Construction of the Muscle Fatigue Evaluation Model based on Accuracy of Power

Akihiro Suzuki, Norihiko Kato, Yoshihiko Nomura, Hirokazu Matsui

Mie University, Kurimamachiya1577, Tsu Mie Japan
(Tel : 81-59-231-9473; Fax : 81-59-231-9663)
(suzuki@robot.mach.mie-u.ac.jp)

Abstract: We develop a rehabilitation support system that assists the exercise training to reduce the physical load of therapists. In this study, we propose a muscle fatigue evaluation method to decide appropriate momentum for patients. Lots of studies of the muscle fatigue by EMG have been reported. However, muscle fatigue evaluation by EMG has disadvantages of complexity of preparation and gives patients mental stress. To solve this problem, in this study, we propose the muscle fatigue evaluation by the accuracy of muscle power. We verify proposed method on abduction/adduction of shoulders. We investigate how the accuracy of the muscle power changes under abduction/adduction repeatedly maintaining constant power of tangential direction. From the experimental results, we confirm correlation increase of amplitude of EMG and increase of power in direction of normal by power direction shift from tangential direction that is direction of target as the muscle fatigue increase.

Keywords: Rehabilitation, Robotics, Shoulder, Muscle, Fatigue, Motor Unit

I. INTRODUCTION

Recent years, the load of therapists and caregivers increases with the declining birthrate and a growing proportion of elderly people of the society. We aim to assist and reduce the load of the physical therapists who train rehabilitation, especially the exercise therapy training (maintenance and increase training for joint's range of motion, muscle-strengthening exercise, endurance training, and cooperated movement training, etc.), and then, we develop and the program of easy-to-use robot arms which assists these training operation and evaluate them.

We propose the muscle fatigue evaluation method to decide appropriate momentum for patients. Lots of studies of the muscle fatigue by EMG have been reported. In the muscle fatigue evaluation by EMG, as the muscle fatigue increases, amplitude of EMG increases. Generally speaking, it is said that is because of the increase of the amplitude by the collection of muscle fibers to keep its power, shifting from large and faster motor unit to a small and low one, and also shifting of the frequency element to the low-frequency area by the synchronizing ignition which ignites all motor units at the same time. However, muscle fatigue evaluation by EMG has the disadvantage of complexity of preparation and making the patients mentally stressful. To solve this problem, in this study, we propose the muscle fatigue evaluation by accuracy of muscle power. We investigate correlation of the muscle fatigue evaluation by the EMG and accuracy of the muscle power, and propose muscle fatigue evaluation model.

II. REHABILITATION SUPPORT SYSTEM

As shown in Figure 1, robot arm with 7 degrees of freedom is used, and the force-torque sensor is installed in the tip of the arm. We control the motion by operating robotic arm based on the information of power and the torque measured by the sensor.

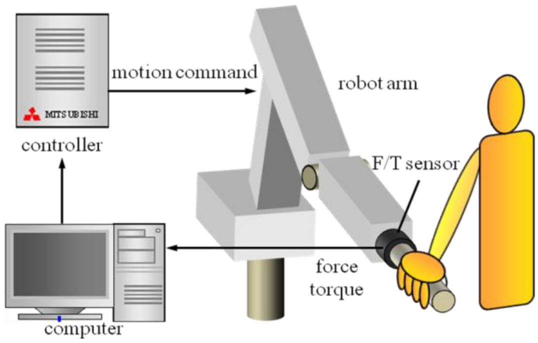


Fig.1. Rehabilitation Support System

III. MUSCLE FARIGUE EVALUATION

In this study, we propose the muscle fatigue evaluation based on the accuracy of the power. We verify the accuracy of the power according to the muscle fatigue from two viewpoints such as amount and the direction. As shown in Fig.2, we divide the power in *Fr* of subject into normal direction element *Fn* and tangential direction element *Ft* centers on the shoulder joint, and evaluate them respectively. As shown with *Fg* in Fig.2, it aims at the movement which only the value is specified only for a tangential direction works effectively. We verify the accuracy of amount of power by the increase and the decrease of the difference from the targeted value |*Fg-Ft*|. And about, we verify direction of power because of the increase and decrease of the normal direction element of power |*Fn*| by power direction shifted from tangential direction that is the direction of target. We calculated BIN average of the measuring data every one degree in the movement angle and compared with the total values of every one round trip.

