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Effects of Repetitive Finger Movements on the Short-Latency Somatosensory-Evoked Potentials

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Abstract

When performing a movement, many features of sensory information are used as inputs and integrated. Smooth movement is possible by selecting necessary information from all-sensory inputs. The somatosensory input of movement is adjusted at different levels such as at the level of the spinal cord, brainstem, and sensory cortex. However, sensory tests used by physical therapists provide only the sensory information that is perceivable through the parietal association fields. On the other hand, there is a somatosensory-evoked potentials (SEPs) in the tests of the somatic sensory function. An understanding of the SEPs enables the evaluation of the posterior track. Therefore, it is possible to determine if the adjustment of somatosensory inputs occurs at any stage. The SEP amplitude is decreased by passive and voluntary movement. Further, characteristic decrease in the SEP amplitude is noted with an increase in the speed and intensity of movement. Thus, it is important for us to understand the relationship between motor tasks and somatosensory inputs. In this chapter, we introduce our study on the relationship between physical movements and somatosensory inputs, and make recommendations for practicing physical therapy.

Keywords: somatosensory-evoked potentials, finger movements, somatosensory

1. Introduction

When performing a movement, all sensory information is not perceived at a conscious level, and the necessary sensory information is selected from all available information. For example, elaborate movements of the finger require conscious perception of somatosensory and optic information, but the sensory information associated with the trunk and lower limbs is not consciously perceived. In addition, the sensory information to execute finger movement changes

according to the location of the body parts and direction of the motor task. In this manner, it is possible to perform smooth movements by extracting the necessary sensory information from the vast sensory information available. Somatosensory inputs are integrated by sensory receptors and through the somatosensory area and the parietal association fields. Mechanisms that adjust the sensory inputs to the sensory conducting pathway before and during movement exist. These mechanisms act at various stages, ranging from the spinal cord to the cerebral cortex. For example, the reflex is patterning the movement output from sensory input by spinal cord and brainstem. Walking and chewing are automatically generated movements based on sensory inputs delivered to the midbrain and the pons. The need for the cerebral cortex to act in order to execute these movements is optional. The initial stages of motor learning are associated with extensive sensory feedback. Advancement of motor learning requires adjustments of sensory inputs in advance by feed-forward mechanisms. It has been shown that the necessary sensory inputs and integration mechanisms vary depending on the exercise conditions. However, sensory tests used by physical therapists require subjects to recognize and judge movement based on sensory information from the sensory receptor. Therefore, it is difficult to evaluate the exact somatosensory pathway associated with movement.

The inspection of the sensory function has led to the observation of somatosensory-evoked potentials (SEPs). SEPs are able to evaluate the funiculus posterior. SEPs can be classified into short-latency, middle-latency, and long-latency, based on the latency of the SEP waveform. A 50 ms from stimulation electrical is a component of short-latency. In particular, the component within 20 ms is called short-latency SEPs. Short-latency SEPs are stable-evoked potentials generated in the cerebral cortex through inputs from peripheral nerves, and they are hardly affected by the level of consciousness. Potentials evoked with a latency of 50–100 ms are classified as middle-latency SEPs, while those evoked with a latency beyond 100 ms are called long-latency SEPs. Since middle-latency SEPs are generated in the cerebral cortex, they are susceptible to the attention level and can be modulated by the sleep state. Next is explaining of latency and components in short-latency SEP in upper limbs. SEPs can be defined by their polarity (positive/negative) and latency (short/middle/long). The N9 waveform is first recorded from the upper limbs upon electrical stimulation of the median nerve with the wrist joint. The N9 is a negative wave appearing at the latency of about 9 ms from electrical stimulation. The origin of N9 is believed to be the action potential derived from the brachial plexus. The N13 waveform is recorded next, and it is said to originate from the postsynaptic potential derived from the brachial plexus. The N20 and P25 waveforms are recorded following the N9 waveform. The origin of N20 is believed to be the 3b area while that of P25 is said to be postsynaptic potential derived from the one area [1].

