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Effect of lower body resistance training on upper body strength adaptation in trained men.

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Running Head: Effect of lower body strength training on upper body.

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ABSTRACT

The aim of this study was to examine the effect of two different lower body strength training schemes on upper body adaptations to resistance training. Twenty resistance-trained males (4.25±1.6 y of experience) were randomly assigned to either a high-intensity (HI; n=9; age=24.9±2.9 y; body mass=88.7±17.2 kg; height=177.0±5.6 cm) or a mixed high-volume and high-intensity resistance training program (MP; n=11; age=26.0±4.7 y; body mass=82.8±9.1 kg; height=177.54±5.9 cm). HI group followed a high-intensity training for both upper and lower body (4-5 reps at 88-90% of 1-RM), while the MP group performed high-volume training sessions focused on muscle hypertrophy for lower body (10-12 reps at 65-70% of 1-RM) and a high-intensity protocol for the upper body. Maximal strength and power testing occurred before and after the 6-week training program. Analysis of covariance was used to compare performance measures between the groups. Greater increases in MP groups compare to HI group were observed for bench press 1-RM (p = 0.007), bench press power at 50 % of 1-RM (p = 0.011) and for AMA (p = 0.046). Significant difference between the two groups at post-test were also observed for fat mass (p = 0.009). Results indicated that training programs focused on lower body muscle hypertrophy and maximal strength for upper body, can stimulate greater strength and power gains in the upper body compared to high-intensity resistance training programs for both the upper and lower body.

Keywords: Resistance; Methodology; Fitness; Transfer Effect

INTRODUCTION

Strength improvements in skeletal muscle that has not been directly activated during training has been reported for a number of years (2, 21, 24). Several studies have reported enhanced strength performances in the untrained limb during unilateral strength training (2, 4). This phenomenon is usually defined as "cross-education", and has been suggested to be related with both neural and hormonal factors (4, 7). It has been suggested that the neural adaptations associated with "cross-education" involve increased motor output from spinal motoneurons, and some form of motor learning related to neural plasticity of the motor cortex, premotor complex and cerebellum (5).

A transfer effect has also been observed between the lower and upper body (13, 28), Madarame and colleagues (28) reported increased arm muscle size and strength when lower body resistance exercises with blood flow restriction were added to the upper body training program. Others have reported a greater relative effect in upper body isometric strength gains when lower body training was combined with upper body training compared to upper body training only (13). The investigators also reported an augmented hormonal response to a whole body training program, compared to exercising with the upper body only. To the best of our knowledge, only two investigations have examined the effects of lower body resistance training on upper body strength performance, and both reported greater increases in arm strength when legs were trained simultaneously (13, 28). However, whether the transfer effect on upper body strength improvement is greater using a high-intensity strength training protocol or a high-volume strength training protocol for the lower body is not well understood.

The longer duration of time under tension during high volume training sessions (10-15 repetitions per set at 60-70% of 1-RM), may result in reduced muscle oxygenation, which may play a critical role in growth hormone stimulation (9, 15, 19, 25, 26). Considering that growth hormone is an anabolic hormone with relevant effects in the regulation of metabolism (32), it is likely that high-volume training sessions performed with the lower body may have a greater impact on body composition than lower body high-intensity training sessions. Thus, the purpose of this study was to compare the effect of a lower body hypertrophy training program (5 sets of 10-12 reps at 65-70% of 1-RM with 2-min and 15-sec recovery time between each set) to a maximal strength lower body training program (5 sets of 4-5 reps at 88-90% of 1-RM with 3 min recovery time between each set) on upper body strength and power adaptation.

METHODS

Experimental Approach to the Problem

Participants were randomly assigned into 2 experimental groups and provided a 6-week training program. The first group (HI group) performed a high-intensity training program for both upper and lower body. The second group (MP group) followed a training program focused on muscle hypertrophy for lower body and a high-intensity protocol for the upper body. Participants were assessed before and after the training period for body composition, maximal strength and power of both upper and lower body. Participants were also requested to not participate in any other training or competition.

