

EFFECT OF CONCURRENT TRAINING AND DETRAINING ON ANTI-INFLAMMATORY BIOMARKER AND PHYSICAL FITNESS LEVELS IN OBESE CHILDREN



ORIGINAL ARTICLE

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ABSTRACT

Objective: To examine the effect of 12 weeks of (3 days/week) concurrent training and 4 weeks of detraining on serum adiponectin concentrations and physical fitness levels in obese boys without dietary intervention. **Methods:** 24 healthy boys, 11-13 years old with body mass index >28 voluntarily participated in the study. They were divided into two groups, experimental (n = 12) and control (n = 12). **Results:** Adiponectin concentrations after 12 weeks presented significant decline in both experimental and control group compared with the baseline (p < 0.05). VO₂ peak, flexibility, strength, endurance of sit-ups and agility significantly increased in the experimental group compared with the control group (p < 0.05). It was shown that after a 4-week detraining, serum adiponectin did not significantly change in the experimental group and that beneficial physical fitness was gradually decreased. **Conclusion:** Our results suggest that the beneficial effects of exercise training on physical fitness are temporary. Since the process of adaptation is reversible, it seems that adiponectin concentrations were inevitably affected by morphological and hormonal changes that occurred during puberty in boys.

Keywords: endurance training, resistance training, adiponectin, physical fitness, obese children.

Article received on 9/7/2012 and approved on 1/21/2013.

INTRODUCTION

The obesity incidence has increased in developed and under development countries and such fact cannot be only attributed to genetic factors since the human genes have not modified lately¹. Habitual physical activities among humans are complex characteristics which are determined by the interaction of biological and psychosocial factors as well as the physical environment². Among the younger population, physical activity plays an important role in normal growth, maturation and development. In fact, physical activity is a central concept in the pediatric exercise science field². There is a real concern with the body overweight as well as lack of regular physical activity or lack of physical fitness are associated with risks of type 2 diabetes, hypertension and other chronic diseases in progressively younger individuals including children and adolescents, and it may lead to recurrent morbidity, bad quality of life and early death⁴. Regular exercise reduces the risk of chronic metabolic and cardiorespiratory diseases since it causes anti-inflammatory effects. Thus, regular physical activity for long periods may protect the body against the development of chronic diseases⁴. It is known that the adipocytes secrete a diverse group of proteins named adipocytokines, which participate in different biological functions including immunity, insulin sensitivity, appetite, angiogenesis, metabolism of lipids, vascular function and inflammation⁵. Adiponectin is considered an anti-inflammatory adipocytokine with capacity to reduce many inflammatory markers⁶. It has attracted a lot of attention lately due to its anti-inflammatory, anti-diabetic and anti-atherogenic effects. Low serum levels of adiponectin are related to obesity⁷. The adiponectin levels increase with obesity⁸. Comparatively with other adipocytokines, the adiponectin expression seems reduced in adipose tissues of obese mice and humans⁹.

The anti-inflammatory effects of regular exercise may be mediated through the reduction of visceral fat mass (with subsequent decreasing release of adipokines) and induction of anti-inflammatory environment with each exercise set⁴. Different training methods are commonly used for improvement of physical fitness and health. The training methods include: aerobic training, resistance training, interval training, circuit training, among others.

Concurrent training has been studied by new methods to reduce obesity rates. This term is used to characterize the method through which aerobic and resistance exercises are performed in the same training session¹⁰. Endurance training, resistance training and the combination of endurance and resistance training present positive influence in the physical and metabolic fitness¹¹. We firstly evaluated the variables of a physical training program and subsequently a concurrent training program was designed. Having the second as grounding, we defined volume, intensity, duration, intensity monitoring and exercise confidence, to name some. Intensity, duration and volume of concurrent training were gradual and progressively increased depending on the children's abilities, who were supervised by a physical education teacher.

The physical training effect on the adiponectin concentrations is currently controversial. There are some reports that exercise may lead to increase of the adiponectin levels^{12,13}, while others did not present any alteration in the adiponectin concentrations^{14,15}. Little is known about the alterations of the adiponectin levels during puberty and even less information about the detraining role after physical training on physical fitness as well as about the levels of adiponectin in the blood plasma of obese children. It is not clear for how long the positive effects of physical training remain after detraining. It is important to highlight new information on this field and alert the professionals about the problem.

Thus, the main goal of this study was to examine the effect of 12 weeks (3 days/week) of concurrent training followed by four weeks of detraining in the adiponectin concentrations and levels of physical fitness in obese boys without dietetical intervention.

