Effects of Low-Intensity Resistance Exercise With Short Interset Rest Period on Muscular Function in Middle-Aged Women

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ABSTRACT

We investigated the effect of low-intensity resistance exercise training on muscular size and strength where the interset rest period was shortened so as to reduce the metabolite clearance. Female subjects (aged 45.4 ± 9.5 years, n = 10) performed bilateral knee extension exercises in a seated position on an isotonic leg extension machine. The exercise sessions consisted of 3 sets of exercise at a mean intensity of ~50% 1RM with an interset rest period of 30 seconds and was performed twice a week for a period of 12 weeks. The strength and the cross-sectional area (CSA) of the knee extensors and flexors were examined with an isokinetic dynamometer and magnetic resonance imaging (MRI), respectively. The CSAs of the knee extensors and flexors increased by 7.1 ± 1.6% (p < 0.01, Wilcoxon signed rank test) and 2.5 ± 1.4% (not significant), respectively. Isometric and isokinetic strengths increased significantly (p < 0.01) at all velocities examined, whereas no significant change was observed in those of knee flexors. These results indicate that a low-intensity resistance exercise with a short interset rest period is substantially effective in inducing muscular hypertrophy and concomitant increase in strength.

Key Words: interset rest period, intramuscular environment, muscular hypertrophy, resistance training


Introduction

Muscular function declines with aging. In particular, reductions in both the muscle fiber area (6) and the number of muscle fibers (9) have been shown to cause a marked decrease in muscular strength in older people. Muscular strength is a basic precondition for any human movement such as lifting, holding, and carrying loads, all of which should be closely related to the daily activities for life. Thus middle-aged and elderly people must keep their muscular strength for health and well-being. In general, heavy resistance training has effectively induced muscular hypertrophy (3, 5, 16) and an improvement of nervous control to exert force in older people (1, 13). However, resistance exercise with high intensity (>80% 1 repetition maximum [1RM]) may bear a risk for injury, and thus may have to be applied to older people with precaution because it has been reported that ~20% of the subjects aged 70–79 years show some symptoms of orthopedic injury after an exercise at 1RM (15). In addition, a dramatic increase in systolic blood pressure (up to 250 mm Hg) has been reported to occur even in young subjects during heavy resistance exercise at an intensity of ~8RM for large muscle groups (4).

We have previously shown that low-intensity resistance exercise combined with vascular occlusion induced a marked hypertrophy and concomitant increase in strength in elbow flexor muscles of older women, even if the load of exercise was much lower than expected to induce muscular hypertrophy (20). The processes related to such an effect of externally applied occlusive stimulus have been interpreted as follows: (a) additional recruitment of fast-twitch fibers in a hypoxic condition, (b) moderate production of reactive oxygen species (ROS) promoting the tissue growth (19), and (c) stimulated secretion of catecholamines and growth hormone by intramuscular accumulation of metabolic subproducts (18). These studies indicate that local hypoxic and acidic intramuscular environment during the low-intensity resistance exercise with vascular occlusion potentiates muscular adaptation (hypertrophy) to resistance exercise.

Externally applied occlusion would not be necessarily required for regional accumulation of metabolites if muscles would be forced to contract in a hypoxic condition and the metabolite clearance would be simultaneously suppressed. Under normal circulation, sustained contractions at >40% maximal voluntary contractions (MVCs) have been shown to inhibit both blood inflow to and outflow from the muscle (2, 12). Thus the above condition during exercise is expected to be satisfied, at least partially, when intensity at
>40% MVC is combined with the short interset rest period. Indeed, Kraemer et al. (7, 8) have shown that secretions of growth hormone are strongly stimulated by conventional resistance exercises with a shortened interset rest period (~1 minute) in both men (7, 8) and women (7), although the intensity was as high as 80% 1RM. In men, a similar exercise has been shown to cause an increase in plasma testosterone concentration (7). However, long-term effects of such resistance exercises with a short rest period have not been fully investigated.

