ORIGINAL ARTICLE

Eight days KAATSU-resistance training improved sprint but not jump performance in collegiate male track and field athletes

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The purpose of this study was to investigate the effects of short-term KAATSU-resistance training on skeletal muscle size and sprint/jump performance in college athletes. Fifteen male track and field college athletes were randomly divided into two groups: KAATSU (resistive exercise combined with blood flow restriction, n=9) and control (n=6) groups. The KAATSU group trained twice daily with squat and leg curl exercises (20% of 1-RM, 3 sets of 15 repetitions) for 8 consecutive days while both KAATSU and control groups participated in the regular sprint/jump training sessions. Maximal strength, muscle-bone CSA, mid-thigh muscle thickness (MTH), and sprint/jump performance were measured before and after the 8 days of training. The muscle-bone CSA increased 4.5% ($p<0.01$) in the KAATSU group but decreased 1% ($p>0.05$) in the control group. Quadriceps and hamstrings MTH increased ($p<0.01$) by 5.9% and 4.5%, respectively, in the KAATSU group but did not change in the control group. Leg press strength increased (9.6%, $p<0.01$) in the KAATSU group but not (4.8%, $p>0.05$) in the control group. Overall 30-m dash times improved ($p<0.05$) in the KAATSU-training group, with significant improvements ($p<0.01$) occurring during the initial acceleration phase (0-10m) but not in the other phases (10-20m and 20-30m). None of the jumping performances improved ($p>0.05$) for either the KAATSU or control groups. These data indicated that eight days of KAATSU-training improved sprint but not jump performance in collegiate male track and field athletes.
Key words: muscle-bone cross-sectional area, B-mode ultrasound, muscle hypertrophy, sport performance

INTRODUCTION

Off-season resistance training is an important part in the recovery and training process for seasonal sports athletes. Usually, there is insufficient time for significant muscle hypertrophy to take place during the off-season, since most studies have reported that substantial muscle hypertrophy does not occur until 3-4 months of vigorous resistance training has been completed (Jones and Rutherford, 1987; Staron et al., 1994; Abe et al., 2000). It would therefore seem logical that the development of a more effective and efficient method to promote muscle hypertrophy, in a relatively short period of time, would be very advantageous to coaches and their athletes.

The combination of low-intensity (20% of 1-RM) resistance training with restricted venous blood flow to the working muscle, KAATSU-resistance training, may provide an alternative training method to the traditional high-intensity (HIT, 80% of 1-RM) resistance training programs currently being used (Shinohara et al., 1998; Takarada et al., 2000a). It has been demonstrated that the magnitude of muscle hypertrophy is similar between KAATSU-resistance training and HIT when training frequencies and volumes are the same (Takarada et al., 2000b). Interestingly, KAATSU-training does not require long recovery periods between training sessions due to the very low mechanical stress and minimal muscle damage produced when a load of only 20% of 1-RM is used. Recently, Abe et al. (2004) reported that two weeks of twice-daily KAATSU-training produces muscle hypertrophy that was similar in magnitude to those reported after 3-4 months of the more traditional HIT programs. However, there are no published data concerning the effects of KAATSU-training induced muscle hypertrophy on sports and exercise performance. Thus the purpose of the present study was to investigate the effects of short-term KAATSU-resistance training on skeletal muscle size and sprint/jump performance in college athletes.

METHODS

Subjects

Fifteen male track and field college athletes (sprinters and jumpers) volunteered to participate in the present study. All subjects trained regularly 5 days per week in both sprinting/jumping and resistive exercise training programs. The subjects were randomly divided into two groups: KAATSU-training (n=9) and control (n=6) groups. All subjects were informed of the procedures, risks, and benefits, and signed an informed consent document before participation. The study was approved by the Tokyo Metropolitan University Ethics Committee for Human Experiments.

Training protocol

The KAATSU-training group trained twice per day (7:00-8:00 and 17:00-18:00) for 8 consecutive days. After a standard warm-up, subjects performed 3 sets of 15 repetitions of squat and leg curl exercises at an intensity of 20% of one repetition maximum (20% of 1-RM). Subjects rested for 30 seconds between sets and exercises and the routine was kept constant for the duration of the training period. A specially designed elastic belt (Sato Sports Plaza Ltd., Tokyo, Japan) was placed around the most proximal portion of both legs during the exercise sessions in the KAATSU-training group (Takarada et al., 2002). The belt contained a small pneumatic bag along its inner surface that was connected to an electronic pressure gauge that monitored the restriction pressure (MPS-700, VINE, Tokyo, Japan). A cuff pressure of ~240 mmHg was selected for the occlusive stimulus as this pressure has been suggested to restrict venous blood flow and cause pooling of blood in capacitance vessels distal to the cuff, and ultimately reduces arterial blood flow (Takarada et al., 2000b). On Day 1, the cuff pressure was set at 160 mmHg and was then increased by 20 mmHg each day until a final training cuff pressure of 240 mmHg (Day 5) was reached. The restriction of muscular blood flow was maintained for the entire exercise session (including rest periods) and was released immediately upon completion of the session. The control group did not perform any resistive exercises during the present study, however, both KAATSU and control groups performed regular sprint/jump training during the study period.

