Effects of short-term immobilization of the upper limb on the somatosensory pathway: a study of short-latency somatosensory evoked potentials

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Abstract. [Purpose] Previous studies have reported that the nervous system is influenced during short-term cast immobilization. However, the effects of short-term inactivity on somatosensory information processing systems are not well understood. This study investigated the effect of 10 h of upper limb immobilization on the somatosensory pathway using short-latency somatosensory evoked potentials. [Participants and Methods] Twenty right-handed healthy participants (mean age 21.7 years) were enrolled in this study. The participants’ left hands and forearms were wrapped in a soft bandage at a 90° elbow flexed position. The participants were instructed not to move their left hand for 10 h. To obtain short-latency somatosensory evoked potentials, we used a multimodal evoked potential system. The left median nerve was electrically stimulated at a rate of 5 Hz for a duration of 0.2 ms. The intensity of the stimulus was adjusted to induce mild twitches of the thumb. The amplitudes and latencies of the short-latency somatosensory evoked potential components (N9, N13, and N20) were measured before and after immobilization. [Results] The amplitude of the N9 component significantly increased after immobilization. [Conclusion] Our results indicated that the changes in the excitability of the peripheral somatosensory nerve were due to 10 h of inactivity. Key words: Limb immobilization, Somatosensory pathway, Short-latency somatosensory evoked potentials

INTRODUCTION

Joints are commonly immobilized in a cast used for rest after ligament injuries and fractures. For tissue repair, limb immobilization is advised as part of conservative treatment. However, it is well known that limb joint immobilization leads to muscle atrophy1, 2). In addition, neurophysiology studies have suggested that cast immobilization may alter the response of the human nervous system. Electrophysiological techniques such as transcranial magnetic stimulation (TMS) have been applied to assess changes in spinal and corticospinal excitability before and after limb or joint immobilization in humans. Facchini et al. and Ngomo et al. observed reduced amplitudes of motor evoked potentials (MEPs) following 4 days of finger immobilization3, 4). However, although no changes were observed in corticospinal excitability following 1 week of wrist immobilization, increased corticospinal excitability was observed in arm and hand muscles following longer periods of immobilization ranging from 10 to 45 days5–7). The results derived from the TMS experiments are inconsistent, but these results appear to vary depending on the duration of immobilization.

Several studies have suggested that the amplitudes of MEPs are altered following very short periods of immobilization. Avanzino et al. and Huber et al. demonstrated that a brief period (10–12 h) of hand immobilization reduced the amplitudes of MEPs and decreased the excitability of the contralateral primary motor cortex8, 9). Interestingly, 12 h of upper limb immobi-
lization induced synaptic remodeling in the corresponding somatosensory cortical area\(^9\). A previous animal study indicated that monkeys experienced severe difficulty in learning new skills with the hand contralateral to the ablated somatosensory cortex\(^{10}\). These results suggest that alterations to the somatosensory cortex following limb immobilization may inhibit the learning of novel motor skills after cast removal. However, the association between limb joint immobilization and the somatosensory information processing system remains unknown.

Short-latency somatosensory evoked potentials (S-SEPs) are the electrical potentials generated in somatosensory pathways at the peripheral, spinal, subcortical, and cortical levels of the nervous system by application of transcutaneous electrical stimulation to the skin over the trajectory of the peripheral nerves\(^{11,12}\). The main analysis consists of latency and amplitude, and S-SEPs are widely used to evaluate the presence or absence of sensory disorders in patients with neurological diseases and to investigate the sensory inputs transmitted in the central nervous system. The Erb’s point potential is designated N9 (with latencies of approximately 9 ms) and arises from the brachial plexus trunk\(^{13}\). The cervical N13 potential (with latencies of approximately 13–14 ms) reflects the neuronal activity of the cuneate nucleus\(^{14}\). It has been speculated that the generator of the S-SEP component on the scalp (N20, with latencies of approximately 20 ms) may be located in Brodmann Area (BA) 3b and/or BA 1, and reflects the first stage of cortical somatosensory processing\(^{12}\). A previous study indicated that short-term upper limb fixation altered the response of the somatosensory cortex at 35–45 ms (P45) after stimulation of the median nerve\(^{13}\). We speculated that the effect of fixation on the somatosensory information processing system at stages earlier than 30–45 ms could be evaluated using S-SEPs. Thus, the aim of this study was to investigate the effect of 10 h of upper limb immobilization on the somatosensory pathway using S-SEPs.

PARTICIPANTS AND METHODS

Twenty right-handed healthy participants (mean age, 21.7 ± 0.5 years; 10 males and 10 females; height 165 ± 6.7 cm) were enrolled in this study. No participants had a history of significant medical, neurological, or psychiatric disease. Potential participants with a history of ligament injuries or fractures of the upper limb were excluded. The study was performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from each participant after the nature of the experiment was fully explained. The study was approved by the ethics committee of the local ethics committee (15-IIfh-29).

The participants’ left hands and forearms were fixed with a soft bandage from immediately above the elbow to the middle phalanx at a 90° elbow flexed position. The immobilized left upper limb was supported with a sling to minimize shoulder movement.