On the topic of the influence of movement on SEPs, Giblin reported for the first time that the amplitude of cerebral cortex SEPs decreased during voluntary movement [2]. Numerous papers have reported the changes in SEPs during upper and lower limb movements. It is known that the SEP amplitude decreases during voluntary movement. In other words, sensory inputs are inhibited during voluntary movement [2]. This decrease in the SEP amplitude is called gating and can be mediated by two mechanisms, namely centripetal gating and centrifugal gating. In centripetal gating, the afferent impulse from the peripheral receptor due to voluntary movement and the afferent impulse from the peripheral nerve stimulation

are input at the same time, resulting in interferences such as occlusion and lateral inhibition. In centrifugal gating, efferent impulses from exercise-related areas in response to voluntary movement suppress afferent impulses from peripheral nerve stimulation [3]. Voluntary movement affects both centripetal and centrifugal gating mechanisms. The SEP amplitude decreases with increases in movement speed [4] and load [5, 6]. This gating is thought to play a role in performing accurate movement by eliminating unnecessary somatosensory information [7]. We studied the effects of finger movement on short-latency SEPs. Previous studies have reported that the SEP amplitude varies with the type of motor task. Therefore, we will introduce our research on the influence of differences in motor tasks on SEPs and provide recommendations for physical therapy.

2. Effects of repetitive finger movements performed at different frequencies on the somatosensory-evoked potentials

When sensory inputs are facilitated, select the slow movement. It is important to understand the influence of movement frequency and speed on sensory function during physical therapy. Therefore, we examined the effects of repetitive finger movements performed at different frequencies on the sensory system of the ipsilateral upper arm [8]. The sample consisted of 13 healthy adult subjects. The SEPs were recorded by stimulating the right median nerve during movement of the right index finger and while at rest. The subjects were required to perform motor tasks involving repetitive flexion and extension of the metacarpophalangeal (MP) joint of the right index finger, and the movement frequencies used were 0.5, 1, and 3 Hz. The amplitude and latency of SEPs are shown in **Figures 1** and **2**. There was no significant difference in the N9 and N13 amplitudes between rest and task conditions. The amplitudes of the N20 and P25 waveforms were significantly lower at a movement frequency of 3 Hz than those at rest. The latencies of the N9, N13, N20, and P25 waveforms were not significantly different between rest and task conditions.

In this study, the SEPs recorded from the ipsilateral brachial plexus and nucleus cuneatus did not change even if the frequency of repetitive movements of the right index finger was increased. It was suggested that repetitive movements at 3 Hz suppress somatosensory inputs to areas higher in level than the 3b. This inhibition was likely due to an increase in the movement frequency. Sadato et al. reported that significant activation of the primary somatosensory cortex was not observed during flexion of the right index finger at movement frequencies of 0.25 and 0.5 Hz but reported that significant activation was observed as the frequency increased from 1 to 4 Hz [9]. Blinkenberg et al. reported that the contralateral primary motor cortex, primary somatosensory cortex, supplementary motor cortex, and cerebellum were activated at movement frequencies of 0.5–4 Hz during finger tapping movement of the right index finger [10]. In addition, they reported a significant positive correlation between the movement frequency and cerebral blood flow in the primary motor and primary somatosensory cortices. Similarly, this study also noted a possibility of increase in the exercise-related area or the extent of activation with an increase in movement frequency. In addition, it was possible that sensory inputs to proprioceptors and mechanoreceptors increase