Participants

Twenty experienced resistance-trained men volunteered to participate in this study. To be considered for the study, participants were required to be between the age of 18 and 35 years, and have a minimum of 3 years of free weights resistance training experience (mean ± SD; 4.25 ± 1.6y). Exclusion criteria included the use of performance enhancing drugs and injuries occurred at least 1 year prior to the investigation. Participants were familiar with all the exercises used in this study and they typically trained with a load permitting between 8-10 reps in the previous 4 months prior to this present investigation. Participants were randomly assigned to one of the two groups; Group 1 (HI; mean ± SD; n = 9; age = 24.9 ± 2.9 y; body mass = 88.7 ± 17.2 kg; height = 177.0 ± 5.6 cm) used a high-intensity program for both upper and lower body exercises, Group 2 (MP; n = 11; age = 26.0 ± 4.7 y; body mass = 82.8 ± 9.1 kg; height = 177.5 ± 5.9 cm) used a high-intensity protocol for the upper body exercises and a high-volume program for the lower body exercises. All participants signed an informal consent document and the study was approved by the "Alma Mater Studiorum - University of Bologna" bioethics committee. Participants were asked to maintain their normal diet throughout the study.

Resistance Training Protocols

Both training programs were composed of the same exercises that are shown in Table 1. All participants exercised 4-days per week for 6-weeks. The HI and MP group used the identical high-intensity training program for the upper body. Both groups performed 5 sets of 5 reps at 88% in the first four weeks, and 5 sets of 4 reps at 90% in the last two weeks of training for the upper body exercises. Recovery time between each set was of 2 min and 15 seconds. The HI groups used the same high-intensity protocol for the lower body exercises, while the MP group followed a training program that focused on muscle hypertrophy. Participants in MP performed 5 sets of 12 reps at 65 % of their 1-RM for the first four weeks, and 5 sets of 10 reps at 70 % of their 1-RM during the last two weeks of training. Recovery time between each set was 1-min. The upper body training program always preceded the lower body training program. Subjects were encouraged to increase the resistance used per workout if they performed the maximum number of repetitions required for two consecutive exercise sessions. If the participants were not able to obtain the number of repetitions provided, than the load was reduced in the subsequent set to enable completion of the required number of repetitions for each training protocol. No forced or assisted reps were used in either protocol. All training sessions were supervised by certified coaches. Participants recorded all workouts in a logbook, which was collected by one of the investigators following each workout. Feedback was provided in regards to changes in load used per exercise.

[Place Table 1 here]

Anthropometric and Performance Assessments

Anthropometry: Body mass was determined to the nearest 0.1 kg using a standard mechanical weighing scale (Detecto, Missouri, USA). Skinfold measurements (collected by a Lange Skinfold Caliper, Cambridge Scientific Industries, Cambridge, USA) and anthropometric measures were used to examine changes in body composition. Body density was estimated with a 7-site skinfold test (20) and the body fat percentage was calculated using Siri equation (34). Estimation of middle arm muscle area was performed using the formula of Heimsfield (15):

$$\text{AMA (cm): (middle-arm circumference} - \pi \times \text{triceps skinfold)}^2 / 4\pi$$

Middle arm circumference and skinfold were measured midway between the acromion and olecranon process of the left arm. Intraclass coefficients were 0.96 (SEM: 3.13 cm^2; MD: 2.2 cm^2) and 0.99 (SEM: 0.74 kg; MD: 0.92 kg) for AMA and fat mass (FM), respectively. The same investigators performed all of the anthropometric analyses during each assessment period.

Strength assessment: Participants did not train for two days prior to the strength assessments to allow for appropriate recovery. Prior to the testing protocol, each participant performed a standardized warm-up based on previously published literature (29). The warm-up consisted of

5-min of cycling at a cadence of 70 rpm and intensity of 70 W, 10 body weight squats, 10 walking lunges, 10 walking "knee hugs" and 10 walking "butt kicks" (29).

Upper body power was assessed via the seated medicine ball throw (30). Participants were asked to throw rubber medicine balls weighing 2-kg, 3-kg and 4-kg. All throws required the participants to sit on the floor against a wall and push the medicine ball from the center of the chest with both hands. Participants were required to remain in contact with the wall during the test. Each participant had three attempts to throw as far as possible. Rest time between each attempt was 45 sec. The distance of each throw was measured using a 20-m fiberglass tape. The longest throw was recorded. ICC's were 0.82 (SEM: 0.32 m; MD: 0.74 m), 0.86 (SEM: 0.23 m; MD: 0.63 m) and 0.90 (SEM: 0.18 m; MD: 0.48 m) for the 2-kg, 3-kg and 4-kg medicine ball throw, respectively.

