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Original Article

Impact of combined aerobic–resistance exercise training without dietary intervention on irisin serum levels in overweight and obese girls

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Abstract:
Problem Statement. Obesity is a major threat to public health across the world. The progressive trend of overweight is serious among the children and adolescents. Physical activity is a useful way of proper development of the young adolescents. Irisin, a hormone secreted by skeletal muscle, protects body against the side effects of obesity such as increased body weight and insulin resistance. **Purpose.**This semi-experimental research aimed to investigate the impact of an 8 week combined exercise training program on specific physical fitness factors, as well as on the serum levels of irisin and insulin resistance in children classified as obese or overweight. **Materials and methods.** Twenty female students classified as obese or overweight (mean age: 10.85 ± 1.03 years, weight: 49.07 ± 9.64 kg, BMI: 23.25 ± 2.73 kg/m^2) were selected using convenience (availability) sampling and subsequently randomized into two groups: intervention and control. The intervention group underwent an 8-week program consisting of combined resistance–aerobic exercise training (with a 3:2 ratio on alternate days), totaling five sessions per week. Conversely, the control group adhered to their regular daily routines. Baseline and post-training assessments included measurements of anthropometric and physical fitness indices. Blood samples were collected 24 h before and after the intervention. To analyze the data, Shapiro–Wilk tests assessed normality, RM-ANOVA examined intragroup changes, and ANCOVA tests evaluated intergroup differences, with a statistical significance level set at $p \leq 0.05$. **Results.** The inferential analysis unveiled a significant difference between the two groups, specifically in insulin resistance, lower-body and static strength, VO2max, and dynamic balance. However, no significant disparities were observed in irisin levels, lower-body explosive power, upper body strength, BMI, weight, fat percentage, and fat-free mass. Notably, irisin levels exhibited a significant increase within the intervention group. **Conclusions.** This study shows that a combined aerobic (rope skipping)–resistance exercise training regimen holds promise for enhancing selected physical fitness indices. Additionally, this exercise modality significantly reduces insulin resistance in obese and overweight children.
Key words: Combined training, obesity, irisin, insulin resistance

Introduction

Chronic disease of obesity is a major threat to public health across the world. Worldwide statistics show a great number of 155 million overweight children in the age range of 5-17 (Lau et al, 2010). According to WHO, Middle East is exposed to progressive rate of obesity. Among the Iranian children, the escalating trend of overweight is serious (Kelishadi et al, 2014). By 2025, it is expected that Iran will have an estimation of four million overweight children and adolescents. Obesity and overweight are associated with increased level of cardio-vascular diseases (Chen et al, 2016) and adulthood all-cause mortality (Hajhashemy et al, 2022).

Lower cardiovascular fitness is related to more risk factors. One metabolic equivalent increase in peak oxygen consumption is associated with %15 and %13 decrease in cardiovascular disease risk and all-cause mortality, respectively (Castro et al., 2017). A healthy lifestyle including interventions such as exercise training may be useful for children and adolescents (Calcaterra et al., 2022). An optimal level of physical activity is demonstrated to stimulates development, improves cardiac function and muscle and joint flexibility, and reduces mental or physical discomfort (Görner & Reineke, 2020). Huang et al (2022) showed that 12 weeks of home-based rope jumping promotes speed, endurance, power and core muscular endurance in middle school students (Huang et al, 2022). Cengizel et al (2022) stated that jump rope training is more usefull than plyometric trainig in improving athletic performance of adolescent basketball players (Cengizel & Cengizel, 2022). From another viewpoint, resistance training is proposed as a safe and effective way of conditioning for the youth to improve their body composition (Lau et al., 2010). Findings suggest that resistance training increase muscle mass and strength and improves performance (Peyghambarzadeh et al, 2022). Resistance training is a good option to engage overweight and obese children and adolescents in physical activity and may be more likely to create a positive experience for these participants (Stricker et al, 2020). However, reserchers have shown that, from many

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aspects, combined exercise training is the most effective intervention for overweight and obese children and adolescents (Huang et al, 2023). For example, Tomschi et al. (2018) demonstrated a greater impact of combined training on muscle strength and cardiovascular endurance (Görner & Reineke, 2020). Some researchers consider combined training as the effect modulator of each aerobic or resistance training programs alone (Askari et al, 2015).

