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FUNDAMENTAL STUDY FOR ROLLING-OVER MOTION OF THE BODY BY FUNCTIONAL ELECTRICAL STIMULATION(FES)

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INTRODUCTION

Spinal cord injured subjects must be confined to beds for long time. Since they can hardly move their bodies, they suffer severs bedsores(decubitus). Rolling-over motion is effective to prevent bedsores, but it requires the help of nurses or others. If the subjects can roll-over without helpers, the workload of their helpers can be lightened, and efficiency with which the subjects are cared for can be improved.

In order for the subjects to achive rolling-over by themselves, we have proposed the cont-ol of the paralyzed body by means of Functional Electrical Stimulation(FES).[1] The FES technique has been widely applied to restoration of the motor function of upper or lower extremities,[2-5] but not to body control. In this paper we would like to report the results of stimulation experiments and EMG measurements, and consider the feasibility of rolling-over by means of FES.

ELECTRICAL STIMULATION OF THE MUSCLES

We reported on the EMG analysis during rolling-over motion before.[1] Based on the results, we applied electrical stimulation to a normal subject using surface electrodes, and individual muscle contraction was observed. The muscles stimulated in the experiment are indicated in Table 1. The surface electrodes were placed on the skin near the motor point of each muscle. The stimulation protocol of this experiment was the same as that of upper extremities for clinical application,[6] i.e. 1) standard stimulation data were made by reference to EMGs using normal subjects, 2) the threshold voltage and the maximum voltage for each muscle of a subject were measured, 3) actual stimulation data for the subjects were then fixed, 4) stimulation was applied to the subject according to the data. In this experiment, the rolling-over motion can be divided into several motions, e.g. hip extension, body

rotation. when we simultaneously stimulated two or three muscles of the normal volunteers, appropriate individual joint motions, which caused a part of rolling-over, were obsered. Thus, the fundamental feasibility of body control by FES was proved by the experiments. The whole, synthesized rolling-over motion may be controlled with the well-coordinated multichannel stimulation waveforms.

ANALYSIS OF THE ROLLING-OVER EMG WITH UPPER EXTREMITY MOTION

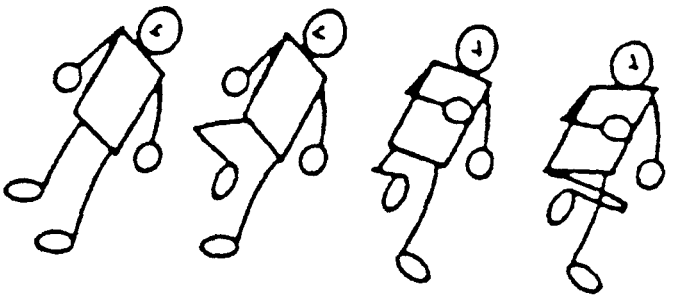
It was considered that the rolling-over motion might be performed with the muscles of the body and lower extremities, as we reported on the EMG analysis of those muscles.[1] However, it was proved that the stimulation to those muscles using surface electrodes were not enough to realize rolling-over. In order to solve this difficulty, additional motions of upper extremities were considered. If upper extremities are also stimulated, greater force can be generated without significantly increasing the stimulus to each muscle. To analyze the function of upper extremities during the rolling-ovver, we measured the EMGs in normal subjects. The muscles which were analyzed are M. biceps brachii, M. pectoralis major, and the muscles shown in Table 1.

Table 1. Objective muscles used in the stimulation experiment for rolling-over.

1. Lower extremities	2. Trunk
M. tibialis anterior	M. obliquus externus abdominis
M. gastrocnemius	M. erector spinae
M. quadriceps femoris	
M. hamstring	
M. adductor magnus	
M. gluteus maximus	
M. gluteus medius	

The rolling-over of a normal subject was achieved as follows : 1) first, the subject lay on his back ; then 2) raised the right knee by flexion both the right knee and the right hip ; 3) performed the rolling-over with the flexion of the right elbow, the abduction of shoulder girdle and the internal rotation of the right hip ; and finally 4) took the lateroabdominal position. These motions are shown in Fig. 1 schematically, 14-channel EMGs were simultaneously measured by a bipolar method using surface electrodes, and recorded in a data recorder. EMG wavefoms were full-wave rectified and averaged with time constant 0.3 sec. These are indicated in Fig. 2.

