = .17, P = .7), week (F2,12 = 9.39, P = .004), Order × Week (F2,12 = .49, P = .6).

Finally, a reduction of depressive symptoms was also observed: the BDI score was lower at the end of the treatment (mean score = 11) than before treatment (14, t = 2.43, P = .05).

**Discussion**

The main finding of the present study is that a 5-day treatment of anodal tDCS of the motor cortex induces a persistent reduction of chronic postamputation PLP, stable up to 1 week, as compared to a 5-day treatment with sham tDCS. After the active tDCS week, patients reported an average 41% decrease in background PLP, with 4 patients among 8 reporting a reduction greater than 30%. A 30% pain relief can be considered as a clinically significant difference, being superior to the maximal placebo effect (<25%) observed in nonpharmacologic randomized double-blind clinical trials conducted on PLP5,36 and featuring good responders to rTMS (>30% pain relief following active rTMS).10 The frequency of PLP paroxysms decreased at an average of 33%, with a reduction greater than 30% in 4 of 8 patients. Noteworthy, 1 patient (namely patient 1, who had PLP since 19 months; see Table 1) even showed a complete (100%) PLP relief on both measures (background pain level and paroxysms), which was maintained the week after the treatment. Overall, these results witness a robust analgesic effect of tDCS. The absence of an influence of the order of the weeks of active and sham tDCS, along with the lack of an immediate PLP relief by sham tDCS, further indicates that the sustained tDCS effects are driven by the active stimulation. Moreover, a decrement of depressive symptoms also emerged after the treatment (on average, BDI score was reduced by 3 points).

Our second finding is related to the immediate tDCS effects. As soon as each daily session of active tDCS was completed, patients reported an instant reduction of PLP intensity; in contrast, after sham tDCS, their responses were variable, marked by an increase or decrease of their PLP levels from the pre-tDCS assessment. No change in nonpainful sensations was found following

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**Figure 1.** Immediate tDCS effects. Change in VAS scores induced by sham and active tDCS at each day of treatment. VAS scores are normalized against the pre-tDCS assessment (immediately before the beginning of the stimulation) and displayed as percentage of change at the post-tDCS assessment (immediately after the end of the stimulation). Zero value then indicates absence of change, negative values indicate a reduction of VAS score from pre-tDCS levels, and positive values indicate an increase of the VAS score from pre-tDCS.
either active or sham tDCS, a result that confirms previous evidence and further supports the clinical dissociation between painful and nonpainful phantom phenomena.4

Another novel finding of the present study is the immediate increased feeling of motor control over the phantom limb brought about by active tDCS: The phantom limb moved more easily at the end of active tDCS, whereas no change, or even a decrement, of phantom motor control took place after sham tDCS. Intriguingly, the immediate PLP relief by anodal tDCS of M1 was associated with the increased movement of the phantom limb brought about by the same stimulation. Accordingly, an increased ability to move the phantom limb was shown to reduce PLP, whereas amputees with greater PLP are less able to move their phantom limb. One possible explanation of this relationship is that the analgesic action of the anodal tDCS of the deafferentated motor cortex may promote a reinforcement of the motor representation of the phantom limb, which in turn is helpful for alleviating PLP. The reactivation of the cortical representation of the amputated limb in M1 was shown to play a role in PLP relief, and in fact behavioral therapies targeting the cortical motor representation of the phantom limb (such as the mirror box therapy, motor imagery training, the use of a myoelectric prosthesis) show clear analgesic effect. Of course, the association between PLP relief and increased phantom limb movements deserves deeper investigation, for instance, by measuring with transcranial magnetic stimulation the treatment-induced changes in the cortical motor map representing the missing limb and its level of excitability (as done, for instance, in).2

Two other results are remarkable, although we acknowledge that no definitive conclusion can be drawn in light of the small sample size. First, the immediate PLP relief was not associated with the sustained effects of tDCS on PLP background intensity and paroxysms, pointing to a possible dissociation between the short- and long-term analgesic mechanisms activated by tDCS. TDCS-induced enduring effects on pain likely recruit plastic cortical changes that require multiple tDCS applications to take place. Second, the patients’ responses to sham tDCS were not correlated with those to active tDCS (for both the immediate and sustained effects), hence ruling out a possible association between the patients’ placebo responses to sham tDCS and the real improvement brought about by the active stimulation.

