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Surface electromyography of lower extremity muscles during the sustained isometric knee extension compared with a difference of the feedback method.

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ABSTRACT:

In the physical therapy after the musculoskeletal disorder, we often experience cases with fearfulness in their activity due to not a weakness but a poorness of exertion of muscle strength. In this study, to clarify the relationship between the feedback type and the performance of adjustment of the muscle performance, characteristics of muscle output during the maintaining a constant torque with an alteration of the feedback methods was investigated. Subjects were twenty healthy males, who maintained isometric contraction of knee extension at 60 degrees flexion using BIODEX. EMG was recorded from bilateral tibialis anterior, medial gastrocnemius, peroneus, vastus medialis, rectus femoris and vastus lateralis. As the feedback task, the presence or absence of visual feedback (VF) and verbal instruction (VI) was adopted as follows; A: VF without VI, B: VI without VF, C: neither VF nor VI. And following parameters were compared: Integral EMG (IEMG), the area constituted by torque curve and target torque line, and the number of intersections of torque curve and target torque line. There was no significant finding in the IEMG among task A, B and C, and in the result of the areas between tasks of non-dominant side leg. However, IEMG of task C was significantly increased than task A in dominant side. The intersected number of task A significantly increased than task C, bilaterally. There was a large difference between the demonstrated torque and the target torque in task C. So, there was a clear difference for the degree of difficulty between tasks. However, the clear findings in EMG were not obtained. From the result of this study, there is a need to continue to study in combination of EMG and other indicators.

KEY WORDS muscle strength, feedback, torque, electromyography

INTRODUCTION

In the field of sports physiotherapy, for the return to play after musculoskeletal injury, some people can smoothly return to competition despite the insufficient physical findings. On the other hand, there is the case who sports activity cannot be acquired smoothly despite no problem in physical findings such as muscular strength, range of joint motion, performance battery test and so on. In the physiotherapy after the musculoskeletal injury, we often experience cases with fearfulness in their activity due to not a weakness but a poorness of adjustability of muscle strength. Therefore, adjustability of muscle strength is important as well as maximum value of muscle strength and endurance [1]. A decrease in this ability can have a negative impact on daily life (e.g., postural maintenance, coordination of fine movements, etc.) and sports performance. However, the physiological and adaptive mechanisms that influence adjustability of muscle strength are unknown. Therefore, it is currently impossible to create effective programs to improve steadiness.

The changes in nerve function in the maintenance of constant muscle exertion are considered influencing changes in excitability of the upper centers and changes in peripheral muscle activity and other factors. Daikuya et al. [1,2] reported on the relationship between proprioceptive sensation of the knee joint and excitement of central nervous function in healthy participants without sports habits. The aspect of Long Latency Reflex in the upper limb during constant muscle strength of knee extension was examined. And, the results suggested that the excitability of central nervous function related to the upper limb may increase when adjustment is required in motor tasks of the lower limb [1]. In addition, to clarify the excitability of central nervous function in feedback methods such as visual feedback and without auditory, changes in the duration of silent periods recorded from the opponens pollicis muscle during the motor task were examined. And, the results suggested that when motor control of the non-dominant side is not skillful, motor control without auditory and visual feedback requires more afferent activation [2]. From the above, the aspect of proprioceptive sensation related to the adjustment of knee extensor muscle strength is related to the excitability of central nervous system function during the adjustment of knee extensor muscle output.

The purpose of this study was to clarify the possibility of changes in excitability of the upper center due to changes in peripheral muscle activity as one of the factors of the results obtained in previous studies. For this purpose, the deviation from target torque and the aspect of muscle activity as peripheral function were examined and whether the force product of the area and the number of point of intersections during isometric contraction become one of index which indicate adjustability of muscle strength or not. And, the characteristics of muscle output during constant torque with different kinds of feedback methods were examined adjustability of muscle strength.