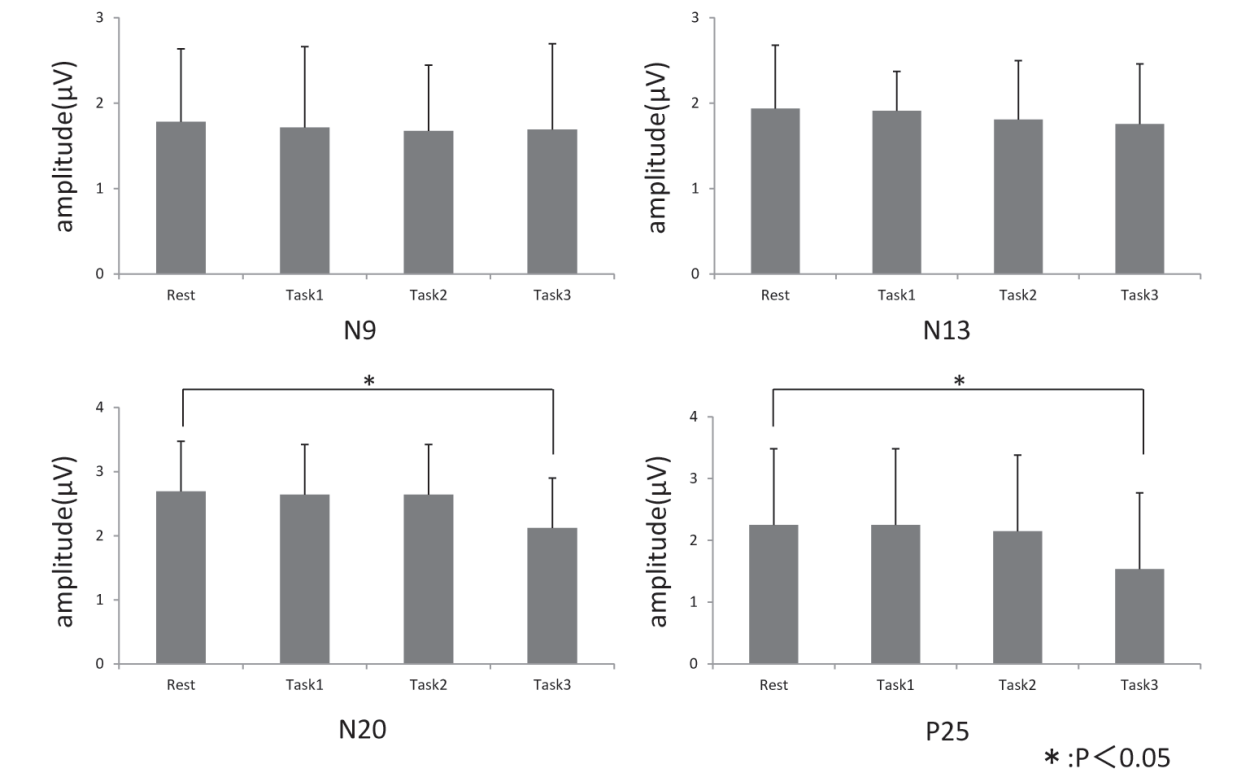


Figure 1. The change on the somatosensory-evoked potential amplitude when repetitive finger movements performed at different frequencies.