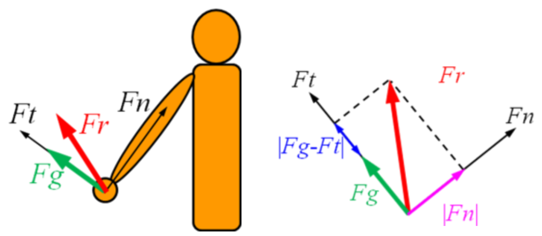


Fig.2. Evaluation of Muscle Fatigue

IV. EXPERIMENT

4.1. Method

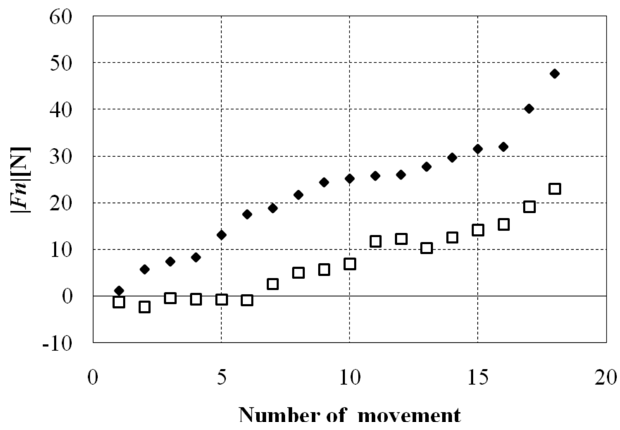
The subjects are nine healthy persons. We had them move their arms within the angle of 30 to 90°. Load was set to be 30% of maximum isometric contraction for three seconds in 60°. We had them keep working until they become less than set amount with the constant movement angular speed (8deg/sec). To understand the muscle activity under the movement, we measured EMG of Deltoid (middle, anterior, posterior), Cowl muscle that relates to the abduction and Pectoral major muscle relates to the adduction.

We had the subjects exercise to follow the targeted value of the power and the target orbit displayed in the monitor as much as possible.

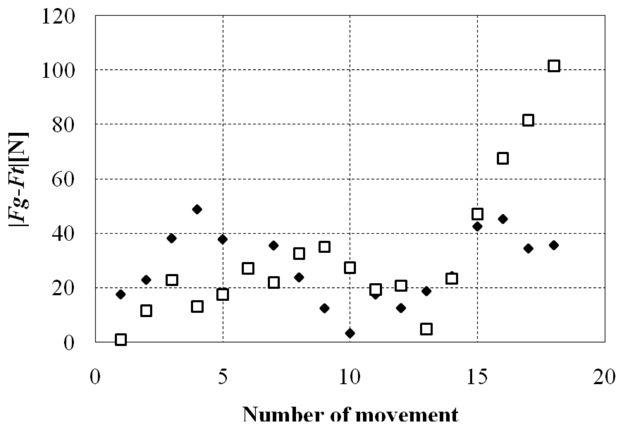
4.2. Result

4.2.1. Change in Accuracy of Power of Each Movement Frequency

We show the normal direction element |*Fn*| of each movement frequency by abduction/adduction in Fig.3 (a) and the difference of the targeted value of the tangential direction element |*Fg-Ft*| in Fig.3 (b) by average moving deviations of every round trip of five. We confirmed that the normal direction element |*Fn*| increased every time the movement frequency was piled up. The similar tendency was not shown on the tangential direction element |*Fg-Ft*|.



(a) Normal Direction Element |*Fn*|



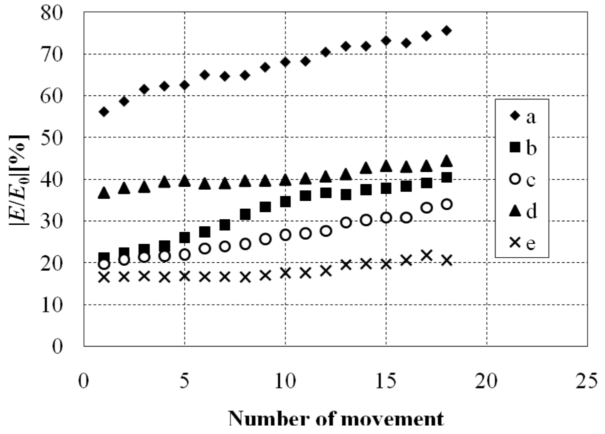
(b) Tangential Direction Element |*Fg-Ft*|

Fig.3. Accuracy of Power of each Movement Frequency

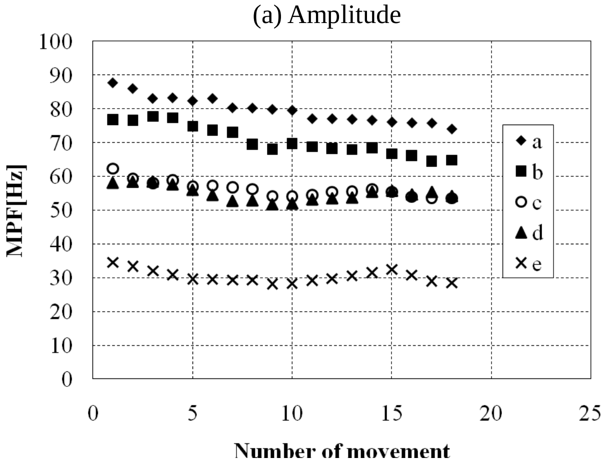
4.2.2. Amplitude of EMG of Each Movement Frequency

In Fig. 4(a), a relative value which was taking at the maximum isometric contraction of 100% in 6o° is shown. As the movement frequency is piled up, we confirmed the increase in the level of each muscle activity level.

