Evaluation of Skeletal Muscle Contraction during
Pedaling of Recumbent Bicycle using MMG / EMG Hybrid Transducer

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Abstract: Electromyogram (EMG) is recorded electrical muscle contraction, mechanomyogram (MMG) indicates cross-sectional area change of muscle, reflect mechanical muscle contraction. By simultaneously measuring both signals, it is possible to multifaceted evaluation of muscle contraction. However, MMG measurement at voluntary movement was difficult. Therefore, the authors developed MMG / EMG hybrid transducer capable of simultaneous measurement of MMG and EMG. This study evaluated MMG and EMG of rectus femoris (RF) and hamstrings using recumbent bicycle of easy load regulation. As result, dMMGbase (baseline of displacement MMG) indicated cross-sectional area change of muscle at pushing down and pulling up of pedal. In addition, EMG and dMMGbase increased with pushing down of pedal in RF, dMMGacc (acceleration dMMGbase) showing muscle contraction force was output simultaneously. Each signal of hamstrings had output that antagonize RF. By simultaneously measuring MMG and EMG at recumbent bicycle pedaling, it was possible to evaluate muscle contraction of voluntary movement.

Keywords: Mechanomyogram, Electromyogram, Recumbent bicycle

1. Introduction
In evaluation of skeletal muscle contraction, simultaneous measurement of electromyogram (EMG) and mechanomyogram (MMG) is useful. Previously, the accelerometer was used in MMG measurements, it was necessary to measure by fixed body for effects of motion artifacts. Also, MMG measurement at the time of voluntary movement was very difficult. To solve this problems, the authors had developed small MMG / EMG hybrid transducer capable of simultaneous measurement of MMG and EMG. The transducer was equipped with a photo-reflector, it was possible to measure the baseline of displacement MMG (dMMGbase). The appearance of shape was a cantilever, Ag - AgCl electrodes for EMG were attached to lower support portion, shown in Fig. 1. It could be used during the exercise to have wireless function.

As introduction experiment to voluntary movement during body movement, this study evaluated MMG and EMG using MMG / EMG hybrid transducer of rectus femoris (RF) and hamstrings during recumbent bicycle pedaling of easy load regulation of pedal.

![MMG / EMG hybrid transducer](image)

Fig.1 MMG / EMG hybrid transducer

2. Methods
The MMG / EMG hybrid transducer was attached to center of RF and hamstrings surface of right foot of male subject at 24 years old. The transformer was connected to the logger (LP-WSD1402-0A, Logical Product, Japan), and wireless communication to the PC via a receiver. After attachment of this transducer, MMG and EMG waveforms was confirmed that isometric force exerted of subject was normally output. The subjects rode recumbent bicycle (C545R, SportsArt, USA) at a moderate natural sitting posture. The experimenter instructed not to move upper body to subject. The 9-axis wireless motion sensor (LP-WSD002-0A, Logical Product, Japan) was attached to left crank. The subject was pedaling at rate of one rotation to two seconds using metronome. After pedaling velocity of subject is confirmed to be constant, measurement was performed for ten seconds. The loading was three levels (39W, 68W, 100W). The rest was provided sufficient time between experiments. For signals analysis by crank angle, it was taken out three cycles of dMMGbase and integrated EMG (IEMG) waveforms on basis of the lowest point of pedal by the geomagnetic sensor of the 9-axis wireless motion sensor. Time and signal of dMMGbase, IEMG and pedal height were normalized by maximum value. The dMMGacc was calculated value obtained by second derivative of dMMGbase. The experiment was performed with approval of the ethic committee of Okayama University.

3. Results and discussion
Fig.2 shows typical waveforms of IEMG and dMMGbase in RF, load 38W. The muscle electrical activity appeared approximately every two seconds. Correspondingly, dMMGbase showed as peak of waveform. It indicated that cross-sectional area of muscle with electrical activity was increased or decreased during rotation of pedal. Fig.3 shows effect of load in RF. Based on the point that was shifted 15 degrees from the top dead center on subject side, it separated phases (1-4) by 45 degrees in rotation direction of pedal, and calculated average of summed IEMG and dMMGbase. The both signals from phase1 to phase3 was increased along with load. However, load 68W and 100W indicated similar changes at dMMGbase. Similar to previous study, IEMG and load are proportional relationship, but dMMGbase that is focused on muscle cross-sectional area might reach a plateau with increasing load. The dMMGbase is effective evaluation index in the range of low muscle contraction force. Therefore, for evaluation of high muscle contraction, it may be necessary to establish a method other than dMMGbase. Fig.4
shows normalized dMMGbase, IEMG, dMMGacc and pedal height that has superimposed three cycles in RF and hamstrings, load 38W. The broken line was height of pedal. In RF, dMMGbase and IEMG were showed peak (100%) during pushing down of pedal (phase 1-2 in Fig.3). After that, it decreased during pulling up of pedal (phase 3-4 in Fig.3). Also dMMGacc, change is observed. In hamstrings, IEMG and dMMGbase were showed the peak during pulling up of pedal. Although RF is two joint muscles, posture of upper body of the subject was fixed by recumbent bicycle. By only to pushing down of pedal, in other words, by the lower leg is extended, RF exerts contraction force, it is assumed to be reflected in IEMG and dMMGbase. On the other hand, hamstrings are these opposite phenomena. The antagonistic relationship between RF and hamstrings are seemed to appear in IEMG and dMMGbase.

4. Conclusions

The purpose of this study was skeletal muscle contraction evaluation of voluntary contraction during recumbent bicycle pedaling using MMG / EMG hybrid transducer. It was possible to evaluate state of contraction of RF and hamstrings contraction during body exercise. In the future, this study is expected in the application of sports and rehabilitation, etc.

Reference

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