METHODOLOGY

Sample

This study was semi-experimental. Twenty-four healthy boys (aged between 11 and 13 years) with body mass index (BMI) > 28, students from a local school (Taleb – Amoli) voluntarily participated in the study. Height and weight of participants were measured by standard procedures (in underwear, but barefoot) with a Seca 220 scale (22089 Hamburg, Germany). The BMI was calculated with weight in kilos divided by the height in square meters [kg/m^2]¹⁶. The children did not previously exercise or had any previous participation in weight loss programs (at least during the last three months), or had history of cardiovascular diseases, diabetes or any other medical problem. Moreover, the subjects did not smoke or made use of any medication. Obesity was defined according to suggestion by Cole *et al.*¹⁷. After blood samples collection, body composition was assessed within the first week previous to beginning of the physical training program of 12 weeks; the obese children were then randomly divided in two groups, experimental (n = 12) and control (n = 12). The experimental group received a concurrent training of 12 weeks (3 days/week) and the control group did not receive any physical training during the study period, but was tested before and after the 12 weeks (the control subjects were asked not to change their daily usual activities).

At the end of the concurrent training of 12 weeks, the experimental group was asked to return to its daily life style for the next four weeks without any training (detraining phase). At the end of detraining, he boys were invited to participate in the tests previously mentioned here.

The obese children were asked to avoid any exercise besides the necessary to the study. Before training, the parents of the obese children were invited to collect all the information about the study. Both the parents and the children received complete information about the nature and aim of the study, and afterwards, the free written consent form was signed. The procedures followed were in agreement with the ethical standards of the committee responsible for experimentation on humans as well as the Declaration of Helsinki from 1975 and revised in 1983, and it was approved by the Ethics Committee in Research (FWA00017681).

DATA COLLECTION

Anthropometry

Body composition was assessed by the Body Composition Analyzed *InBody* 220 for all the obese children under equal conditions. Body composition assessment is one of the most important pieces of information of the *InBody* test. *InBody* 220 directly measures bioimpedance of each body part allowing that the current and voltage go through the body through eight electrodes (precision approved with correlation coefficient value close to 98%).

Blood test and measurements of physical fitness

The blood test was performed in the morning after the obese

children had fasting of 12-14 hours. Fast blood samples were collected on three stages (baseline, after 12 weeks of concurrent training and four weeks of detraining) of each sample for adiponectin measurement. The subjects did not perform any exercise for 48 hours before the blood collection. The plasma was separated and stored at -80°C for subsequent analysis. Adiponectin levels were assessed by the ELISA method. Cardiorespiratory fitness was assessed with the oxygen consumption peak (VO_2 peak) measured by the Coureton test¹⁸. Flexibility of spine and hamstring muscles was measured by the sit and reach test¹⁹. The abdominal test (crunches) measures the abdominal muscle strength, endurance and hip flexors²⁰. The Illinois agility test was used to assess running agility²¹.

Designing of the concurrent training

The variables of the physical training program were assessed, and based on them, the concurrent training was designed.

Training intensity: the training intensity is one of the most important variables in the designing of resistance training programs²². The intensity of the resistance training was based on the previous repeated maximum exercise. The endurance training intensity was based on the maximum heart rate (HR_{max}) estimated by: $220 - \text{age}$. These trainings started with 50 to 60% of HR_{max} on the two first weeks of the program to guarantee that the participants developed a sense of achievement and positive self-esteem at the beginning of the program²³. Subsequently, the endurance training intensity was increased in 5% at each two weeks, and, as a result, on the 12th week the heart rate (HR) increased up to 80-85% of HR_{max} . During the endurance training sessions, HR was continuously monitored with a HR monitor (Polar, RS100th *cardio running*). The HR target zone was defined by a physical education teacher for each session. Moreover, with the help of a target-zone alarm, the subjects could be sure that the exercise was with the correct intensity. When the target-zone of the heart rate thresholds was activated, the wrist unit sounded an alarm when there were thresholds above or below their limits. The subjects received instructions about the use of the Polar watches during the physical training session.

Training volume: The training volume refers to the total work amount which is performed in a training session²⁴. The resistance training volume was calculated by the number of sets x repetition x weight of the subjects. For the two first weeks, the running time was 10 min and then weekly increased in two minutes. Thus, on the 12th week the running time reached 30 min. On the first four weeks, the time to climb up and down the stairs was six min (2 sets x 3 min = 6 min); for the second four weeks, 1 min for each set (2 sets x 4 min = 8 min) and for the last four weeks one extra set (3 sets x 4 min = 12 min) was added.