METHODS

Participants were twenty healthy males (Age: 27.5 ± 4.1 years) who did not show any abnormality in the neurological function and musculoskeletal system. All study tasks were carried out in accordance with the Declaration of Helsinki. Prior to the experiment, all of the participants were informed the purpose of this study based on the descriptions, and their agreement for participation was obtained from all of the participants. This study was approved by the Ethical Review Committee of our Hospital.

The experimental situation was the knee extension torque was maintained of isometric contraction at the 60 degrees flexed position of knee joint using BIODEX system3 (BIODEX). The duration and intensity of contraction was 20 seconds and 25% of their individual peak torque of maximal voluntary isometric contraction.

During the task, Electromyography (EMG) of tibialis anterior (TA), medial gastrocnemius (MG), peroneus longus (PL), vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL) was recorded. Electrodes were placed approximately in parallel with the muscle fibers over the muscle bellies using Myosystem1400 (Noraxon). The skin was carefully prepared by rubbing with abrasive gel and alcohol. The distance between electrodes was 20mm. Pairs of surface electrodes were put the following: TA; the approximate midpoint of the muscle belly, MG; 7 cm below the caput fibulae, PL; 2cm distal to the head of the fibula, VM; 15 cm above the base of patella, RF; 15 cm above the base of patella, VL; 8 cm above the base of patella [3-5]. The EMG data were band pass filtered (10 - 500 Hz) prior to sampling at 1 kHz.

BIODEX system3 and Myosystem1400 were synchronized. The obtained signal was A/D converted (Analog-to-Digital Conversion) and loaded into a personal computer. Relative value of integrated EMG (IEMG) was calculated, and it was divided by IEMG of the rest position, and the value was adopted as the average amplitude value. The force product of the area in the torque curve during isometric contraction of knee extension deviated from the target torque line was calculated (Figure1). And, the number of intersections with the torque curve during isometric contraction of knee extension using the target torque line was also determined. Relative value of IEMG, force product, and number of point of intersections were calculated by analyzing 10 seconds within the 20 seconds of measurement time, excluding the 5 seconds at the start and end (Figure1).

As the feedback condition, the presence or absence of visual feedback (VF) and verbal instruction (VI) was adopted as follows; Task A: VF without VI, Task B: VI without VF, Task C: neither VF nor VI. And following parameters were compared: Relative value of IEMG, the area constituted by torque curve and target torque line, and the number of intersections of torque curve and target torque line. One-way analysis of variance was used to determine the effects of the relative value of IEMG, the areas and the intersected number. And, Tukey's post-hoc test was used to identify significant comparisons. For the data analysis, SPSS Statistics 24.0 for Windows (IBM SPSS Japan, Tokyo, Japan) was used. The significance level was determined at 0.05.

STATISTICAL RESULTS

The results of the measured parameters are shown in Table 1 and Figure 2,3.

There was no significant finding in the relative value of IEMG among Task A, B and C, and in the result of the areas between tasks of non-dominant side leg. However, the area of Task C (23.8 ± 24.8 Nm・sec) was significantly increased than Task A (10.9 ± 4.7 Nm・sec) in dominant side ($p < 0.05$). The intersected number times of Task A (dominant / non-dominant: 146.6 ± 58.6 times / 138.3 ± 75.8 times) significantly increased than Task C (dominant / non-dominant: 73.1 ± 83.7 times / 73.5 ± 80.4 times), bilaterally ($p < 0.05$).

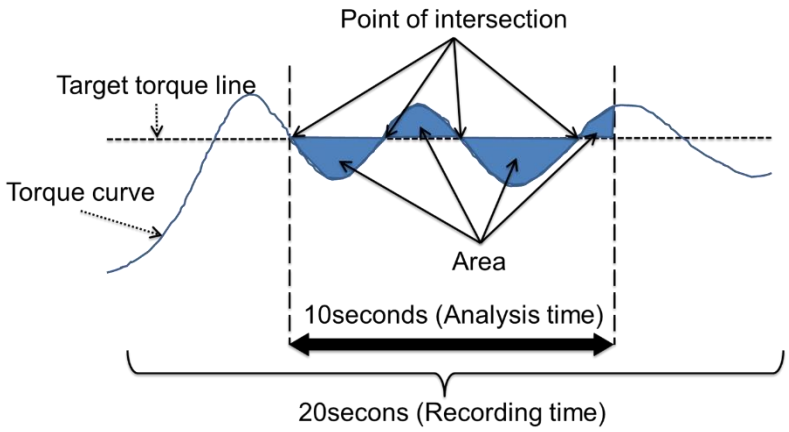

Figure 1. Calculation of the area and point of intersection (schematic figure)
The area constituted by torque curve and target torque line.
The number of point of intersections in torque curve and target torque line.