In the present study, we investigated the long-term effects of resistance exercise with relatively low intensity (~50% 1RM) and a short interset rest period (30 seconds). The results showed considerable effects of the exercise regimen in inducing muscular hypertrophy and a concomitant increase in strength, suggesting the importance of manipulating the interset rest period in resistance exercise for older people.

Methods

Experimental Design

The present experiment was made to see whether low-intensity resistance training with a shortened interset rest period is substantially effective in gaining muscular size and strength. Since it was carried out as a part of health-related service programs for citizens, the same provisionally effective exercise regimen (with the short rest period) was to be applied to all subjects. The exercise used for experiments was a bilateral leg extension at a mean intensity of ~50% 1RM. Strengths and muscular cross-sectional areas of both knee extensors and flexors were measured before and after the 12-week training period. Variables obtained after the exercise training were compared with those obtained before the exercise training within the same individuals. Variables for knee flexors were used as untrained “internal control.”

Subjects

Ten healthy women aged 41–62 years (45.4 ± 9.5 years [mean ± SD]) volunteered for the study. After complete examinations of health status and medical history, they engaged in the resistance exercise of knee extensor muscles. Their physical characteristics were the following: height, 155.7 ± 5.6 cm; weight, 53.5 ± 9.4 kg (mean ± SD). Five subjects were postmenopausal. None of them were on medications or hormonal therapy or had prior experience with the specialized resistance exercise training. Strength of the knee extensor muscles and muscular cross-sectional area of the midthigh were measured before and after the 12-week training period. The subjects were previously informed about the experimental procedure to be used as well as the purpose of the study, and their informed consent was obtained. The study was approved by the Ethical Committee for Human Experiments at the University of Tokyo.

Regimes for Exercise Training

The subjects performed a bilateral knee extension exercise in a seated position with an isotonic leg extension machine. The range of joint motion was from 0° to 90° (0° at full extension). Based on our previous study (20), exercise was performed twice a week and lasted for 12 weeks, including the period for instruction and orientation (24 sessions in total). In the exercise session, the subjects performed 3 sets of exercise, each separated by an interval of 30 seconds. The intensity of exercise was 54.2 ± 3.5% (mean ± SE) of the weight that could be lifted once throughout the complete range of movement (1RM). The 1RM was measured every 4 weeks, and the absolute intensity was adjusted so as to keep the relative intensity constant. The subjects repeated the lifting movement until failure, and the average repetition in each set was 14.3 ± 0.7. The subjects were instructed to lift and lower the load at an approximately constant velocity, taking about 2 seconds for each of the concentric and eccentric actions. They also performed resistance exercises for other muscle groups (i.e., abdominal flexion, seated rowing, arm curl with machines, and back extension without external load [3 sets for each]). The intensity for every exercise was <60% 1RM, and the interset rest period was ~2 minutes.

All of the exercise sessions were preceded by a 10-minute warm-up on a cycle ergometer at about 50% of the physical work capacity and a stretching of the major muscle groups to be trained. Blood pressure (mean systolic pressure, 138.2 ± 5.8 mm Hg; mean diastolic pressure, 86.1 ± 2.7 mm Hg) was periodically measured before and after the exercise session, and no considerable abnormality was observed throughout the period of exercise.

Measurements of Muscular Strength

Isokinetic torque—angular velocity relations of knee extensors and flexors were examined by using an isokinetic dynamometer (Cybex 770-Norm, Ceybex Division of Lumex Inc., Medway, MA). The subjects were familiarized with the testing procedure on several occasions prior to the measurements. They sat on a chair with their back upright with their right leg firmly attached to the lever of the dynamometer. The pivot point of the lever was visually aligned with the rotation axis of the knee joint maintained at that position during all movement. Isokinetic strength was measured at action velocities of 30°, 60°, and 180° per second. The range of angular movement of the knee joint was limited between 0° and 90°. The value of peak torque was measured regardless of where it was developed within the range of movement. Three trials were made at each angular velocity, and the
Resistance Exercise With Short Interset Rest Period

Figure 1. Typical magnetic resonance images showing transverse sections of the mid-thigh, taken before (a) and after (b) the exercise training with a short interset interval, which lasted for 12 weeks. The images show identical, midportion sections along the femur in the same subject. The bar indicates 50 mm. The highest value obtained was used for further analyses. Isometric torque was measured at the knee angle of 80°.

