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EFFECT OF RESISTANCE TRAINING AND DETRAINING ON METABOLIC MARKERS

Jung-Kyu Kim[1], Sunghwun Kang[2], Kyu-Min Park[2]

[1]Laboratory of Exercise Physiology, Department of Sport Leisure, College of Design Sports, Kangwon National University, Samcheok-si, Republic of Korea

[2]Laboratory of Exercise Physiology, Department of Sport Science, College of Art and Culture, Kangwon National University, Chunchoen-si, Republic of Korea

Corresponding Author: Kyu-Min Park: **katc-kyumin@kangwon.ac.kr**

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ABSTRACT

Background and objective
The aim of this study was to determine how resistance training and detraining later affected the growth factors, inflammatory markers, and bone metabolism markers in healthy male college students.

Material and methods
Twenty-two young adults participated in 12 weeks weight training (WT) program. Exercise intensity for WT group included the following: step1, 70% of 1 repetition maximum (1RM); step 2, 80% of 1RM; and step3, 90% of 1RM. After 12 weeks, were classified to the 6 weeks CT(continued training group) and 6 weeks DT(detraining group). In the body composition test, height, weight, body mass index (BMI), %fat, and lean body mass (LBM) were measured by electric impedance. Blood collection was carried out before, after 6 weeks, after 12 weeks, and after 18 weeks of training. In blood analysis, growth factors (GH, IGF-1, and testosterone), inflammatory markers [IL-6, tumor necrosis factor-α (TNF-α), and c-reactive protein (CRP)], and bone metabolism markers [osteocalcin (OC) and alkaline phosphatase (ALP)] were analyzed.

Results
Results showed that IGF-1 level was significantly decreased after 12 weeks of training compared to that prior to training. Testosterone level was also significantly decreased after 6 weeks and 12 weeks of training. Levels of IL-6, TNF-α, and CRP showed no significant differences by training period. Both OC and ALP levels significantly increased after 6 weeks and 12 weeks of training compared to those

prior to training. Detraining period IGF-1 level after 18 weeks was higher than that after 12 weeks in the CT group. IL-6 level after 18 weeks was lower compared to that at 12 weeks in the CT group. TNF-α level after 18 weeks was lower compared to that after 12 weeks in both groups. ALP level after 18 weeks was significantly higher compared to that after 12 weeks in the CT group.

Conclusions

Resistance training induced bone metabolic markers (OC and ALP) after 12 weeks. In addition, training period of more than 18 weeks is needed to reduce inflammatory markers (IL-6 and TNF-α). Six weeks of detraining does not affect metabolic markers in healthy young adults.

Keywords: *growth factors; inflammatory markers; bone metabolic markers*

INTRODUCTION

Muscle hypertrophy through resistance training is very important, because the skeletal muscles are vitally important for preserving and developing health.[1,2] Hormone intervention is essential for increasing muscle strength and mass.[3] Typical anabolic hormones include growth hormone (GH), testosterone, and insulin growth factor-1 (IGF-1).[4] These hormones can indicate temporary or chronic positive reaction following a resistance training program.[3]

Generally, sports can increase bone density by stimulating osteogenesis.[5,6] In clinical tests, bone metabolism biomarkers can be used to determine bone changes because they are synthesized from osteocalcin (OC) osteoblasts and 30% of them are released to the bloodstream. The degree of bone formation can be estimated based on OC level.[7] Alkaline phosphatase (ALP) is also a good indicator of bone formation.[8] Bone absorption and bone formation are achieved through dynamic remodeling process from adolescence to early adulthood.[9] At this point, the acquisition of maximum amount of bone mass can protect the occurrence of age-related osteoporosis.[10] The acquisition of maximum amount of bone mass in early adulthood can determine the bone mass of later phase of life and overcome age-related osteoporosis. High-impact physical activities and resistance training have been reported to increase bone mineral density (BMD).[11] However, some studies suggest that exercise does not improve bone density.[12,13] Improving bone metabolism is more effective in weight loss than exercise.[14] On the other hand, previous studies have shown that short-term exercises can improve bone density.[15] Therefore, results of the effect of exercise on bone density are inconsistent in different studies.