Intervals between sets and stations: Intervals were of 1 min and 3 min for the sets and for the stations, respectively, as well as of 5 min between resistance training and endurance training. Recovery intervals were of 3 min for the endurance station and climb up a step sets. Active recovery occurred between trainings.

Repetition velocity: The beginners had to learn to suitably and gently perform each exercise. It is recommended that untrained obese children perform exercises in a controlled manner and at moderate velocity²⁴.

Training frequency: The concurrent training frequency was of 3 days/week on non-consecutive days, to allow suitable recovery between sessions.

Concurrent trainings were performed under the supervision of a physical education teacher. Each session consisted of a 7-min warm-up session with emphasis on flexibility as well as a 7-min period of relaxation (table 1).

Table 1. Concurrent training program of 12 weeks for obese children.

Type training	Name exercise	Number of series			Reps		
		Week 1	Week 6	Week 12	Week 1	Week 6	Week 12
		Resistance	Crunches	3	4	4	10
Modified push-ups	3		4	4	5	8	11
Squats	3		4	4	8	12	18
Endurance	Run	Week 1	10 min run with HR _{max} = 50% to 60%				
		Week 6	10 min run with HR _{max} = 65% to 70%				
		Week 2	10 min run with HR _{max} = 80% to 85%				
	Step	Week 1	2 sets of 3 min with HR _{max} = 50% to 60%				
		Week 6	2 sets of 4 min with HR _{max} = 65% to 70%				
		Week 2	3 sets of 4 min with HR _{max} = 80% to 85%				
Play soccer with modified rules							

Table 2. Body composition, adiponectin and baseline physical fitness after training and detraining data in the control and experimental groups (mean ± SD).

Variables	Control group		Experimental Group		
	Basal	12 weeks	Basal	12 weeks	Detraining
Weight (kg)	72.19 ± 3.86	74.08 ± 3.71 ⁺	70.15 ± 2.65	71.16 ± 3.61 [§]	71.34 ± 3.27
Body mass index (kg/m ²)	29.22 ± 0.36	29.28 ± 1.11	28.72 ± 0.91	28.57 ± 0.95 [§]	28.65 ± 0.69
Waist-hip ratio	0.955 ± 0.005	0.951 ± 0.0093	0.955 ± 0.020	0.935 ± 0.021 ^{§*}	0.934 ± 0.018
Fat mass (kg)	30.77 ± 2.21	31.67 ± 3.54	29.37 ± 3.44	26.12 ± 3.09 ^{§*}	26.25 ± 2.97
Crunches (number)	20.75 ± 8.17	22.33 ± 8.20	23.5 ± 5.6	41.5 ± 5.35 ^{§*}	36.25 ± 5.38
VO ₂ peak (ml/kg/min)	34.86 ± 0.45	34.74 ± 1.65	35.39 ± 0.83	38.37 ± 2.11 ^{§*}	36.41 ± 1.36 [*]
Flexibility (cm)	23.50 ± 8.88	23.92 ± 9.59	22.92 ± 6.1	33.17 ± 5.15 ^{§*}	31.42 ± 5.50 [*]
Agility (s)	21.77 ± 0.63	21.37 ± 1.04	21.21 ± 0.86	19.78 ± 0.91 ^{§*}	20.65 ± 0.57 [*]
Adiponectin (ng/ml)	20 ± 5.70	14.97 ± 4.64 ⁺	19.7 ± 4.97	14 ± 5.46 [*]	12.23 ± 5.18

Data are presented in mean ± SD * Significant between 0 w, 12 w and 16 w experimental group through ANOVA (P < 0.05). + p < 0.05 before training vs. after training in the control group through paired t test. §p < 0.05 after training in the experimental group vs. after training in the control group through t test of independent samples.

STATISTICAL ANALYSIS

ANOVA and Tukey *post-hoc* analysis were used to evaluate the concurrent training effect in baseline, after 12 weeks of concurrent training (12 w) and after four weeks of detraining in the experimental group. For the control group, a simple paired *t* test was used to compare values obtained in the baseline and 12 w values. An independent *t* test was used to analyze differences between means of variables for the experimental and control groups before and after 12 weeks. The significance level was set at $p < 0.05$. All statistics used the statistical program SPSS version 16/00. All data were expressed as means ± SD.

