RECRUITMENT AND DECRUITMENT OF MOTOR UNITS ACTIVITIES OF M. BICEPS BRACHII DURING ISOVELOCITY MOVEMENTS

Ryuhei Okuno and Kenzo Akazawa
Department of Information Systems Engineering, Graduate School of Engineering, Osaka University, Japan

Abstract— **The purpose of this study is to investigate behaviors of motor units of m. biceps brachii (biceps short head muscle) during flexion movements in wide range of elbow joint angle. In this study, eight surface electromyograms(EMGs) were measured during flexion movements at constant angular velocity (isovelocity) and against constant torque in wide range (from 0 [deg] to 120 [deg]) of elbow joint angle with a surface electrode array. We identified action potensials of each moitor unit and detected recruitment and decruitment of the identified motor units. We found 42 recruitments and 38 decruitments of the motor units in 42 experimental sessions, 6 subjects.**

Keywords— **motor unit, electromyogram, biceps brachii, recruitment, decruitment**

I. Introduction

Behaviors of motor units (MUs) at the isometric contraction of various muscles have been extensively studied on human subjects by many researchers. It has been found that during static muscle contractions graded force development is achieved by a rank-orderd increase in the number of active MUs in combination with an increase in the firing rate of already recruited units [1]-[3].

Contrary to the wealth of experimental data on isometric contraction, some studies have been reported on voluntary movements[4]-[10]. In these studies, comparison of isometric and anisometric contractions have shown that during length changes muscle force variation relies more on MU recruitment than rate cording [4]-[6]. In most of these previous studies, they measured the MU activities in a relatively narrow range of joint angle, because MU action potentials (MUAPs) were recorded with wire or needle electrodes. Measuring of MU activities during movement in wide range of joint angle is needed to reveal the human position control mechanism. Bolhuis et al. measured MUAPs in brachialis and biceps brachii muscles during sinusoidal flexion/extension movements (peak-peak amplitude of elbow joint angle about 30 [deg])[9]. They showed that the relationship between the mean phase lead of the bursts of MUAPs and sinusoidal movements. Some basic characteristics of motor unit activities have not been made clear yet.

The purpose of this study is to investigate behaviors of MUs of m. biceps brachii (biceps short head muscle) during flexion movements in wide range of elbow joint angle. In this study, eight surface electromyograms (EMGs) were measured during flexion movements at constant angular velocity (isovelocity) and against constant load. The MUAPs were identified by decomposition technique and firing time of each MUs was investigated.

II. Method

The experimental task was isovelocity flexing of the elbow joint in a horizontal plane. A schematic diagram of the experimental setup is shown in Figure 1(B). The experiments were performed with three healthy subjects who had given informed consent. Each subject sat on a chair and his body was strapped to the chair with nylon belts. His forearm was supported with a wooden plate and a Styrofoam piece which were settled on a freely rotating acrylic plate. He could flex and extend his elbow joint in the horizontal plane at the height of his shoulder. To extend the elbow joint, his wrist was pulled by the gravitational force of a weight hung from a pulley. The subject's elbow joint angle and the target angle were displayed as thin and thick bright lines, respectively, on the screen of an oscilloscope in front of him. He was instructed to flex his elbow joint at a constant velocity by tracking the bright line. He was also asked to minimize coactivation of the antagonist muscles. While the subject was flexing his elbow from 0 to 120 [deg], the EMG signals, elbow joint angle and torque were measured. The elbow joint angle was measured with a potentiometer. The force applied to the forearm was measured with a load cell. The elbow joint torque was calculated from radius of the acrylic plate and the force applied to the forearm. External loads corresponded to 5 and 7[%MVC] (Subject A,B,C) and 10[%MVC] (Subject D,E,F). The flexion angular velocities were 10[deg/s] (Subject A), 15[deg/s](Subject B,C) and 10,15,20,25 [deg/s] (Subject D,E,F). Measurements with Subject A, B and C were performed five times and Measurements with Subject D, E and F were performed once about each condition respectively

EMG signals were obtained with eight-channel bipolar surface electrode array (Figure 1(A)). The electrode array was consisted of sixteen stainless electrodes of 1mm diameter. EMG signals were measured differentially with a pair of two electrodes placed with inter-electrode spacing of 2.54mm. The eight pair of electrodes are placed in parallel with spacing 2.54mm.