Meanwhile, treatment and pharmacology studies have been carried out to determine whether exercise can suppress chronic inflammation stemming from aging. However, they have been interrupted by side effects.[16] But exercise is an effective way to prevent and delay chronic diseases and inhibit inflammation.[17] Long-term resistance training is physiologically related to the reduction of pro-inflammatory cytokines.[18] In particular, interleukin-6 (IL-6) is a cytokine that can amplify acute inflammation and promote the evolution into a chronic inflammatory state.[19] Pro-inflammation cytokine tumor necrosis factor-α (TNF-α) and systemic inflammatory indicator c-reactive protein (CRP) are most frequently measured.[20]

Regular physical activity can facilitate weight loss and fat reduction. However, the improvement in muscle strength and body fat will be eliminated when physical activity is discontinued. Detraining is a partial or complete loss of physiological and performance adaptation by training.[21] Previous investigations reported that strength can be maintained from 4 to 32 weeks after training has ended in young subjects and from 5 to 27weeks in elderly subjects.[22–24] Thus, detraining shows various results because of subject, exercise intensity, training level and duration of exercise.[25]

The objective of this study, therefore, was to review changes in metabolism-related hormone levels after 12 weeks of traditional periodic resistance training for male college students in their 20s. Results of this study might provide suggestions on how to promote and maintain physical strength by monitoring not only positive effects of resistance training but also the degree of maintenance of the effect when exercise is discontinued after 6 weeks of detraining.

METHODS

Participants

The participants were 30 healthy men age 20-25 years who met the following criteria: (1) no medical illness, (2) neither take drug, (3) without participant in exercise program in the past 6 months. After excluding 8 people who did not perform the program faithfully, a total of 22 participants were selected as the final subjects of this study.

Experiment design

First, experimental design was a 12 weeks resistance training program with linear periodization (LP). Second, subject was divided into two groups: (1) 6 weeks of continued training group (n = 11) and (2) 6 weeks of detraining group (n = 11). In all exercises, the subjects performed 1RM test according to the National Strength and Conditioning Association's (NSCA) guidelines for testing.[26]

PROCEDURES

Basic test and blood collection time point

Participants of body composition (height, weight, LBM, % Fat) were measured using bio-impedance analyzer (Biospace, Korea). For blood collection at rest, the participants were instructed to avoid excessive physical activities and dinner on the day before the experimental and to maintain an empty stomach from 22:00 on ward. After arriving at the laboratory and taking rest for more than 30 min, 10 mL of whole blood sample was collected from the forearm cephalic vein using a disposable syringe for the following time points: before, after 6 weeks, after 12 weeks, and after 18 weeks. Blood sample was added into a serum separator tube (SST) and centrifuged at 3000 rpm for 10 min to collect the serum. Serum samples were stored at –80°C for analysis.

Blood analysis method

Serum GH and level were measured using chemiluminescent immunoassay (CLIA). GH analysis was performed using an Immulite 2000 (DPC, USA) assay, and IGF-1 analysis was performed using a Liaison (DiaSorin, USA) assay. GH level was measured using an Immulite 2000G (Siemens, USA) kit, and IGF-1 level was measured using the Liaison IGF-1 (DiaSorin, Italy) kit. Testosterone and OC levels were measured using radioimmunoassay (RIA). Testosterone and OC analyses were performed using a g-counter (PACKARD, USA).

TABLE 1 Characteristic of body composition

	Age (year)	Height (cm)	Weight (kg)	Body fat (%)	LBM (kg)
12weeks WT (n = 22)	23.33 ± 1.55	174.21 ± 7.58	70.02 ± 9.17	18.91 ± 7.32	56.60 ± 5.72
6weeksCT (n = 11)	22.64 ± 1.57	175.73 ± 7.32	72.81 ± 7.46	16.28 ± 6.18	58.46 ± 5.19
6weeks DT (n = 11)	22.91 ± 1.64	173.27 ± 8.53	69.95 ± 10.66	18.52 ± 8.31	54.74 ± 4.86

Values = Means ± SD, WT; weight training, CT; continued training, DT; detraining.