During each testing session participants performed a maximal effort isometric mid-thigh pull on a force plate (Kisler Force Plate, Winterthur, Switzerland, 500 Hz). Bar height was adjusted in order to obtain a knee angle of 120°. Grip width was also measured to reproduce the same position in all testing sessions. Once grip position was established, participants were strapped to the bar and were instructed to pull as hard as possible, and with maximum explosive intent (11). Each participant performed two trials with a 3-min recovery time between each trial. Force-time curves were recorded and analyzed in order to calculate peak force (PF) and the peak rate of force development (pRFD). As suggested by Haff and colleagues (11), the pRFD was calculated as the highest RFD during 20 millisecond sampling windows (pRFD 20). ICC's were 0.92

(SEM: 164.29 N; MD: 346.6 N) and 0.87 (SEM: 1349.58 N/sec; MD: 3248.7 N/sec) for the PF and pRFD20, respectively.

Maximal dynamic strength of the upper body was assessed by a 1-RM bench press. Bench press testing was performed in the standard supine position. The participant lowered the bar to mid chest and then pressed the weight until his arms were fully extended. Participants were required to pause briefly at the end of the lowering phase and wait for a signal before starting the concentric phase. Lower body maximal dynamic strength was also assessed by a 1-RM free barbell parallel squat. Participants were asked to reach a position where the greater trochanter of the femur was at the same level of the knee. A 3-min recovery time between each attempt was observed. The bench press and squat 1-RM test were conducted as previously described by Hoffman (18). ICC's were 0.98 (SEM: 3.06 kg; MD: 5.48 kg) and 0.95 (SEM: 7.20 kg; MD: 18.9 kg) for the 1-RM bench press and squat 1-RM, respectively.

Following maximal strength assessments, a power test for the bench press exercise was achieved using 30% (POW30) and 50% (POW50) of the previously established 1-RM bench press. Participants were required to perform a single repetition for each load with maximal velocity. Participants performed two attempts for each load, with a 3 min recovery time. The highest value obtained between the two single repetitions was registered. An optical encoder (Globus Real Power, Globus Inc. Treviso, Italia) connected to a personal computer was used for power assessment. ICC's were 0.94 (SEM: 18.59 w; MD: 51.5 w) and 0.88 (SEM: 26.97 w; MD: 44.7 w) for the POW30 and POW50, respectively.

Statistical Analysis

A Shapiro-Wilk test was used to test the normal distribution of the data. Data were statistically analyzed using separate one-way analysis of covariance for anthropometric and performance measures. The pre-test and the post-test values were used as covariate and dependent variable, respectively. For effect size (ES), the partial eta squared statistic was reported and according to Green and colleagues (10) 0.01, 0.06, and 0.14 represented small, medium, and large effect sizes, respectively. The significance level was set at $p \leq 0.05$. Where appropriate, percent change was calculated as follows: (post-test mean – pre-test mean) / (pre-test mean) × 100. All data are reported as mean ± SD. Data were analyzed using SPSS v22 software (SPSS Inc., Chicago, IL).

RESULTS

Anthropometry

Anthropometric parameters of both HI and MP are reported in Table 2. The ANCOVA indicated a significant difference ($F_{1,18} = 48.81$; $p = 0.009$; $\eta^2 = 3.41$) after adjusting for pre-test differences between the groups for fat mass. A decrease in fat mass was noted in MP group (-0.9 ± 1.02 kg), while HI group showed a slightly increased on this parameter (0.02 ± 0.78 kg). Significant differences between the groups at post-test were noted for AMA ($F_{1,17} = 4.62$; $p = 0.046$; $\eta^2 = 0.214$) after adjusting for pre-test differences. The MP group showed an average increase of 5.8 % after the training, while the increase was of 1.7 % in HI group. No significant group differences were observed for FFM ($F_{1,17} = 3.26$; $p = 0.088$; $\eta^2 = 0.161$) and BM ($F_{1,17} = 0.02$; $p = 0.967$; $\eta^2 < 0.001$).

