Lower limb primary sensory and motor cortical activity during voluntary and passive ankle mobilisation

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Abstract. This study investigates cortical involvement during ankle passive mobilisation in healthy subjects. Magnetoencephalographic and tibialis anterior electromyographic activities were collected bilaterally on 7 healthy subjects (aged 29±7 years) during rest (REST), left and right ankle dorsiflexion imparted through the SHADE orthosis (O-PM) or neuromuscular electrical stimulation (NMES-PM), or during active isometric contraction (IC-AM). Primary sensory (FS1) and motor (FSM1) area activities were discriminated by the Functional Source Separation algorithm. Both sources reacted bilaterally during IC-AM in beta band. Only FS1 was also reactive during O-PM. No reactivity of either source resulted during NMES-PM. SHADE was effective in generating repeatable dorsiflexion and inducing primary sensory involvement similarly to voluntary movement.

Keywords: Ankle movement; Sensorimotor; Magnetoencephalography; Functional Source Separation

1. Introduction

The present study aims at describing, by means of magnetoencephalography (MEG), the neural circuits activated in healthy subjects undergoing passive mobilisation (PM) of the ankle joint as produced by neuromuscular electrical stimulation (NMES) or the application of the SHADE orthosis. The SHADE orthosis has been developed to assist in the post-acute rehabilitation treatment of stroke patients (Pittaccio et al., 2007). SHADE was previously proven to be very well accepted by patients and effective in promoting suitable movement ranges at appropriate speeds (Pittaccio et al., 2007). The characterization of central correlates during passive mobilisation in comparison with active movements can be done with great advantages if the participations of primary sensory (S1) and primary motor (M1) areas are well discriminated. This can be achieved by a new source extraction method (Functional Source Separation, FSS, Tecchio et al., 2007), which adds functional constraints to the statistical contrast function of a standard independent component analysis algorithm (ICA). FSS is capable to provide a source activity in a variety of different experimental conditions based on specific information about that source, which can be gained by exploiting a functional ‘fingerprint’ behavior arising under a limited-time experimental condition.

2. Material and Methods

Seven healthy right-handed subjects (mean age 29±7 years, 5 men), participated in the study. Brain magnetic fields were recorded by means of a 28-channel MEG system over sensory-motor regions devoted to leg control (CZ position of the 10-20 International System).

MEG activity and the tibialis anterior (TA) electromyogram were collected during different conditions, namely: rest (2 minutes, open eyes, REST); somatosensory electrical stimulation to the
common peroneal nerve (631 ms inter-stimulus interval, stimulus intensity just inducing a painless foot twitch); voluntary isometric dorsiflexion at 5% of the maximal voluntary contraction (IC-AM); passive movement of the ankle by neuromuscular electrical stimulation (NMES-PM), which was applied through a pair of 3 mm thick saline-soaked synthetic sponge electrodes; passive repeated dorsiflexion of the ankle by the use of the active orthosis SHADE (O-PM), for 10 min.

FSS was applied to identify the cortical neural networks devoted to the ankle muscle representation in primary motor (FSM1) and primary sensory (FSs1) areas. Our functional requirements were i) maximal coherence with TA rectified electromyographic signal for FSM1 extraction and ii) maximal responsiveness to common peroneal nerve stimulation at around 40 ms for FSs1. Involvement of the sources during each experimental condition was estimated through their power band distributions (Hanning window, 512 ms duration, 60% overlap) in the classical frequency bands (alpha: 8-13 Hz, beta: 14-32 Hz, gamma1: 33-60 Hz, gamma2: 61-90 Hz). The estimate was obtained separately for the four experimental conditions.

Repeated-measure ANOVA was applied to each power band of the source activities with Source (FSs1, FSM1), Hemisphere (Left, Right) and Condition (REST, IC-AM, NMES-PM and O-PM) as within-subject factors.

3. Results

FSs1 and FSM1 were suitably identified in both hemispheres for all subjects. The FSs1 and FSM1 positions were spatially distinct in both hemispheres [Source factor [F(3,4) = 13.692; p=.014, figure 1]. The two sources reacted differently to common peroneal nerve stimulation and displayed different coherence levels with muscular activity (Figure 1).

Considering the sources contralateral to the movement, a Condition*Source effect [F(3, 18)=16.860, p<.001, figure 2, top] was found selectively in beta band. Post-hoc comparisons indicated that both FSs1 and FSM1 reacted during IC-AM with respect to REST in both hemispheres (figure 2). During O-PM, solely FSs1 was reactive. No reactivity was found in connection with NMES-PM. FSs1 and FSM1 ipsilateral to the tested ankle behaved in a much similar fashion, particularly in beta band [Condition*Source effect [F(1.8, 10.7)=4.962, p=.033, figure 2 bottom].

4. Discussion

The FSS procedure suitably discriminated the sensory and motor sources devoted to the ankle cortical representation in healthy volunteers. The active movement was clearly differentiated from the rest condition by power spectral analysis in both sensory and motor regions, in agreement with previous results (Müller et al., 2003). Interestingly, we were able to document that selectively primary
sensory areas had a similar behavior during passive and active movements of the lower limb, while primary motor areas were significantly involved only during active movements.

Passive mobilization by the use of SHADE stimulated significant reactivity of the sensory source, particularly in the beta band.

References