The participants were instructed not to move their upper limb during a 10 h period from 09:00 to 19:00. During the 10 h period of immobilization, the participants followed their normal daily activities while wearing the soft bandage and splint. During immobilization, the participants were regularly evaluated for any signs of numbness or tingling in the upper limb. There were no dropouts. To obtain the S-SEPs, we used a multimodal evoked potential system (Neuropack MEB-2200, Nihon kohden, Tokyo, Japan). The participants lay relaxed on a comfortable bed in an air-conditioned room the temperature of which was maintained at 21–23°C. S-SEPs were elicited by electrical stimulation of the median nerve in the left wrist at a rate of 5 Hz for a duration of 0.2 ms. The intensity of the stimulus was adjusted to induce mild twitches of the left thumb. S-SEPs were recorded via Ag-AgCl surface cup electrodes fixed to the skin with conducting paste. The impedance of the electrodes was maintained at <5 kΩ. Surface electrodes were placed at Erb’s point (Erb), cervical spine (C7), and right primary somatosensory area (S1) (C4’; 2 cm posterior to C4) and referenced on Fz (midline frontal) by the International 10–20 system. Bipolar derivation of Erb-Fz was used to record N9 (the potential generated in the cuneate nucleus). The derivation of C7-Fz was used to evaluate N13 (the potential generated in the medial lemniscus). The cortical potential (N20) was evaluated using C4’-Fz. The bandpass filter was 5–2,000 Hz, and the sampling rate was 5 kHz. The analysis time was 50 ms, and the mean of 500 responses was calculated. The peak-to-peak amplitudes and latencies of the S-SEPs components were measured before and after 10 h of immobilization (after cast removal). The peak-to-peak amplitudes were measured from the preceding trough to the peak. The latencies were recorded at the maximal peak of each component. The central somatosensory conduction time (CCT) was defined as the transit time by the peak of the N13–N20 potentials. The significance of the differences in the amplitudes and CCT at rest before and after immobilization were tested using the Student’s t-test (Dr SPSS for windows 21.0). A p-value of <0.05 was considered to be significant. The effect size was then calculated using Cohen’s d-values. Effect size is small if it is <0.2, moderate if it is 0.5, and large if it is >0.8\(^{15}\).

RESULTS

S-SEPs of the three distinct components (N9, N13, and N20) were identified with or without 10 h of immobilization (Fig. 1). The amplitude of N9 was significantly larger after immobilization than before (p<0.01). However, the changes in the amplitudes of N13 and N20 were not significant (N13: p=0.89, N20: p=0.10). Additionally, the CCTs of N13 and N20 after immobilization did not significantly differ from those before immobilization (p=0.79) (Table 1).

The effect size was moderate for N9 (d=0.48) and small for N20 (d=0.16), N13 (d=0.04), and CCT (d=0.05) (Table 1).
DISCUSSION

This study demonstrated that 10 h of upper limb immobilization modulated the excitability of the somatosensory pathway in healthy adults. Interestingly, after 10 h of immobilization, the S-SEP N9 component amplitude was significantly larger than that before immobilization; the corresponding effect size was medium. In contrast, the amplitudes and CCT of the S-SEP N20 and N13 components after immobilization did not exhibit overt changes with immobilization. Since the significant differences were observed in healthy adults, the changes in the excitability of the N9 component were caused by limb immobilization rather than fractures or ligament injuries. Therefore, our results indicate that the changes in the excitability of the peripheral nerve were due to 10 h of inactivity.

Huber reported that 12 h of upper limb fixation inhibited the cortical SEP; this change in somatosensory cortex activity (reduced amplitude and increased latency of the P45 component) suggests that the plastic changes induced by arm immobilization are likely due to synaptic depression\(^9\). The P45 component originates in the secondary somatosensory area (SII), including BA 5\(^9\). The SII is known to process the high-order features of the stimulus, such as in the context of attention\(^7\), learning\(^8\), and memory functions\(^9\). However, SI is mainly involved in the processing of the stimulus frequency and intensity of the sensory inputs\(^20, 21\). Our study did not observe overt changes in SI activities after upper limb immobilization. Thus, our results suggest that immobilization did not elicit an effect at the first stage of cortical somatosensory processing after sensory input. However, the amplitude of the N9 component in this study was found to be modulated by immobilization. The S-SEP N9 component reflects conduction from Ia afferents in the peripheral nerves of the upper median or ulnar nerves on the brachial plexus trunks\(^13\). Okamoto reported that, in both inflamed and long-term (6 weeks) immobilized rat knees, medial articular nerve activity was increased during continuous passive motion compared to that in the normal control rat knees, and the sensory afferent information was sensitized in both models\(^19\). The findings indicated that the sensory receptors were sensitized in a similar manner by immobilization and inflammation. Thus, the brachial plexus trunk might be modulated...
by sensitization due to even 10 h of inactivity. However, the neural mechanisms underlying this phenomenon have not been fully elucidated.

Some limitations of the present study must be acknowledged when interpreting the results. First, the inactivity model of this study used the soft bandage and splint; this may not have fully immobilized the arms. In addition, the relationships between electrophysiological and physiotherapy test results and somatosensory function were not clear. Further studies with larger sample sizes are needed to overcome these limitations.

In conclusion, this study demonstrates that short-term immobilization of the upper limb increases peripheral nerve excitability but does not significantly affect the first stage of cortical somatosensory processing. Previous studies have suggested that 12 h of cast immobilization in healthy adults results in abnormal hand trajectories and inhibits interjoint coordination, which was reminiscent of that observed in deafferented patients. Therefore, changes in the excitability of the peripheral nervous system after short-term cast immobilization may be one of the factors that inhibit interjoint coordination. Our results indicate the need for clinical evaluation for somatosensory dysfunction during cast immobilization after fracture and ligament injury using S-SEPs. However, it is not possible for cast immobilization to be limited to 10 h; thus, the long-term effects are unknown. Therefore, the clinical significance of these results is unknown. Further study will be necessary to explore this effect.

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**Conflict of interest**

The authors declare no conflict of interest.

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