INTRODUCTION

Ballistic contraction is regarded as feed-forward neural muscle control which does not receive the influence of peripheral feedback information (Desmedt & Godaux, 1979). This means that sets of command information that are output from the cortical motor center reaches muscles directly without receiving modification. Therefore it is strongly conjectured that analysis of the muscle discharge is connected to the program of the cortical motor center. This study investigated the sequential command flow that controls the rapid knee joint extension in a range of 50% maximum voluntary contraction (MVC). We obtained values of iEMG reset at 10msec each during a ballistic force exertion, and then estimated the density of neural information in knee extensions during the brief effort. According to previous studies, the agonist-antagonist linkage in the force trajectory control of rapid isometric movement has been shown. This has suggested to us the necessity of studying the difference of control modality between agonist and antagonist muscles in ballistic contraction.

METHODS

The subjects were 8 healthy males (20~25 years old). The experimental arrangement is explained in Figure 1. The subjects sat on a chair for the experiment and their right knee joints were fixated to a 90degree angle. The ballistic force exertion was done straightforwardly to knee joint extension direction. The monitor was set in the front of the subject and showed the target level and the force produced by the subjects.

Figure 1: Schematic representation of subject and experiment apparatus. The subjects sat down on the chair, and their right knee joints were fixated to a 90degree angle. The ballistic force exertion was done straightforwardly to knee joint extension direction. The monitor was set in the front of the subject and showed the target level and the force produced by the subjects.

Figure 2: Diagram of the flow analysis from raw EMG to integrated and showing data according to 10msec divisions. The integral value was reset every 10msec and returned to zero. Each 10 msec division formed a line sequentially in the force curve. The muscle discharge time (Electromyogram Dwell Time: EDT) and sequential amount of the muscle discharge were obtained from electromyogram. Furthermore, iEMG was processed by resetting at intervals of 10msec each (series of 10msec division) during the muscle discharge time (Figure 2). The mean iEMG value of 100 trials was calculated about division sequentially. The fluctuation of nerve information density from the cortical motor center can be made a comparative study by analyzing the variation of values of the divisions. The variability was shown by CV (Coefficient of Variation: CV=SD/Avr.x100).
RESULTS

The force exertions under 60% MVC were done by all the subjects under 3 levels of target force in this research. However, the forces of exertion to target did not necessarily show normal distribution nearby the target for each subject. It was also found that there was an underestimation to the higher target and an overestimation to the lower target. A diversity of distribution patterns among subjects in ballistic contraction was observed (Figure 3). Even if the force was enhanced, the times of TPF and EDT were nearly constant without changing (Figure 4). It was found that the discharge was enhanced along with the increase of force at each division. The average amount of discharge and SD derived from 100 times exertion increased in the first half and decreased in the latter half of ballistic discharges (Figure 5).

The coefficient of variation (CV) of the muscle discharge in the series of sections is shown in Figure 6. When knee extension was done under the same task, the validities of CVs in the first half to 100msec in agonist (RF, VM, VL) were smaller than those in the latter half, and the validity of CV in antagonist (ST) did not show differences like those in agonist. The values of CV in antagonist (ST) became generally larger than those in agonist (RF, VM, VL). However the validities of CVs in the trial matched the target level (within ±5%) became smaller in all divisions. It was said that these corresponded to the particular muscles. The difference between the first half and the latter half was the same in agonist. As for antagonist (ST), the difference between the agonist and the synergist was not shown.

![Figure 3](image1.png)

**Figure 3:** The distributions of the force exertion for each target are shown. The force exertion distributions in four people of all the subjects are also shown in this figure. The force exertion did not necessarily show normal distribution nearby the target for each subject. All of the trials which were analyzed were included in this figure. It was shown that the force exertions to the 10%target became overestimated, and that to the 50%target was underestimated. But the force exertion to the 30%target was scattered in a wide range among subjects.
Figure 5: The section integral value and standard deviation of each muscle to 3 targets are shown for one typical subject. Columns of each “INT” represented the divisions that were divided into 10msec interval from the onset time of muscle discharge to TPF. (see legend in Figure 2)

Figure 6: The coefficient of variation (CV) of each muscle is shown. CVs were obtained from the amounts of discharge and standard deviation that were shown in Figure 5. The upper line shows the change of degree of freedom.
DISCUSSION

TPFs and EDTs of ballistic contraction showed little change even if ballistic forces increased. It is suggested that a pulse height control mechanism could be adopted in this contraction (Ghez & Gordon, 1987b). The coefficient of variation of amount of EMG in three knee extensors showed a lower variability in the first half. That means higher uniformity. It might be said that the movement commands in the latter half which were output from the motor center to execute the ballistic contraction task were modified widely. Therefore, it seems likely that motor commands for a rising phase of ballistic contraction should be constituted by the successive neural programs that caused the unitary force reinforcement. And it also suggested that the sequential neural control of ballistic contraction in the synergist would be performed in a similar manner. Otherwise the large validity of motor commands in antagonist during the ballistic contraction were shown in all cases over the terms of muscle discharge. It has been suggested that antagonists do not play a force rising specific function, but play some auxiliary role during the ballistic contraction (Ghez & Gordon, 1987a).

REFERENCES