There is a growing body of evidence showing the efficacy of anodal tDCS of the motor cortex in chronic pain syndromes that are known to be refractory to medical treatments and to be associated with maladaptive plastic changes in the central and peripheral nervous systems.29,32,40 Our study extends this line of evidence, showing that tDCS can also induce a persistent and stable relief from chronic postamputation PLP.

**Figure 2.** Association between PLP relief and increased movement of the phantom limb. The graph illustrates the negative correlation between the immediate PLP relief and the immediate increased motor control over the phantom limb brought about by active tDCS of M1.

**Figure 3.** Sustained tDCS effects. Average change at the daily diary during the 2 weeks of treatment (1 week of active tDCS, 1 week of sham tDCS) and in the first week after the treatment (1-week follow-up). The VAS scores of the diary are normalized against the average scores in the baseline period (the week before the treatment) and are displayed as percentage of change on the diary’s VAS during the 2 weeks of treatment and during the follow-up week. Negative values indicate a reduction of PLP from baseline levels.
Different physiologic mechanisms mediate the analgesic action of tDCS, comprising changes in both the perceptual processing of pain and the emotional component of the pain experience. Upregulation of motor cortex excitability by anodal tDCS might modulate pain perception through indirect effects over pain-modulating structures, such as the thalamus. Indeed, epidural motor cortex stimulation changes the activity of thalamic and subthalamic nuclei; similar effects are induced by anodal tDCS of M1. The activation of thalamic nuclei triggered by tDCS, likely mediated by direct corticothalamic projections, would influence several pain-related structures, such as the anterior cingulate, the periaqueductal gray, and the spinal cord, that could ultimately modulate both the affective-emotional and the ascending sensory components of nociception. Moreover, a recent work has shown that a single session of anodal tDCS of the motor cortex results in an instant reduction of mu-opioid receptor binding of an exogenous receptor ligand in the pain matrix (ie, nucleus accumbens, anterior cingulate cortex, insula, thalamus), suggesting that the analgesic effect of M1 tDCS may possibly be due to a direct increase of endogenous opioid release.

The long-term analgesic effects of motor cortex stimulation could also follow, at least partially, the restoration of defective intracortical inhibitory processes, shown to be impaired following amputation. In our previous single case report, anodal tDCS also resulted in a positive modulation of stump pain. We aimed at confirming such evidence in this study, but here the majority of our amputees did not report stump pain, and when present it was mild (on average <1 on the VAS) and thus not of clinical relevance.

In conclusion, our findings provide another step toward the investigation of treatments for PLP aimed at inducing plasticity within the motor cortex, here using tDCS as the neuromodulatory method. Notwithstanding the limitations of the present study, such as the small sample size, the relatively short follow-up period, and the lack of investigation of possible cortical excitability changes brought about by the treatment, our results indicate that tDCS may be a promising therapeutic tool for the management of PLP. PLP represents a significant burden for amputees and an important clinical problem for clinicians, being a main contributor to a patient's poor quality of life and necessitating novel, effective therapeutic options. Our findings encourage the conducting of further clinical trials on the rehabilitation potential of tDCS for the treatment of PLP. Another possible use of tDCS could be to prevent PLP by blocking the development of maladaptive plasticity in acute postamputation stage; also, because there is evidence that the pain experienced before the amputation is a risk factor for the development of PLP, tDCS could be also used to reduce the preamputation pain before the planned surgery in order to prevent central sensitization.

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References