We classified the MUAPs based on the waveform of eight EMGs; the classification was performed interactively on the CRT monitor with an aid of template matching, which was similar to the decomposition algorithm by Mambrito and DeLuca [11] (Figure 2). Subsequently, firing time of each MUs was investigated on all classified MUs.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Recruitment and Decruitment of Motor Units Activities of M. Biceps Brachii During Isovelocity Movements	**Contract Number** **Grant Number** **Program Element Number**
Author(s)	**Project Number** **Task Number** **Work Unit Number**
Performing Organization Name(s) and Address(es) Department of Information Systems Engineering Graduate School of Engineering Osaka University, Japan	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)** **Sponsor/Monitor's Report Number(s)**

Distribution/Availability Statement
Approved for public release, distribution unlimited

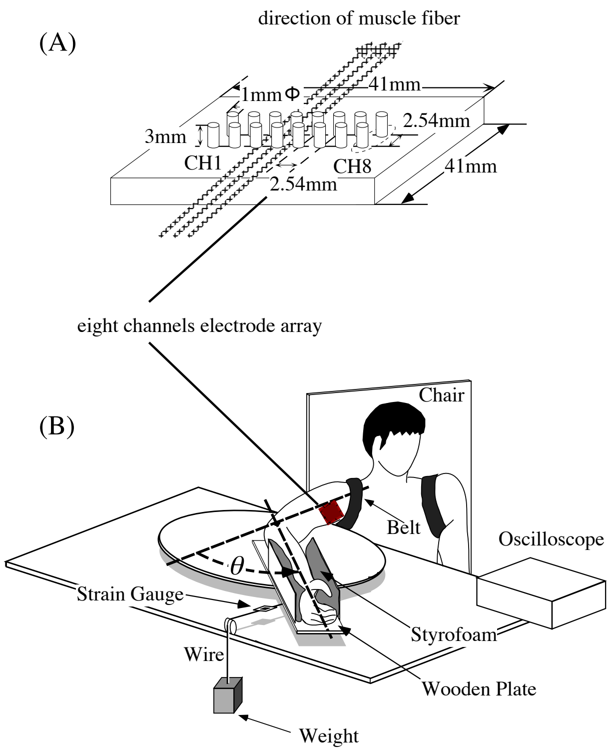
Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4



(B)

Fig. 1. Schematic drawing of experimental setup; (A) sixteen poles (eight channels) electrode array. (B) experimental setup for isovelocity flexion movement.

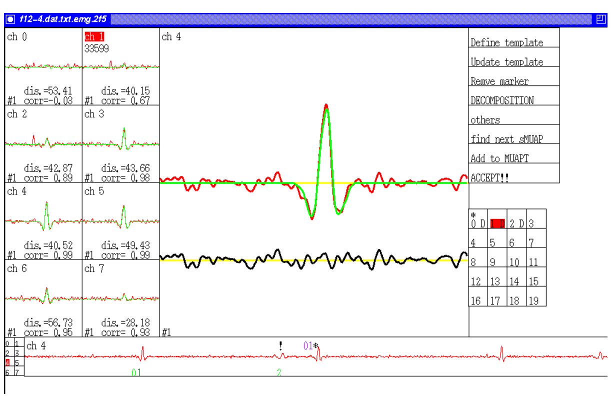


Fig. 2. Screen shot of identification and decomposition of MUs program. waveforms of MUAPs and template were displayed.

III. Results

Figure 3 shows a typical measured elbow torque, elbow joint angle and EMGs. In Figure 3(A), the subject started to flex his elbow joint at the time of approximately 1 [s] after the recording. The torque around elbow joint angle and the angular velocity are almost constant during flexion movement.

Figure 3(B) shows EMGs obtained with the eight-channel electrode array. CH1 is the EMGs measured with a pair of bipolar electrodes (ch1) of the electrode array. In Figure 3(B) CH1, it is shown that MUAPs were started to record at the time of approximately 6 [s]. These MUAPs trains moved from CH1 to CH5 and waveforms of the MUs were changed gradually. Because relative distance between the MUs and electrode array changed during flexion movements.