Skeletal muscle and adipose tissue are very active endocrine organs secreting molecules known as myokines and adipokines, respectively (Amanat et al, 2020). Recently, some of these molecules are identified in obese peoples, providing a justification for the mechanism of metabolic disorders associated with obesity (Ren et al, 2022). Irisin, discovered by Bostrum et al (2012), is released into the blood circulation via proteolytic cleavage of FNDC5 (Boström et al, 2012). Irisin production is regulated by PGC-1α (Peng & Wu, 2022). A rapid elevation of PGC-1α via AMPK is reported during exercise which returns to baseline level post- exercise (Calcaterra et al, 2022). Furthermore, it has been shown that irisin increases PGC-1α expression in skeletal muscles (Peng & Wu, 2022). A positive direct relationship between waist girth, and body fat mass, and an inverse one between lipid profile and serum irisin level is reported. Irisin protects body against the side effects of obesity such as increased body weight and insulin resistance. It increases energy expenditure and may be a major prognostic agent for conditions such as obesity and diabetes mellitus (Amanat et al, 2020).

There are many studies analyzing activity patterns in childhood and adolescence and the risks of sedentary behaviors that can induce morbidity (Morelli et al, 2020). In their study on children, Çatli et al (2016) reported a significant correlation of irisin level with HDL-C, fasting insulin and insulin resistance assessed through Homeostasis Model Assessment (HOMA-IR). The authors suggested that this provides evidence about irisin role in insulin sensitivity and lipid metabolism related to childhood obesity (Çatlı et al, 2016). Studies about the effect of exercise on irisin levels have shown its significant change after acute exercise activities (Tsai et al, 2021) compared to chronic training (Ghalamsiah & Nourshahi, 2023; Luo et al, 2023). There is an inconsistency between researches focused on the effect of different modes of extra movements on plasma irisin levels in children (Blüher et al, 2014; Palacios-González et al, 2015) and adults (Polyzos et al, 2015; Timmons et al, 2012). Moreover, other researchers suggested that there is no consistent data about relationship between overweight and irisin in children (Blüher et al, 2014; Reinehr et al, 2015) and adults (Elsen et al, 2014; Polyzos et al., 2015). Considering well documented influence of exercise on irisin and paucity of researches studying the effect of exercise training on the changes of this hormone in children, the current research purpose is to study the effect of eight weeks aerobic- resistance training on irisin levels, insulin resistance and some of the physical fitness indices of obese and overweight girls.

Material & methods

Participants & Procedures

This semi-experimental study included two experimental and control groups with pre- and post- tests. The study population involved obese and overweight girl children (9-12 years old) living in Sabzevar, Iran (N=1050). Thirty (30) healthy girls were selected using convenient sampling and provided by information about the experimental procedures of the research. Inclusion criteria were physical health (health questionnaire and medical examination), BMI higher than 85th percentile for age and gender as overweight, or higher than 95th percentile as obese, and non-participation in other physical activities. Table 1 presents the participants' demographic data. Firstly, the subjects' parents submitted their consent letter. Then, participants were randomed into two intervention (n=15) and control (n=15) groups. Anthropometric (height, weight, fat percent, WC and WHR), physical fitness (static and muscular strength, dynamic balance, VO_2max, and explosive power) were measured at baseline and after training period. Considering irisin half-life and to remove the effect of the last training session, blood samples were drawn 24 hours before the first session and after intervention period completion. Ethical permission No. IR. iAu.ReE.1397.5 was obtained from the ethics committee of Sabzevar University of Medical Sciences. No dietary intervention was considered for the purpose of this study and parents were informed in this respect. Six subjects (two and four subjects from intervention and control groups, respectively) were omitted from the study due to various reasons such as personal problems and absence, and, therefore, excluded from the statistical analysis.

