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The effect of high-intensity interval cycling sprints subsequent to arm-carl exercise on muscle strength and hypertrophy in untrained men: A pilot study

Short title: Concurrent interval sprints and strength training

Naoki Kikuchi, Ph.D., CSCS*D[1], Shou Yoshida, M.S.[2], and Koichi Nakazato, Ph.D.[2]

[1]Sports Training Center, Nippon Sport Science University, Tokyo, Japan

[2]Department of Exercise Physiology, Nippon Sport Science University, Tokyo, Japan

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Correspondence to:

Name: Naoki Kikuchi, Ph.D., CSCS*D

Mailing address: 7-1-1, Fukasawa, Setagaya-ku, Tokyo 158-8508, Japan

Telephone: +81-45-963-7946

Fax: +81-45-963-7946

E-mail: naoki.k@live.jp

ABSTRACT

The purpose of this study was to examine whether or not lower limb sprint interval training following arm resistance training influences training response of arm muscle strength and hypertrophy. Twenty men participated in this study. We divided subjects into resistance training group (RT, n=6) and concurrent training group (CT, n=6). The RT program was designed to induce muscular hypertrophy (3 sets x 10 repetitions (reps) at 80% 1 repetition maximum [1RM] of arm curl exercise), and was performed in an 8-week training schedule carried out 3 times per week on nonconsecutive days. Subjects assigned to the CT group performed identical protocols as strength training (ST) and modified sprint interval training (4 sets of 30-s maximal effort, separated in 4m 30-s rest intervals) on the same day. Pre- and post-test maximal oxygen consumption (VO2max), muscle cross-sectional area (CSA), and 1RM were measured. Significant increase in VO2max from pre- to post-test was observed in the CT group (*p*=0.010, ES=1.84), but not in the RT group (*p*= 0.559, ES= 0.35). Significant increase in CSA from pre- to post-test was observed in the RT group (*p*=0.030, ES=1.49), but not in the CT group (*p*= 0.110, ES= 1.01). Significant increase in 1RM from pre- to post-test was observed in the RT group (*p*= 0.021, ES= 1.57), but not in the CT group (*p*= 0.065, ES= 1.19). In conclusion, our data indicate that concurrent lower limb sprint interval training interfere with arm muscle hypertrophy and strength.

Key words: concurrent training, hypertrophy, strength, endurance

INTRODUCTION

The concomitant integration of resistance and endurance training is termed concurrent training. Many sports require the improvement of muscular strength, power, and size, and endurance simultaneously for success. However, previous studies reported that concurrent training relative to resistance training alone resulted in decrement in strength (7, 11, 14), hypertrophy (11, 14), and power (14).

A recent review indicated interference effects of concurrent training are associated with training variants such as exercise modality, frequency, and duration of the endurance training (21). Jones et al. (12) reported the effect of differing ratios of time spent in each strength and endurance exercise modality per session on adaptation of muscle strength and hypertrophy. The results suggested that a protocol of an endurance and strength training ratio of 3:1 increased the magnitude of the interference response on strength and hypertrophy, compared to a protocol of strength training only; or an endurance and strength training ratio of 1:1; after 3 times per week for 6 weeks. Their findings indicate that the ratio of endurance to strength training performed during concurrent training influences the degree of interference. Therefore, maintaining the volume and duration of endurance training is important if the primary focus of the training intervention is improving strength and hypertrophy.

Previous studies for investigating concurrent training have implemented continuous or interval endurance training prior to or subsequent to strength training. Recently, many studies suggested that high-intensity endurance exercise, specifically sprint interval training (SIT), results in similar adaptations as low-intensity, high-volume endurance training (4, 9). These studies demonstrated significant improvements in peak oxygen uptake at a substantially less training volume. In fact, the weekly training volume for SIT was ~90% lower than that for the continuous endurance training group (i.e., 225 vs. 2,250 kJ) (4). Therefore, in addition to similar physiological adaptations, SIT may be an optimal complement to strength training in a concurrent training program. Recently, Cantrell et al. (5) suggested that separate days of concurrent strength and sprint interval training, like strength training, will not interfere with muscle hypertrophy and strength. To our knowledge, no data exist which examine chronic physiological adaptations (i.e., muscle cross-sectional area (CSA), and one repetition maximum (1RM)) to the same day protocol of concurrent sprint interval and strength training.