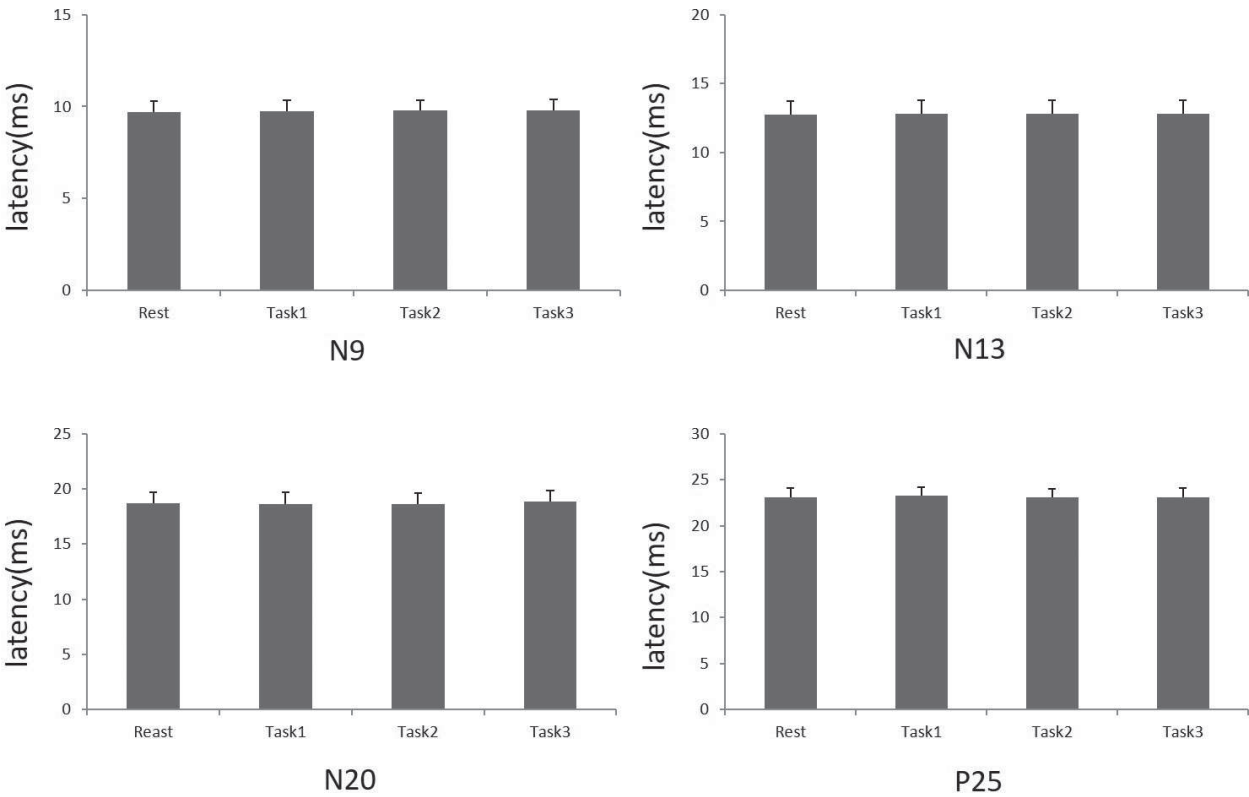


Figure 2. The change on the somatosensory-evoked potential latency when repetitive finger movements performed at different frequencies.

with movement. In precedence study of SEPs, it reported that the SEP amplitude decreased with an increase in the movement speed [4]. Both centripetal gating and centrifugal gating mechanisms might play a role in this effect. Similarly, this study also noted the possibility of suppression of the somatosensory input by the two gating mechanisms at a repetitive finger movement frequency of 3 Hz. Repetitive finger movements at low frequencies (such as in tasks 1 and 2) may elicit significant activation of exercise-related areas and decreases in the sensory input. Therefore, it was not affected by gating and no change in somatosensory inputs between rest and task conditions was expected. Cheron et al. reported that most gating arises in the cortex [11]. In this study too, it was considered that gating occurs at the cortical level, which may be the reason for why no change was observed in the nucleus cuneatus activation.

3. Effects of non-periodic repetitive finger movements on the short-latency somatosensory-evoked potentials

Periodic movements, such as walking, involve patterns of movement that mainly employ feed-forward neural mechanisms. On the other hand, non-periodic and unpredictable movements require sensory feedback for online modulation of movement. It is believed that the exercise programs employed for periodic and non-periodic movements are different. Therefore, we studied the effects of non-periodic repetitive finger movements on short-latency somatosensory evoked potentials (SEPs) [12]. A total of 11 healthy adult subjects were included in the study. The motor task involved flexion and extension of the right index finger MP joint in response to a specific auditory signal. Task 1 involved presenting a sound with a 1000-ms periodic interval, while task 2 involved randomly presenting sounds with 750-, 1000-, and 1250-ms periodic intervals. The number of movements performed during each task was the same. The amplitude and latency of SEPs are shown in **Figures 3** and **4**. The N9 and N13 amplitudes were not significantly different between rest and either of the tasks. The N20 and P25 amplitudes were significantly lower in task 2 than at rest. The N9, N13, N20, and P25 latencies were not significantly different between rest and either of the tasks.