RESULTS

Blood samples could not be obtained in the control group after detraining because their subjects were excluded from the analysis. There were no baseline differences between experimental and control groups for any of the descriptive variables measured (table 2).

A *t* test of independent samples (table 2) revealed that after 12 weeks of concurrent training, cardiorespiratory fitness, flexibility of low back and hamstrings, abdominal strength and endurance and hip flexors and running agility significantly increased

in the experimental group in comparison with the control group ($p < 0.05$). The same test evidenced that after 12 weeks of concurrent training differences were not found for the adiponectin levels in the experimental group compared with the control one ($p < 0.05$). The paired *t* test showed that in both groups the adiponectin concentration significantly decreased during the 12 weeks ($p < 0.05$). The same test evidenced that in the control group cardiorespiratory capacity, flexibility of low back and hamstring muscles, strength and endurance of abdominals and hip flexors and running agility did not present alteration during 12 weeks ($p < 0.05$). ANOVA test for three different periods (before training, 12 weeks of training and four weeks of detraining) revealed significant differences in adiponectin, flexibility, abdominals, agility and VO₂ peak in the experimental group ($p < 0.05$). However, the data analysis for pre and post-training as well as the data for four weeks of detraining, evidenced that adiponectin was significantly decreased in the experimental group after 12 weeks of training compared with the pre-training stage ($p < 0.05$). It could be observed that at the end of the 16th week (following four weeks of detraining) the adiponectin levels have not been significantly altered in the training group ($p < 0.05$). The same test revealed that cardiorespiratory fitness,

flexibility of low back and hamstring muscles, strength and endurance of abdominals and hip flexors and running agility significantly increased in the experimental group after 12 weeks of concurrent training ($p < 0.05$). After four weeks of detraining, running agility and VO_{2peak} significantly decreased in the experimental group and remained at the same level until the end of the assessments ($p < 0.05$).

DISCUSSION

The most important finding in the present study was that concurrent training of 12 weeks (3d/w) improved physical fitness, while did not affect the circulating adiponectin levels in the experimental group. After four weeks of detraining, the serum adiponectin did not significantly alter in the training group, but the beneficial physical fitness was gradually decreased. Childhood and adolescence are crucial periods in our lives, since dramatic physiological and psychological changes take place in those years²⁵. Many studies were conducted with obese children²⁶⁻²⁹; these studies reveal that physical training programs improve physical fitness and health status.

These results suggest that, in obese children, a concurrent training program of 12 weeks improves cardiorespiratory fitness – 8% (VO_{2peak}), flexibility of low back and hamstring muscles – 45%, strength and endurance of abdominals and hip flexors – 76% and running agility – 7%. Undoubtedly, regular practice of physical training programs is beneficial to fitness levels and health in children and adolescents; however, a challenge even bigger is not clear yet: how long do the beneficial effects of physical training last after detraining? The present study is pioneering in evaluating the effects of four weeks of detraining after 12 weeks of concurrent training in the physical fitness levels and alterations in the adiponectin concentrations in obese children.

In this study, at the end of the concurrent training of 12 weeks, the participants of the experimental group were asked to return to their previous life style for the next four weeks, without any training (detraining phase). According to the results, cardiorespiratory fitness (VO_{2peak}) (figure 1), flexibility of low back and hamstring muscles, strength and endurance of abdominals and hip flexors as well as running agility at the end of the 16th week (following four weeks of detraining) reverted and decreased.

An interesting finding of the present study was that after the concurrent training of 12 weeks, strength and endurance adaptation of the abdominals and hip flexors and flexibility of low back and hamstring muscles quickly increased, but after four weeks of detraining these variables gradually reverted. Comparatively, adaptation of cardiorespiratory fitness and running agility quickly reverted after four weeks of detraining.

Our results demonstrated that resistance and endurance trainings did not present negative effects to improve strength and endurance nor played any negative effects in flexibility and agility in obese children.