[Place Table 2 here]

Performance Assessment

Strength and power performances measures of HI and MP are reported in Tables 3 and 4, respectively. The ANCOVA indicated a significant difference ($F_{1,18}$ = 9.31; p = 0.007; η² = 0.354) among the group means for post-test 1-RM bench press values after adjusting for pre-test differences. Following the training intervention, the 1-RM bench press showed an increase of 7.2 % and of 2.1 % in MP and in HI group, respectively. A significant difference ($F_{1,18}$ = 8.11; p = 0.011; η² = 0.323) was also observed for POW50 values, after adjusting for pre-test differences. Power expression was significantly different in MP group (+8.6%) compared to HI (-0.78%). No significant differences between the two groups at post-test were noted for maximal isometric strength expressed at the mid-thigh pull ($F_{1,18}$ = 4.10, p = 0.059, η² = 0.194), pRFD 20 ($F_{1,18}$ = 0.52; p = 0.479; η² = 0.030), 1-RM squat ($F_{1,18}$ = 1.35; p = 0.264; η² = 0.082) and for POW30 ($F_{1,18}$ = 4.30; p = 0.053; η² = 0.202). No significant differences between the groups were also observed for the 2-kg ($F_{1,18}$ = 0.01; p = 0.916; η² = 0.001), 3-kg ($F_{1,18}$ = 0.13; p = 0.724; η² = 0.007) and 4-kg ($F_{1,18}$ = 0.70; p = 0.415; η² = 0.039) medicine ball throws.

[Place Tables 3 and 4 here]

DISCUSSION

The results of the present study indicate that a 6-week strength training program using a combination of high-volume and high-intensity resistance training for lower and upper body exercises, respectively, promoted a greater increase in upper body strength, power and arm muscle size compared to a high-intensity only training program. Although significant increases were observed in anthropometric measures (FFM and AMA), and in maximal and dynamic strength for both MP and HI, participants in MP experienced a significantly greater increase in 1-RM bench press and in POW50 compared to HI.

The resistance training protocols used were focused on maximal strength and hypertrophy development, and not on muscle power development. Interestingly, a significant increase in bench press power occurred in MP only. Although several studies have reported that strength gains are velocity specific (6), increases in maximal strength may cause a positive shift of the force-power curve (3, 31). Considering that participants in MP experienced a significantly greater increase in upper body maximal strength and muscle hypertrophy compared to HI, this may provide some explanation for these results. The greater gains in arms muscle size occurred in the MP group suggest that anabolic effects of high volume sessions of squat may stimulate gains on upper body muscles. The high intensity squat workouts, comprised of 5 sets of 3-4 reps, may not have been sufficient to activate a transfer effect between the lower and the upper body. Training sessions characterized by high training volumes are associated with greater changes in circulating levels of anabolic hormones compared to higher intensity workouts focused on maximal strength (8, 15). As reported by Linnamo et al. (27), hormonal changes appear to be related to the amount muscle mass activated, and to the training-protocol used. Although speculative, the high-volume training protocol, involving large muscle mass exercises in the lower body, likely, stimulated an increase in circulating plasma GH concentrations. The elevation in this anabolic hormone circulating throughout the body may have also influenced protein synthesis in the upper body musculature as well.

A transfer effect between the lower and upper body may be also related to neural mechanisms. Cross-education has been extensively studied in relation to injured limb and immobilization (17). Reduction in strength during limb immobilization, when the healthy limb was trained, has been attributed to complex mechanisms such as motor irradiation (4) and hemispheric interaction (20) that emanate from the spinal cord and cortical brain areas. Although some investigators have reported that neural factors have only little to no transfer effect from the lower to upper body (13), others have suggested that intensive lower body training could influence arm strength by reducing inhibitory feedback from the Ib afferent nerves from Golgi tendon organs (1). Inhibitory interneurons activated by Golgi organs can be down-regulated by corticospinal pathways stimulated by strength training (1). Both central and peripheral neural mechanisms, enhanced by high-volume training sessions for lower body, may have stimulated neural adaptations in motor units not directly involved in lower body exercises. Although both MP and HI training group included lower body strength training, the high volume training sessions in MP were characterized by a longer time under tension compared to the high intensity workouts of HI program (10-12 reps compared to 4-5 reps). The squat exercise has been recognized as a 'whole-body' exercise, not involving just the lower body muscles but also torso extensors and shoulder muscles (35). The prolonged upper body and arm muscle isometric contractions performed to sustain the barbell during the high volume sessions may have further stimulated upper body muscle strength and size adaptations. To the best of our knowledge, no experimental studies have investigated arms and shoulder muscle activation in the back squat at different exercise intensities. Prolonged upper body muscle activation during the squat exercise may be an important mechanical factor for stimulating muscle adaptation in the upper body. The potential for strength improvement in experienced, strength-trained individuals are significantly lower compared to untrained subjects (14). The present study suggests that high volume, lower body strength training can provide a greater stimulus for increasing upper body strength and power in a resistance-trained population. Although a significant difference between the two groups was found for the loss of fat mass during the training period, the variation was beyond the measurement error for this parameter.

