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Research paper

Acute effects of muscle vibration on sensorimotor integration

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HIGHLIGHTS

- Sensorimotor integration was investigated before and after a vibration intervention.
- Transcranial magnetic stimulation was conditioned by afferent inputs.
- Responders and non-responders were identified.
- Responders were characterized by decreased inhibition and increased facilitation.

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ABSTRACT

Projections from the somesthetic cortex are believed to be involved in the modulation of motor cortical excitability by muscle vibration. The aim of the present pilot study was to analyse the effects of a vibration intervention on short-latency afferent inhibition (SAI), long-latency afferent inhibition (LAI), and afferent facilitation (AF), three intracortical mechanisms reflecting sensorimotor integration. Abductor pollicis brevis (APB) SAI, AF and LAI were investigated on 10 subjects by conditioning test transcranial magnetic stimulation pulses with median nerve electrical stimulation at inter-stimuli intervals in the range 15–25 ms, 25–60 ms, and 100–200 ms, respectively. Test motor evoked potentials (MEPs) were compared to unconditioned MEPs. Measurements were performed before and just after 15 min of vibration applied to the muscle belly of APB at a frequency of 80 Hz. SAI and LAI responses were significantly reduced compared to unconditioned test MEPs ($P = 0.039$ and $P < 0.001$, respectively). AF MEP amplitude was greater than SAI and LAI one ($P = 0.009$ and $P = 0.004$, respectively), but not different from test MEP ($P = 0.511$). There was no significant main effect of vibration ($P = 0.905$). However, 4 subjects were clearly identified as responders. Their mean vibration-induced increase was 324 ± 195% in APB SAI MEP amplitude, and 158 ± 53% and 319 ± 80% in AF and LAI, respectively. Significant differences in SAI, AF and LAI vibration-induced changes were found for responders when compared to non-responders ($P = 0.019$, $P = 0.038$, and $P = 0.01$, respectively). A single session of APB vibration may increase sensorimotor integration, via decreased inhibition and increased facilitation. However, such results were not observed for all subjects, suggesting that other factors (such as attention to the sensory inputs) may have played a role.

1. Introduction

While proprioceptive inputs are essential at the spinal level [11], they also play a major role in motor control at the cortical level [33]. It has previously been reported that the motoneuron firing rate may be reduced by up to 30% in the absence of afferent feedback [17]. Conversely, several studies reported that modulation of afferent inputs through peripheral nerve electrical stimulation can induce persistent neuroplastic changes in motor cortical areas [13,25]. This suggests that projections from the somesthetic cortex modulate motor cortical excitability. Modulation of afferent inputs can also be achieved by tendon and muscle vibrations which are known to be powerful stimuli for muscle spindle primary endings [8,26]. Vibration can generate evoked cortical potentials in sensory and motor cortical areas [20–22], reinforcing the hypothesis that vibratory stimuli may also influence the cortical level. Accordingly, numerous studies have demonstrated using transcranial magnetic stimulation (TMS) an increase in corticospinal excitabil-

Abbreviations: AF, afferent facilitation; APB, abductor pollicis brevis; EMG, electromyographic; ISI, inter-stimuli interval; FDI, first dorsal interosseous; LAI, long-latency afferent inhibition; MEP, motor evoked potential; rMT, resting motor threshold; SAI, short-latency afferent inhibition; TMS, transcranial magnetic stimulation.

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ity (i.e. increased motor-evoked potential (MEP) amplitude or area) within seconds of the initiation of vibration of hand and wrist muscles [3,14]. After periods of vibration, it was reported changes in motor map organization [10] and in corticospinal excitability [2,16,31]. Some studies used paired-pulse protocols to analyse intracortical processes such as short-interval intracortical inhibition and intracortical facilitation [15]. Christova et al. [2] reported for abductor pollicis brevis (APB) and its antagonist first dorsalis interosseus (FDI) decreased inhibition and increased facilitation up to 2 h after 20 min of 25 Hz whole-hand vibration. Conversely, Rosenkranz and Rothwell [27,28] reported that 15 min of APB vibration had no effect on levels of APB and FDI inhibition. However, the latter studies reported changes in the sensorimotor organization. While the vibration-induced activation of muscle afferents can increase corticospinal excitability and decrease intracortical inhibition (homotopic effect), with opposite effects to adjacent muscles, 15 min simultaneous vibration of APB and FDI led to an expansion of homotopic effect onto the adjacent muscle [27,28].

Since projections from the somesthetic cortex are believed to be involved in the modulation of motor cortical excitability, it is of interest to investigate in a more specific manner these sensorimotor pathways. The influence of proprioceptive afferent inputs on corticospinal excitability can be studied by analyzing a test TMS pulse conditioned by a peripheral nerve electrical stimulation, and time-dependent modulation of motor cortex excitability can so be observed. When peripheral stimulus is applied ∼20 ms before TMS, conditioned MEP is decreased compared to unconditioned test MEP. This has been called short-latency afferent inhibition (SAI) [32]. Inhibition can also be observed at longer inter-stimuli intervals (100–500 ms), mechanism called long-latency afferent inhibition (LAI) [1]. With intervals between those of SAI and LAI, motor cortical excitability can be enhanced (or at least disinhibited); mechanism termed afferent facilitation (AF) [6]. SAI, AF and LAI are considered to reflect sensorimotor integration. These pathways were reported to be modulated following neuromuscular electrical stimulation [18], or with age [5]. To our knowledge, the effects of vibration on sensorimotor circuits remain to be determined.

