Parameter change of propagating waves in dominant arms and non-dominant arms using multichannel surface electrogram

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***Abstract*— In this study, muscle potentials were obtained by applying various loads to the dominant arm and the non-dominant arm, and analysis was performed using the Multi Channel method (m-ch) to investigate the muscle contraction mechanism. In the conventional methods, only the size of the integrated electromyogram was compared, but according to the m-ch method, the type of motor units active in the dominant arm and the non-dominant arm, and the tendency of motor units to participate in the contractile activity of each arm was clarified.**

***Keywords*— dominant arm, non-dominant arm, surface EMG, motor unit, multi channel method**

I. Introduction

Skeletal muscle is a type of striated muscle, attached to the skeleton and they are used to facilitating movement, by applying force to bones and joints via contraction. Skeletal muscle is made up of thousands of muscle fibers that run the length of the muscle. An action potential occurs when the membrane potential of a specific axon location rapidly rises and falls[1]. Action potential of muscle fibers is related to the neuromuscular junction which is a chemical synapse formed by the contact between a motor neuron and a muscle fiber. Within a muscle, the muscle fibers are functionally organized as motor units (MU). A motor unit consists of a single motor neuron and all of the muscle fibers it innervates. There are 2 different types of motor units: 1) Fast motor units 2) Slow motor units. While the Slow motor units do not produce as much force as fast motor units, they are able to develop the force in a relatively long period and they are very resistant to fatigue compare to Fast motor units. The propagation velocity of the action potential is called muscle fiber conduction velocity[2][3][4][5], and surface EMG is used for measurement[6][7] [8][9] [10].

In the previous work [11] [12] [13] [14], Kosuge et al. proposed a method (m-ch method) of extracting all propagation waves from multi-channel surface EMG and quantitatively determining the velocity and number of them to investigate the features. A calculation method was designed to measure the conducting waves' propagation velocity.

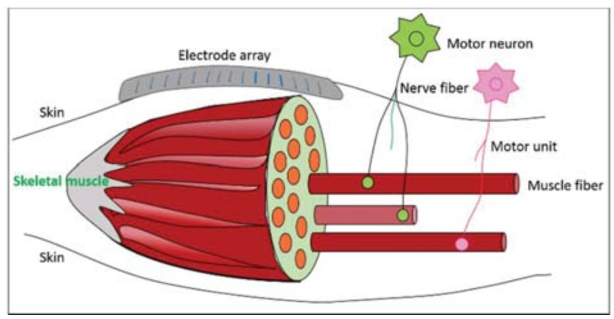

Fig. 1. The structure of muscle

As an application for efficient muscle strengthening training, consideration is given to the type of motor unit involved in contraction from the parameter change of the dominant and non-dominant arms obtained by using the m-ch method. There are few studies [15] on dominant and non-dominant arms using Integrated Electromyogram and they had been considered just on amplitude. There is no consideration on the type of MU, such as the slow and fast motor units.

In this study, we analyzed the difference of muscle fibers composition and influence on cortex and spinal cord from the type of MU in dominant and non-dominant arms. It is expected that the results of this research will be a new indicator for strengthening muscle during rehabilitation and training.

II. Experiment

In the experiment, the biceps brachii muscle of left and right hands was used as the test muscle. The subjects were 5 healthy adult males with an average age of 22. The subjects were asked to keep the elbow joint angle at 90 degrees in the sitting position to measure 100% of their maximum voluntary contraction (MVC); maximum muscular strength. After that the subjects were asked to keep the same posture for 2 different experiments.

