

## **COMPARISON BETWEEN TWELVE AND SIX SETS OF HIGH LOAD LEG EXTENSION ON MUSCLE STRENGTH**

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### **Abstract**

Numerous studies can be found in the body of literature on muscle strength after eccentric exercise. However, muscle strength after weight resistance exercise, including the concentric and eccentric phases usually performed in resistance training, has not been fully investigated. This study aims to compare the effects of mid- and high-volume weight resistance exercise on muscle strength. Sixteen subjects were divided into a high-volume group with participants who performed 12 sets (12SET, n=8), and a mid-volume group with participants who performed 6 sets (6SET, n=8). The participants performed leg extensions on the first day. The exercise load was 4~6 RM. The rest between sets was three minutes. Maximal voluntary contraction (MVC), isokinetic strength (30°/ sec.: ISOK30, 60°/ sec.: ISOK60, 150°/ sec.: ISOK150, 240°/ sec.: ISOK240), muscle soreness, and thigh circumference were measured before (PRE), after (POST) exercise, as well as one day, two days, three days, five days, and seven days after exercise. The only significant effect was time in all measurements. Although MVC decreased at POST, it recovered to the level of PRE one day after exercise. ISOK150 and ISOK240 showed similar results to MVC. ISOK30 showed a lower value one day after exercise. ISOK60 did not change throughout the experiment. Muscle soreness was higher at POST, one day and two days after exercise. Peak muscle soreness was higher for 12SET than for 6SET. Thigh circumference was higher at POST and one day after exercise. These results indicated that muscle damage was lower than previously reported after eccentric exercise. In addition, there was no difference between 12 sets and 6 sets of weight resistance exercise, except for peak muscle soreness. Our results suggest that muscle strength after leg extension recovers by two days, irrespective of whether 12 sets or 6 sets of high load leg extension are performed.

*Keywords:* Leg extension, high-volume exercise, MVC, isokinetic strength

## **Introduction**

Resistance training is carried out for the purpose of muscular strength increase. After one bout of resistance exercise, muscle damage (e.g. prolonged reduction in voluntary force and delayed muscle soreness) is induced (Cheung, Hume, & Maxwell, 2003; Thiebaud, 2012). Previous research into muscle damage has usually been based on eccentric exercise (Nosaka, Newton, & Sacco, 2002; Nosaka & Newton, 2002; Takizawa, Soma, Nosaka, Ishikawa, & Ishii, 2012). These studies reported that Maximum Voluntary Contraction (MVC) did not recover to the level before the exercise by four or five days after exercise (Nosaka et al., 2002; Takizawa et al., 2012). In contrast, a study that compared concentric exercise with eccentric exercise for their effects on muscle damage showed that the latter induced greater damage than the former (Lavender & Nosaka, 2006). In addition, the time needed for recovery was longer in the eccentric exercise group (Lavender & Nosaka, 2006). Thus, the extent of muscle damage is different between contraction types, even for the same exercise loads.

The weight resistance exercise usually performed in resistance training includes both concentric and eccentric phases (Fleck & Kraemer, 2008). No previous study has investigated muscle damage after typical weight training that includes the concentric and eccentric phases. Furthermore, only one study that investigated the effect of differential exercise volumes on the extent of muscle damage also examined eccentric exercise (Nosaka et al., 2002). Thus, there are no studies that have investigated muscle damage after typical high intensity resistance exercise.

We consider that clarification of the muscle damage effect on muscle strength after mid- and high-volume weight resistance exercise would be meaningful for understanding the dose-response relationship of resistance training.

Therefore, the purpose of the present study is to compare the effect of mid- and high volumes of resistance exercise on muscle strength. We hypothesized that the time needed for recovery would be longer in the high-volume group than in the mid-volume group.