Table 1. Basline demographic characteristics for intervention (n=13) and control (n=11) groups in obese and overweight girls.

Characteristic	Intervention group (n=13) $\bar{X}$±S	Control group (n=11) $\bar{X}$±S	P-value	F-value
Age (years)	10.30±0.94	11.40±0.84	0.01	7.5
Height (cm)	141.90±4.67	148.12±7.27	0.04	4.8
Weight (kg)	44.80±6.68	48.81±4.55	0.16	2.09
Fat (%)	30.54±2.05	32.04±2.02	0.06	3.8
BMI (kg/m^2)	22.68±2.79	23.83±2.69	0.3	0.87

Notes: $\bar{X}$±SD refers to Mean ± Standard Deviation

Training protocol

Subjects in experimental group participated in 8 weeks combined resistance (3 days per week) and rope-skipping training (2 days per week) on alternate days. A workout session included warming- up (10 minutes), main part of training and cooling- down (10 minutes). Resistance training stations included push up, sit-up with medicine ball, overhead medicine ball throwing, squat jump, medicine ball overhead throw sit-up (with partner), knee Tuck jump, step jump squat, and reverse push up (2-5 sets of 8-10 repetitions during the first to the last week). Rope skipping workouts (8 repititions) started from two 30s sets in the first week progressing to three 60s sets in the last week. subjects in the control group had no physical activity during this time.

Assessments

The subjects' weight and height were measured by digital scale (without shoes and with the least clothes) and wall mounted stadiometer, respectively. BMI was calculated following the formula cited by literature. Waist and hip circumferences were measured as indicated in Kelishadi et al (Kelishadi et al, 2010). Fat percent values were calculated according to the proposed method of Slaughter et al (Slaughter et al, 1988) as follows:

If sum (Σ) of two skinfolds (subscapular and triceps) was greater than 35 mm, then equation (1), and otherwise, equation (2) was used for the calculation of fat percent:

$$\text{Fat percent} = 0.546\,(\Sigma) + 9.7 \quad (1)$$

$$\text{Fat percent} = 0.33\,(\Sigma) - 0.013\,(\Sigma)\,2 - 2.5 \quad (2)$$

The subjects' aerobic endurance was assessed by One Mile Walking test. Subjects warmed up for ten minutes and then started walking by hearing "Go" command. Time to walk 1 mile and heart rate at the end of the track were recorded. Then VO_2max was calculated according to Sung et al (Sung, 2013) as follows (equation 3):

$$VO_2\text{max} = 120.702 + (4.114 \times \text{gender } [F=0, M=1] - (2.918 \times \text{time}) - (2.841 \times \text{age}) \quad (3)$$

Dynamometer was used to measure static handgrip strength in kilogram (Matsudo, Matsudo, Rezende, & Raso, 2015). Upper- and lower-body strength was determined using Brzycki's indirect 1RM of chest press and leg extension, as follows (equation 4) (Brzycki, 1993).

$$1RM = \text{Weight: } [0.95 - (\text{number of repititions} - 2)\,(0.025)] \quad (4)$$

Dynamic balance was assessed in three movements directions (anterior, posteromedial and posterolateral) on each leg (results for dominant leg are reported in this study) through Y balance test according to Shaffer et al, (Shaffer et al, 2013). The maximum reach in each direction, after three attempts, was recorded and, the subjects' dynamic balance was calculated using equation (5) as follows:

$$\text{Dynamic balance} = (\text{sum of reach in three directions})/3 \quad (5)$$

Lower-body explosive power was determined by broad (standing long) jump (Fjørtoft et al, 2011). With swang arms and bended knees to provide forward drive, subjects were fixed behind a line marked on the ground with feet slightly apart and took a two-foot jump. The longest distance jumped of two attempts, without falling backwards, was considered as their record.