In addition, it is well known that a cross-transfer effect (20), which provides increased exercise performance during exercise with the untrained limbs or parts, exist in strength and aerobic exercises. Pogliaghi et al. (16) evaluated the effect of upper-body endurance training (arm cranking) and low-body endurance training (cycling training) for 12 weeks on maximal and submaximal exercise capacity of each untrained limb in elderly subjects. They reported a significant effect of arm cranking and cycling training on both peak and submaximal untrained limb performance, which increased by 10% of pre-training values in each group (13). These results suggest that nonspecific improvement of aerobic capacity occur independent of which muscle is exercised. In a practical sense, it is usual that arm strength training and aerobic bike training are performed in a same training session. Thus, we wished to know whether strength training performed in one body part is affected by aerobic training performed in another part.

Previous studies evaluated concurrent lower-body strength training and lower-body endurance training (10,15) or concurrent whole-body strength training and lower-body endurance training (7,12). Dolezal et al. (7) reported concurrent interference: eight weeks of concurrent whole-body strength training and lower-body endurance training was observed to lower the percent change of 1RM bench press (12%) compared with the strength training only group (24%). Dolezal et al. (7) suggest that, the cross-transfer effect (20) increases exercise performance during exercise with the untrained limbs, and should be considered as one of the causes of concurrent interference.

The purpose of this study was to examine whether or not high-intensity interval cycling sprints and subsequent upper body strength training influences training response of muscle strength and hypertrophy. We hypothesized that sprint interval training, which is lower in total volume compared with traditional endurance training, subsequent to strength training does not interfere with muscle hypertrophy and strength. We also tested whether sprint training performed with the lower limbs influenced arm strength training via the cross transfer effect (20).

METHODS

Experimental approach to the problem

Subjects were randomly assigned to the experimental group: concurrent resistance and sprint interval group (CT) and resistance training alone group. A supervised progressive resistance training (RT) program designed to induce muscular hypertrophy (3 sets of 10 repetitions (reps) at 80% 1RM of bilateral arm-curl exercise) was performed in 8 weeks, with training carried out 3 times per week on nonconsecutive days. Subjects assigned to the CT group performed protocols identical to the ST and modified sprint interval training group, with 4 sets of 30s maximum sprint, on the same day. One repetition maximum, muscle CSA and maximal oxygen consumption (VO2max) were measured pre- and post-training in both groups. All testing and training were supervised by a National Strength and Conditioning Association, Certified Strength and Conditioning Specialist (NSCA–CSCS).

Subjects

Fourteen Japanese male subjects (age, 20 ± 1.8 years; height, 171.2 ± 4.9 cm; weight, 64.5 ±

4.7) volunteered to participate in this study. All participants had previous experience in weight training. Two subjects did not complete all training sessions, providing no explanation. None of the subjects was taking any medication. All the participants were informed about the potential risks of the experiment and gave their written consent to participate in the experiment. The study was approved by the ethics committee of XXXXX and was in accordance with the Declaration of Helsinki for Human Research.

Procedures

Training protocol

Resistance training group

A supervised progressive RT program designed to induce muscular hypertrophy (3 sets of 10 reps at 80% 1RM of bilateral arm-curl exercise, separated 90 s rest intervals) was performed for 8 weeks using arm-curl machine, with training carried out 3 times per week on nonconsecutive days (Fig.1). A warm-up set of 8–10 repetitions was performed at 50% of the individual's measured maximum. The subjects performed to failure in the final set. The training intensity was increased 5% over baseline 1RM if the final working set exceeded 12 repetitions in a given workout. All subjects were individually supervised by experienced instructors during each training session in order to reduce deviations from the study protocol and to ensure subject safety.

[Insert Fig. 1 approximately here]

Concurrent training group

The sprint interval training was performed in 4 sets of 30s maximal effort, separated in 4m 30s rest intervals, on a PowerMaxV II (Combi, Tokyo, Japan) using a resistance equal to 7.5% of the subject's body weight. Each subject was then given a 3–5 min warm-up period on a cycle ergometer, whereby they strived to achieve a warm-up heart rate of 130–140 beats per min. Subjects assigned to the CT group performed protocols identical to the ST and modified sprint interval training group, on the same day.