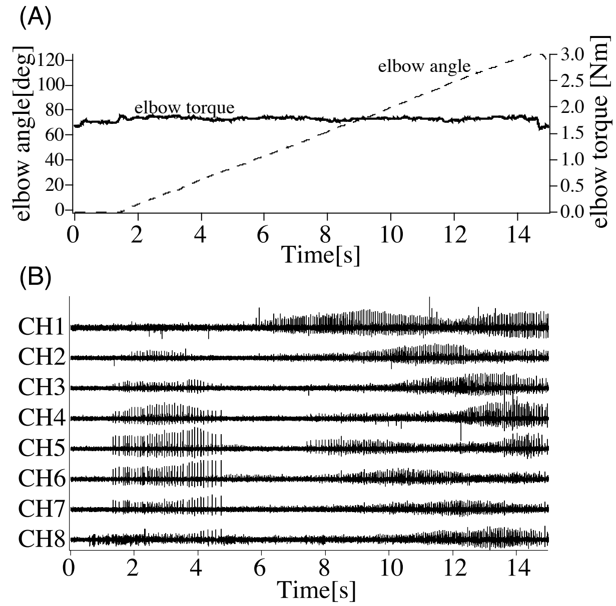


Fig. 3. Typical measured elbow joint angle, torque around elbow joint and eight EMGs obtained with the electrode array. (A) elbow joint angle and torque around elbow joint, (B)eight-channels EMGs. Subject A, load 7 [%MVC], angular velocity 10 [deg/s]

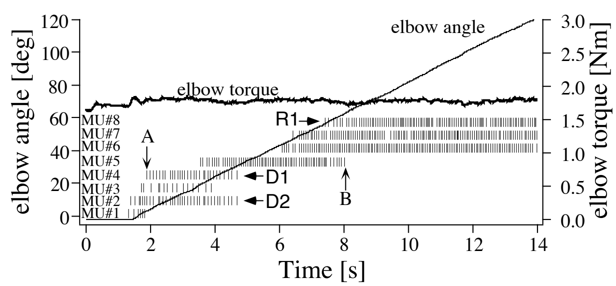


Fig. 4. Measured elbow joint angle and firing time of each identified MUs. Subject A, load 7 [%MVC], angular velocity 10 [deg/s]

Figure 4 shows the measured elbow torque, elbow joint angle and firing time of each identified MUs. A vertical stick in the Figure 4 is the firing time of each MU. The each MU was numbered consecutively from MU#1 to MU#8 in order of identification.

In Figure 4, firing of MU#4 was started to recorded at the time of approximately 2 [s]. MU#4 was being moved from the outside of the measuring range of the electrode to the inside. The recruited time of MU#4 could not been observed clearly. So, we could not regard MU#4 as recruitment of MU. The recruited time of the other MUs except MU#8 could not been observed clearly too.

Figure 5 shows that the measured EMGs at the time of R1. At the time of 7.42 [ms] firing of MU#8 was started to record in the center of the electrode array, CH4, CH5 and

CH6. It was not seemed that MU#8 moved from outside of range measuring with the electrode array to inside of one. We regarded MU#8 as a recruited MU.

In Figure 4, firing of MU#4 stopped at the time of approximately 4.7 [ms] during flexion movement. Figure 6 shows that the measured EMGs at the time of D1. The recorded MUAPs train of MU#4 stopped to record at the time of 4.72[ms]. We regarded MU#4 as a decruited MU. MU#2 were decruited at the alomost same time (see D2 in Figure 4). However, the other MUs were being moved from the inside of the measuring range of the electrode to the outside or Waveform of the MUAPs were superimposed on others, the time that the MUs decruited could not obtained clearly. Figure 7 shows decruitment of MU in the another experiment with other subject. Decruitments of MUs were founds in other subjects.

Table 1 and Table 2 shows the total number of recruitment and decruitment of MUs observed from each subject in this study. In Table 1, the total number of experimental sessions with Subject A were ten times. In these experiments, the number of recruited MUs was found ten and the number of decruited MUs was four. In Table 2, the total number of experiments with Subject D were four. The number of recruited MUs was found one and the number of decruited MUs was sixteen.

TABLE I
THE NUMBER OF RECRUITMENT AND DECRUITMENT (SUBJECT A, B, C).

Subject	load[%MVC]	5	7
A 10[deg/s]	recruitment	4	6
	decruitment	2	2
B 15[deg/s]	recruit	2	2
	derecruit	2	4
C 15[deg/s]	recruit	10	12
	derecruit	5	7

TABLE II
THE NUMBER OF RECRUITMENT AND DECRUITMENT (SUBJECT D, E, F).

