Sensory training with vibration-induced kinesthetic illusions improves proprioceptive integration in patients with Parkinson's disease

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ABSTRACT

The present study investigates whether proprioceptive training, based on kinesthetic illusions, can help in re-educating the processing of muscle proprioceptive input, which is impaired in patients with Parkinson's disease (PD).

The processing of proprioceptive input before and after training was evaluated by determining the error in the amplitude of voluntary dorsiflexion ankle movement (20°), induced by applying a vibration on the tendon of the gastrocnemius-soleus muscle (a vibration-induced movement error). The training consisted of the subjects focusing their attention upon a series of illusory movements of the ankle.

Eleven PD patients and eleven age-matched control subjects were tested. Before training, vibration reduced dorsiflexion amplitude in controls by 4.3° (P < 0.001); conversely, vibration was inefficient in PD's movement amplitude (reduction of 2.1°, P = 0.20). After training, vibration significantly reduced the estimated movement amplitude in PD patients by 5.3° (P = 0.01).

This re-emergence of a vibration-induced error leads us to conclude that proprioceptive training, based on kinesthetic illusions, is a simple means for re-educating the processing of muscle proprioceptive input in PD patients. Such complementary training should be included in rehabilitation programs that presently focus on improving balance and motor performance.

1. Introduction

Muscle proprioceptive information is known to be of prime importance in the sense of posture and movement, and in the regulation of motor activities [1,2]. This peripheral muscle feedback seems to be spared in patients with Parkinson's disease (PD), as found through microneurographic recordings of muscle proprioceptive afferents [3]. By contrast, the central treatment of this sensory feedback is impaired in PD patients as shown, for example, by the higher threshold for detecting passive movements [4,5], localization errors in hand position matching tasks [6], and in altered proprioception-related evoked potentials during passive movements [7]. Changes in the supraspinal processing of proprioceptive input in PD have been demonstrated by analyzing the effect of mechanical vibration applied to the tendon of a muscle stretched during voluntary movements [8,9].

Vibratory stimulation activates muscle spindle afferents, particularly primary endings [10], where the muscle feedback is not only related to the movement performed, but also to the vibration-induced response. In healthy subjects, this increased feedback changes the sense of movement, where the subject has an impression that the movement was performed at a higher velocity, leading to a reduction in the amplitude of the desired movement and a vibration-induced movement error [11,12]. In PD patients, this vibration-induced error is decreased, which indicates an altered processing of proprioceptive sensory information [8,9]. Changes in the cerebro-basal ganglia loop are thought to be responsible for this altered proprioceptive integration [4]. The defective utilization of such proprioceptive information contributes to the movement issues that characterize this disease, notably in terms of postural control [13,14]. Thus, any therapy that could alleviate kinesthetic deficits may be considered important in the treatment of these patients [15].

The present study aimed at improving the integration of muscle proprioceptive inputs by supraspinal structures. For that purpose, PD patients and age-matched healthy subjects completed a training task during which they were asked to focus their attention upon illusory movements that were induced by muscle tendon vibration, in order to identify the illusory direction and velocity. The effect of the training was evaluated by measuring the vibration-induced movement error, as...
The movement was (Fig. 1). At the beginning of the experiment, the subjects experienced a muscles; both were kept in place by means of Velcro elastic bands healthy subjects, or the foot on the more severely a their feet unsupported. A goniometer was placed on the left foot in written, informed consent for the participation in the study. stimulation turned on, providing optimal conditions to reduce brady-
Parkinsonian medications and with the deep brain subthalamic nucleus 55 subjects with no history of neurological or psychiatric disease (range 63.2 ± 6.2 years; six females), all of whom had stimulating electrodes 2.1. Subjects 2. Materials and methods 2.3. Mechanical vibration and velocity was perceived higher during the trials where a 1° stretching of the vibrated muscle was added. The vibration applied to the tendon of the GS muscle, by the experimenter, in order to increase the velocity of the sensation of illusory dorsal flexion movement. Likewise, in 10 of the 20 trials with TA vibratory stimulation, a slow 1° manual stretching of the TA muscle was imposed to increase the velocity of the sensation of illusory plantar flexion movement. Immediately after each trial, the subjects were asked to verbally report both movement direction (dorsiflexion or a plantar flexion) and whether the perceived movement was of low (no stretching) or high (with stretching) velocity. All the participants (PD and control) felt clear sensations of illusory movement of the ankle joint and the parameters (direction and velocity) were as expected: a dorsiflexion or a plantar flexion when vibration was applied to the tendon of the GS or TA, respectively. Furthermore, for all the participants (PD and control) the velocity was perceived higher during the trials where a 1° stretching of the vibrated muscle was added. 2.3. Mechanical vibration Vibrations (frequency: 80 Hz; peak-to-peak amplitude: 0.5 mm) were delivered via mechanical vibrators (DC motors with eccentric masses, 1.5 cm in diameter, 4 cm in length, Technoconcept, France). In the pre- and post-training sessions, during the V trials, vibration lasted for 2 s, i.e. the GS vibrator was turned on and off, on the go and stop auditory cues, respectively. In the training session, the GS or TA vibrator was activated during 8 s, i.e. a time sufficient to induce a clear sensation of ankle movement, but not for too long so as to prevent disagreeable sensations such as exaggerated plantar flexion displacements. 2.4. Statistics The movement amplitudes measured without and with vibratory stimulation were compared before and after the training session, using a paired t-test, in each of the patient and healthy subject groups. As in previous studies [8,9], the vibration induced errors in amplitude were expressed by the ratios of V/NV movement amplitude. The level of significance was set at an alpha of $P \leq 0.05$ level (p values are given to three decimal places). Finally, the magnitude of the effect was estimated by calculating Cohen’s d, where 0.2 is a small magnitude, 0.5 is a medium magnitude, and 0.8 is a large magnitude effect [16]. Statistical analyses were performed using commercially available statistical software (Statistica, USA). 3. Results The results obtained with one PD patient are shown as an example representative of the population, in Fig. 2. In the pre-training session, the patient underestimated the amplitude of voluntary ankle dorsiflexion performed, since the movement surpassed the target amplitude
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