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Detection of Muscle Fatigue by the Surface Electromyogram and its Application

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***Abstract*—The muscle is moved by muscle fiber contraction receiving command from the brain. But, energy that moves muscle is not infinity. If muscle get into energy shortage, no matter how send command from the brain, muscle is not moved. Such a temporary muscular dysfunction is muscle fatigue. If muscle becomes excess fatigue condition, it may decrease work efficiency, or muscle strain. If we are able to measure muscle fatigue objectively, improve work efficiency, or avert muscle strain. Therefore, it is necessity to measure muscle fatigue. It is able to objectively measure with a surface electromyogram(EMG). The characteristic of muscle fatigue are increase in amplitude and make the transition from high frequency spectrum to low frequency spectrum. We evaluate muscle fatigue Mean Power Frequency (MPF). to evaluates frequency of surface EMG. We assume muscle recovery process is converse phenomenon from muscle fatigue, and it is able to evaluate elevated MPF. The purpose of the present study is to design of system that effective training, or improve work efficiency, or avert muscle strain uses feature of muscular fatigue and muscle recovery process.**

***Keywords*-surface EMG; muscle fatigue; recovery; Mean Power Frequency;**

I. Introduction

The muscle is moved by muscle fiber contraction receiving command from the brain. We can move muscle freely, but we can 't keep moving it infinity. If we exercise intensely or carry on similar type of motion, our muscle fatigue. If muscle fatigue, we become loss of coordination. In consequence, we can 't train efficiently and fall off work efficiency potential for serious injury. Therefore muscle fatigue is vital information when we build muscular strength or work. Thereby, it is necessary to evaluate muscle fatigue quantitatively. And so as to quantify muscle fatigue is necessary objective evaluation. However, general evaluation of muscle fatigue is unclear. Because there are great differences between individuals or individual condition. (For example, time, number of time, weight up to fatigue.) Therefore , we evaluate using biological signal to evaluate muscle fatigue objectively. If we quantify muscle fatigue, we can work out adequately, or decrease the possibility of injury. In addition, we think that we can evaluate the muscle recovery process to evaluate muscle fatigue of break time. Many studies of muscle fatigue have been done so far. However most studies have not focused on muscle recovery process. If we define relation between the recovery process and muscle fatigue,we can figure out muscle condition.,and propose way of effective recovery. The purpose of this study is primary study to design of application that effective training, or improve work efficiency, or avert muscle strain, uses feature of muscular fatigue and recovery process.

II. Method

In this study we use electromyogram(EMG)to measure muscle fatigue ,because measurement is readily and it is application possibility to analyze in real time. EMG have two kind of measuring method, surface EMG needle EMG. In this study we use surface EMG, because,it is more nonstressed and readily than needle EMG. Surface EMG signal is biological signal that is measured on skin by electrode pasted up. The feature of muscle fatigue appear at surface EMG.

- increase in amplitude
- transition from high frequency spectrum to low frequency spectrum

In this study we use frequency feature to evaluate muscle fatigue and recovery. We evaluate frequency by Mean Power Frequency (MPF).

A. MPF

First,compute Fourier transformation of surface EMG signal. We use fft function of numerical software matlab.

$$y_{p+1} = \sum_{j=0}^{n-1} \omega^{jp} x_{j+1}$$

Vector X of length n compute Fourie transformation vector Y of length n. Here, ω is n th power root complex number. $\omega_N = e^{(-2\Pi i)/N}$ is nth root on unit circle. I is imaginary unit. p and j is between 0 and $n-1$. Data of vector X is cut by time $dt = 1fs$ or space $ds = 1fs$ .Here fs is sampling frequency. Y is complex number ,absoluate figure in index $p+1$ is frequency $f = p(fs/n)$ Mean power freaquency is average of above Fourier transformation.

$$MPF(n) = \frac{\sum_{f=fl}^{fh} fP(f,m)}{\sum_{f=fl}^{fh} P(f,m)}$$

$fl = 5Hz$,$fh = 300Hz$,$P(f,m)$ is power spectrum in the m th trail Fourier transformation.

In this study, evaluate fatigue per trial to observe trend fatigue process. To do it, we clip surface EMG signals. The means that search bottom value and clip there. Bottom value is between trial.