## **Methods**

### *Subjects*

A total of 16 healthy, active university students participated in the present study. All subjects were free of injury in their right leg. They were randomly divided into two resistance exercise groups: 12SET (n=8, 21.0 ± 1.7 years, 173.4 ± 4.7 cm, 64.2 ± 5.6 kg) and 6SET (n=8, 19.9 ± 1.1 years, 170.9 ± 7.4 cm, 67.2 ± 9.6 kg). We notified each subject to avoid performing intense exercise or training of the lower extremity (e.g., running and resistance). In addition, we instructed each subject to avoid consuming alcohol during the experimental period. All subjects were informed of the protocol, purpose, and risks of the present study, and informed consent was obtained from all subjects. All the

procedures involved in this study were approved by the institutional Ethics Committee in accordance with the Declaration of Helsinki.

## **Procedures**

Subjects had previously joined pre-measurement as described in the next section, and their 1 Repetition Maximum (1RM) leg extension in the right leg was measured. One week later, subjects performed leg extension and measurements. Measurements were conducted before (PRE) and after (POST) exercise, as well as one day, two days, three days, five days, and seven days after exercise. Each subject's leg extension 1RM was determined according to the guidelines set by the National Strength and Conditioning Association (Baechle, Earle, & Wathen, 2008). We divided subjects into two groups: 12SET and 6SET. Participants in 12SET performed 12 sets, while those in 6SET performed six sets of exercise. The 1RM was  $50.7 \pm 9.6$  kg in 12SET, and  $53.0 \pm 5.2$  kg in 6SET. On the first day, each subject came to the laboratory and measured muscle soreness and thigh circumference. They then measured maximal voluntary contraction torque (MVC) and isokinetic strength of each angular velocity (30°/ sec.: ISOK30, 60°/ sec.: ISOK60, 150°/ sec.: ISOK150, 240°/ sec.: ISOK240). They subsequently moved to the training room and performed leg extensions. After the exercise, muscle soreness and thigh circumference were measured immediately, after which they returned to the laboratory for measurement of MVC and isokinetic strength of each angular velocity. The experiments of each day for each subject were performed at the same time of day in consideration of circadian rhythm.

### *High-intensity leg extension exercise*

Subjects were then requested to perform leg extensions. The intensity was set at 90% of the previously-determined 1RM. When they could perform over seven repetitions, the weight was slightly increased. From the 2nd set, the target load was set at 4~6RM. We did not regulate the exercise tempo. Subjects extended their knee at maximal effort. For this leg extension exercise, it is reported that strength is maximal when the knee angle is about 70 degrees (Pincivero, Salfetnikov, Campy, & Coelho, 2004). When the knee angle is less than 70 degrees, the smaller the knee angle becomes, the lower the strength. Therefore, because it was difficult to perform a full extension for all reps, even if the subjects could not perform a full extension, they continued their exercise. They stopped exercising when they could not move the pad from the starting position at all. The interval between sets was set at three minutes. Participants in 12SET performed 12 sets of exercise, while participants in 6SET performed six sets. The number of sets was determined according to previous research. Since Lavender and Nosaka (2006) compared six sets of concentric exercise with eccentric exercise, we adopted six sets for the mid-volume group in the present study. Rhea, Alvar, Burkett, & Ball (2003) reported that performing four sets is optimal for increasing muscle strength. Twelve sets is 3-fold this number, hence, can be considered high-volume.

The repetition numbers for each set were as follows: 1st set was  $8.1 \pm 3.5$  reps in 12SET and  $7.6 \pm 2.0$  reps in 6SET. Because the number of reps in the 1st set was a little higher than our assumption (4~6RM), the weight was increased. From the 2nd set, the

repetition number was approximately appropriate ( $4.0 \pm 0.8$  -  $6.6 \pm 1.6$  reps / set in 12SET and  $4.8 \pm 1.3$  -  $6.4 \pm 1.2$  reps / set). The total repetition number was  $61.5 \pm 5.1$  reps in 12SET, and  $34.6 \pm 3.3$  reps in 6SET.

When each set was over, subjects were asked to rate their perceived exertion (RPE) for each set using Borg's CR-10 scale (Borg, Ljunggren, & Ceci, 1985). PRE was over 6 (hard), except for  $5.6 \pm 1.8$  in the 1st set of 6SET. The average RPE was almost 7 (very hard) throughout the exercise (12SET:  $7.5 \pm 1.3$ , 6SET:  $7.0 \pm 1.3$ ).