Maximum strength measurements

Maximum dynamic strength (1-RM) was evaluated prior to (pre-testing), and for two days after the final training session (post-testing), by using an isotonic leg press machine (Universal). All subjects were instructed on proper lifting techniques and allowed to practice. After a standard warm-up, the leg press load was set at 80% of the predicted 1-RM. Following each successful lift the load was increased by 5% until the subject failed to lift the load through the entire range of motion. A test was considered valid if the subject used proper form and completed the entire lift in a controlled manner without assistance. On average, six trials were required to complete a 1-RM test. Approximately 2-3 min of rest was allowed between each attempt to ensure recovery. One subject in the control group did not perform the 1-RM strength testing because of a previous orthopedic problem.

Muscle size measurements

Anthropometry ($\pi\,[r - (Q\text{-}AT + H\text{-}AT) / 2]^2$) was used to estimate the muscle-bone CSA for the mid-thigh each morning prior to the training session and prior to the post-testing. Where r was the radius of the thigh calculated from mid-thigh girth of the right leg, and Q-AT and H-AT were ultrasound-measures of anterior and posterior thigh adipose tissue thickness, respectively. The estimated coefficient of variation (CV) of this measurement was 1.5 %.

Muscle thickness (MTH) of the anterior and posterior mid-thigh was measured using B-mode ultrasound with a 5 MHz scanning head (SSD-500, Aloka, Tokyo, Japan). The scanning head was prepared with water-soluble transmission gel that provided acoustic contact without depression of the skin surface. The scanner was placed perpendicular to the tissue interface at the predetermined marked sites. MTH was measured directly from the screen with the use of electronic calipers and was determined to be the distance from the adipose tissue-muscle interface to the muscle-bone interface. Validity of the image reconstruction and distance measurements was established by comparing the ultrasonic and manual measurements of tissue thicknesses using human cadavers (Fukunaga et al., 1989). The CV of this MTH measurement was 1% (Abe et al., 1994).

Sprint/jumping performance test

Running and jumping tests were conducted on an outdoor tartan track. For the 30-m dash, subjects began from a standing position with a self-start. Time was measured with an electronic timing system (nearest 0.01 s, Timing Systems, Brower). Three consecutive trials, with 2-5 min of recovery between trials, were performed for each subject. The average score of the fastest two trials was used for data analysis. Three different jump tests (standing jump, standing triple jump, and standing 5-step jump) were performed using a long-jump pit. Subjects began each jump with an even stance (i.e. feet shoulder width apart) and three trials of each jump were performed with the top score (nearest 1 cm) for each jumping condition used for data analysis (Table 1).

Statistical Analyses

Results are expressed as means ± standard deviations (SD) for all variables. Data were analyzed using a two-way analysis of variance (ANOVA) with repeated-measures (group and time). When significant main effects and/or interaction were observed, post-hoc testing was performed by a paired t-test. Baseline differences between the KAATSU-training group and the control group were evaluated with a one-way ANOVA. Person product correlation coefficients were calculated between parameters of interest. Statistical significance was set at $p < 0.05$.

RESULTS

Baseline measurements

There were no differences ($p>0.05$) in body mass, mid-thigh girth, 1-RM strength or sprint/jump performance times (Table 1), or quadriceps and hamstrings MTH (Figure 2) between KAATSU and control groups at pre-testing (Table 1).

Changes in skeletal muscle size

Muscle-bone CSA gradually increased ($p<0.01$) in the KAATSU-training group but not in the control group. The muscle-bone CSA increased 4.5% ($p<0.01$) at post-testing for the KAATSU-training group, while the muscle-bone CSA decreased by 1% ($p>0.05$) for the control group (Figure 1). Quadriceps and hamstrings MTH increased ($p<0.01$) by 5.9% and 4.5%, respectively, in the KAATSU-training group but did not change in the control group (Figure 2).