We show the mean power frequency (MPF) of each movement in Fig.4 (b). We confirmed the muscle fatigue from the increase of the amplitude of EMG and the shift of the frequency element to the low frequency region.



(a) Amplitude



(b) Mean Power Frequency

Fig.4. EMG

a: Deltoid Middle

b: Deltoid Anterior

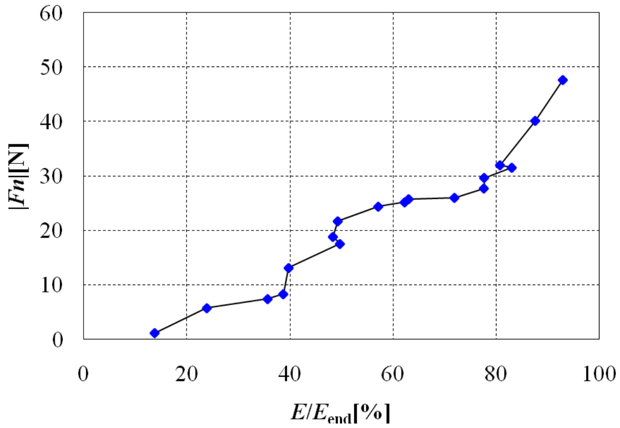
c: Deltoid Posterior

d: Cowl Muscle

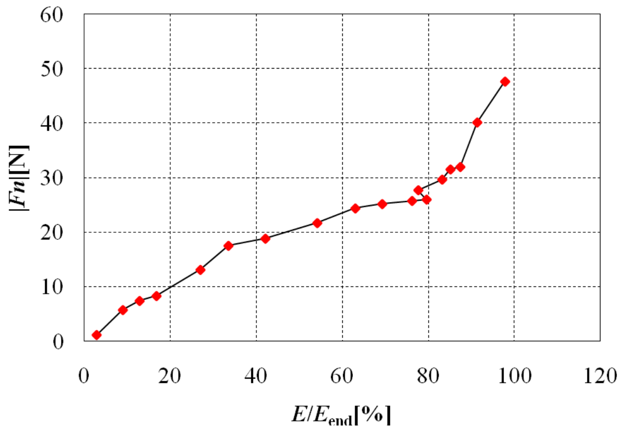
e: Pectoral Major Muscle

4.2.3. Correlation of Amplitude of EMG and Accuracy of Power

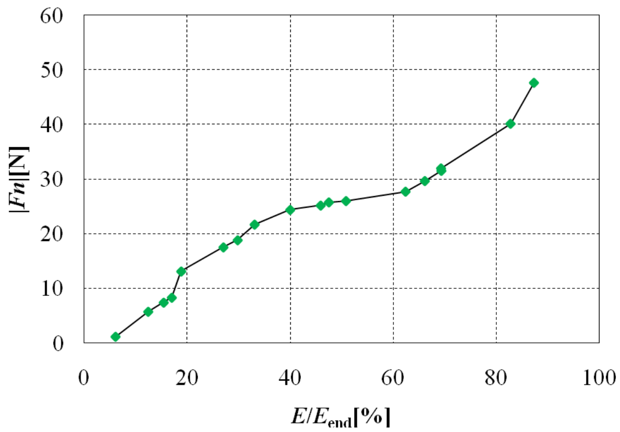
We show the correlation for the amplitude of EMG in each muscle and normal direction element of power $|Fn|$ in Fig.5. The horizontal axis in the graph shows is the value in which measured amplitude of EMG assuming the first mean value of three round trips to be standard value of 0, and makes the last mean value of three round trips a relative value as 100. The vertical axis in the graph shows the normal direction element of power in difference by the first mean value of three round trips. As the amplitude of EMG increases, we confirmed the increase of the normal direction element of power $|Fn|$. We show the correlation coefficient of the amplitude of EMG of each muscle and normal direction element of power in Table 1. We confirmed that there was a strong correlation between muscle fatigue and the accuracy in direction of power.