Table 2. Relative value of IEMG

	dominant side			non-dominant side		
	TaskA	TaskB	TaskC	TaskA	TaskB	TaskC
TA	11.8 ± 4.9	11.3 ± 4.4	11.3 ± 4.4	17.1 ± 23.6	11.3 ± 4.1	11.8 ± 5.0
MG	16.0 ± 10.2	16.4 ± 10.9	16.9 ± 13.7	14.5 ± 6.5	15.5 ± 7.1	15.3 ± 7.9
PL	9.9 ± 2.8	9.9 ± 3.0	9.9 ± 3.5	9.9 ± 3.0	10.0 ± 3.4	10.3 ± 3.5
VM	35.7 ± 16.2	35.7 ± 16.3	35.7 ± 15.2	47.7 ± 23.4	46.3 ± 22.4	47.7 ± 24.2
RF	76.5 ± 33.7	74.2 ± 33.7	72.9 ± 32.7	68.6 ± 47.6	67.5 ± 49.3	68.8 ± 47.8
VL	46.8 ± 33.7	47.0 ± 32.8	45.9 ± 34.3	60.6 ± 42.8	60.8 ± 43.5	61.5 ± 41.2

Mean ± SD.

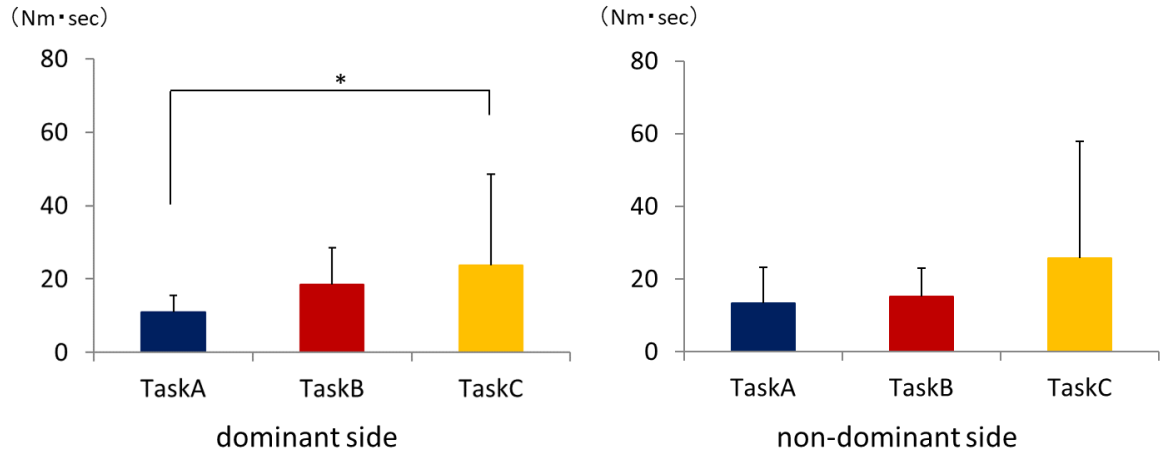

*Figure 2. The force product of the area in the torque curve during isometric contraction of knee extension. The area of Task C was significantly increased than Task A in dominant side. *: p < 0.05.*