One repetition maximum

All subjects performed the test of 1RM using the arm-curl machine. Before the test, subjects were given instructions on proper techniques and test procedures. After a warm-up consisting of several sets of 6 to 10 repetitions using a light load, each participant attempted a single repetition with a load believed to be approximately 90% of his/her maximum. If the attempt was successful, weight was added depending on the ease with which the single repetition was completed. If the attempt was not successful, weight was removed from the bar. A minimum of 3 min of rest was allowed between maximal attempts. This procedure continued until the participant was not able to complete a single repetition through the full range of motion. A subject's 1RM was considered when the exercise could be performed in proper form by using the heaviest load, and was usually achieved in 3 to 5 attempts.

Muscle cross sectional area (CSA)

Using a 0.3 T magnetic resonance (MR) system AIRIS II (HITACHI Tokyo, Japan), the CSAs of the femoral muscle were calculated using T1-weighted cross-sectional images of the upper arm at 50% area between the lateral epicondyle of the humerus and acromial process of the scapula (spin echo method; repetition time, 700 ms; echo time, 20 ms; slice thickness and slice space, 10 mm). Among the 3 slices (50% of upper arm, 10 mm distal and 10 mm proximal), the muscle CSA of the biceps and the brachialis were calculated twice by the same investigator, and the mean value was used for subsequent calculations. The CSA of each muscle was traced and calculated by Image J computer software (National Institutes of Health, Bethesda, Maryland).

VO2max

A maximal graded exercise test was performed on a cycle ergometer (PowerMaxV II, Combi, Tokyo, Japan) to measure VO2max. After a warm-up consisting of several minutes using light resistance, subjects began the test at 100 W with an increase of 20 W every minute thereafter. Pedaling rate was maintained between 55 and 65 RPM throughout test. Expired gases were collected and analyzed by AE100i (Minato, Tokyo, Japan).

Statistical analysis

The SPSS statistical package, version 22.0 for mac, was used to perform all of the statistical evaluations. A two-way ANOVA (group vs. time) with repeated measures was performed to assess training-related differences in the ST and CT groups for each dependent variable. In addition, the Bonferroni post-hoc test was performed to evaluate training-related changes within groups. Cohen's d effect sizes, reported for all observations, with ≤0.20 representing a small effect, 0.50 representing a medium effect, and ≥0.80 representing a large effect (6), were estimated to compare with the magnitude of the training response. The level of significance was set at $p < 0.05$.

RESULTS

Of the 14 subjects enrolled in the study, 12 successfully finished and were included in the analyses. Pre- and post-test VO2max, CSA, and 1RM are shown in Table 1 and Table 2. No differences were observed between groups in all parameters at baseline. An interaction effect was observed in VO2max ($p = 0.001$) but not in CSA and 1RM. In addition, a significant Mein effect (Time) was observed in only 1RM using a 2-way ANOVA. Significant increase in VO2max from pre- to post- test was observed in the CT group ($p = 0.010$, ES = 1.84, 95%CI

0.38 to 3.02), but not in the RT group (p = 0.559, ES = 0.35, 95%CI -0.81 to 1.47). Significant increase in CSA from pre- to post- test was observed in the RT group (p = 0.030, ES = 1.49, 95%CI 011 to 2.63), but not in the CT group (p = 0.110, ES = 1.01, 95%CI -0.26 to 2.13). Significant increase in 1RM from pre- to post- test was observed in the RT group (p = 0.021, ES = 1.57, 95%CI 0.18 to 2.72), but not in the CT groups (p = 0.065, ES = 1.19, 95%CI -0.11 to 2.31). There was no significant change of body weight from pre- to post- test in both groups.

