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How repeatable are the physiological effects of TENS?

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Abstract

Objective: Several studies suggest that transcutaneous electrical stimulation (TENS) can have a variety of effects on the central nervous system (CNS). In this study, we tried to replicate the physiological effects of TENS and to explore its effects on intracortical circuits.
Methods: We used transcranial magnetic stimulation (TMS) and spinal reflex testing to examine excitability of intracortical and spinal cord circuits before and after a 30-min period of TENS over the flexor carpi radialis (FCR) muscle. We measured the amplitude of TMS-evoked muscle responses (MEP), short interval intracortical inhibition (SICI), intracortical facilitation (ICF) and cortical antagonist inhibition (CAI) in flexor and extensor carpial radialis (FCR, ECR) muscles as well as spinal reciprocal inhibition (RI) and presynaptic inhibition (PI) from ECR to FCR.
Results: TENS had no significant effect on any of these measures apart from a reduction in median nerve induced facilitation of FCR when testing CAI.
Conclusions: When compared with previous studies, our results suggest that the effects of TENS are highly variable and unreliable, likely by the difficulty in defining precise parameters of stimulation in individual subjects.
Significance: Care should be taken in assuming that effects after TENS observed in small populations of subjects will apply equally to a wider population.

Keywords: Transcranial magnetic stimulation; Transcutaneous electrical stimulation; Intracortical inhibition; Intracortical facilitation; Spinal excitability

1. Introduction

There is a strong evidence that the excitability of the motor cortex can be modulated by afferent input. In humans, initial experiments concentrated on the immediate effects of sensory input on the amplitude of EMG responses evoked by transcranial magnetic stimulation of motor cortex. Thus, suitably timed electrical stimuli applied to peripheral nerve were found to increase or decrease MEP amplitude, consistent with a short latency afferent influence on motor cortex excitability (Deuschl et al., 1991; Bertolasi et al., 1998; Maertens de Noordhout et al., 1992; Rossini et al., 1996; Tokimura et al., 2000). Later experiments showed that this input also influenced the excitability of intracortical circuits tested with paired pulse TMS protocols (Ridding and Rothwell, 1999; Sailer et al., 2002; Kujirai et al., 1993). More natural inputs, such as muscle vibration, were also shown to modulate motor

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cortical excitability (e.g. Rosenkranz et al., 2003). Recently, the long-term effects of afferent input that outlast the period of stimulation have become an important issue. Thus, in healthy subjects, a prolonged period of peripheral nerve electrical stimulation (10 Hz) at low intensity has been shown to increase corticomotoneuronal excitability in the stimulated body parts (Hamdy et al., 1998; Ridding et al., 2000; Kaelin-Lang et al., 2002).

Transcutaneous electrical nerve stimulation (TENS) has been used for many years as a possible treatment for chronic pain (Hansson and Lundeberg, 1999). Although the mechanism is debated and the results are variable, it is possible that it leads to long-term effects on sensory transmission in the central nervous system. Indeed, TENS has been demonstrated to reduce somatosensory and pain evoked cortical potentials (Hoshiyama and Kakigi, 2000), and when applied over the hand (Mima et al., 2004), can increase sensory thresholds and reduce MEPs in hand muscles. Tinazzi et al. (2005a) reported that 30 min TENS over the flexor compartment of the forearm reduced MEPs in the flexor carpi radialis (FCR) muscle and increased MEPs in the antagonist (ECR) for the following 10–35 min. They postulated that part of this effect might have been via an action of afferent input on the excitability of reciprocal inhibitory connections between antagonist muscles at spinal or cortical levels (Bertolasi et al., 1998). Such effects of TENS on motor excitability may explain the effectiveness of TENS in the treatment of spasticity and dystonia (Foley-Nolan et al., 1990; Bending and Cleeves, 1990; Tinazzi et al., 2005b).

Given the known variation between subjects in the clinical response to TENS, the first aim of this work was to try to confirm the initial observations of Tinazzi et al. (2005a) on modulation of motor cortical projections to forearm muscles. In addition, we hoped to test whether the reciprocal effects on excitability of antagonist muscles were mediated by spinal or by intracortical circuits of reciprocal inhibition.

2. Materials and methods

2.1. Subjects

Eight healthy subjects (25–33 years old) were studied. All subjects gave a written informed consent to study, which was approved by the Research Ethics Committee of the Institute of Neurology. Subjects were comfortably seated in an armchair with the right forearm positioned on a moulded armrest in a supinated position while the forearm and hand muscles were relaxed. Parameters of motor excitability were recorded before and after 30 min transcutaneous electrical nerve stimulation over the flexor carpi radialis.

2.2. EMG recording

Surface electromyographic (EMG) recordings in a belly-to-tendon montage were made from the flexor carpi radialis (FCR) and the extensor carpi radialis (ECR) muscles. The raw signal was amplified and filtered with a band-pass filter of 30 Hz to 1 kHz (Digitimer Ltd). Signals were digitized at 2 kHz (CED Power1401, Cambridge Electronic Design, Cambridge, UK) and stored on a laboratory computer for off-line analysis.

2.3. Transcranial magnetic stimulation (TMS)

TMS was performed using two MAGSTIM 200 stimulators connected by a Y-cable to a figure-of-eight-shaped coil with an internal wing diameter of 7 cm (Magstim, Dyfed, UK). The coil was held with the handle pointing backwards and laterally approximately perpendicular to the central sulcus, to evoke anteriorly directed current in the brain, and was optimally positioned to obtain MEPs in the contralateral FCR and ECR muscles. Stimulation intensities are quoted in the text as a percentage of maximal stimulator output. The position of the coil was marked on the scalp so that it could be kept at exactly the same site along the session. Motor threshold (MT) was determined in the FCR as the main target muscle. MTs were defined as the lowest stimulus intensity that evoked an MEP with an amplitude >50 μV in at least five of the 10 successive trials in muscles at rest.

Short interval intracortical inhibition (SICI) and intracortical facilitation (ICF) were recorded using techniques which have been previously described (Kujirai et al., 1993; Ridding and Rothwell, 1999). Paired magnetic stimuli at different interstimulus intervals (ISI) were applied at the optimal scalp site for evoking responses in FCR and ECR while the subject was at rest. The test (second) stimulus was set to intensity sufficient to evoke a response in the target muscles (FCR and ECR) of approximately 1–1.5 mV. The conditioning (first) stimulus was at intensity 70% of stimulator output below the passive threshold for the target muscle. The interval between conditioning and test stimuli was 2 and 3 ms for the investigation of SICI and 10, 15 ms for the investigation of ICF. Inhibitory, excitatory timings and TMS alone were incorporated into a single block of 60 stimuli. Therefore, in total there were 12 trials for each condition, and the orders of presentation of the conditions were randomised.

Cortical antagonist inhibition was studied by a protocol which has been previously described (Bertolasi et al., 1998). The protocol involves peripheral nerve stimulation as a conditioning stimulus followed by a TMS test pulse. Bipolar electrical stimulation (cathode proximal) was delivered to the median nerve at the elbow (interelectrode distance, 20 mm; diameter of each stimulating electrode, 9 mm) with a square pulse of 0.1 ms and at an intensity producing a minimum activation of motor axons as monitored by the presence of a small M wave (generally smaller than an isoelectric peak amplitude of 50 μV in forearm flexors) that was used to confirm consistency of the stimulation during each experimental session. The conditioning-test intervals were 13, 15 and 19 ms. The intensity of TMS test pulse