Strength training during bed rest attenuates the decline in steadiness
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Introduction
When an individual performs a steady contraction, the exerted force fluctuates about an average value. The fluctuations in force during a steady contraction vary with the level of force, the muscle used for the task, the age of the subject, and the type of contraction performed. The greater fluctuations in force especially exhibited by the old adults correspond to a decline in the steadiness of the contraction (Enoka et al., 1999). Although the exact mechanisms for the steadiness are not established, it has been discussed that the changes in the motor unit number, size, discharge characteristics of motor units, and muscle coordination may contribute significantly to the age-related decline in the ability to control muscle force (Galganski et al., 1993).

The fluctuations in force are mutable with interventions such as strength training (Keen et al., 1994). However, other than the effects of aging, effects of reduction in muscle activity per se on the fluctuations is unknown. The purpose of the study was to determine the effects of prolonged reduction in muscle activity on the magnitude of the force fluctuations during steady contractions. Dramatic reduction in muscle activity can be realized by a prolonged bed rest, which induces substantial decrease in muscle mass and strength of the leg muscles (Akima et al., 2000). Also, strength training during bed rest can counteract the deconditioning of the muscles. Therefore we tested the effects of bed rest and the effects of bed rest combined with strength training on the fluctuations of the force by leg muscles.

Methods
Twelve young males (22.6 ± 1.1 yr) participated in a bed rest study for 20 days. Six subjects were assigned to the non-training group (Control), and 6 subjects were assigned to a strength-training group (Trained). The subjects were reclined with the body tilted (head down) at 6 degrees relative to the horizontal at all times throughout the bed rest period, except for during strength-training for the Trained group. The training comprised of a dynamic plantar-flexion exercise and a dynamic leg-extension exercise by using a modified leg-press training machine (Leg Press VR-4100, Cybex). For each exercise, subjects performed 5 sets of 10 repetitions every day with a load that corresponded to 70% of the maximal voluntary contraction (MVC) force. The training load was adjusted to maintain the 70% of MVC throughout the bed rest period.

Before and after the 20 days of bed rest, all subjects performed submaximal isometric contractions by the plantarflexor muscles and by the knee extensor muscles. The ankle joint angle and the knee joint angle were maintained at 90 deg during plantar flexion and knee extension tasks, respectively. The subjects were instructed to exert a steady force to match the target force displayed on an oscilloscope for the duration of 30 s. The target forces (2.5, 5.0, 7.5, and 10% of MVC force) were presented in a randomized order. The surface electromyogram (EMG) was picked-up by bipolar silver-silver chloride electrodes from the belly of the medial gastrocnemius and soleus muscles for plantarflexion, and the vastus lateralis and rectus femoris muscles for knee extension. The amplified EMG and torque signals were continuously stored on a personal computer after analog-to-digital conversion with sampling frequency of 1000Hz. Steadiness was quantified by the coefficient of variation (CV) for force over the middle 16 s of the contraction. Neuromuscular activity was evaluated by the root mean square value of EMG for the same period.

Results
Figure 1 shows the group data of the changes in CV of force during isometric plantarflexion (top panels) and knee extension (bottom panels) at 2.5, 5, 7.5, and 10% of MVC force in the Control group (left panels) and in
the Trained group (right panels). In both tasks, CV of force decreased as the level of the target force increased, indicating that it is more difficult to perform steady contraction as the level of exerted force is decreased.

After 20 days of bed rest, CV of force increased significantly (p < 0.05) at the lower target forces for the plantarflexor muscles (3.1x at 2.5%, 1.7x at 5%) and knee extensor muscles (1.3x at 2.5%, 1.3x at 5%) of the Control group. For subjects in the Trained group, there were only minor changes in CV of force after 20 days of bed rest. There were no changes for the knee extensor muscles and modest changes at the lowest forces for the plantarflexor muscles (1.7x at 2.5%, 1.5x at 5%). The root mean square value of the EMG for the steady contractions increased significantly at the highest forces in the Control group, but not in the Trained group. The ratio in root mean square value of EMG of the synergistic muscles was calculated to investigate the changes in inter-muscle coordination (Fig.2). In the Control group (left panels), alteration of the ratio was observed as a tendency to increase in the knee extensors (vastus lateralis / rectus femoris, 34%, p = 0.053; bottom panels) and as a significant increase in the plantarflexors (medial gastrocnemius / soleus, 73%, p < 0.01; top panels). In the Trained group (right panels), there was not a significant change for this ratio.

Discussion
This is the first study that investigated the changes in steadiness of lower leg by bed rest. There were two main findings: (1) the steadiness of submaximal contractions performed with leg muscles declined after 20 days of bed rest in the young subjects; (2) daily strength training mostly counteracted the decline in steadiness.

In the constant-force tasks by a single muscle of the first dorsal interosseous, Laidlaw et al. (2000) have demonstrated that the motor unit discharge rate was more variable for the old adults and that was strongly associated with the larger fluctuations in force. It seems, therefore, that the increase in the coefficient of variation of the force fluctuations after bed rest could partly be accounted for by possible alterations in the characteristics of motor unit discharge rate in the individual muscle.
The tasks in the present study, however, involved synergistic contractions of multiple muscles to control a steady force. From the changes in the ratio of EMG root mean square values between the synergists, it was shown that the distribution of activity among the synergists was altered in the Control group, but not in the Trained group. Changes in the ratio of EMG amplitude may well be the manifestation of the relatively depressed fine-regulation and of the alterations in the inter-muscle coordination among the multiple muscles after bed rest in the Control group. It appears that these changes were counteracted by the strength training during bed rest.

In conclusion, a 20-day bed rest resulted in a significant decrease in the steadiness for both plantar flexor and knee extensor muscles. Moreover, strength training during bed rest diminished the decline in steadiness. These changes seem to be related to alterations in the inter-muscle coordination.

References

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