Recent reviews about anti-inflammatory effects of exercise focused on three possible mechanisms: reduction of visceral fat mass, increased production, release of anti-inflammatory cytokines derived from contractile skeletal muscles (called myokines) and reduced expression of *Toll-like* receptors (TLRs) in the monocytes and macrophages⁴. Short-term acute exercise (< 60 min), long-term

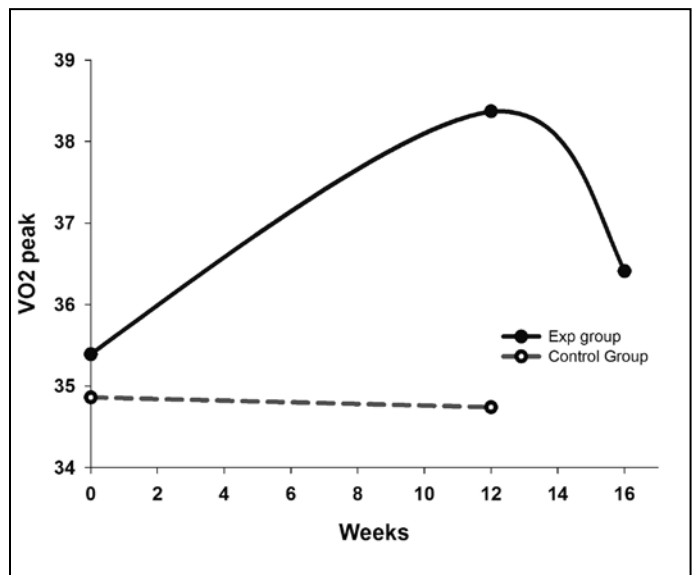


Figure 1. Mean alterations in VO_{2peak} (0 w, 12 w training and 4 w detraining) between experimental and control groups.

exercise (≥ 60 min) and adiponectin – Ferguson *et al.*¹⁴ investigated the acute effects of the cycling exercise on adiponectin in healthy men and women. The subject cycled at 65% of VO_{2max} for 60 min. The adiponectin did not alter with the exercise in men or women. In another study, 10 subjects completed exercise for two hours at 50% of VO_{2max} at fasting and non-fasting conditions and plasma and muscle biopsy samples were obtained during the protocol³⁰. The investigators did not report alterations in the plasma adiponectin levels in response to the test nor in expression of receptors 1 and 2 of adiponectin of the muscle, being different between experiments.

Short-term exercise (< 60 min) – Nine subjects with overweight performed submaximal exercise for 45 min (65% of VO_{2max}). The adiponectin concentration was measured before the exercise and immediately 24 and 48 h after exercise. The authors mentioned there were not significant alterations in adiponectin with time. The results of this study indicated that a submaximal aerobic exercise did not result in significant alterations in adiponectin until 48 h post-exercise in subjects with overweight³¹.

Long-term exercise (≥ 60 min) – The cycling exercise effect (60 min at 65% of VO_{2max}) in the adiponectin response of healthy men and women was studied showing that post-exercise in men or women did not present alterations in adiponectin or leptin concentrations. It was concluded that acute exercise did not affect the adiponectin concentrations in any of the sexes³¹. Generally speaking, these studies revealed that long and short-term acute exercises did not affect the adiponectin concentrations. Conversely, Saunders *et al.*¹³ reported that both acute and short-term aerobic exercises (~1 week) resulted in significant increase in the plasma levels of adiponectin in obese men abdominally inactive, regardless of the exercise intensity.

Short-term training (< 12 weeks) and adiponectin – Kelly *et al.*⁵ reported that physical training of eight weeks (4 d/w) consisting in static cycling in overweighted children did not improve the adiponectin profile in the absence of weight loss. The effect of 10 weeks of aerobic training in the adiponectin concentrations was investigated

in young and middle-aged women. After the training program, the serum adiponectin concentrations were increased in both groups³¹.

Long-term training (≥ 12 weeks) – Moghadasi *et al.*¹² investigated the mRNA adiponectin and plasma concentrations in middle-aged overweight and obese men after high-intensity physical training of 12 weeks (4 d/w) with 75-80% of individual maximum oxygen consumption for 45 min and after one week of detraining. The results showed that the plasma adiponectin concentrations increased after training in the experimental group compared with the control group ($p < 0.05$). After one week of detraining, the variables did not present significant alterations in the training group. Nassisa *et al.*³² showed that the adiponectin concentration did not change after aerobic exercise training after 12 weeks (3 d/w) in obese girls and with overweight (age – 13 years). Conversely, Donoso *et al.*³³ reported increase in the concentrations of circulating adiponectin all through puberty in female ballet dancers. In overweight and obese adolescents following 12 weeks of an aerobic training program, serum adiponectin, interleukin (IL)-6 and C-reactive protein (CRP) remain unchanged⁹. In another study, 12 obese male subjects were investigated before and after three months of dynamic resistance training. After the training, total body weight, adiponectin, IL-6 and TNF- α remained unchanged³⁴. The most recent studies present mixed results about the physical training effects in the adiponectin concentrations. Unfortunately, the mechanism from these controversial data is still unclear. It is believed that the differences between the results may be due to the application of different methodologies, data results and many intensities, volume, training duration or may be affected by morphological and hormone alterations which occur after different types of training programs.