To determine daily calorie intake during the study period, subjects were asked to record their consumed nutrients for three non-consecutive days in two stages (at the beginning and the end of the intervention period) completely and with all details. Then, exact value and size of nutrients were extracted from FoodStuffs Album by Ghaffarpour et al (Ghffarpour et al, 2008) and analyzed using nutrition software N4.

Blood Sampling

Blood aliquots, taken after overnight fasting from the cubital vein in the supine position, were prepared for immediate analysis and for storage at -73 °c. Plasma irisin and insulin concentrations were measured by ELISA kits Zelbio GmbH, Ulm, Germany (intraassay CV%:7.3; sensitivity: 1 pg/mL) and Monobind, CA, USA (intraassay CV%:6.0; sensitivity:0.7 μIU/mL), respectively. Insulin resistance (IR) was calculated through Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) (equation 6) following Cauza et al (Cauza et al, 2005):

$$\text{HOMA-IR} = \frac{\text{insulin}\,(\mu IU/mL) \times \text{fasting glucose}\,(mL/mmol)}{22.5} \quad (6)$$

Statistical analysis

All statistical assessments were performed using SPSS version 23. Data normality, between group differences and within group changes were determined by Shapiro-Wilk, ANCOVA and Repeated measures ANOVA tests, respectively. Data are presented as Mean± Standard deviation and interpreted at the significance level of p≤0.05.

Results

According to data in Table 2, groups were not different significantly in respect of weight (p=0.90), fat percent (p=0.09), BMI (p=0.94), Fat Free Mass (p=0.15) and WHR (p=0.35). Waist circumference of two groups showed significant difference with a non-significant decrease for intervention (p=0.7) and significant increase for control (p=0.02) groups.

Table 2. Anthropometric parameters for intervention (n=13) and control (n=11) groups before and after training in obese and overweight girls.

Variable	Group	Before $\bar{X}$±SD	After $\bar{X}$±SD	Within groups P	Between groups P
Weight (kg)	Intervention	44.80± 6.68	45.32±6.81	0.08	0.90
	control	48.81±4.55	49.52±5.09	0.12	
Fat Free Mass (kg)	Intervention	31.00±3.71	31.60±3.84	0.01	0.15
	control	33.50±2.70	33.95±3.20	0.19	
Fat Percent (%)	Intervention	30.54±2.05	30.00±2.41	0.08	0.09
	control	32.04±2.02	32.51±2.51	0.20	
Body Mass Index (kg/m^2)	Intervention	22.68±2.79	22.51±2.35	0.5	0.94
	control	23.83±2.69	23.60±2.87	0.1	
Waist Circumference (cm)	Intervention	78.80±6.54	78.50±7.09	0.7	0.03*
	control	83.10±8.43	86.30±9.05	0.02	
Waist-to-Hip Ratio (m)	Intervention	0.92±0.05	0.91±0.04	0.6	0.35
	control	0.90±0.06	0.91±0.06	0.2	

Notes: $\bar{X}$±SD refers to Mean ± Standard Deviation*significant at p≤0.05

As presented in Table 3, the groups' insulin level (p=0.018) and insulin resistance (p=0.015) was different and intervention group experienced significant improvement in these two indices (p=0.001 and p=0.002, respectively). No significant difference was found in irisin levels of two groups (p=0.12), but a significant increase was seen for the intervention group compared to its baseline values (p=0.04).

Table 3. Biochemical parameters for intervention (n=13) and control (n=11) groups before and after training in obese and overweight girls.