## **Measurements**

### *1. MVC and isokinetic strength*

MVC and isokinetic strength were measured with a KIN-COM<sup>®</sup> dynamometer (Chattecx, Inc., USA). Each subject sat on the equipment, and their body was fixed in position with belts. Their arm was crossed at the front of their body. The subject's knee angle was set at  $90^\circ$  (1.57 rad). MVC was measured twice for three seconds (1 minute between the measurements). The higher value of the two measurements was used for the analyses.

After MVC measurement, isokinetic strength of each angular velocity was measured. Subjects extended their knee from  $90^\circ$  to  $0^\circ$  (full extension) with maximal effort. The pad was returned to the starting position ( $90^\circ$ ) by the investigator. Isokinetic strength was also measured two times for each angular velocity, and the higher value of the two was used for the analyses.

### *2. Muscle soreness*

Muscle soreness of the anterior surface of the thigh of the right leg was assessed by a visual analogue scale (VAS) consisting of a 100-mm line with "no pain" at one end, and "extremely sore" at the other, while flexing the knee.

### *3. Thigh circumference*

Thigh circumference was measured at 15 cm from the top center of the patella with the subject standing. A marker pen was used to ensure measurement of the same point throughout the experiment.

## **Statistical analyses**

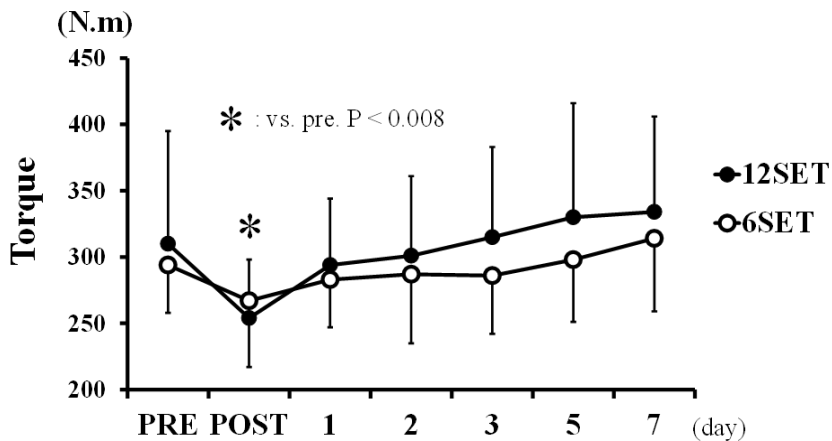
Statistical evaluation of MVC, isokinetic strength at each angular velocity, thigh circumference, and muscle soreness in the experiments for both groups (12SET and 6SET) and times (PRE, POST, one day, two days, three days, five days, and seven days after exercise) was accomplished by repeated-measures two-way analysis of variance (ANOVA). When a significant time effect was accepted, a student's t-test with Bonferroni correction was conducted to compare PRE with the other six time points. In addition, the peak muscle soreness value was compared by an independent t-test. Statistical significance was set at  $p < 0.05$  for the ANOVA and t-test, and at  $0.05 / 6 =$

.008 for the student's t-test with Bonferroni correction, because of the multiple comparisons of six time points.