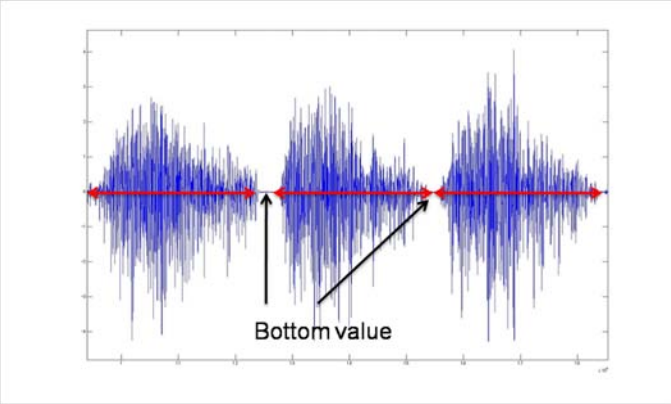

Figure 1. The Way Clip Bottom Value

B. recovery process

The feature of muscle fatigue by EMG, include increase amplitude and transform from high frequency spectrum to low frequency spectrum. So we assume that fatigue and recovery are converse phenomenon. Concrete speaking ,decrease amplitude and transform from low frequency spectrum to high frequency spectrum as feature of muscle recovery by EMG. And we evaluate recovery by increase of MPF in similar way to fatigue.

III. EXPERIMENT

Aim of this experiment are measuring surface EMG, and detection process of fatigue and recovery from agonist and antagonist muscle. In this experiment we used dumbbell as the burden, and measured surface EMG of biceps brachii and triceps brachii. Intended motion is dumbbell curl. The base position was leftside of fig:2. The trial subject lifted up sets of dumbbell like right sid of fig:2. And he set back base position. We defined these motions as 1 trial.

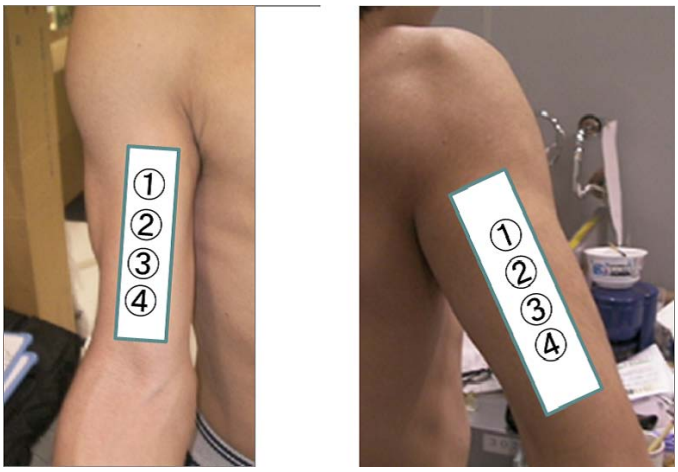

Figure 2. The Intended Motion

The following steps is 1set.

- First,we measured fatigue process 12th trials.
- Second,we measured break during one and a half minutes. The method is measuring same motion as dumbbell curl per 5 seconds, here without burden not to prevent recovery.
- Third, we measured fatigue process 12th trials.

We measured them continuously observed fatigue and recovery process. And we use two type dumbbells (6kg ,8kg) to weigh the differences them. We pasted four points each electrode in biceps brachii and triceps brachii along muscle fiber like fig:3.

Figure 3. Points of Electrode

Table I
EXPERIMENTAL DETAIL

Number of channel	8ch
Sampling frequency	4kHz
Trial subject	21 years,Normal man
Motion	Dumbbell curl
Number of trial	12th - break(one and a half minutes) - 12th 2set
Trial muscle	biceps brachii and triceps brachii
Burden	6kg,8kg

IV. RESULT

Vertical axis is MPF vlue.Abscissa axis is Number of tial.

A. 6kg burden

Each channels show that decrease trend of MPF up to12th-trial ,and from 12th-trial up to 30th-trial(without hindrance) show vary value both agonist and antagonist. After break trial show that decrease trend of MPF both muscles. This set shows no difference between before and after break,

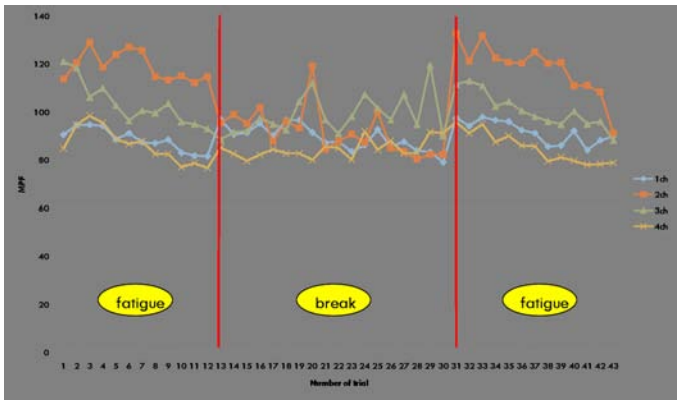

Figure 4. 6kg 1st set(agonist)