Variable	Group	Before $\bar{X}$±SD	After $\bar{X}$±SD	Within group P	Between group P
Irisin (pg/ml)	Intervention	16.03±10.24	19.01±10.46	0.04	0.12
	control	14.82±8.56	15.49±10.52	0.4	
Insulin (μIU/mL)	Intervention	12.90±4.55	6.20±4.99	0.001	0.017*
	control	6.14±4.38	6.78±5.27	0.03	
Insulin Resistance Homa-IR	Intervention	28.75±10.34	15.25±12.63	0.007	0.015*
	control	14.73±11.98	16.80±13.19	0.19	

Notes: $\bar{X}$±SD refers to Mean ± Standard Deviation; Homa-IR: Homeostatic Model Assessment for Insulin Resistance*significant at p≤0.05

According to Table 4, two groups were different significantly in VO_2max (p=0.002), static strength (p=0.005), lower-body strength (p=0.007), and dynamic balance (p=0.002). However, upper-body strength and lower-body explosive power were not different significantly (p=0.4 and p=0.07, respectively). Though, it must be noted that the intervention group showed a significant improvement in upper-body strength relative to its baseline values (p=0.04).

Table 4. Physiological-functional parameters for intervention (n=13) and control (n=11) groups before and after training in obese and overweight girls.

Variable	Group	Before $\bar{X}$±SD	After $\bar{X}$±SD	Within group P	Between group P
VO_2max (ml.kg^{-1}.m^{-1})	Intervention	36.51±2.39	43.98±5.81	0.004	0.002*
	control	36.56±2.67	36.40±2.77	0.86	
Static strength (kg)	Intervention	13.10±4.25	19.20±4.80	0.001	0.005*
	control	13.60±3.23	15.90±3.54	0.03	
Upper- body strength (kg)	Intervention	13.80±4.39	15.90±4.06	0.04	0.4
	control	16.20±4.32	16.50±3.55	0.7	
Lower- body strength (kg)	Intervention	34.50±8.64	53.00±17.02	0.001	0.007*
	control	36.50±8.18	41.00±7.37	0.06	
Dynamic balance (cm)	Intervention	72.44±7.62	84.63±10.47	0.002	0.002*
	control	70.56±6.07	70.87±7.08	0.86	
Lower- body explosive power (cm)	Intervention	117.70±14.39	122.80±17.08	0.12	0.07
	control	111.80±11.50	109.00±12.42	0.40	

Notes: $\bar{X}$±SD refers to Mean ± Standard Deviation; Vo2max: Maximum oxygen uptake
*significant at p≤0.05

Our results in Table 5 indicated a significant difference in total daily calorie. At the end of training period, significant increase of calorie intake was observed for the subjects in intervention group compared to their control counterparts (p=0.01). However, intragroup changes showed significant increase in calorie intake for both groups (p=0.01)

Table 5. Intake of calories from macronutrients for intervention (n=13) and control (n=11) groups before and after training in obese and overweight girls.

Variable	Group	Before $\bar{X}$±SD	After $\bar{X}$±SD	Within group P	Between group P
Total calorie (g/d)	Intervention	1143.33±120.96	1506.66±190.08	0.01	0.01*
	control	1183.33±160.72	1316.00±189.29	0.01	
Carbohydrate (g/d)	Intervention	686.00±72.58	828.60±104.54	0.02	0.05*
	control	710.00±43.96	790.00±113.57	0.01	
Protein (g/d)	Intervention	217.23±22.98	301.33±38.01	0.01	0.003*
	control	224.83±30.53	223.8±32.18	0.4	
Fat (g/d)	Intervention	240.10±25.40	376.66±47.52	0.01	0.005*
	control	248.50±33.75	302.83±43.53	0.01	

Notes: $\bar{X}$±S refers to Mean ± Standard Deviation
*significant at p≤0.05

Discussion

The aim of this study was to examine the effect of eight combined (aerobic- resistance) exercise training on some anthropometric, physiological and biochemical indices in overweight and obese girl children.