J Mens Health Vol 15(2):e37-e46; June 3, 2019

TABLE 2 Resistance exercise program

Group	Phase	Target	%RM	Set	Frequency (time/week)	Break time (s)
WT	Step 1 (1–4 weeks)	Hypertrophy and endurance	70	3	4	60
	Step 2 (5–8 weeks)	Basic strength	80	3	4	60
	Step 3 (9–2 weeks)	Strength and power	90	3	4	60
CT	Step 4 (13–18weeks)	Maintenance	80	3	4	60
DT		Interruption of exercise				
	Mon, Thu	**Part**	**Tue, Fri**	**Part**	**Time (min)**	
Program	Warm up		Warm up		10	
	Barbell bench press	Chest	Barbell squat	Leg	50	
	Dumbell fly		Leg curl machine		50	
	Dumbell pull over		Leg extension machine		50	
	Lat pull down machine	Back	Barbell shoulder press	Shoulder	50	
	seated row machine		Lateral raise		50	
	Pull up		Dead lift	Back and leg	50	
	Lying triceps extension	Triceps	Barbell curl	Biceps	50	
	Cable push down		Arm curl machine		50	
	Crunch	Abdominals	Crunch	Abdominals	50	
	Cool down		Cool down		10	

WT, weight training; CT, continued training; DT, detraining.

Testosterone was analyzed using a Testosterone REACT (Asbach Medical Products, GmbH, USA) kit, and OC was analyzed using an Osteocalcin BGD (BRAHMS, Germany) kit. IL-6 and TNF-a levels were measured using ELISA kit. IL-6 and TNF-a analyses were performed using a Microplate Reader (Molecular device, USA). IL-6 level was measured using a Quantikine HS Human IL-6 immunoassay (R&D, USA) kit, and TNF-a level was measured using a Quantikine HS Human TNF-a (R&D, USA) assay. CRP level was measured using an immunoturbidimetric assay. CRP analysis was performed using molecular analytics (Roche, Germany) and a CRP HS (Roche, Germany) kit. ALP level was measured using colorimetry with PNPP. ALP analysis was performed using molecular analytics (Roche, Germany) and using an APL (Roche, Germany) kit.

Statistical analysis

SPSS 23.0(IBM Corp., Armonk, NY, USA) Statistical package was used to calculate the mean and standard deviation for all items in the data obtained from this study. To make a comparison of the difference depending on the time point, analysis of variance (ANOVA) based on a repeated measurement was performed.

In addition, if statistically significant differences were detected, post-hoc test was performed by the application of Duncan's post-hoc test method. Statistical significance was set to $p < 0.05$.

RESULTS

Results of body composition during the training 12 weeks training period are shown Table 3. There are no significant differences between baseline values. Results of body composition during the 6weeks detraining period are shown Table 4. Also, there are no significant differences between 12 weeks.

Results of related factors analyzed during the training period are shown in Table 5. The IGF level decreased significantly ($p < 0.05$) after 12 weeks of training compared to that prior to training. The testosterone level decreased significantly ($p < 0.05$) after 6 weeks and 12 weeks compared to that prior to training. The IL-6, TNF-α, and CRP levels showed no significant differences by periods. The OC and ALP levels increased significantly ($p < 0.05$) after 6 weeks and 12 weeks compared to those prior to training. Results of metabolism markers analyzed during the detraining period are shown in Table 6. The IGF-1 level increased ($p < 0.05$) after 18 weeks and 12 weeks in the CT (continued training) group. The IL-6 level declined ($p < 0.05$) in the CT group after 18 weeks compared to that at 12 weeks. Both groups experienced a significant ($p < 0.05$) decrease in TNF-α level after 18 weeks compared to that at 12 weeks. The ALP level increased significantly ($p < 0.05$) after 18 weeks in the CT group.

DISCUSSION

The purpose of this study was to determine changes in metabolic markers through 12 weeks of resistance training program and examine the maintenance of effect during the detraining period for the next 6 weeks. The main finding of this study was that 12 weeks of regular resistance training for male college students improved bone metabolism markers and 6 weeks of detraining decreased inflammatory markers. However, 12 weeks of resistance training did not any produce positive changes for inflammatory markers such as IL-6 and TNF-α, while 18 weeks of training seemed to be effective.

