Regional-specific muscle hypertrophy induced by single- and multi-joint resistance training

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SUMMARY
The purpose of the present study was to compare the region-specific muscle hypertrophy induced by single- and multi-joint resistance training. One group of 12 subjects trained their elbow extensors with a single joint exercise of the elbow (SJ). Another group of 12 subjects trained their arm by a multi-joint exercise (MJ) that involved elbow extension and shoulder flexion. The two training regimens consisted of the same program variables (80% of one repetition maximum, five sets of eight repetitions, and 90 s rest between sets). Both groups trained three sessions per week for 12 weeks. Cross-sectional areas (CSA) of the triceps brachii muscle before and after the training were measured from series of magnetic resonance images (MRI) of the upper arm. In the proximal region, changes in the CSA relative to the values before training were significantly greater in SJ than in MJ. On the other hand, no significant group difference was found in the relative change in CSA in the central or distal regions. The results suggest that the regional difference in muscle hypertrophy induced by resistance training is dependent on the type of exercise performed.

INTRODUCTION
It is well documented that muscle size increases after chronic resistance training (hypertrophy). The extent of the hypertrophy induced by resistance training has been found to vary along the length of the muscle [1]. One possible explanation for the nonuniform muscle hypertrophy is the regional difference in muscle activation during resistance exercise [2]. The muscle activation pattern of an agonist muscle varies between single- and multi-joint resistance exercises [3]. Therefore, it is hypothesized that resistance training with the two types of exercise mode may induce differential hypertrophic responses in a given muscle. The purpose of the present study was to test this hypothesis for the elbow extensor muscles.

METHODS
A total of 24 healthy men participated in the present study. They were divided into two groups. One group of 12 subjects trained their elbow extensors by a single joint exercise (SJ) of the elbow (“lying triceps extension”). They lay supine with the shoulder joint flexed at 90°. They moved the forearm upward and downward with a dumbbell in their hand, while maintaining the same shoulder joint angle throughout the exercise. The other group of 12 subjects trained their arm by a multi-joint exercise (MJ) that involved elbow extension and shoulder flexion (modified “dumbbell press”). They lay supine and raised a dumbbell vertically from just above the chest until the elbow was fully extended, and then lowered it. Although not strictly controlled, the range of motion of the elbow joint was similar between the two exercises. The two training regimens consisted of the same program variables (80% of one repetition maximum, five sets of eight repetitions, and 90 s rest between sets). Both groups trained three sessions per week for 12 weeks.

MRI was used to determine the CSA of the triceps brachii muscle before and after the training period. The MRI was acquired by using a T1-weighed spin-echo sequence (echo time: 11 ms, repetition time: 520 ms, slice thickness: 10 mm, matrix: 256 X 192, field of view: 180 mm). The boundary of the triceps brachii muscle was manually digitized in the images at 4 cm intervals from the elbow joint (seven images). Relative changes in the CSA induced by the resistance training were calculated for each slice.

Two-way analysis of variance (ANOVA) with repeated measures was used to analyze the effects of group (SJ and MJ groups) and region (7 regions) on the relative changes in the CSA of the triceps brachii muscle. The ANOVA was followed by post hoc tests with Bonferroni correction.

RESULTS AND DISCUSSION
Relative changes in the CSA of the triceps brachii muscle after training are shown in Figure 1. Significant main effects of the group and region were found for the changes in CSA with a significant interaction between the two factors. The relative changes in the CSA at 24 and 28 cm from the elbow joint were significantly greater in SJ than MJ. On the other hand, the corresponding differences were not significant for the other regions. In the SJ group, significantly greater increases in the CSA were observed at 16-28 cm from the elbow than at 4 cm. In the MJ group, the relative changes in the CSA were significantly greater at 8-16 cm than at 28 cm.

In the acquired MR images, the CSAs of the triceps brachii muscle in the proximal regions were almost exclusively occupied by the long head. The group difference in the hypertrophic change in the proximal regions, therefore, should be attributable to that in the long head. The long head crosses the shoulder joint as well as the elbow joint. Hence, the
muscle fiber length, the changes in the fiber length and the activation of the long head would differ between SJ and MJ. Among them, the differences in the muscle fiber length and its changes during the exercises might not have a significant effect on the hypertrophy, because it has been shown that the differences in the joint angle (i.e. muscle fiber length) [4] and in the contraction type (i.e. changes in the muscle fiber length) [5] during resistance exercise do not cause a difference in the extent of muscle hypertrophy. On the other hand, electromyographic activity of the bi-articular muscle (rectus femoris) has been shown to be greater during the single-joint exercise (knee extension) than during the multi-joint exercise (squat and leg press) [3]. Taken together, the activation of the long head might differ between SJ and MJ, and the difference might be a factor that accounts for the differential hypertrophy in the proximal regions.

CONCLUSIONS
The present study demonstrated that the region-specific changes in the CSA of the triceps brachii muscle were different between the single- and multi-joint resistance training. The results suggest that the regional difference in muscle hypertrophy induced by resistance training is dependent on the type of exercise performed.

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REFERENCES