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5.7.3: EMG and Applications

Muscle Afferent Activity Recorded During passive Extension-Flexion of Rabbit's Foot

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ABSTRACT

In this investigation we studied the recorded neural activities from muscle afferents regarding ankle joint kinesthesia using cuff electrodes in a reduced rabbit model of human peripheral nerves. The ankle was passively rotated in an extension-flexion plane while the neural activity was recorded from tibial and peroneal nerves. The recorded signals mainly reflected a mixture of activity from primary and secondary muscle afferents. The activity from either nerves increased when the corresponding muscle group is stretched, an abrupt decrease in activity occurred when the muscles were shortened. The evoked activity was dependent on the initial joint position and velocity of ankle rotation.

I. INTRODUCTION

Functional electrical stimulation (FES) can be used to restore function in paralyzed patients. One of the main problems with open loop FES systems is the lack of feedback information resulting in imprecise and inefficient movements. Natural sensors, which are already present in the body, may provide information ideal for feedback control in an FES system. However the main challenge is to extract the appropriate information to be used for a FES system. Studies with a tetraplegic individual who had a recording cuff implanted around a digital nerve and used FES for grasp function, revealed that information about slippage could be used in an artificial reflex to arrest the slippage [1]. In recent studies [2], afferent signals from muscle spindles were used as feedback for controlling ankle joint position using intrafascicular electrodes.

The objective of the present study was to record information regarding ankle joint kinesthesia (extension-flexion) from muscle spindles using cuff electrodes in a rabbit model of human peripheral nerves. Neural activities were recorded simultaneously from tibial nerve and peroneal nerve during passive trapezoidal motion. A variety of velocities, excursions and starting positions were investigated.

II. MATERIALS and METHODS

The experimental apparatus consist of a computer controlled position servo system to rotate the rabbit's ankle at programmable rates in a flexion-extension plane while holding the knee at a desired angle. Ankle joint position and torque were recorded in addition to the neural signals from the common peroneal and the tibial nerves. Acute experiments were conducted on New Zealand White adult rabbits (Approximately 3-5 Kg). Animals were anesthetized with an intramuscular injection of FENTANYL/FLUANISION (.095 mg/kg and .30 mg/kg respectively) . An Incision was made on the lateral side of the left hind limb to expose the sciatic nerve approximately 3 cm above the knee. The tibial and the peroneal nerves were carefully separated proximally to create enough length to install 22 mm long spiral cuff electrodes around each nerve while the sural nerve was transected to eliminate its cutaneous input. The muscles and the skin were then closed at the incision site. Two more incisions were made proximal to the ankle joint on the lateral and medial sides of the shank to expose the descending branches of tibial and peroneal nerves that innervate the foot and the ankle. Both branches were transected eliminating proprioceptive inputs from ankle joint and foot. Finally the incisions were closed.

The animals were lied on their right side on the base plate while the left foot was securely placed in a cradle. The ankle joint was coupled to the motor shaft and the foot was secured in the cradle allowing only movement in the extension-flexion plane. The neutral position was defined as 100° (where 180° corresponds to the foot being in line with the tibia) with a maximum excursion angle of $\pm$ 30° on each direction. The left knee was also clamped to the base plate at a fixed angle of 85° between the tibia and the femur.

Nerve signals were pre-amplified, band pass filtered at 1-5 kHz and sampled at 10kHz along with ankle torque and position signals. Rectification, averaging, and all other signal processing were performed digitally.

III. RESULTS

During ankle flexion, the extensor muscle group was stretched and most of the recorded activity was from the tibial nerve. Conversely during extension the flexor muscle group was stretched and most of the recorded activity was from the common peroneal nerve (Fig. 1). We expect that the evoked activity mainly derives from muscle stretch receptors since we eliminated the cutaneous input from the foot and because infusion of lidocaine into the joint capsules of the ankle and knee did not appreciably diminish the responses. The recorded activity was a combination of velocity sensitive primary (Ia) and position sensitive secondary (II) afferents. In Figure 1, the ankle was rotated from maximum extension, 130°, to maximum flexion, 70°, at a rate of 30 (deg/sec). As the extensor muscle group stretched, there was a strong rate dependent discharge recorded from tibial nerve returning to a tonic level during the plateau. As the foot began to extend, the activity from tibial nerve dropped sharply and the peroneal activity increased due to the stretch of the flexor muscle group. We also observed silent periods where there is no significant neural activities in either tibial or peroneal nerves. These silent periods, which are more noticeable during extension phase, occur when the joint is near its neutral position (100°). Both the tibial and the peroneal activity was remarkably reproducible for similar excursions. During the last trial, the slow decline in peroneal activity, contrary to the sharp drop in the ascending trials is due to the fact that the flexor muscles were maintained in a stretch state.