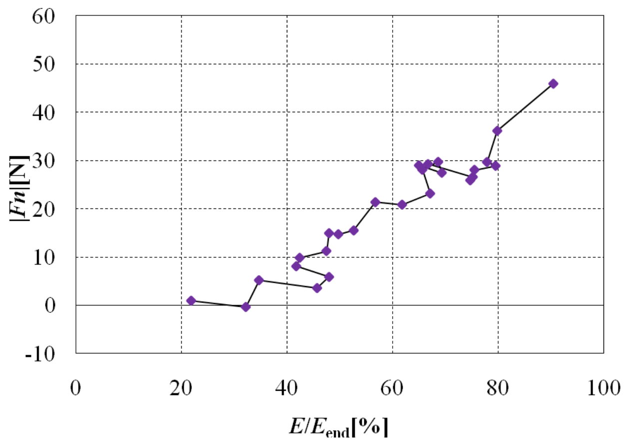
(a) Deltoid Middle



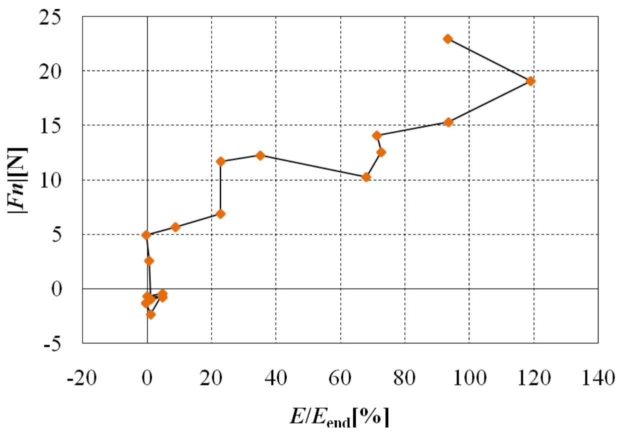
(b) Deltoid Anterior



(c) Deltoid Posterior



(d) Cowl Muscle



(e) Pectoral Major Muscle

Fig.4. Correlation of Amplitude of EMG and |*Fn*|

Table 1 Correlation Coefficient

	Coefficient Correlation
Deltoid Middle	0.964
Deltoid Anterior	0.958
Deltoid Posterior	0.971
Cowl Muscle	0.950
Pectoral Major Muscle	0.903

V. CONSIDERATION

We had subject isotonic movement under low load, and confirmed that the normal direction element of power increases by the decline of the accuracy in direction of power with increase of the muscle fatigue.

Immediately after the movement begins, the power is maintained by the muscle which is comparatively small (ST-MU) because of the load was set low. When the tension of ST-MU decreases, the power is made up by restarting of stopping muscle that motor unit is comparatively large. It is thought that the control of power roughens, and the decrease of accuracy of power was caused by this. In addition, the smoothness of muscle contraction is ruined by the synchronization phenomena of motor unit that all motor units is mobilized, and it becomes an explosive activity style in the vicinity of the movement limit. Therefore, we think that accuracy of power decreased more

VI. CONCLUSION

In this study, we proposed muscle fatigue evaluation based on accuracy of power under a low load, and confirmed that there was a strong correlation in the relation between increase of normal direction element of power caused by the decrease of accuracy in direction of power and muscle fatigue.

The comparative study of a load and the movement speed that differs and depends is necessary as future tasks. Moreover, we should consider the individual variation depends on the subjects by constructing the model type because there is a difference in the value of |*Fn*| when muscle fatigue reaches to the critical limit.

Also, we should verify whether our proposal technique is useful for actual rehabilitation patients who are waiting for.

REFERENCES

[1] Jyunichirou Aoki, Yuu Satou, Isao Muraoka (2005), sports physiology
[2] Syuu Yatojima, Asahiro Kiduka, Hioroshi Yajima (2003) Influence that movement leg position and angle variation when shoulder abduction on activity aspect of surroundings muscle of shoulder
[3] Syuu Yatojima, Asahiro Kiduka, Naoki Mukai, Jin Siragi, Yutaka Miyanaga, Muscle activity characteristic when shoulder abduction on different movement condition
[4] Sinichi Huruya, Fatigue
[5] Haruo Sugi (2003), The muscle is mysterious, Shown mechanism that gives birth to power
[6] Noriyuki Hayami, Eiishi Tanaka, Souta Yamamoto, Hiorki Takeuchi, Modeling of muscle fatigue that considers difference of fatigue tolerance of motor unit type
[7] Yasushi Itoh, Kumi Akataki, Katsumi Mita, Watakabe Makoto, Kunihiko Itoh (2003), Time of Mechanomyogram of continuation contraction with muscle fatigue- Frequency analysis