Subject	speed[deg/s]	10	15	20	25
D 10[%MVC]	recruit	1	0	0	0
	derecruit	3	2	3	3
E 10[%MVC]	recruit	1	0	0	0
	derecruit	3	1	1	0
F 15[%MVC]	recruit	1	1	1	1
	derecruit	0	0	0	0

IV. Discussions

Recruitments of MUs during movements were investigated by many researchers, however, there were few reports on decruitments of MUs. Kato et al reported decruitment of MUs of human tibialis anterior muscle after finishing of flexion movements. In this study, decruitments of MUs were found during flexion movements.

Decruitments of MUs could not be found in every experimental sessions. Because we regarded MUs that we could obtain clearly last firing time of one as decruited MUs. To investigate basic characteristics of motor unit activities, for examples, relationship between recruitment and decruitment of MUs and elbow joint angle, we have to develop program with new methods (wavelet transform, time-frequency analysis and so on) for decomposition of MUAPs.

V. Conclusions

Recruitment and Decruitment of MUs of biceps short head muscle were investigated during flexion movements in wide range of elbow joint angle.

Eight surface electromyograms(EMGs) were measured during flexion movements at constant angular velocity and against constant torque in wide range (from 0 [deg] to 120 [deg]) of elbow joint angle. We identified each MUAPs, and detected recruitment and decruitment of each MUs. We identified 42 recruitments and 38 decruitments with 42 experimental sessions.

Acknowledgement

This work was supported financially in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

References

[1] R. S. Person and L. P. Kudiana, "Discharge frequency and discharge pattern of human motor units during voluntary contraction of muscle," Electroencephalogr. Clin. Neurophysiol., **32**, 471–483 (1972)

[2] H. S. Millner-Brown, R. S. Stein and R. Yemm, "The orderly recruitment of human motor units during voluntary isometric contractions," J. Physiol., **230**, 359–370 (1973)

[3] Z. Erim, C. J. DeLuca, K. Mineo and T. Aoki, "Rank-ordered regulation of motor units," Muscle Nerve, **19**, 563–573 (1996)

[4] J. Mariani, B. Maton and S. Bouisset, "Force gradation and motor unit activity during voluntary movements of man," Electroencephalogr. Clin. Neurophysiol., **48**, 573–582 (1980)

[5] M.Kato, S.Murakami, K.Yasuda, "Behavior of Single Motor Units of Human Tibialis Anterior Muscle during Voluntary Shortening Contraction under Constant Load Torque," Experimental Neurology, **90**, 238–253 (1985)

[6] A. Gydikov, A. R. Kossev, D. Kosarov and K. G. Kostov, "Investigations of single motor units firing during movements against elastic resistance," Biomechanics **X-A** , 227-232 (1987)

[7] A. A. M. Tax, J. J. Diner van der Gon, C. C. A. M. Gielen and C. M. M. van den Temple, "Differences in the activation of m. biceps brachii in the control of slow isotonic movements and isometric contractions," Exp. Brain Res., **76**, 55-63 (1989)

[8] S. J. Garland, J. D. Cooke, K. J. Miller, T. Ohtuski and T. Ivanova, "Motor unit Activity During Human Single Joint Movements," Journal of Neurophysiology, **76**, 1982–1990 (1996)

[9] B. M. van Bolhuis, W. P. Medendorp, C. C. A. M. Gielen, "Motor unit firing behavior in human arm flexor muscles during sinusoidal isometric contractions and movements," Experimental Brain Research, **117**, 120–130 (1997)

[10] K. S øgaard, H. Chirstensen, N. Fallentin, M. Mizuno, B. Quistorff and G. Sj øgaard, "Motor unit activation patterns during concentric wrist flexion in human with different muscle fibre composition," Eur. J. Appl. Physiol., **78**, 411-416 (1998) .

[11] B. Mambrito and C. J. A. DeLuca, "Technique for the detection, decomposition and analysis of the EMG signal," Electroencephalogr. Clin. Neurophysiol., **59**, 175–188 (1984)

