Opponens pollicis silent period during a precision motor task with the isometric contraction of the ipsilateral knee extension

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ABSTRACT:

To clarify the excitability of the central nervous system function via a difference in the feedback method, we examined the alterations in the duration of the silent period recorded from the opponens pollicis muscle during a precision motor task by cross-sectional study with an A-B-A task-order design. This task involved isometric knee extension using visual feedback and verbal conduction. 12 healthy adults (7 males and 5 females; mean age: 23.7 ± 2.1 years) participated in this study. SP was recorded from the opponens pollicis muscle during a precision motor task involving with isometric contraction during ipsilateral knee extension with constant torque by two kinds of feedback. The precision motor task was carried out as follows; Subjects maintained knee extension torque at a constant strength using the BIODEX SYSTEM 3 with 60° of knee flexion. The knee extension torque was set at 25% of individual maximum effort. We monitored the torque using two methods. The first method used subjects’ own visual feedback with gazing at the BIODEX screen (Task A). The second task featured torque adjustment by the examiner’s verbal instruction. Subjects’ eyes were bandaged to eliminate visual feedback (Task B). Silent period was recorded from the opponens pollicis muscle while subjects maintained ipsilateral isometric knee extension during an A-B-A task order. As a stimulus condition, a constant current rectangular wave with a frequency of 0.5 Hz and a duration of 0.2 ms, was added 16 times in the median nerve at the wrist with the intensity of supra-maximum, which maximal M wave was evoked. We compared the duration of silent period between tasks in each dominant and non-dominant side. As the result of this study, there was no significant difference on the dominant leg side. However, during Task B on the non-dominant leg side, the duration of silent period was shortened (Tukey’s test, p = 0.01, 0.08). In conclusion, during less-skilled motor adjustment using the non-dominant leg, the motor control with verbal conduction and no visual feedback requires more afferent activation. In these cases, central nervous system function excitability associated with ipsilateral upper extremity increases, even if the task involves the lower extremity.

KEY WORDS silent period; electrophysiology; cortical excitability; Motor skill
INTRODUCTION

The mixed nerve silent period is defined as the electrical inactivity, which is a transient suppression of muscle activation, produced by electric stimulation to the innervating nerve during continued muscle effort [1]. This period results from several physiological mechanisms. In our previous study, we longitudinally investigated the silent periods, recorded from soleus muscle during rehabilitation process after anterior cruciate ligament reconstruction of the knee [2] [3]. Here, the silent period was shortened and long latency reflexes, which usually disappear during the silent period, emerged. This suggested increased excitation of supraspinal nerves during repetitive training and high-level task learning.

To pursue these factors, it is needed to verify the alteration of electrophysiological index under several conditions such as swelling, ischemia (blood flow), skillfulness and difficulty of recording conditions, and so on. In our previous study, the aspects of the long latency reflex from opponens pollicis muscle during ipsilateral sustained knee torque using a different feedback task was investigated [4]. In that study, the late components of the long latency reflex increased in the non-dominant side with the torque maintenance using examiner verbal feedback (without subjects’ own visual feedback) than with the subjects’ own visual feedback. Central nervous function excitability relating to upper extremity function increased with increasing motor task complexity, even if in the task involved the lower extremity.

In this study, we investigated silent period variation recorded from opponens pollicis muscle during sustained maintenance of isometric knee extension torque with or without visual feedback, which is same condition as the previous study.

METHODS

12 healthy adults participated in this study. There were 7 males and 5 females (mean age: 23.7 ± 2.1 years), with normal neurological and musculoskeletal system function. The dominant leg regulated the kicking of the ball. All study tasks were carried out in accordance with the Declaration of Helsinki. Prior to experiment, according to the decision of the board meeting of the institution belonged first author, we explained in advance the outline and invasion of this experiment and the presence / absence and form of publication, and then conducted subjects who obtained written consent to the purpose of this experiment.

The experimental situation is displayed on Figure 1. The outline of experiment was as follows;

1. Measurement of maximal knee extension torque
2. Sustained contraction of 25% of maximal knee extension torque at 60 degrees knee flexed position by two kinds of feedback methods; visual and verbal guidance
3. Silent period was evoked during sustained contraction of knee extension from opponens pollicis muscle
4. Results of silent period were compared with alteration of feedback methods and between dominant and non-dominant

The silent period from the ipsilateral opponents pollicis muscle was recorded during a precision motor task involving isometric contraction during knee extension each dominant and non-dominant side. The precision motor task was carried out as follows. Subjects maintained knee extension torque at a constant strength using the BIODEX SYSTEM 3 (Biodex Medical System, Inc.). As shown Figure 1, the knee extension torque was set at 25% of individual maximum effort with 60° of knee flexion. The torque was monitored on the screen and instructed by following two methods. The one was the subjects’ own visual feedback with gazing at the BIODEX screen (Task A) and the another was the examiner’s verbal instruction under the condition of subjects’ eyes were closed (Task B).

The silent period was recorded from the opponens pollicis muscle during maintaining isometric knee extension under the A-B-A task order. As a stimulus condition for recording the silent period, a constant current rectangular wave with the frequency of 0.5 Hz, the duration of 0.2 ms and the numbers of 16 times was added in the median nerve at the wrist. And the intensity was supra maximum, which the maximal M wave can be evoked. It is needed the muscle contraction to evoke the silent period. So subjects performed a gentle grasping the rubber ball to elicit the contraction of opponens pollicis muscle. We calculated the average of the duration of silent period from waveforms generated during each trial. We compared the durations, between tasks on both the dominant and non-dominant sides.