Subjects' anthropometric indices were not different significantly after training period. Lau et al (2010), and Lee et al (2012) reported consistent findings. A direct relation is demonstrated for plasma adiponectin values and lipid metabolism such that higher levels of this hormone is associated with increased lipid metabolism. Researches have shown that obese people have a lower resting level of adiponectin compared to their thin counterparts (Alizadeh Pahlavani, 2022). It may be stated that aerobic exercise training improves functions of the body fat metabolic enzymes, accelerates lipids consumption and catabolism, and effectively prevents from lipid synthesis. In the study of the effect of short- term resistance training on leptin levels and anthropometric indices of obese adolescents, Lau et al (2010) reported no change in weight, fat mass and lean body mass of their subjects. To explain the results, they stated that resistance training is possibly useful only when it is associated with energy restriction, as it needs low metabolic cost (Lau et al, 2010). Also, Heijden et al (2010) reported that aerobic exercise without dietary intervetion or weigth loss has no effect on 24-h energy expenditure of obese adolescents. They suggested a higher energy expenditure of obese adolescents, due to their possible greater size of metabolically active lean body mass (as an important determinant) as the reason of their results. Zhang et al (2016) and Kim et al (2007) reported decreased weight of their experimental subjects after 22- and 12-weeks training, respectively. A possible reason for their inconsistent results may be our shorter duration of intervention. Furthermore, a higher levels of diet fat and carbohydrates at the end of intervention, especially for intervention group, may justify our results, as we imposed no limitation on the subjects' calorie intake.

The participants' irisin level was not different significantly after the intervention. However, subjects in the experimental group showed its significant increase relative to their baseline values. He et al (He et al, 2018) reported simillar results. Irisin may be expressed in subcutaneous adipose tissue and skeletal muscle which result in its increased release into circulation (Wang et al, 2023). Moreover, He et al (He et al, 2018) outlined the concepts of individual differences and exercise training "responders Vs. non-responders" and proposed fitness level as the best response predictor of irisin with more irisin response to exercise in more fitted peoples. On the other hand, in a one-year supervised exercise program, Bluher et al (Blüher et al, 2014) studied obese and overweight children (mean age of 12) and reported increased levels of irisin at the end of their program. They reported no correlation between irisin and anthropometric or inflammatory indices. Their exercise program was conducted at high intense level and included advanced facilities. The researchers suggested that difference in exercise training intensity and the students' mean age may justify inconsistent results. Diaz- Castro et al (2021) implemented a program of physical activity in schoolchildren for 6 months and demonstrated increased level of irisin and decreased weight and BMI in the exercise group. In this study, a greater percent of subjects in the exercise group reported adherence to mediterranean diet which may be an extra reason for their results.

In this study, insulin resistance and insulin levels were different significantly between two groups and the experimental group experienced a considerable reduction. Kim et al (2020) reported similar results by implementing a 12 week jump- rope exercise for obese adolescents. Also, in a study by Amanat et al (2020), 12 weeks of aerobic, resistance and combined training were associated with significantly reduced insulin resistance. Lower insulin value during exercise is in favor of glucose mobility from liver into circulation and allows its circulation homeostasis. Kim et al (2007) examined the effect of exercise interventions on obese adolescents and reported consistent findings. According to them, greater fat accumulation results in insulin resistance through two ways: adipocyte –derived cytokines and lipotoxicity- related insulin signaling. The researchers proposed that improved insulin sensitivity after exercise training may be related to AMPK mediated change in insulin peripheral sensitivity by AMP or other insulin signaling pathways. However, adipose accumulation reduction after long- term exercise training may provide greater changes in adipokine levels and insulin sensitivity.

The participants' VO_2max showed a significant difference between two groups and the experimental group experienced a significant improvement. Recent evidences indicate that just two weeks of training will be enough to induce fuctional improvement. This is while bradycardia and ventricular hypertrophy would be attained after at least two months of regular exercise training. In fact, cardiac functional properties including maximal oxygen uptake are prior to its morphological and electrical changes (Oláh et al, 2023). Resistance training influences on neuro-muscular system and, in this way, improves function of the cardio-vascular system by decreasing heart rate and or blood pressure. Also, increased muscular strength and power after resistance training reduces the exertion level of physical activities to be done and, as a result, there will be a lowered burden on one's cardio-vascular system (Kanegusuku et al, 2011).