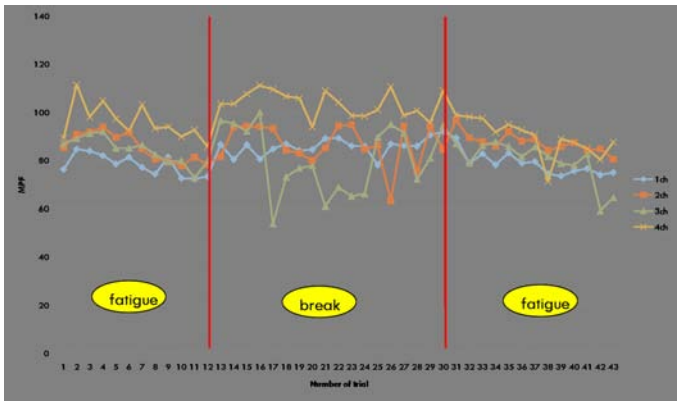

Figure 5. 6kg 1st set(antagonist)

Up to12th-trial, in agonist each channel show that decrease trend of MPF. However in antagonist, each channel show no change. From 12th-trial up to 30th-trial (without hindrance) show marked increase at first three points (for 15 seconds).,after that, in agonist show gradual increase except 4ch, in antagonist show vary value. After break trial, in agonist show that decrease trend of MPF except 4ch, and lower than before break trial totally.

B. 8kg burden

Up to12th-trial, in agonist each channel show that decrease trend of MPF. However in antagonist, each channel

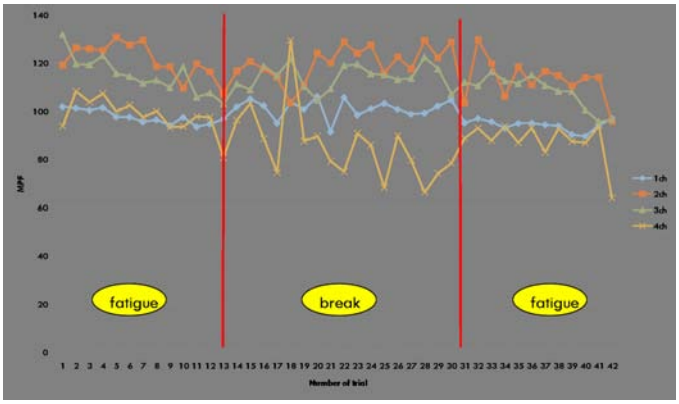

Figure 6. 6kg 2nd set(agonist)

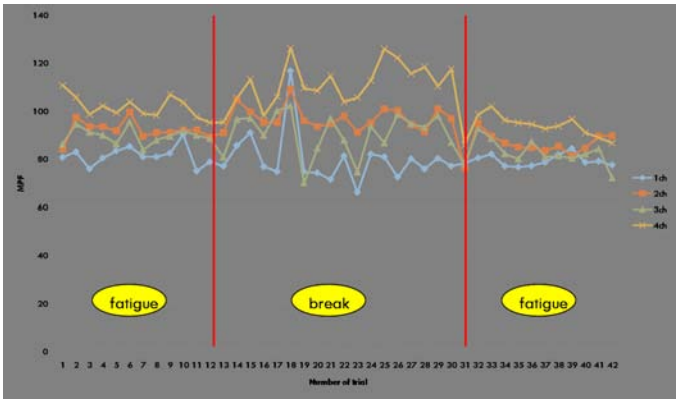

Figure 7. 6kg 2nd set(antagonist)

show no change. From 12th-trial up to 30th-trial (without hindrance) show marked increase at first three points (for 15 seconds).,after that, in agonist show gradual increase except 4ch, in antagonist show vary value. After break trial, in agonist show that decrease trend of MPF except 4ch, and lower than before break trial totally.

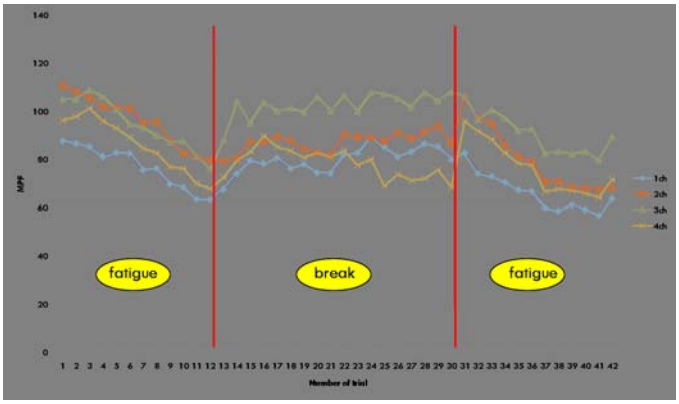

Figure 8. 8kg 1st set(agonist)