Magnetic Resonance Imaging

To obtain cross-sectional images of the thigh, magnetic resonance imaging (MRI) was performed by using a 0.5 T superconducting system (Gyrosan T5 II, Philips Medical Systems Int., Best, The Netherlands) with a wraparound body coil. The coil covered the whole thigh, including markers attached to the skin. Twelve serial sections were acquired with a 6- to 10-mm sectional thickness and a 0.6- to 1.0-mm intersection gap. The field of view was 350 mm. Pulse sequences for spin-echo T1-weighted images were performed with a repetition time of 500–552 ms and an echo time of 20–25 ms. Two signal acquisitions were used. The scan matrix and reconstruction matrix were 205 × 256 and 256 × 256, respectively. The image acquisition was started immediately after the subject lied in a supine posture to minimize the effect of gravity-induced fluid shift. The time required for the whole sequence was about 4–6 minutes.

For each subject in the training group, the range of serial sections was deliberately determined on longitudinal images along the femur so as to obtain sections of identical portions before and after the period of exercise training. Among the photographs of 12 cross-sectional images obtained, those of 2 portions near the midpoint of the thigh were chosen for the measurements of the muscular cross-sectional area (CSA). Photographic negatives were digitized into an 8-bit grayscale at a space resolution of 144 pixels per inch and stored in a computer with an Epson ART-8500G scanner. Determinations of tissue outlines and measurements of CSAs for muscles and other tissues were made by using National Institutes of Health Image (version 1.25) software. The measurements were repeated 3 times for each image and their mean values were used. Deviation in these 3 sets of measurement was less than 2%.

Statistical Analyses

All variables are shown as means and the standard errors (±SE). Wilcoxon signed ranks test was used to compare differences between pre- and posttraining variables within the same individuals. For all statistical analyses, the 0.01 level of significance was used.

Results

Changes in Muscle Cross-Sectional Area After Exercise Training

Typical examples of the cross-sectional MRI of an identical midportion of the thigh are shown in Figure 1. The images taken before (Figure 1a) and after (Figure 1b) the period of exercise training with a short interset-interval (12 weeks) exhibit a marked increase (by ~12%) in the CSA of knee extensors after the period of training. To reduce errors in measurements associated with a slight mismatch between the sectional portions obtained before and after the period of exercise training and incidental deformations of muscles during the processes of the MRIs, 2 sections around the mid portion of the femoris, each separated by ~20 mm, were selected from 12 serial sections, and mean tissue CSAs were obtained from these 2 sections. The CSA of knee extensors showed significant (p = 0.0001) increases after the exercise training, and the percentage increase in CSA was 7.1 ± 1.6%, whereas no significant change was observed in knee flexors and femurs (Figure 2).
Changes in Muscular Strength After Exercise Training

The 1RM of the knee extension exercise increased by 38.2 ± 8.5% (p = 0.0001) after the period of training. Figure 3 shows changes in isokinetic force-velocity relations. All values of isokinetic torque were normalized to pretraining values of the isometric torque. The exercise training induced significant increases in both isometric and isokinetic strengths at all velocities examined (Figure 3a), whereas no significant change was observed in those of knee flexors (Figure 3b). When averaged throughout all velocities, the percentage increase in knee extension strength after the exercise training was 16.9 ± 3.1%. Maximal isometric torque per unit CSA (in Nm⁻¹) increased significantly from 2.36 ± 0.17 to 2.55 ± 0.19 (p = 0.0003). The ratio between knee extension torque and knee flexion torque also increased significantly at 3 out of 4 velocities examined (Figure 3c), indicating that the increase in strength is an exercise-specific effect.