The rate dependency of the afferent response can be observed in Figure 2. The recorded activities from the rising part, in both nerves, was greatly influenced by the slope of the ramp. However the maximum peak is similar for all trials regardless of the rate of rotation.

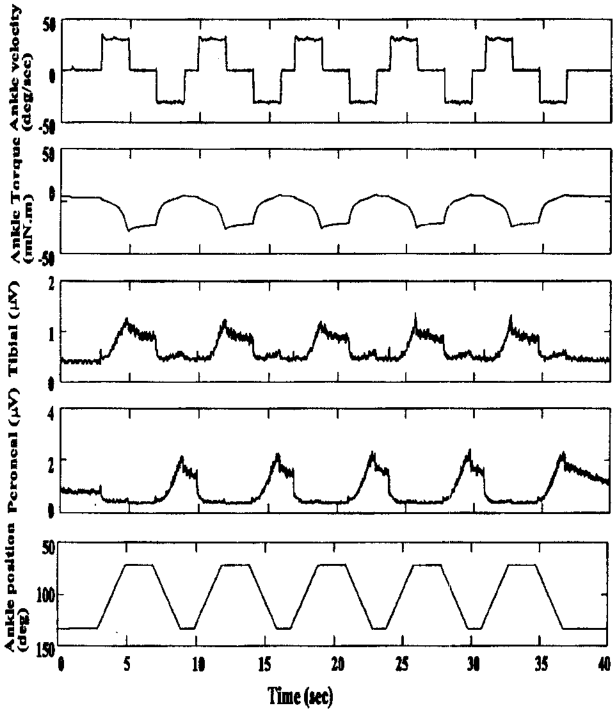

Fig. 1. Recorded activities from tibial and peroneal nerves during flexion-extension of the foot. The ankle joint was moved passively at a rate of 30 (deg/sec).

IV. CONCLUSIONS

Afferent neural activity recorded from tibial and peroneal nerves, corresponding to afferent discharge, during extension-flexion movement of the rabbit foot occurs in a complimentary "push-pull" fashion throughout most of the ankle joint range of motion.

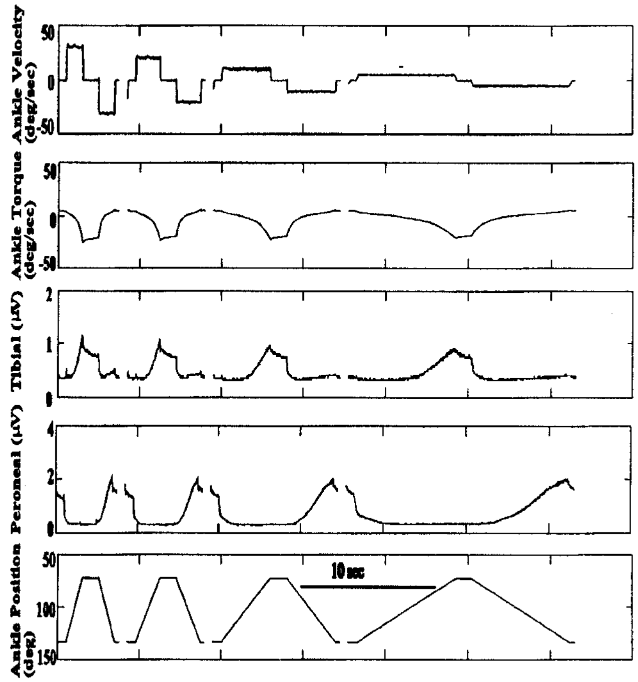

Fig. 2. Activities from tibial and peroneal nerves during flexion-extension at different velocities. Each trial is an average of ten individual trials. From left to right, each trial corresponds to rates of 5, 10, 20 and 30 (deg/sec).

We observed pronounced hysterises (where there is little activity during the relaxation phase of the stretching stimulus) in recorded activity from both the tibial and the peroneal nerves. In an FES application, the hysterises effects can be overcome by only using the activity from the tibial nerve during flexion and the activity from the peroneal nerve during extension motion. However, the presence of silent periods with no significant afferent discharge can further complicate development of an effective controller. We conclude that simultaneous recording of muscle afferent signals from the foot flexors and extensors maybe useful as feedback in a closed loop FES system.

REFERENCES

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