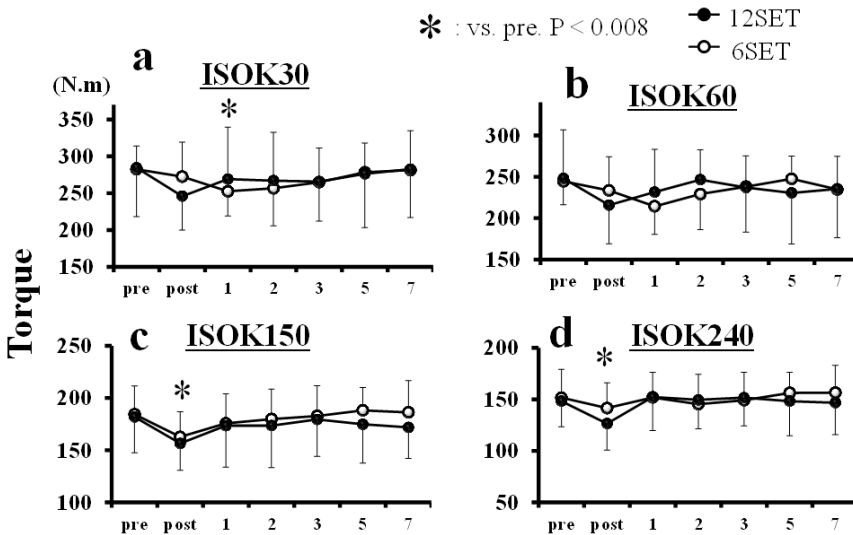
## Results

### 1. MVC and isokinetic strength

No significant effect was recognized. POST was significantly lower than PRE (Figure 1). MVC at one day after exercise was not significantly different from PRE. There was no significant interaction effect for each angular velocity (Figure 2). A significant time effect was observed for all angular velocities. ISOK30 was decreased one day after exercise compared to PRE. POST and two days after exercise was not different from PRE. There was no difference in ISOK60 by Bonferroni correction. ISOK 150 and ISOK240 decreased in POST compared to PRE. There were no significant differences between one day after exercise and PRE. Some subjects' MVC or isokinetic strength increased in POST compared to PRE; MVC: one subject in 12SET, two subjects in 6SET; ISOK30: one subject in 12SET, three subjects in 6SET; ISOK60: one subject in 6SET, four subjects in 12SET; ISOK150: three subjects in 6SET; ISOK240: two subjects in 12SET.



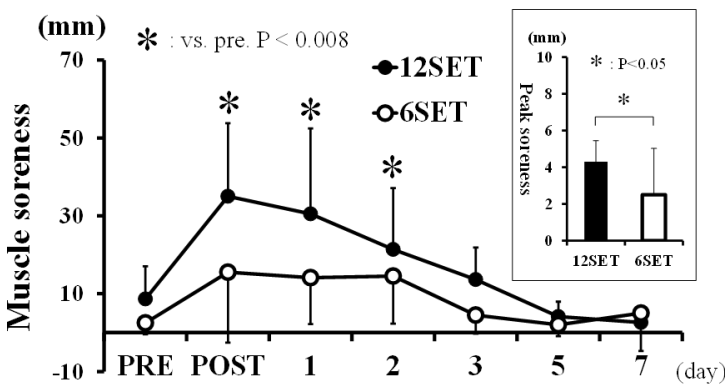
**Figure 1:** Comparison in changes in MVC. There was no interaction effect. \* indicates significantly ( $p < 0.008$ ) lower value than PRE.



**Figure 2:** Comparison in changes in isokinetic strength of each angular velocity. a: 30°/ sec., b: 60°/ sec., c: 150°/ sec., d: 240°/ sec. There was no interaction effect. \* indicates significantly (p < 0.008) lower value than PRE.

### 2. Muscle soreness

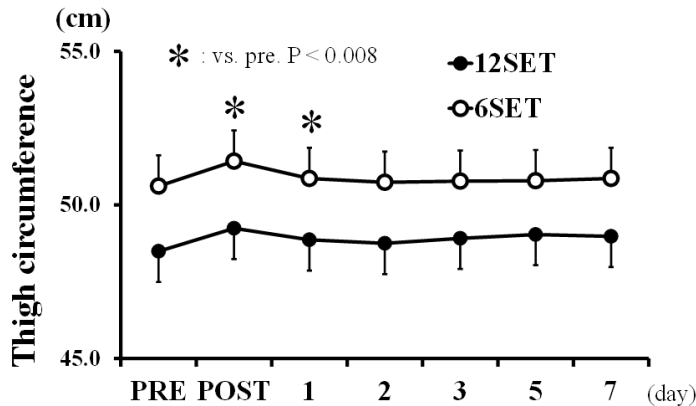
There was a significant time effect. POST, one day and two days after exercise were higher than PRE (Figure 3). Peak soreness was higher in 12SET than in 6SET.



**Figure 3:** Comparison in changes in muscle soreness. There was no interaction effect. \* indicates significantly higher value than PRE. Comparison in peak muscle soreness was described in the box. \* indicates that peak muscle soreness of 12SET was significantly (p < 0.05) higher than 6SET.