Studies of exercise and bone metabolism have varied according to variables such as gender,

TABLE 4 Change of body composition during detraining

	Group	12 weeks	18 weeks
Weight (kg)	CT	72.81 ± 7.46	73.12 ± 7.92
	DT	69.59 ± 10.66	69.76 ± 10.83
BMI (kg/m^2)	CT	23.75 ± 2.87	23.74 ± 2.87
	DT	23.26 ± 3.86	23.30 ± 4.03
Body fat (%)	CT	16.28 ± 6.18	16.89 ± 6.12
	DT	18.52 ± 8.31	19.15 ± 8.36
LBM (kg)	CT	60.83 ± 4.84	60.49 ± 5.22
	DT	56.13 ± 5.714	57.65 ± 6.41

Values = Means ± SD; CT, continued training; DT, detraining.

TABLE 3 Change of body composition after 12 weeks

	Group	Before	6 weeks	12 weeks
Weight (kg)	WT	70.02 ± 9.17	71.11 ± 9.04	71.20 ± 9.13
BMI (kg/m^2)	WT	23.19 ± 3.37	23.39 ± 3.16	23.49 ± 3.31
Body fat (%)	WT	18.91 ± 7.32	17.23 ± 7.28	17.40 ± 7.23
LBM (kg)	WT	56.60 ± 5.27	58.34 ± 5.89	58.48 ± 5.70

Values = Means ± SD; WT, weight training.

TABLE 5 Change of metabolic marker after 12 weeks

	Group	Before	6weeks	12weeks	Post-hoc
GH (ng/mL)	WT	0.30 ± 0.43	0.18 ± 0.26	0.06 ± 0.30	
IGF-1 (ng/mL)	WT	248.66 ± 36.51	241.63 ± 37.51	223.40 ± 31.03	A > C
Testosterone (ng/mL)	WT	7.67 ± 2.46	6.35 ± 2.13	6.11 ± 1.67	A > B, C
IL-6 (pg/mL)	WT	1.17 ± 0.48	1.25 ± 0.42	1.03 ± 0.61	
TNF-α (pg/mL)	WT	1.37 ± 0.42	1.45 ± 0.38	1.56 ± 0.42	
CRP (mg/L)	WT	0.34 ± 0.10	0.56 ± 0.53	0.46 ± 0.48	
OC (ng/mL)	WT	8.16 ± 2.25	9.71 ± 2.45	9.32 ± 2.69	A < B, C
ALP (U/L)	WT	49.59 ± 6.62	62.68 ± 10.77	67.45 ± 12.24	A < B, C

Values = Means ± SD; GH, growth hormone; IGF-1, insulin-like growth factor-1; IL-6, interleukin-6; TNF-α, tumor necrosis factor-α; CRP, c-reactive protein; OC, osteocalcin; ALP, alkaline phosphatase; WT, weight training, before(A), 6 weeks(B), 12weeks(C); $^{*}p < 0.05$.

TABLE 6 Change of metabolic marker during detraining

	Group	12 weeks	18 weeks
GH (ng/mL)	CT	0.21 ± 0.42	0.09 ± 0.06
	DT	0.10 ± 0.10	0.11 ± 0.08
IGF-1 (ng/mL)	CT	225.17 ± 25.41	247.29 ± 31.44*
	DT	221.64 ± 97.00	229.71 ± 29.66
Testosterone (ng/mL)	CT	6.11 ± 1.83	6.27 ± 2.30
	DT	6.09 ± 0.29	6.34 ± 2.28
IL-6 (pg/mL)	CT	1.08 ± 0.85	0.69 ± 0.21*
	DT	0.98 ± 0.29	0.84 ± 0.28
TNF-α (pg/mL)	CT	1.49 ± 0.53	0.92 ± 0.23*
	DT	1.63 ± 0.27	0.86 ± 0.18*
CRP (mg/L)	CT	0.32 ± 0.13	0.33 ± 0.12
	DT	0.60 ± 0.64	0.58 ± 0.42
OC (ng/mL)	CT	9.48 ± 3.21	9.85 ± 3.34
	DT	9.16 ± 2.18	8.83 ± 1.80
ALP (U/L)	CT	62.18 ± 10.49	66.18 ± 11.64*
	DT	72.80 ± 11.98#	72.27 ± 12.87