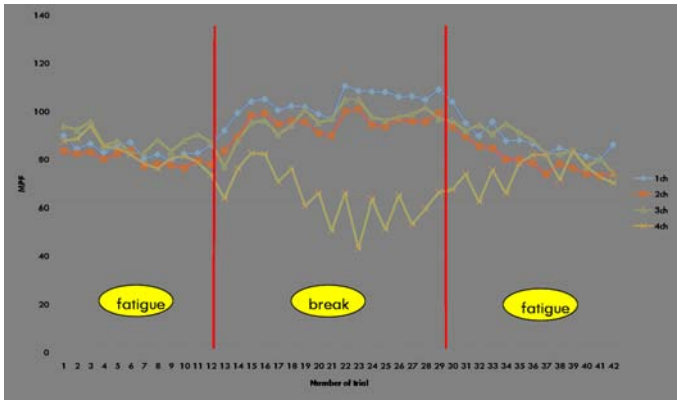

Figure 9. 8kg 1st set(antagonist)

Up to12th-trial, in agonist each channel show that decrease trend of MPF both of muscle. From 12th-trial up to 30th-trial (without hindrance) show marked increase at first three points (for 15 seconds), after that,each channels show gradual increase except 4ch of antagonist. After break trial each channels show that decrease trend of MPF except 4ch of antagonist . In agonist this set shows that after break trial lower than before break trial. However, in antagonist shows no change between after break trial and before break trial.

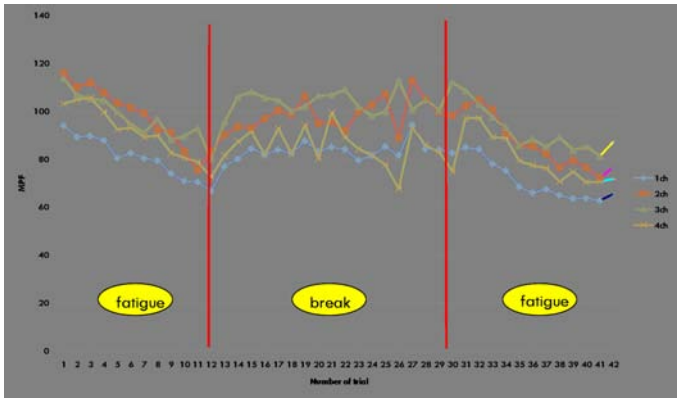

Figure 10. 8kg 2nd set(agonist)

V. CONSIDERATION

We consider the relationship agonist and antagonist. The case of agonist, any channel show the decrease trend of MPF in the trial using dumbbell. As a result, we successfully detected muscle fatigue by EMG. The case of antagonist, the result showed similar trends agonist muscle fatigue only when the burden is 8kg. The cause are elevation of upper arm stability, because not enough only agonist to lift up burden. This phenomenon is co-contraction. Therefore antagonist fatigue as in agonist. We consider detection of recovery process. In this study, we assume that increase of MPF is recovery and evaluate it. In the cases of 6kg ,13th 15th

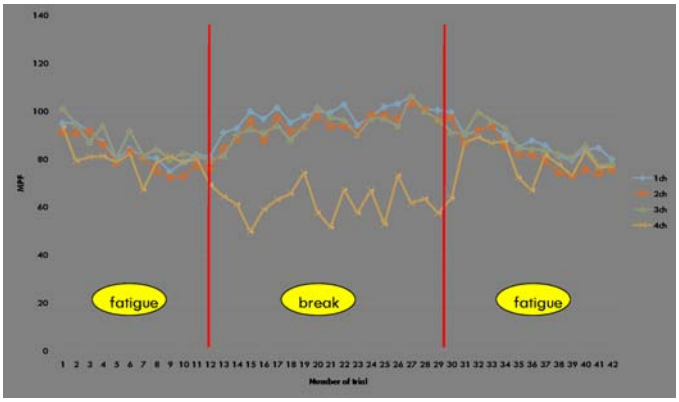

Figure 11. 8kg 2nd set(antagonist)

trial increase MPF in the 2nd set. However, we didn't detect defined recovery. MPF value varied totally. This is due to burden is inadequacy for trial subject. Because fatigue trend of 6kg lower than 8kg. In the case of 8kg , increase MPF both agonist and antagonist. In consequence almost recover for about 15 seconds. This is due to, select burden of appropriate wight to observe fatigue and recovery process. Moreover in the 8kg case each sets show that after break trial lower than before break trial. This is due to fatigue accumulated.

VI. CONCLUSION

In this study, we use surface EMG to detect fatigue and recovery process objectively. The feature of muscle fatigue make the transition from high frequency spectrum to low frequency spectrum. We evaluate muscle fatigue Mean Power Frequency (MPF) to evaluates frequency of surface EMG. We assume muscle recovery process is converse phenomenon muscle fatigue. In the experiment we used 8kg and 6kg dumbbell as the burden, and measured surface EMG of biceps brachii and triceps brachii. Intended motion is dumbbell curl. As a result,in the 6kg cases, we can't observe defined recovery trend. This is due to vary totally. In the 8kg cases, we observe recovery processes. Each processes almost recovered for about 15 seconds.

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