The results of our study (figure 2) show that after 12 weeks, the adiponectin levels significantly increased in both groups, experimental (29%) and control (25%). Moreover, after four weeks of detraining, the process of adiponectin reduction still went on. Transitory decrease of the adiponectin level was found in boys aged between 10 and 12 or younger, but not in girls. The pubertal decrease of the adiponectin levels in boys agrees with the remarkable increase in the testosterone concentration. A negative correlation between testosterone levels and adiponectin concentrations was also verified in boys. Some authors reported transitory decrease of the adiponectin level during male puberty, which relates to increase in the testosterone level in boys³⁵. Transitory decrease associated with puberty of the adiponectin levels in boys which is associated with increase in the testosterone levels was reported in Taiwanese children aged between 6 and 18 years⁸. In our study, the decline in adiponectin in boys during puberty may be due to increase in the testosterone levels, even with regular exercise. While highlighting the careful importance to biological factors (e.g. heredity, sex, adiposity, puberty, among others), it seems that the puberty factors should be considered for the evaluation of impact of the physical training in obese boys.

CONCLUSION

A concurrent training program and its gradual gain under supervision of a physical education professional in obese children may lead to functional as well as health benefits. Apparently, the positive effects of physical training are temporary, but the adaptation process is reversible. The strength and muscle flexibility adaptations

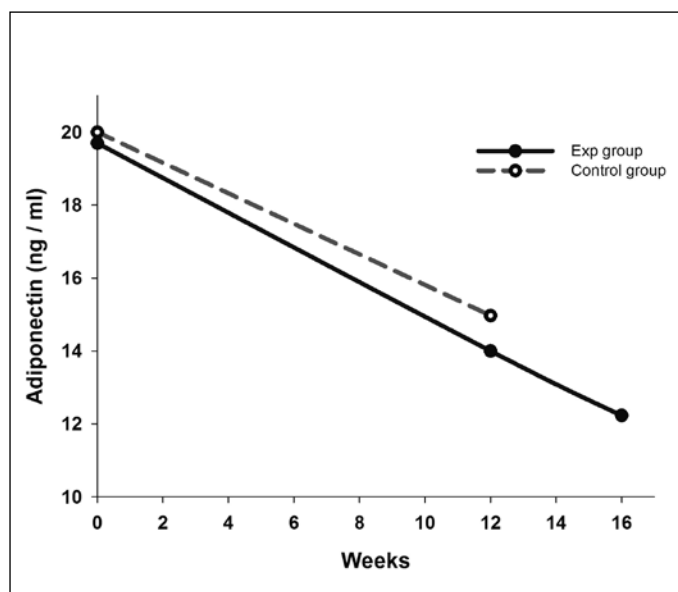


Figure 2. Mean alterations in adiponectin concentration (0 w, 12 w training and 4 w detraining) between experimental and control groups.

reduced after four weeks of detraining in a much slower rate than the cardiorespiratory fitness ($VO_{2\text{picco}}$) and agility in obese children. Our results demonstrated that resistance and endurance trainings do not present negative effects to the improvement of strength and endurance and do not have a negative effect on flexibility and agility in obese children. Endurance and resistance trainings are two common modalities of physical training. The results show that concurrent training, which is a combination of endurance and resistance training, may result in specific adaptations to both types of exercise. It seems that the adiponectin concentrations were inevitably affected by morphological and hormone alterations which occur during puberty in boys, given the potential connections between neuroendocrine alterations and body composition during puberty and the decline in physical activity during this period. Future multidisciplinary investigations in children should be encouraged in order to provide better understanding about the biological and physiological grounding of the physical activity during puberty. It should be mentioned that the need for future research to clearly demonstrate the direct and indirect molecular mechanisms through which physical exercise influences on the biological profile and physical fitness in obese children. There is no doubt that regular exercise is benefic to health; however, encouraging the general population to engage in physical training is a great challenge. It is imperative that more attention is given to the promotion of physical fitness during childhood, adolescence as well as adulthood.

ACKNOWLEDGEMENTS

We thank Ebrahim Nemati, Mohammad Varamini and Harutyun Stepanyan for their contribution. We also would like to thank the volunteer children who participated in this study and for their parents' cooperation.

All authors have declared there is not any potential conflict of interests concerning this article.

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