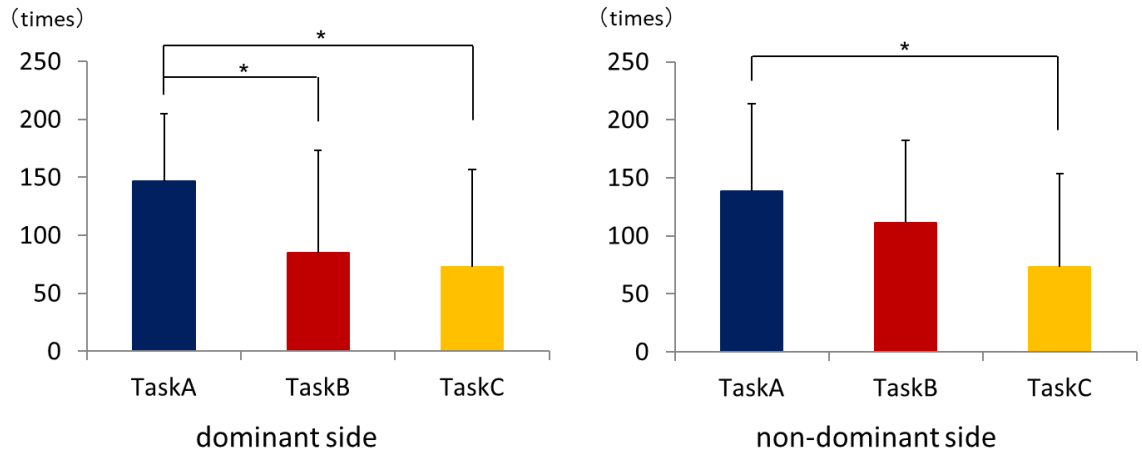

Figure 3. The number of point of intersections in torque
*The intersected number times of Task A significantly increased than Task C. *: p < 0.05.*

DISCUSSION

In this study, the characteristics of muscle output when maintaining a constant torque with a different kind of feedback methods were examined targeting the knee extensor muscle group, which has an important role in sports performance, because degree of difficulty is different by difference of the feedback. Relative value of IEMG, the force product of the area and the number of intersections of torque were adopted as an index. The increase of the area shows that the many errors and torque

curve depart from target torque line were existed. Also, the increase of the number of intersections shows that the trial to make fine adjustments to output of a muscle contraction force were presented.

In this result, to make an error was confirmed much at Task C more than Task A in dominant side. In addition, the increase of the number of point of intersections was indicated much at Task A more than Task C, Task A more than Task B in dominant side. And, the increase of the number of point of intersections was found much at Task A more than Task C in non-dominant side.

Therefore, it was considered that the knee extension torque could be controlled by fine adjustment at both Task A more than Task C and Task A more than Task B. Also, in the dominant side, differences of feedback method between tasks were observed in several parameter items, however, in the non-dominant side, the differences of feedback method were only between Task A and Task C in the number of point of intersections.

The result indicated that the non-dominant side had less adjustment ability than the dominant side, and differences of feedback had less effect on the parameter items. Thus, we assumed that to slight adjustment with muscle activity of lower leg and participation of the central nerve function are necessary for difficult task. However, the clear findings in relative value of IEMG were not obtained. As the reason why relative value of IEMG didn't change, torque curve was moved the same degree based on the target torque line. As a hypothesis, we thought that the degree that the muscle contraction becomes strong and the degree that the muscle contraction becomes weak were the same degree.

In dominant side, there was a different adjustability of muscle strength by feedback method. On the other hand, in non-dominant side, there was little different adjustability of muscle strength by feedback method. It was found that there was a different pattern to adjust the muscle strength between dominant side, which is thought high adjustability of muscle strength and non-dominant side, that is thought low adjustability of muscle strength. For that reason, the force product of the area and the number of point of intersections during isometric contraction using this time were thought that it may become one of index which indicate adjustability of muscle strength. It was cleared that to set the feedback method individually in dominant side and non-dominant side, to adjust muscle strength and unconscious operation under the process of the acquisition of various motor function.

From the result of this study, when the constant knee extension torque kept by VF or VI, the area and the number of intersections was change with a difference of the feedback. However, muscle activity of lower extremity was not change.

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