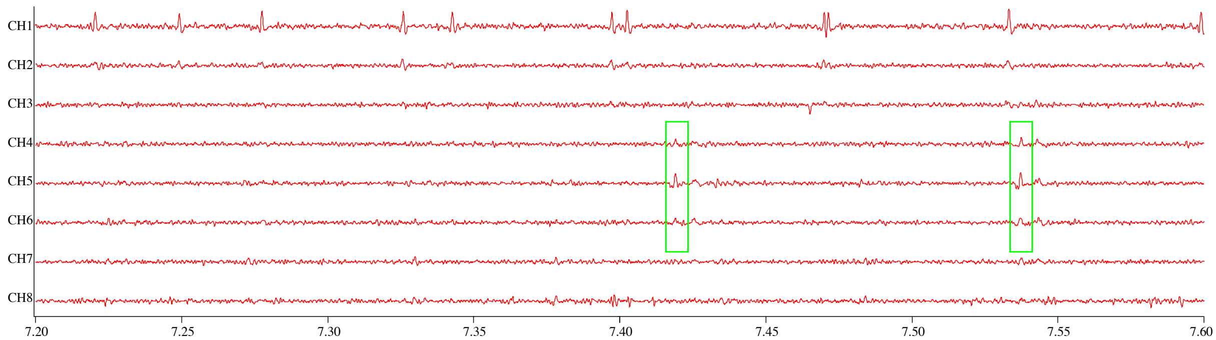


Fig. 5. Measured eight channels EMGs at the time of approximately 7.5 [s]. MUAPs in square were MU#8. Subject A, load 7 [%MVC], angular velocity 10 [deg/s]

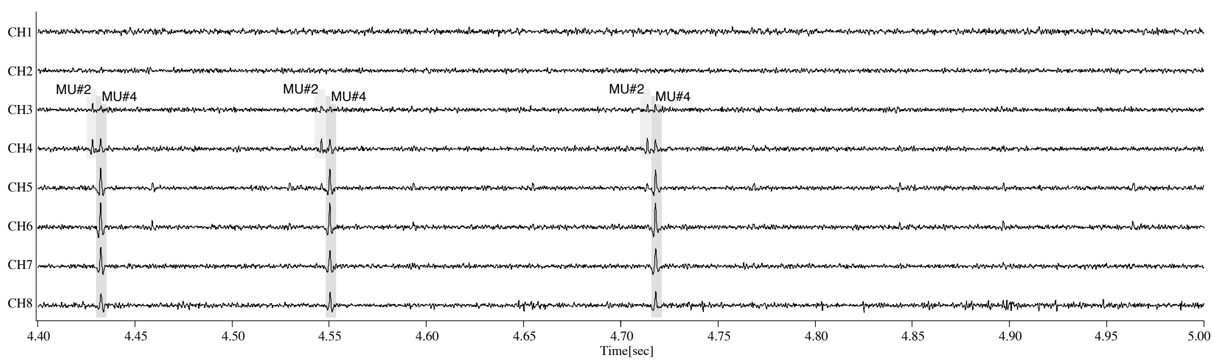


Fig. 6. Measuring EMGs at the time of approximately 4.7 [s]. MUAPs in hatching area were a MU#2 and MU#4. Subject A, load 7 [%MVC], angular velocity 10 [deg/s]

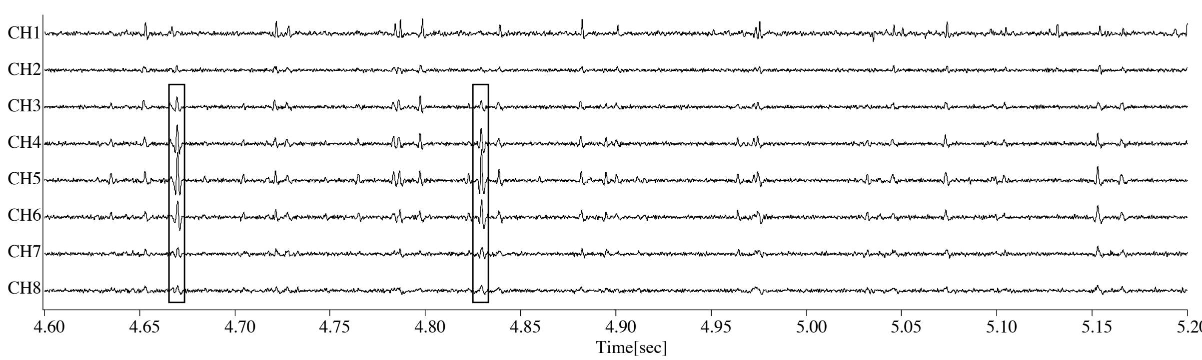


Fig. 7. Measuring EMGs at the time of approximately 4.7 [s]. MUAPs in square were a decruited MU. Subject B, load 7 [%MVC], angular velocity 15 [deg/s]