Changes in 1-RM strength and sprint/jump performance

Leg press strength increased significantly (9.6%,

Table 1. Effects of "Kaatsu" resistance training on muscle size and sprint/jump performance

	Kaatsu-Training		Control-Training	
	Pre	Post	Pre	Post
N	9	6		
Standing height (cm)	173.9 ± 5.1	176.8 ± 6.0		
Body mass (kg)	66.1 ± 4.0	66.5 ± 3.6	67.6 ± 4.4	67.8 ± 4.9
Mid-thigh girth (cm)	51.8 ± 2.8	52.5 ± 2.7 ¶	53.3 ± 1.9	53.3 ± 2.1
Thigh fat thickness (mm)	4.7 ± 1.3	4.2 ± 0.8	4.2 ± 0.8	4.3 ± 0.8
Muscle -bone CSA (cm^2)	190 ± 21	198 ± 22 ¶	204 ± 15	202 ± 17
Leg press 1RM (kg)	208 ± 70	228 ± 75 ¶	208 ± 53	218 ± 62
30-m dash (sec)	4.34 ± 0.14	4.26 ± 0.13 †	4.25 ± 0.19	4.20 ± 0.16
0-10m dash (sec)	1.95 ± 0.11	1.86 ± 0.08 ¶	1.88 ± 0.12	1.83 ± 0.10
10-20m dash (sec)	1.23 ± 0.04	1.23 ± 0.04	1.22 ± 0.05	1.23 ± 0.04
20-30m dash (sec)	1.16 ± 0.04	1.17 ± 0.05	1.15 ± 0.05	1.15 ± 0.04
Standing jump (m)	2.42 ± 0.11	2.43 ± 0.13	2.53 ± 0.15	2.49 ± 0.16
Standing triple jump (m)	7.20 ± 0.29	7.26 ± 0.37	7.51 ± 0.54	7.44 ± 0.43
Standing 5 jump (m)	12.49 ± 0.66	12.47 ± 0.71	13.04 ± 0.81	12.81 ± 0.65

¶ P<0.01, † P<0.05 pair-t test

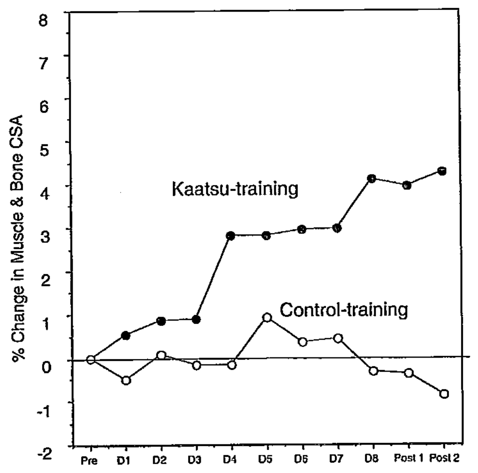

Figure 1. Percent change in estimated muscle-bone cross-sectional area (CSA) for the low-intensity resistance training combined with restriction of muscular blood flow (Kaatsu-training, filled symbols) and control (unfilled symbols) groups measured before, during (every morning prior to the training session), and after the training period. Values are mean ± SD.

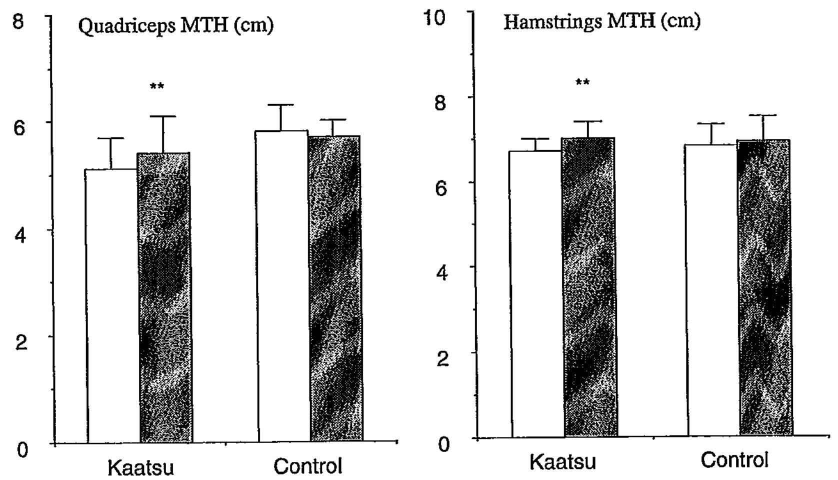

Figure 2. Changes in quadriceps and hamstrings muscle thickness (MTH) for the low-intensity resistance training combined with restriction of muscular blood flow (Kaatsu) and control groups measured before (unfilled) and after (filled) the training period. Values are mean ± SD. **P<0.01 between before and after training.