*Values = Means ± SD; GH, growth hormone; IGF-1, insulin-like growth factor-1; IL-6, interleukin-6; TNF-α, tumor necrosis factor-α; CRP, c-reactive protein; OC. osteocalcin; ALP, alkaline phosphatase; CT, continued training; DT, detraining; *indicated significant different post 12; #indicated significant different group;* $^{*}p < 0.05$.

age, exercise method, exercise intensity, and so on. Health of bone can be transformed into a development and reconstruction process by weight loading stimulation.[27] Among the various biochemical markers of bone formation and absorption, OC and ALP are typically used.[28] According to previous studies, short-term training has a positive effect on bone formation.[15,29] ALP and OC levels are increased as a result of medium strength aerobic exercise of 12 weeks for adults in their 40s and 30s.[30] In addition, with aerobic exercise together with diet limit for 6 weeks for overweight men and women, OC and ALP levels are reported to be increased.[29] On the other hand, there is no change in ALP level after 8 weeks of training for men and women in their 20s.[31] However, both groups have significant increases in OC and ALP levels after 6 weeks and 12 weeks of training compared to those prior to training. Therefore, a minimum of 6 weeks of training is required to have positive change for bone metabolic markers when conducting a resistance training program for male college students who do not have training experience. However, there was no difference in levels of OC or ALP during the 6 weeks of detraining, suggesting that the positive effects of the exercise lasted for 6 weeks.

IL-6 is secreted mainly by monocyte or macrophage cells. It can also be produced by T cells and tissue cells. It is a useful indicator of inflammatory reactions.[32] TNF-α is a cytokine associated with obesity. Increased TNF-α level decreases muscle mass and muscle strength correlated with vascular diseases.[33] Moreover, CRP can be induced by IL-6 and TNF-α. CRP is markedly increased in disorders such as necrosis of the lung tissue. CRP level is known to appear higher in obese people with prognosis for coronary artery disease. It is highly indicative of chronic inflammatory condition.[21] Reduced levels of IL-6 and CRP after resistance training program for men in their 20s have been reported.[34] A weight loss program consisting of anaerobic and aerobic exercise can decrease IL-6 level in obese women.[35] In addition, it has been reported that 10 weeks of knee extensor program can reduce IL-6 level.[36] It was also reported that 4 weeks of detraining after 12 weeks of resistance training and aerobic training for middle-aged men, didn't show any change in the levels of TNF-α and CRP every period of these weeks, but an increased in of IL-6 level was observed is after detraining.[37] In this present study, no change in levels of IL-6, TNF-α, or CRP was observed after 12 weeks of resistance training for physically healthy men. However, levels of IL-6 and TNF decreased in the continuous training group for another 6 weeks. This suggests that 18 weeks of training can have positive changes of inflammatory markers for people in their early 20s. Decreased level of TNF-α during 6 weeks of detraining indicated that the effect of the training persisted although training was discontinued.

Exercise itself is a type of physiological stress. Generally, moderate exercise can stimulate GH, and resistance training can increase muscle hypertrophy and levels of GH and testosterone.[4] However, when high intensity exercises are performed for male high school students who have no exercise experience, inflammatory factors IL-6, IL-1, and TNF-α can inhibit GH and IGF systems without changes in growth-related hormones.[38] As a result of this study, training period IGF-1 level decreased after 12 weeks compared to that prior to training. Testosterone level also decreased after 6 weeks and 12 weeks of training compared to that prior to training. In addition, the fact that IL-6 and TNF-α levels decreased after 18 weeks while IGF-1 level increased in the CT group shows that growth-related hormone is changed along with positive changes in inflammatory hormones.

CONCLUSION

After LP resistance training for healthy male college students who had no exercise experience, 12 weeks of resistance training showed a significant increase on bone metabolism markers. In addition, 6 weeks of detraining after 12 weeks of training showed that the positive effect of the exercise continued. To reduce inflammatory markers, more than 18 weeks of training period is required. Six weeks of detraining after 12 weeks of training can maintain the effectiveness of the training because it does not increase inflammatory markers.

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