Discussion

The present study showed that a low-intensity resistance exercise with a short interset rest period (30 sec-

Figure 2. The cross-sectional areas (CSAs) of the knee extensor, flexor, and femur measured before (square) and after 12 weeks of exercise training (dotted square), shown as means ± SE (n = 10). The asterisk represents statistically significant changes from pretraining values (p < 0.01).
ond) is effective in inducing muscular hypertrophy and a concomitant increase in strength. The intensity used in the exercise was as low as the ~50% 1RM throughout the period of training, which corresponded to ~30–40% of the maximal isometric force measured with an isokinetic dynamometer (maximal voluntary contraction [MVC]). Exercise training with such a low intensity has generally been thought to be ineffective in muscle gain of size and weight (10). Indeed, a 16-week training session with a low-intensity workout (~50% 1RM) and longer interset rest period (1 minute) did not induce muscular hypertrophy in elbow flexors of older women (20), in spite of the same exercise intensity as that in the present study. Therefore, the present effect of low-intensity resistance exercise with a short interset rest period would be caused primarily by the shortened interset rest period, which may share the common mechanism operating in a low-intensity resistance training combined with vascular occlusion (20).

We have previously shown that a low-intensity resistance exercise combined with vascular occlusion induced a marked hypertrophy and concomitant increase in strength in elbow flexor muscles of older women, even if the load of exercise was much lower than expected to induce muscular hypertrophy (20). The vascular occlusion causes a hypoxic and acidic intramuscular environment during the exercise, which then induces an additional motor-unit recruitment of type II fibers to keep a given level of force (18), as has been shown in contractions under ischemic (14, 17, 18) and fatiguing conditions (11). In addition, our recent study with young male subjects also showed that a low-intensity (20% 1RM) exercise with occlusion for the lower extremities caused a 290-fold increase in the plasma concentration of growth hormone, whereas no such effect was seen after the exercise without occlusion (18). These processes may therefore play a part in the potent effect of low-intensity exercise with occlusion in inducing muscular hypertrophy.

When contractions are made at increasing percentages of MVC, full occlusion and ischemia occurs at approximately 40–60% MVC (2, 12). Therefore, resistance exercise at an intensity >40% MVC would cause an ischemic intramuscular environment during the exercise, the recovery from which would largely depend on the 10-interset rest period. Kraemer et al. (7) have demonstrated that a sufficient volume of high-intensity exercise (at an intensity of ~80% 1RM for large muscle groups) done with an interset rest period as short as 1 minute transiently provokes more than a 10-fold increase in the plasma concentration of growth hormone in women. Because such a dramatic increase in plasma growth hormone concentration was not seen after exercises with a longer interset interval (3 minutes), it has been speculated that local accumulation of metabolites by the shortened interset rest period stimulates the hypophyseal secretion of growth hormone.

In the present study, a low-intensity resistance exercise (~50% 1RM) was performed in combination with a much shorter interset rest period to enhance a hypoxic and acidic intramuscular environment even under normal circulation. Such an exercise training was shown, for the first time, to be substantially effective in inducing increases in muscular size and strength. Although the present study lacks a control experiment (i.e., low-intensity exercise with a longer rest period), it provides important information for prescribing exercise regimens without large mechanical stress for older individuals.

**Practical Applications**

The present study showed that low-intensity exercise training for knee extensors with a short interset rest period is substantially effective in inducing muscular hypertrophy and a concomitant increase in strength. However, the quantitative contribution of a shortened interset rest period in the effect of exercise remains unclear because of the absence of data on the effect of exercise training with the same intensity and a much longer interset rest period. By combining the present data and those of an earlier study on the roles played by endocrine activities (18) and intramuscular blood circulation (18), we can conclude that controlling the interset rest period is important to gain a muscle-trophic effect from resistance exercise. Apart from the precise mechanism for its effect, the usefulness of the present, low-intensity exercise with a shortened interset rest period should provide important information to practitioners who may have to prescribe exercise regimens for people without sufficient physical strength. In particular, it may work in introductory regimens for older people and those in the early stages of rehabilitation.

**References**


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