1) 30 seconds with 10% of the maximum exertion muscle load of each arm

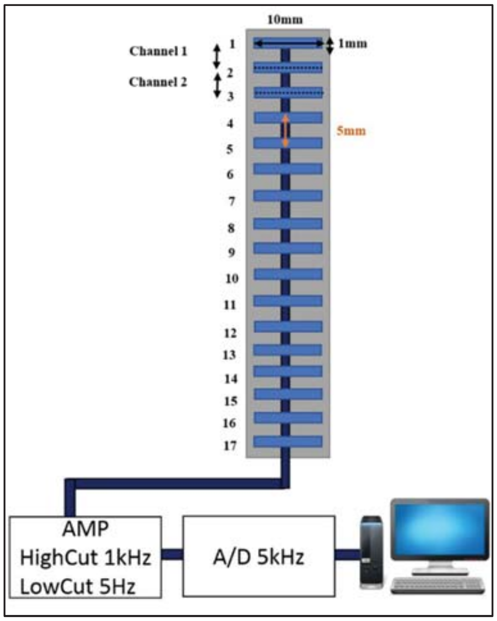

Figure 2. Electrode array

2) 10 seconds with 40% of the maximum exertion muscle load of each arm

And data were acquired. For cutoff frequency, the high-pass filter (Low Cut Filter) was set to 5Hz and the low-pass filter (High Cut Filter) was set to 1kHz. The amplification factor was 80dB and the sampling frequency was 5kHz. All the data was input to a computer to be analyzed. Data was collected for 10 minutes. Next, collected data was analyzed with the high-pass filter (Low Cut Filter) at 5Hz, and the finite impulse response (FIR) filter was added just in case of being sure to define right filters. The experimental system is shown in Fig. 2 and the results and analysis are presented in this paper.

III. Method

In this research, Multi Channel (m-ch) method had been used for analysis. The interval where the zero crossing occurs twice is defined as the analysis unit, and the channel with the analysis unit is defined as the conduction source. The adjacent channels around the conduction source that are within 10 ms before and after the starting point of it (the conduction source) are defined as the conduction destination. The propagation determination is performed over multiple channels, and then the propagation velocity is calculated. In the propagation judgment, if the shape of waveforms between channels is similar, it is determined to be a propagation wave, and the similarity ratio and wavelength ratio are 0.9 Hz or more, and the amplitude ratio is 0.7 dB or more.

IV. Result and Discussion

①It can be seen that by increasing the load from 10% MVC to 40% MVC, propagation waves with high amplitude values for both dominant and non-dominant arms were extracted. On the other hand, the number of propagating waves extracted per second from the dominant and non-dominant arms were different depending on the load applied.

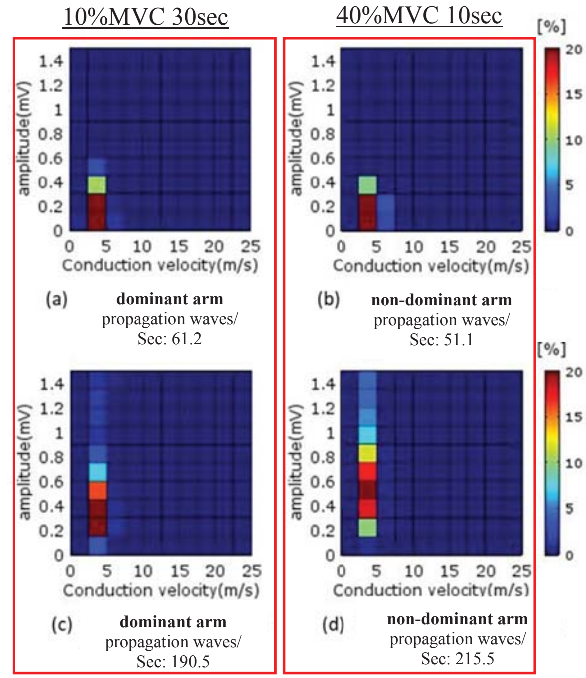

Figure 3. The relation of frequency and Speed of waves in dominant and non-dominant arms

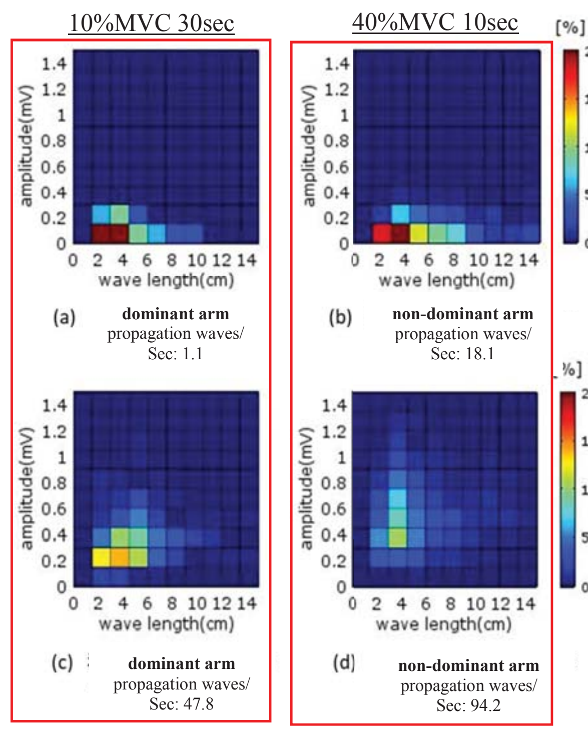

Figure 2. The relation of frequency and length of waves in dominant and non-dominant arms

For a load with 10% MVC, the number of propagating waves in the dominant arm was extracted more than in the non-dominant arm. On the other hand, when the load is 40% MVC, the number of propagating waves in the non-dominant arm was more than the dominant arm.