[Insert table 1 approximately here]

[Insert table 2 approximately here]

DISCUSSION

This study examined whether or not high-intensity interval cycling sprints prior to upper body resistance training influences the training response of muscle strength and hypertrophy. We hypothesized that high-intensity and low-volume interval cycling sprint compared to traditional endurance training (9) subsequent to strength training does not interfere with muscle hypertrophy and strength. However, our data might indicate that concurrent upper body strength training and sprint interval cycling sprints on the same day interfere with muscle hypertrophy and strength due to systemic factors.

Previous research demonstrated that concurrent training, relative to resistance training only, results in compromised strength (7, 11, 14), hypertrophy (14), and power development (14). Conversely, resistance training appears to have little to no negative impact on endurance performance and VO2max (21). In addition, Silva et al. (19) reported that concurrent training performed twice a week promotes similar neuromuscular adaptations to strength training alone; and to concurrent strength combined with one of three types of aerobic training (continuous running; continuous cycling; and interval running) in young women. Our results were in agreement with these previous studies, but against our hypothesis.

As a potential mechanism for local factors causing concurrent interference, the activity of selected negative regulators of protein synthesis, such as AMP-activated protein kinase (AMPK) and eukaryotic translation initiation factor 4E binding protein 1 (4E-BP1), is increased by endurance exercise in an intensity-dependent manner (18). Moreover, previous studies suggest that AMPK activation has a significant inhibitory effect on mammalian target of rapamycin complex 1 (mTORC1) and its downstream signaling targets, thereby negatively regulating protein synthesis and hypertrophy (2, 3). Recently, high intensity interval training has been reported as a potent exercise strategy for inducing signaling related to mitochondrial biogenesis, with associated health benefits and athletic performance (8). Taken together, these studies provide convincing evidence that higher-intensity interval training exacerbates acute molecular interference with muscle hypertrophy induced by resistance training.

As mentioned above, the best characterized local interference mechanism of concurrent training is antagonistic interactions between the AMPK and mTORC1 signaling (2). However, Apro et al. showed that the signaling of muscle growth through the mTORC1-S6K1 axis after high intensity and high volume resistance exercise is not inhibited by subsequent endurance exercise (1). It is possible that a regimen of prior resistance training alters hypertrophic response after an overall concurrent training session.

The systemic factors responsible for concurrent interference with muscle hypertrophy and strength are not clearly known. We hypothesized that concurrent interference due to systemic factors would also be associated with interfering AMPK activity for mTOR signaling in upper-body muscle during and/or after high sprint lower-body exercise. We suggest two of possible mechanisms, one involves the creatine (Cr) concentration and the other involves reactive oxygen species (RONS). High intensity resistance training decreases the concentration of phosphocreatine (PCr) in trained muscle, and this is restored after training (10). Ponticos et al. (17) suggested that AMPK activity is activated by permanently high levels of Cr in the muscle. Slow recovery of increased Cr after resistance training might activate AMPK. High blood flow in arm muscles is required for early recovery of PCr after exercise, but it should be decreased during high sprint leg exercise due to blood redistribution (13), Therefore, we thought that recovery of PCr concentration after resistance training in upper-body muscle might not be sufficient following high intensity lower-body endurance exercise. The slow recovery of Cr might activate AMPK. Another possible factor for systemic concurrent interference is the effect of RONS (15). RONS are produced during exercise, such as the Wingate test, and play a role in regulating calcium calmodulin kinase (CaMK)-AMPK axis signaling pathway (15). We suspect that RONS produced by sprint leg exercise diffuse systemically and interfere with mTOR activation in arm muscles. Since the findings shown in this study suggest that concurrent interference occur systemically, we will investigate mechanisms such as Cr metabolisms, RONS productions, etc. We believe that the key is to interfere with mTOR signaling during concurrent upper-body strength training and lower-body high intensity interval exercise.

In this study, there are several limitations. The first is our small sample size. Therefore, the chance of committing a type II error in evaluating our measurements was high. Second, we could not control for nutrition factors such as diet and intake of supplements, which could influence the results of our study. We could not evaluate muscle volume, as we only measured a single site of arm CSA. In addition, our exercise protocol (arm-curl exercise) was minimalistic. It would be assumed that greater interference would be found when higher volume protocols are employed, particularly involving large, multi-joint movements.

In conclusion, our data of a pilot study may indicate that concurrent strength and sprint interval training interfere with muscle hypertrophy and strength, if performed on the same day.