Therefore, the aim of the present pilot study was to analyse the effects of a vibration intervention on sensorimotor integration. The investigations consisted of evaluating before and after vibration APB motor cortex excitability when conditioned by afferent inputs at intervals eliciting SAI, AF, and LAI.

2. Methods

2.1. Ethical approval

Written informed consent was obtained from all subjects prior to their participation and this study conformed to the standards from latest revision of the *Declaration of Helsinki*. All procedures were approved by the local ethics committee.

2.2. Subjects

10 subjects (2 females and 8 males; age: 27 ± 9 years; height: 180 ± 8 cm; body mass: 71 ± 10 kg) participated in this study. All subjects were free of contraindications to TMS [29] and instructed to abstain from caffeine a minimum of 12 h before each session. Subjects were seated comfortably with their forearm in a semi-pronated, resting position. Shoulder, elbow, and wrist joint angles were maintained at ≈25°, 120° and 180°, respectively.

2.3. Electromyographic activity

Subjects were fist prepared by shaving, gently abrading the skin and then cleaning it with isopropyl alcohol. EMG of abductor pollicis brevis (APB) was recorded with a pair of self-adhesive surface electrodes (Meditrace 100, Covidien, Mansfield, OH, USA) in a belly-tendon montage. Signal was analogue-to-digitally converted at a sampling rate of 2000 Hz by PowerLab system (16/30-ML880/P, ADInstruments, Bella Vista, Australia) and octal bio-amplifier (ML138, ADInstruments; common mode rejection ratio = 85 dB, gain = 5000) with bandpass filter (10–500 Hz) and analyzed offline using Labchart 7 software (ADInstruments).

2.4. Transcranial magnetic stimulation

Transcranial magnetic stimulation was delivered using a figure-of-eight coil connected to Magstim 200 stimulator (The Magstim Company Ltd., Whitland, UK). The coil was positioned over the hand area of the right motor cortex. Optimal coil position was selected so as to elicit the largest left APB MEP amplitude. The coil was held tangentially to the scalp, with the handle pointing backwards and sideways (at a 45° angle from the midline). This position was drawn directly on the silicone swim cap worn by the subjects, and the coil position was verified before the delivery of each stimulus by an experienced investigator. Resting motor threshold (rMT) was determined as the intensity to elicit APB MEP amplitudes >50 μV in at least 3 of 5 consecutive trials with the muscle in the relaxed state [23].

2.5. Median nerve stimulation

The left median nerve was stimulated by single electrical stimuli of 0.2-ms duration via constant-current stimulator (DS7A, Digitimer, Welwyn Garden City, Hertfordshire, UK) and bipolar bar stimulating electrode with 30 mm anode–cathode spacing (Bipolar Felt Pad Stimulating Electrode Part number E.SB020/4 mm, Digitimer) placed at the wrist. Single stimuli were delivered incrementally until the motor threshold was identified, i.e. consistent presence of a small M-wave and identification of a slight thumb twitch. All stimuli were delivered at motor threshold [6,9].

2.6. Muscle vibration

Vibration was applied during 15 min to the muscle belly of APB at a frequency of 80 Hz by a commercialised vibrator (Vibralgic 5, Ysy Medical, Gallargues Le Montueux, France). The amplitude of vibration was in the range 0.8–1 mm, and was subthreshold for perceiving an illusory movement [26]. Subjects were instructed to remain fully relaxed during the intervention.

2.7. Experimental protocol

The first part of the protocol was dedicated to the determination of conditioning-test intervals. Test stimuli (TMS) were adjusted to evoke unconditioned test MEPs of 0.5–1 mV in the APB. MEPs were then conditioned by median nerve stimulation at inter-stimuli intervals (ISIs) in the range 15–25 ms (SAI), 25–60 ms (AF), and 100–200 ms (LAI). Several ISIs were randomly tested for each and optimal ISIs were determined by visual inspection. SAI and LAI were identified as the greatest inhibition compared to unconditioned MEPs (mean ISIs of 19 ± 3 ms and 119 ± 30 ms, respectively). AF was identified as the ISI eliciting the largest conditioned APB MEP amplitude (41 ± 9 ms). It should be noted that facilitation was only observed in 4 of 10 subjects. For the 6 other subjects, AF was characterized by the largest conditioned MEP amplitude and representative of the least disinhibition (i.e. where the amplitude of the conditioned MEP was greater than for SAI and LAI) [18,30].

Two testing sessions were then performed before (PRE) and just after (POST) the vibration intervention. Experimental procedures consisted of measurements of MEPs elicited at 120% rMT (MEP_{120};