The subjects' static strength increased significantly in both experimental and control groups. However, there was a significant difference between groups which may refer to positive impact of our training protocol. Also, lower-body strength was higher significantly in the experimental group compared to their control counterparts. This significant difference was not seen in the subjects' upper-body strength. However, the experimental group documented a significant increase in its upper-body strength relative to its baseline values. Considering unsignificant difference of fat free mass between two groups, it seems that muscle hypertrophy could not be the reason for increase in strength and that it may be a result of special neural adaptations related to training. On the other hand, Martinez Munoz et al (2019) and Kim et al (2015) found a correlation between irisin with handgrip strength and one-leg standing test score. Difference in the results of lower- and upper- body strength is reported by other researchers which has attributed it to various conditioning levels of knee extensors and upper-body muscles (Malina et al, 2004). Due to their weight bearing essence, quadriceps have a greater level of conditioning relative to upper-body muscles (Jung et al, 2023). The results for dynamic balance showed a significant difference between groups with an improvement for the experimental group. On possible reason for this could be increased lower-body strength, recruitment facilitation of fast-twitch motor units, increased muscle coordination and decreased inhibition and stimulation of muscle spindles during strength training (Deng, 2023). In this situation, muscle contraction induces Gama efferent nerve activity within muscle spindles. Increased sensitivity of muscle spindles could improve joint position sense which plays a major role in posture control. Also, in explaining the reason of better dynamic balance of adolescent tennis players after 12 weeks of rope jumping, Shi et al (Shi et al, 2023) referred to improved endurance and strength of the upper and lower extremities and lumbar and abdominal muscles, resulting in hypertrophic changes in muscle fiber structure.

Explosive power was not different for two groups. Intragroup changes indicated a non-significant increase and decrease for the experimental and control groups, respectively. Reinforced coordination of various parts of the body as well as the greater strength/ power are some factors increasing explosive power after exercise training (Chottidao et al, 2022). Also, a high angular velocity is associated with a higher average power during explosive movements (Huang et al, 2023) such as rope jumping. Huang et al (2022) noted contractions of quick stretch- shortening nature during jumping as an effective factor in promoting speed and jump performance. Furthermore, combined training stimulates neuromuscular system and, this way, activates both muscle fibers and the neural system. So, slow- twitch fibers act like fast twitch ones. From a different stance, resistance training increases the motor units' capability for stimulation and reflex reinforcement which may result in better training conditions in the future. Our results for greater strength in experimental group support the researchers' hypothesis. However, non-significant difference between groups may be attributed to higher baseline levels of this variable in the experimental group.

The current study had some limitations some of which are as follows. Our subjects were girl children in the age range of 9-12, so we had no control on their diet, other physical activities and their puberty-related hormonal changes. However, we do our best to exclude all girls with secondary symptoms of puberty (mainly, menstrual cycle) from our study to prevent its effects on the study results.

Conclusion

Our results showed that eight weeks combined exercise training could improve insulin resistance and some physiological indices, irrespective of irisin levels, in the obese and overweight children. Considering irisin-facilitated communication between muscle and adipose tissue, its important endocrine and autocrine functions, and its major role in conversion of white adipose tissue (WAT) to brown adipose tissue (BAT), designing an activity program to improve its levels may be valuable. However, it seems that only physical activity is not enough and exercise along with calorie intake limitation may have a greater effect on well-being and health in this population. So, it may be recommended that future studies consider special calorie intake along with different exercise training protocols to increase irisin health- related effects in this population.

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Conflict of interest The authors declare that there is no conflict of interest.

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