For 10% MVC, which is likely similar to a load which will be used even in daily life, it is speculated that there are many

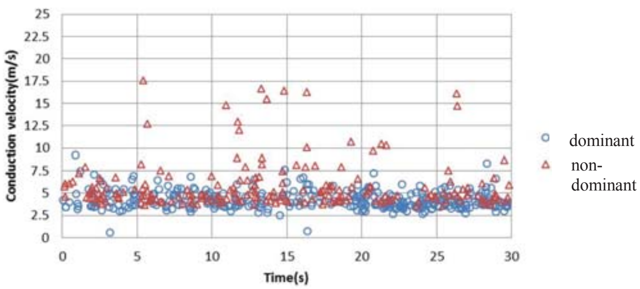

Figure 3. Change of speed over time

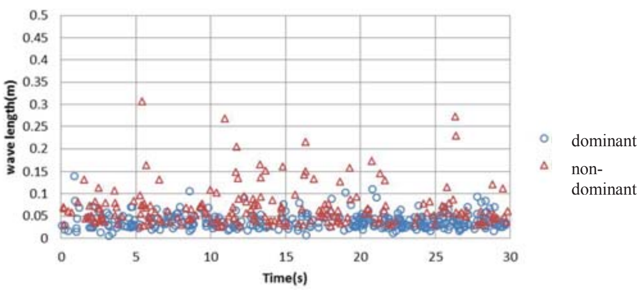

Figure 4. Change of length over time

MUs of the dominant arm that participate in the contraction activities compare to the non-dominant arm. For 40% MVC, which is an extraordinary load, in the non-dominant arm, it is considered that more Mus ignite than the dominant arm to bear the load. The results are shown in figure 3.

② For 10% MVC load, it was confirmed that the distribution spreads relatively similar in the dominant arm among multiple subjects. In the case of a small load (10% MVC) that can be felt in daily life, the MUs of dominant arm participates in the activity, so it is possible that a certain distribution appears. On the other hand, it was possible that if a large load (40% MVC) was used that could not be felt in daily life, a large number of MUs which participate in muscle contraction might be seen on the dominant and non-dominant arms in order to be able to carry the excessive load. For 40% MVC load, the MU needs to perform contraction activity in a large block, so the distribution is considered to be large. The results are shown in figure 4.

③About the time-dependent change of the propagation wave parameter extracted by 3ch propagation judgment of m-ch method, it investigated about the waveform feature in measurement of load 10% MVC for 30 seconds. The amplitude value, propagation velocity and wavelength on the vertical axis and time on the horizontal axis are shown in Figures 5 and 6 respectively. There was no tendency for the amplitude value to change with time.

It can be seen from Fig. 5 that the non-dominant arm tends to extract the propagating wave with a little faster propagation speed than the dominant arm, with respect to the temporal change in the propagation speed. In the non-dominant arm, it is considered that not only the slow MUs but also the fast MUs temporarily participated in the muscle contraction for a load of 10% MVC. Since fast MU is a muscle fiber that is more easily fatigued than slow muscle, the number of Mus participate in muscle contraction decreased after 20 seconds from the start of measurement. In the non-dominant arm which less frequently used as compared to the dominant arm, the MU of the fast muscle tends to participate in the activity over time for the load of 10% MVC.

As shown in Fig. 6, the wave length in non-dominant arm tended to be higher than the dominant arm. It has been thought that for a daily load of 10% MVC, the number of igniting MU of the non-dominant arm is higher than the dominant arm. In addition, since the wavelength of the non-dominant arm tends to increase in 10 to 20 seconds, the effect of muscle fatigue can be seen. It is assumed that in the non-dominant arm, which is used less frequently on a daily basis, the effect of fatigue tends to be more visible than the dominant arm, even with a 10% MVC load.

V. conclusion

In this study, various loads were applied to the dominant arm and the non-dominant arm to obtain muscle potentials. The analysis method was performed in this research is Mukti channel method and it had been used to investigate the muscle contraction mechanism in the dominant arm and the non-dominant arm. In the methods used in other researched, only the size of the integrated electromyogram was compared, but according to the m-ch method, the type of motor unit active in the dominant arm and the non-dominant arm, and the tendency of motor units to participate in the contractile activity of each arm was clarified.

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