### 3. Thigh circumference

There was a significant time effect. POST and one day after exercise were higher than PRE (Figure 4).



**Figure 4:** Comparison in changes in thigh circumference. \* indicates significantly ( $p < 0.008$ ) higher value than PRE.

## Discussion

The present study compared 12 sets with 6 sets of high-intensity leg extensions on muscle strength. We found that the MVC and isokinetic strength for each angular velocity recovered within two days, even after performing 12 sets of high intensity leg extension. In addition, there were no interaction effects on muscle soreness and thigh circumference.

The leg extension performed in the present study induces less muscle damage than the high intensity eccentric exercise reported in previous studies, which were performed in upper extremities (Nosaka et al., 2002; Takizawa et al., 2012). In a previous study, MVC decreased  $25.8 \pm 3.4$  % (Takizawa et al., 2012) and  $41.9 \pm 1.7$  % (Nosaka et al., 2002) immediately after 12 maximal eccentric actions of the elbow flexors. In the present study, MVC decreased  $15 \pm 8$  % in 12SET and  $6 \pm 10$  % in 6SET for POST. In addition, Takizawa et al. (2012) reported that MVC after five days of exercise was  $18.4 \pm 4.2$  % lower than before exercise. Nosaka et al. (2002) showed that MVC after four days of exercise was  $26.9 \pm 2.4$  % lower than before exercise. In contrast, there was no significant difference between PRE and one day after exercise in MVC, ISOK60, ISOK150, ISOK240 and two day after exercise in ISOK30. Jamurtas et al. (2005) compared the effect of eccentric exercise between upper and lower extremities. They reported that the MVC decrease after eccentric exercise is lower in the lower extremity than in the upper extremity (Jamurtas et al., 2005). Many previous studies have assessed the elbow flexor muscle; the present study was the first to compare the effects of exercise volume in the lower extremity.

There were no interaction effects on muscle soreness and thigh circumference. Although the time until recovery was longer for muscle soreness than for MVC and isokinetic strength, this is consistent with previous research (Jamurtas et al., 2005). Jamurtas et al. (2005) reported that recovery from muscle soreness required more time than that of MVC. In addition, Nosaka et al. (2002) showed that MVC is not related to muscle

soreness. In the present study, peak muscle soreness was higher in 12SET than in 6SET. Thus, when performing high volume exercise, we should be careful to prescribe an appropriate volume. There was no significant interaction effect on thigh circumference, and it returned to the PRE level by two days. Therefore, the high intensity exercise performed in this study did not have such a marked effect as the eccentric exercise used in previous studies (Nosaka et al., 2002)

Some subjects' MVC and isokinetic strength increased in POST compared to PRE. These findings might have been due to postactivation potentiation (PAP). In previous research on PAP, muscle strength or power increased after high intensity (e.g., 90% 1RM or 3RM) of conditioning contraction (Esformes & Bampouras, 2013; Seitz, Trajano, & Haff, 2013; Fukutani et al., 2014). The intensity  $\times$  repetitions  $\times$  number of sets was as follows: Esformes, 3RM  $\times$  3 repetitions  $\times$  1 set; Seitz, 90% 1RM  $\times$  3 repetitions  $\times$  1 set; Fukutani, 45% 1RM  $\times$  5 repetitions  $\times$  1 set + 60% 1RM  $\times$  5 repetitions  $\times$  1 set + 75% 1RM  $\times$  3 repetitions  $\times$  1 set + 90% 1RM  $\times$  3 repetitions  $\times$  1 set. As described above, high intensity conditioning contraction was performed for only one set. Thus, 12 sets or six sets in the present study might exceed the conditioning contraction. However, some subjects' MVC and isokinetic strength increased in POST. This might be caused by PAP.

In the present study, since we adopted a single joint exercise, the effect of multiple joint exercises remains unclear. Numerous muscle groups would be recruited by multiple joint exercise, and might require a longer rest period than a single joint exercise (Baechle et al., 2008). Further research is needed to investigate the effect of training volume on multiple joint exercises.

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