PRACTICAL APPLICATIONS

The results of the present study confirm the hypothesis that lower body training can affect upper body adaptations to a high-intensity training program in experienced, resistance-trained men. Results of the present study provide evidence to support the use of different training schemes for upper and lower body during the same training period for optimizing upper body adaptations in men. In particular, greater improvements in upper body maximal strength and power can be achieved using high-volume training programs to optimize upper body adaptations to resistance training. It also may provide support for the use of a multifocal approach to program design, similar to what may be used in non-linear training programs.

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Table 1. Exercises for both HI and MP training programs.

Monday	**Tuesday**
Prone Barbell Row	Bench Press
Chin-Up	Inclined Bench Press
Lat pull Down	Supine Flyes
Squats	Barbell Triceps Extension
Leg Press	Single Arm Triceps Dumbbell Extension
Leg Extension	Leg Curl
Thursday	**Friday**
Barbell Front Press	Prone Barbell Row
Dumbbell Front Press	Bench Press
Lateral Raises	Upright Row
Squat	Reverse Dumbbell Flyes
Leg Extension	Leg Press
Calf Machine	Leg Curl

Table 2. PRE to POST comparison in anthropometric assessments.

Anthropometric assessments		**MP group (mean ± *SD*)**	**HI group (mean ± *SD*)**
Body Mass (kg)	PRE	83.5 ± 9.1	85.4 ± 17.5
	POST	84.3 ± 8.2	86.1 ± 17.2
FFM (kg)	PRE	73.7 ± 8.6	72.8 ± 7.7
	POST	75.4 ± 7.5	73.5 ± 7.7
Fat Mass (kg) *	PRE	9.8 ± 5.2	12.5 ± 11.6
	POST	8.9 ± 4.6	12.5 ± 11.0
AMA (cm^2)*	PRE	79.2 ± 19.8	79.3 ± 15.8
	POST	83.8 ± 17.8	80.6 ± 12.9

* indicates a significant difference between the groups at post-test after adjusting for pre-test differences ($p < 0.05$). MP = mixed high volume/high intensity program; HI = High Intensity.

Table 3: PRE to POST comparisons in strength assessments.

Performance assessments		MP group (mean ± *SD*)	HI group (mean ± *SD*)
Squat 1-RM (kg)	PRE	141.1 ± 40.1	144.4 ± 35.8
	POST	144.4 ± 35.8	152.8 ± 34.3
Bench Press 1-RM * (kg)	PRE	108.2 ± 22.8	106.7 ± 19.5
	POST	115.2 ± 19.5	108.9 ± 18.3
MTP Peak Force (N)	PRE	3331 ± 588	3425 ± 711
	POST	3536 ± 502	3430 ± 723
pRFD 20 (N/sec.)	PRE	10901 ± 3189	14263 ± 3536
	POST	12508 ± 3220	15036 ± 4338

* indicates a significant difference between the groups at post-test after adjusting for pre-test differences ($p < 0.05$). MP = mixed high volume/high intensity program; HI = High Intensity; MTP = mid thigh pull; pRFD 20 = peak rate of force development.

Table 4: PRE to POST comparisons in power assessments.

Performance assessments		**MP group (mean ± *SD*)**	**HI group (mean ± *SD*)**
2 kg medicine ball throw (m)	PRE	7.2 ± 0.9	7.7 ± 0.6
	POST	7.3 ± 0.7	7.79 ± 0.7
3 kg medicine ball throw (m)	PRE	6.2 ± 0.8	6.4 ± 0.5
	POST	6.3 ± 0.7	6.5 ± 0.4
4 kg medicine ball throw (m)	PRE	5.4 ± 0.8	5.5 ± 0.3
	POST	5.5 ± 0.7	5.5 ± 0.3
POW30 (W)	PRE	353.6 ± 89.5	349.2 ± 71.9
	POST	374.2 ± 88.0	347.3 ± 69.0
POW50 (W)*	PRE	398.9 ± 91.9	407.1 ± 68.8
	POST	431.2 ± 95.3	397.1 ± 59.9

* indicates a significant difference between the groups at post-test after adjusting for pre-test differences ($p < 0.05$). MP = mixed high volume/high intensity program; HI = High Intensity; POW30 = bench press power with 30% of 1-RM; POW50 = Bench press power with 50% of 1-RM; CMJ = counter movement jump.