This sequence of rolling-over motion was constructed of two phases. The first phase included the flexion of the knee and the hip. The activity of M. hamstring(a knee flexor) was not clearly observed. It appears that the flexion of a lower extremity was mainly performed by the hip flexor, which was accompanied by the knee flexion,



a) Supine position
b) Flexion of knee & hip
c) Flexion of elbow, abduction of shoulder girdle, & internal rotation of hip
d) Lateroabdominal position

Fig. 1 Rolling-over motion

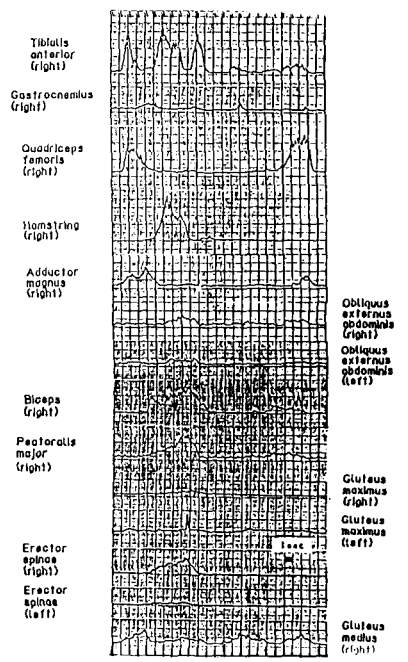


Fig. 2 EMG recordings during rolling-over motion.

This may be proved more conclusively by measuring the EMG of other hip flexors(e.g. M.iliopsoas).

The second phase was the flexion of the elbow, the abduction of shoulder girdle and the internal rotation of the hip. These motions performed the real rolling-over of the body. In this phase, an effect of using the upper extremity was observed, i.e. the activities of M.obliquus externus abdominis and M.erector spinae were decreased as compared to the case where no upper extremity was used by the same subject. It may suggest that the rotation with an upper extremity motion makes it easy to roll-over the body. Thus stimulation of an upper extremity can contribute significantly to an efficient rolling-over motion.

DISCUSSION

In this paper we reported on the electrical stimulation and the EMG measurement necessary to perform body control by FES, and verified

the fundamental feasibility of the technique for rolling—over the body. However, the good rolling—over motion which can be used in clinical application is difficult to perform by FES using surface electrodes, even though upper extremities are also stimulated.

In our study, both experiments were performed with surface electrodes, so that the muscles as the objects were only superficial ones. In order to perform the good motion, deep muscles (e.g. M.iliopsoas) should be also stimulated, and it may be necessary to use percutaneous electrodes.

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-Abstract-

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A method to roll-over the paralyzed body by means of Functional Electrical Stimulation(FES) is considered. It is demonstrated that individual joint motions necessary for the rolling-over are realized by electrical stimulation. EMG measurements are also performed to analyze the cooperative activities of the muscles during rollingover motion in a case where an upper extremity was used. These results of two experiments using normal subjects verifies the fundamental feasibility of body control by FES.

Key words : functional electrical stimulation(FES) ; rolling-over motion

—초록—

기능적전기자극에 의한 체간제어의 기초적인 연구

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호시미야

기능적전기자극(FES)을 이용하여 중추신경장해환자의 체간제어를 행하는 방법을 고안하여 체간제어에 필요한 각 각의 관절운동을 실현시켜 보았다.

건강인에게 전기자극실험을 행하고 기능적전기자극에 의해 체위변환의 실현가능성을 검증했다. 또한 상지를 함께 이용한 체위변환시의 근전도를 해석하여 보다 적절한 체위변환의 방법을 검토했다.