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ORIGINAL ARTICLE/ARTICLE ORIGINAL

After-effects of peripheral neurostimulation on brain plasticity and ankle function in chronic stroke: The role of afferents recruited

Effets de la neurostimulation périphérique sur la plasticité cérébrale et la fonction de la cheville en AVC chronique : le rôle des afférences recrutées

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KEYWORDS
Repetitive peripheral magnetic stimulation;
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Brain plasticity;
Neurorehabilitation;
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Summary
Aims of the study. — This study tested the after-effects of neuromuscular electrical stimulation (NMES), repetitive peripheral magnetic stimulation (rPMS) and muscle tendon vibration (VIB) on brain plasticity and sensorimotor impairments in chronic stroke to investigate whether different results could depend on the nature of afferents recruited by each technique.
Materials and methods. — Fifteen people with chronic stroke participated in five sessions (one per week). Baseline measures were collected in session one, then, each participant received 4 randomly ordered interventions (NMES, rPMS, VIB and a 'control' intervention of exercises). Interventions were applied to the paretic ankle muscles and parameters of application were matched as closely as possible. Standardized clinical measures of the ankle function on the paretic side and transcranial magnetic stimulation (TMS) outcomes of both primary motor cortices (M1) were collected at pre- and post-application of each intervention.

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Results. — The ankle muscle strength was significantly improved by rPMS and VIB ($P \leq 0.02$). rPMS influenced M1 excitability (increase in the contralesional hemisphere, $P = 0.03$) and inhibition (decrease in both hemispheres, $P \leq 0.04$). The group mean of a few clinical outcomes improved across sessions, i.e. independently of the order of interventions. Some TMS outcomes at baseline could predict the responsiveness to rPMS and VIB.
Conclusion. — This original study suggests that rPMS and VIB were efficient to drive M1 plasticity and sensorimotor improvements, likely via massive inflows of 'pure' proprioceptive information generated. Usefulness of some TMS outcomes to predict which intervention a patient could be more responsive to should be further tested in future studies.

MOTS CLÉS
Stimulation magnétique périphérique répétitive ;
Stimulation électrique neuromusculaire ;
Vibration musculo-tendineuse ;
Plasticité cérébrale ;
Neuroréadaptation ;
Déficiences sensorimotrices

Résumé
Objectifs de l'étude. — Tester si les effets de la stimulation électrique neuromusculaire (NMES), la stimulation magnétique périphérique répétitive (rPMS) et la vibration musculo-tendineuse (VIB) sur la plasticité cérébrale et les déficiences sensorimotrices en AVC chronique dépendent des afférences recrutées par chaque intervention.
Matériels et méthodes. — Quinze personnes avec AVC chronique ont participé à cinq sessions (une par semaine). La première servait de ligne de base, et les interventions (NMES, rPMS, VIB et une intervention « contrôle » d'exercices) ont été réalisées dans les quatre sessions suivantes, dans un ordre aléatoire entre participants. Chaque intervention visait les muscles parétiques de la cheville, leurs paramètres étant le plus possible semblables. Différentes mesures cliniques et neurophysiologiques [stimulation magnétique transcrânienne (TMS) du cortex moteur primaire (M1)] ont été mesurées avant et après chaque intervention.
Résultats. — rPMS et VIB ont amélioré la force des muscles de la cheville ($p \leq 0{,}02$), mais seule rPMS a influencé l'excitabilité du M1 (augmentation dans l'hémisphère contra-lésionnel, $p = 0{,}03$) et l'inhibition intracorticale (levée d'inhibition dans les deux hémisphères, $p \leq 0{,}04$). Quelques mesures cliniques ont démontré des améliorations progressives entre les sessions, et certaines mesures TMS étaient prédictives du succès clinique des interventions.
Conclusion. — Cette étude exploratoire supporte que rPMS et VIB seraient plus efficaces que NMES pour induire des changements plastiques dans M1 et des améliorations sensorimotrices, probablement étant donné leur activation minimale des afférences cutanées permettant un recrutement « pure » des afférences proprioceptives. Ces résultats, incluant l'utilité pronostique de certaines mesures TMS, devront être approfondis dans des études futures.

Introduction

Non-invasive peripheral stimulation (NIPS) consists of applying an external stimulating device over a nerve, muscle or spinal root to depolarize the conductive structures within the peripheral nervous system [9]. NIPS use in research and in clinical settings has increased in recent years for a myriad of pathological conditions [5,9,47,58,90]. In particular, peripheral stimulation alone or in combination with rehabilitation regimens to induce muscle contractions and joint movements have been studied in patients with post-stroke spastic hemiparesis [5,8,47,90]. These studies reported improvements of sensorimotor deficits and functional independence, in parallel with plastic changes of the sensorimotor cortices, as tested by brain imaging and transcranial magnetic stimulation (TMS). It was proposed that the massive recruitment of sensory afferents by NIPS could activate the lemniscal and extra-lemniscal pathways and influence the excitability of spinal and cerebral networks (intra- and interhemispheric) and the corticospinal tract, thus contributing to promote sensorimotor function on the affected side [5,9,20,74].

Neuromuscular electrical stimulation (NMES) and repetitive peripheral magnetic stimulation (rPMS) are two NIPS devices that have shown promising results in populations with pathological affections [14,51,90,95], but some specific pros and cons may impact their use in routine stroke rehabilitation (for a review see [9]). Briefly, the rPMS equipment is bulky (generator, coil of stimulation) and expensive, but this stimulation is painless and less affected by the depth and impedance of the structures beneath the coil, as compared to NMES [9]. Also, when applied at intensities above the contraction threshold, rPMS and NMES seem to recruit proprioceptive afferents the same way, i.e. directly by the depolarization of sensory fibers terminals and indirectly via the induction of repeated contractions and joint movements [5,9]. However, NMES recruits cutaneous receptors, whereas rPMS seems to generate almost pure proprioceptive information during muscle contraction and joint movement (i.e. with limited recruitment of cutaneous