Statistical analyze: By using repeated measure ANOVA we tested the effects of feedback methods (A-B-A difference). Post hoc analysis for within group effect was applied by using the Tukey’s test. And to compare the between dominant side and non-dominant side, a paired t-test was used. All statistical analyses were conducted at the 95% level of significance.
ISOMETRIC CONTRACTION OF THE IPSILATERAL KNEE EXTENSION

Figure 1. Experimental Situation.

Figure 2. Typical waveforms.
Subject: 25-year-old male. The figure is a superimposition of 16 waveforms in each task.

Sweep: 20 ms / div, Amplitude sensitivity: 10 mV / div, (up to 20 ms), 500 μV / div (after 20 ms).
Table. Silent period between Task A and B

|                      | Task A          | Task B          | Task A          |
|----------------------|-----------------|-----------------|-----------------|
| Dominant leg side    | 109.1 ± 5.2     | 105.2 ± 7.2     | 107.6 ± 6.7     |
| Non-dominant leg side| 111.3 ± 6.1     | 105.9 ± 4.4     | 109.3 ± 4.4     |

Silent periods were shortened on the non-dominant leg side in Task B (Tukey’s test, p = 0.01*, 0.08**).

STATISTICAL RESULTS

Typical waveforms acquired during this study are shown in Figure 2. The duration of silent period recorded from opponens pollicis muscle on the dominant leg, was 109.1 ± 5.2 ms (Task A), 105.2 ± 7.2 ms (Task B), and 107.6 ± 6.7 ms (Task A). And those on the non-dominant leg was 111.3 ± 6.1 ms (Task A), 105.9 ± 4.4 ms (Task B), and 109.3 ± 4.4 ms (Task A) (Table). There was no significant difference in the duration of silent period on the dominant leg side. However, during Task B on the non-dominant leg side compared with the one of Task A, the duration of silent period was tended to be shortened (Tukey’s test, p = 0.01, 0.08).

DISCUSSION

The duration of silent period in this study reflects the total circuit time from the peripheral nerve stimulus point to the central nervous system. M wave, F wave (V1 response), and long latency reflexes (V2 response) are included in the evoked electromyographical silent period[5] [6]. Therefore, the shortening of the duration of silent period indicates the neurological temporal and spatial concentration and summation, and it demonstrates the increase of the excitability of the corticospinal function. Also, the large variation of the duration of silent period in each trial represents that the electrical stimulus given to median nerve thorough the skin at the wrist may arrive at various levels, which is brainstem, midbrain and so on, of the central nervous system, and this can be paraphrased as the neurological temporal and spatial dispersion. Therefore, the alteration of the duration of silent period can become an index of the excitability of the central nervous function. We are attempting to apply silent period examinations to functional evaluation procedures in the field of physiotherapy and sports medicine [2] [3] [7-9]. On the other hand, in the study on the relationship between a precision motor task and nerve function, Pearce and Kidgell examined the little finger adduction muscle and found that precision and cortical excitability increased as task difficulty increased [10]. In contrast, for the influence of motor task of the limb on the contralateral extremity, the involvements of hemispheric inhibition during dynamic motor tasks [11] and reduced hemisphere inhibition during sustained contraction [12] have been reported.

In this study, we examined the relationship between the precision motor task of lower extremity and the excitability of the central nervous system function related to the ipsilateral upper extremity. The motor task we used involved sustained isometric knee extension using constant torque with visual feedback or verbal conduction (without visual feedback). When subjects adjusted torque using visual feedback, the output adjusted to the target torque via visual perception [13]; therefore, the possibility that it depends largely on feedforward control was considered. In contrast, when adjusting the torque using the examiners’ verbal conduction and not the subject’s own visual feedback, the use various afferent feedback including depth sense more advantageously than with the adjustment by visual perception was considered. In our previous study regarding the long latency reflex from the opponens pollicis muscle, the late component of the long latency reflex increased when subjects maintained constant isometric knee extension torque with verbal conduction and without visual feedback on the non-dominant leg side [4]. In this study, the duration of silent period from the opponens pollicis muscle was also shortened under the same condition as our previous study about the long latency reflex. It appears that the excitability of the central nervous system function related to the ipsilateral upper extremity increased during the precision motor task of non-dominant leg without visual feedback. In other words, it was cleared that the excitability of the central nervous system function increased, which resulted from the fine and difficult torque adjustment by verbal conduction without visual feedback, because the only verbal instruction without visual feedback is more difficult than that of by visual feedback.

In the field of physiotherapy, the task needs to be performed nearly unconsciously, using minimum awareness and attention in raising difficulty of exercise task. The involvement of the central nervous system is greater during high-difficulty tasks, until adequate skill levels are acquired. Therefore, under the process of the acquisition of various motor
function, we recommend setting the feedback method individually for each subject, to facilitate smooth and unconscious operation.

The limitation of this study was that we selected as the healthy subject but not athlete. And mixed nerve silent period was express as the peripheral phenomenon although cortical alteration. So, in the future, farther research by cortical response via cortical i.e., trance cranial magnetic stimulation with athlete was needed.

**Conclusion:** During less-skilled motor adjustment using the non-dominant leg, the motor control with verbal conduction and no visual feedback requires more afferent activation. In these cases, central nervous system function excitability associated with ipsilateral upper extremity increases, even if the task involves the lower extremity. In returning to sports, evaluation of central nervous system function is recommended because there is a fear that recruitment of central nervous function is not normal in the case with a problem with skillness in exercise.

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