This study suggests that non-periodic movement were decreased of the N20 and p25 amplitudes. In addition, it was guessed that non-periodic movement were suppress somatosensory inputs to areas higher in level than the 3b. Thaut reported that changes of 20% or more from the baseline interval due to sound was able to easily notice a change of time interval [13]. In this study, the time interval of non-periodic movement was set to 25% of that before and after 1000 ms. Laultz et al. reported that when comparing periodic and non-periodic movements, cerebral blood flow related to non-periodic movement was significantly higher in the ipsilateral cerebellar nuclei, contralateral thalamic dorsal lateral nucleus, and contralateral sensory motor area [14]. This report indicated that the activity in the cerebellum-thalamus-sensory motor pathway can control and correct the movement. Ivry et al. reported that the cerebellum lobus posterior pars lateralis participated in the regulation of exercise timing during non-periodic movements [15]. These reports show that non-periodic movement was influenced by the timing of exercise; this effect is mediated by the cerebellum lobus posterior pars lateralis and the online control of movement is achieved

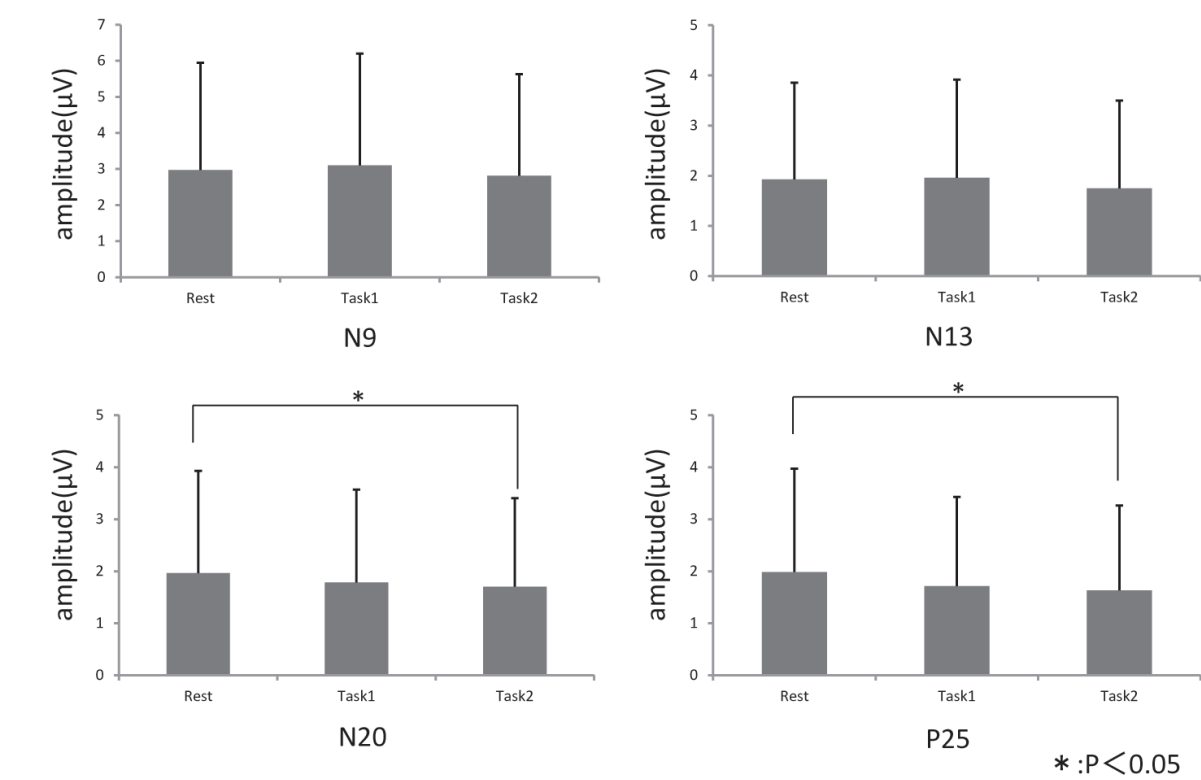


Figure 3. The change on the somatosensory-evoked potential amplitude when non-periodic repetitive finger movements.

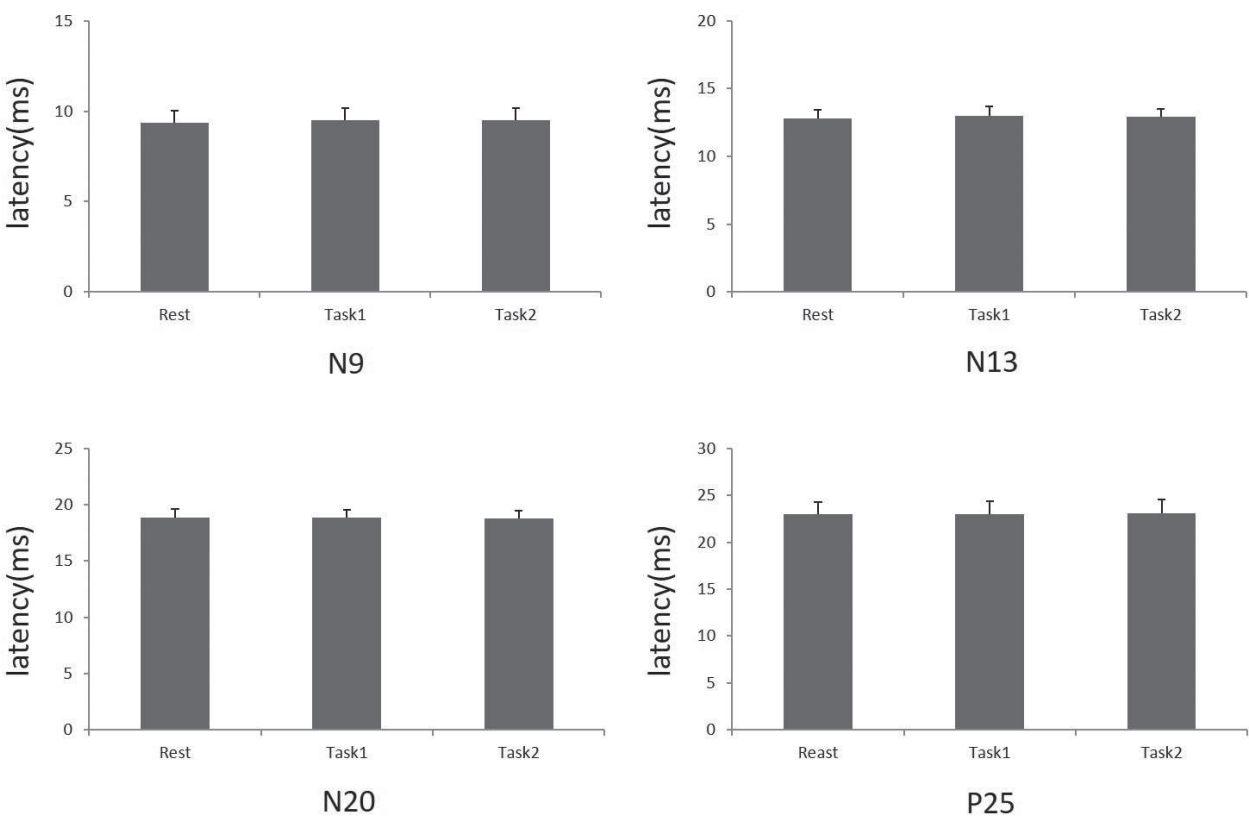


Figure 4. The change on the somatosensory-evoked potential latency when non-periodic repetitive finger movements.