PRACTICAL APPLICATIONS

In this study, the CT group performed sprint interval training immediately after resistance training. A recent review reported that concurrent strength and endurance training on the same day has higher effect on hypertrophy and strength responses than the two trainings on separate days, although this difference was not statistically significant (21). Cantrell et al. (5) examined the chronic effect of concurrent strength and sprint interval training on strength and hypertrophy on separate days. They suggested that sprint interval training performed concurrently with heavy strength training on separate days does not appear to interfere with the development of maximal strength. In addition, aerobic performance appears to respond positively to low volume, high-intensity sprint interval training. These studies indicate the influence of duration of session interval between resistance training and endurance training; and the order of exercise performance, on the effects of concurrent training. One explanation could be that endurance training after hypertrophic molecular response does not interfere with anabolic adaptation for resistance training, considering numerous animal and human studies have shown activation of mTORC1 signaling in response to strength training more than 24 hours after resistance exercise. .

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Figure legends

Fig.1 The arm-curl machine used in the present study (A), the starting position of arm-curl exercise (B) and final position (C).

Table 1. Effect on VO2max, CSA, 1RM, and body weight of 8 weeks of concurrent training (n=6) and resistance training alone (n=6).

Parameter tested	Training Condition	Pre-Treatment	Post-Treatment	P value	ES (95%CI)
VO_2max (ml/kg/min)†	CT	51.3±6.3	63.0±6.4	**0.010***	1.84(0.38-3.02)
	RT	51.8±5.9	54.7±10.0	0.559	0.35(-0.81-1.47)
CSA (cm^2)	CT	13.6±1.4	16.3±3.5	0.110	1.01(-0.26-2.13)
	RT	14.2±2.0	16.6±1.1	**0.030***	1.49(0.11-2.63)
1RM (kg)§	CT	19.2±5.6	27.5±8.1	0.065	1.19(-0.11-2.31)
	RT	21.7±4.1	29.6±5.8	**0.021**	1.57(0.18-2.72)
Body weight (kg)	CT	63.3±4.1	63.3±2.1	0.993	0.00(-1.13-1.13)
	RT	65.6±5.4	65.0±6.3	0.866	-0.10(-1.24-1.04)

CT, concurrent training; RT, Resistance training; VO2max, maximal oxygen consumption; CSA, Cross- sectional area of muscle; 1RM, 1 repetition maximum; ES, Effect size; 95%CI; 95% confidence interval. Values are mean ± S.D.

†p<0.05 significant interaction effect by 2-way ANOVA, § p<0.05 significant main effect (time) by 2-way ANOVA

*p <0.05 significant difference after training by Bonferroni post-hoc test.

Table 2. Individual training response of VO2, CSA and 1RM in CT and RT group

	Training Condition	**VO_2max (ml/kg/min)**		**CSA (cm^2)**		**1RM (kg)**	
		Pre	Post	Pre	Post	Pre	Post
Subject A	CT	49.6	62.3	14.3	17.5	15.0	25.0
Subject B	CT	57.2	69.4	15.7	22.2	20.0	30.0
Subject C	CT	52.3	61.3	13.4	13.8	15.0	25.0
Subject D	CT	46.8	61.3	13.3	16.8	17.5	22.5
Subject E	CT	59.2	70.6	11.4	11.4	17.5	20.0
Subject F	CT	42.6	52.9	13.8	12.4	30.0	42.5
Subject G	RT	48.0	51.1	17.3	17.2	20.0	30.0
Subject H	RT	55.5	63.1	11.9	16.2	20.0	30.0
Subject I	RT	60.5	66.3	12.4	17.5	20.0	27.5
Subject J	RT	54.0	60.0	13.5	15.5	20.0	28.0
Subject K	RT	48.8	41.3	15.6	16.5	20.0	22.5
Subject L	RT	44.1	46.3	14.7	15.8	30.0	40.0

CT, concurrent training; RT, Resistance training; VO2max, maximal oxygen consumption;

CSA, Cross- sectional area of muscle; 1RM, 1 repetition maximum;


(A) Arm-curl machine
(B) Start position
(C) Final position
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