$p<0.01$) in the KAATSU-training group but not (4.8%, $p>0.05$) in the control group. There was a strong correlation between 1-RM leg press strength and estimated muscle-bone CSA during both pre-testing ($r=0.81$, $n=14$, $p<0.01$) and post-testing ($r=0.85$, $n=14$, $p<0.01$) when both groups were combined. The 1-RM leg press strength per unit estimated muscle-bone CSA was similar ($p>0.05$) at both testing periods.

The overall 30-m dash time improved ($p<0.05$) in the KAATSU-training group with the improvement occurring in the first 10m ($p<0.01$). Standing jump correlated ($r=-0.82$, $p<0.01$) with 30-m dash time at pre-testing. None of the three jumping performances improved ($p>0.05$) for the KAATSU-training group and there were no changes ($p>0.05$) for any of the sprint/jump performances between pre- and post-testing for the control-training group.

DISCUSSION

In the present study we found that eight days of twice daily KAATSU-training increased estimated skeletal muscle-bone CSA (4-5%) and 1-RM leg press strength (10%) in male track and field athletes. The magnitude of increase in muscle-bone CSA and strength were relatively small but were consistent with previously published data (Abe et al., 2004). As shown in Figure 1, muscle-bone CSA gradually increased throughout the study in the KAATSU group and greater muscle hypertrophy may have occurred if the training was continued as previously reported. Our subjects were highly trained athletes and conventional resistance training does not readily produce muscle hypertrophy and strength gain in this population (Hakkinen et al., 1987). Therefore our data suggests that KAATSU-training can provide an effective hypertrophic stimulus even for well trained athletes.

Interestingly, the training subjects in the present study performed 16 total sessions (two sessions per day) of KAATSU-training exercise for eight consecutive days while also performing their normal sprint/jumping training (training frequency: 5 days per week). In general, seasonal athletes avoid high-intensity, high-volume resistance training during the competitive season in order to avoid over-training. The optimal training protocol is based on the theory of "super-compensation" which attempts to generate the greatest growth stimulus while still allowing for sufficient rest between exercise sessions (Kraemer, 2000). The combination of a vigorous resistance training program in combination with a sprint/jump training program can lead to poor event performance since athletes do not have sufficient recovery time between training sessions. However, KAATSU-training at an intensity of 20% of 1-RM produces a strong hypertrophic stimulus with only minimal muscle damage (Takarada et al., 2000a), therefore less recovery time is required. The data from the present study demonstrated that KAATSU-training can be combined with regular season training to provide an effective and efficient method for muscle hypertrophy in seasonal sports athletes without a loss of performance.

Sprint running is usually divided into three phases: initial acceleration (0-10 m), achieving maximal speed (10-40 m), and maintenance of maximal speed (40~ m) with each phase corresponding to specific physical abilities. Our findings indicated that muscle hypertrophy and strength gain induced by KAATSU-training resulted in an improved 30-m dash time, especially during the first 10m (0-10m). These data are consistent with previous studies. For example, Delecluse et al. (1995) selectively altered the first and/or second phases of maximal sprinting performance by using different types of strength training. In that study, high-intensity resistance training resulted in an improved initial acceleration (first phase) while high-velocity plyometric training (unloaded) improved the rate at which maximal speed was reached (second phase). Additionally, relative muscle strength (e.g., maximal dynamic strength per body mass) has been related to sprint starting ability, measured between 0 and 2.5 m, during a maximal 50-m sprint (Young et al., 1995). Taken together with the present study, these data suggest that the initial acceleration phase of sprinting can be improved by increasing muscle strength.

Previous KAATSU-training studies (Takarada et al., 2000b and 2002) suggest that in spite of the low level of force generation during KAATSU-training, a large number of fast-twitch muscle fibers are recruited and experience hypertrophy (Yasuda et al., 2004). The moderate muscle hypertrophy and strength gains of the present study, however, were not sufficient to improve jumping performance. Studies that have demonstrated strength training induced improvements in jumping performance have reported much larger gains in muscle size and strength (Maffiuletti et al., 2000; Bruhn et al., 2004). It may be that longer KAATSU-training may cause larger muscle hypertrophy which might then be able to improve jumping performance. To date, no such studies have been conducted.

In conclusion, eight days of twice-daily KAATSU training increased skeletal muscle-bone CSA and maximal strength. The gains in skeletal muscle-bone CSA and strength resulted in an improved 30-m sprint performance, especially during the initial acceleration phase. Therefore, we have concluded that KAATSU-training can be performed together with regular season training in order to provide an effective and efficient method for enhanced muscle hypertrophy without a loss in performance.

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