through activity in the cerebellum-thalamus-sensory motor pathway. Furthermore, Ivry et al. reported that bilateral activities in the supplementary motor area, prefrontal cortex, gyrus cinguli, sensory motor cortex, and basal ganglia, and continuous attention paid to the time of non-periodic movement allowed for the prior preparation for the movement [15]. These reports showed that non-periodic movement was influenced by preparation and attention and timing and control. This study suggests that non-periodic movement was influenced to timing of exercise participating in the cerebellum lobus posterior pars lateralis and to controls exercise participating in the cerebellum-thalamus-sensory motor pathway. In addition, the results suggest that non-periodic movement is influenced by preparation, attention, timing, and control, and that this effect may be mediated by activity in the prefrontal cortex, gyrus cinguli, and supplementary motor area. However, it was reported that awakening (sleep/wake state) and attention influence long- and medium-latency SEPs, but not short-latency SEPs. In this study, decreases in the amplitudes of N20 and P25 SEPs were not influenced by the level of preparation or vigilance/awakening, and their amplitudes were influenced by exercise timing and control. The activity of motor-related areas was considered to have an inhibitory effect on the SEPs recorded from the somatosensory area, thalamus, and posterior nucleus. In addition, it was guessed that nerve cells possible to excited against somatosensory input by overlap of the motor-related area and electrical stimulation. Based on these findings, a mechanism underlying the effects of non-periodic repetitive finger movements on the SEPs was proposed: Activity of the cerebellum lobus posterior pars lateralis and cerebellum-thalamus-sensory motor cortex pathway inhibited activity in the thalamus and primary somatosensory cortex, which led to the inhibition of somatosensory inputs projecting from the primary motor cortex to the primary somatosensory cortex. And it was thought that refractory period occurred against stimulation of upper limb due to increase of activity of primary somatosensory cortex. Each amplitude of periodic movement showed no significant difference in each task compared with the rest. Sadato et al. reported that the activity of the primary somatosensory cortex in the flexion movement of the right index finger does not show a significant difference at the movement frequency of 4000 and 2000 ms [10]. However, it reported that a significant difference was recognized as increasing from 1000 to 250 ms. Del et al. reported that activity of the cerebellum was high with 500 ms than 2000 ms, 1000 ms in the tapping of the right index finger [16]. It was speculated that significant cerebellar activity was not recognized at an exercise frequency of about 1000 ms (such as that in task 1), and it was not affected by gating from exercise-related areas.

4. Clinical suggestion

In the early stages of motor learning, sensory feedback is required to identify and understand the expected movement. Movement using sensory feedback is slow, which allows for online correction of movement mediated by the cortex. Low-frequency movements (0.5 and 1 Hz) were not observed to be suppressed by sensory inputs, while high-frequency movements (3 Hz) were suppressed by sensory inputs. For performing smooth high-frequency movements, it is critical to suppress unnecessary sensory inputs. Moreover, it is necessary to suppress unnecessary sensory input while performing non-periodic movements for timing adjustment

and motion control. Based on the results of this study, low frequency movement and periodic movement are considered beneficial while performing physical therapy aimed at stimulating sensory inputs. As motor learning progresses, it is necessary to introduce high-frequency and non-periodic movements in the therapy protocol. Thus, the frequency and style of movement and the stage of motor learning must be taken into account when determining the sensory inputs to be used in a physical therapy regimen.

5. Conclusion

It has been consistently reported that the SEP amplitude decreases during exercise. It was believed that this reduction in SEP amplitude suppresses the sensory input by gating and allows for smooth motion control by making use of only the necessary somatosensory information. Therefore, it is important to understand the relationship between sensory input and motor output when performing physical therapy.

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