





The effects of aerobic training, resistance training, combined training, and healthy eating recommendations on lipid profile and body mass index in overweight and obese children and adolescents: A randomized clinical trial

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Original Article

Abstract

BACKGROUND: The aim of this study was to evaluate the effects of 8 weeks of aerobic training, resistance training (RT), combined training, and nutritional recommendations on lipid profile and body mass index (BMI) in obese and overweight children and adolescents.

METHODS: This randomized, clinical trial was conducted on 120 children and adolescents (10-19 years of age) with overweight and obesity. Participants were divided into 4 groups, the 3 intervention groups of high-intensity interval training (HIIT), RT, and combined training, and 1 non-exercising control group with healthy eating recommendations. We considered 24 sessions of training during 8 weeks for the intervention groups. The participants' anthropometric indices and lipid profile were assessed before and after the intervention.

RESULTS: There were no significant differences between the groups in terms of anthropometric indices and lipid profiles before the intervention. After the intervention, there was a significant difference between the groups in terms of HDL level; the control group (37.70 ± 9.45) and the HIIT group (43.65 ± 9.09) displayed the lowest and highest mean, respectively ($P = 0.040$). Comparison of physical variables and blood lipid profiles before and after the intervention showed a significant difference in waist circumference ($P = 0.030$), hip circumference ($P \leq 0.001$), and HDL level ($P = 0.040$) in RT, HIIT, combined, and control groups.

CONCLUSION: These results demonstrate that the combined training program and HIIT program with nutritional recommendations in overweight and obese children and adolescents were more effective in reducing BMI and hip circumference, respectively.

Keywords: High-Intensity Interval Training; Resistance Training; Overweight; Obesity

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Introduction

Obesity is a metabolic disorder described as the accumulation of adipose tissue and chronic inflammatory reactions. The mechanisms of weight control in children depend on genetics, and environment and growth factors, and any disruption in these parameters can lead to the development of obesity.¹ Today, obesity and overweight are two important health problems and one of the most critical challenges in developed and developing countries due to their increasing prevalence and

their association with various comorbidities such as endocrine disorders, cardiovascular disease (CVD),

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the digestive and nervous systems, and mental disorders. Based on scientific findings, the prevalence of obesity and overweight increased by 23.8% in boys and by 22.6% in girls from 1980 to 2013, and its prevalence in Iran in 2011 was 3.22% and 9.27% among boys and girls, respectively.^{2,3} The prevalence of obesity and overweight among high school students in Isfahan, Iran, was 4.3% and 11.5%, respectively.^{4,5} Body mass index (BMI), waist circumference, and hip circumference are useful measurable indices for assessing obesity and overweight. In the study by Ahmadi et al., the waist circumference of adolescents living in urban areas was higher in comparison with that of those living in rural areas.⁶

Among the many treatments for overweight and obesity, the implementation of appropriate sports programs and dietary pattern alteration can be the most useful in preventing and controlling overweight and obesity.¹

However, in many cases, there is a necessity for treatment; dietary changes, medication (such as the use of Omega 3, which can improve endothelial function of the vessels and increase HDL especially in obese people), and surgical methods are some of these treatments.^{7,8} One of the most important ways for preventing and treating obesity and overweight is optimized physical activity that is implemented in children and adolescents in the form of moderate to severe aerobic exercises 3 days a week for at least 1 hour, and is associated with improvements in individual's health conditions.⁹ One of the recommended physical activity programs for controlling overweight and obesity is high-intensity interval training (HIIT) programs, which are a series of physical exercises that include high-intensity short-term courses combined with periods of less intense exercise.^{10,11}

Although short-term exercises may interfere with physiological functions, HIIT is associated with significant improvements in the physiological and respiratory state, metabolic reactions, muscle function, and fat mass reduction. Moreover, investigations have shown the practical roles of HIIT in obesity, overweight, and lipid profile control in children and adolescents.^{9,11}

Previous researches have shown that HIIT programs are generally beneficial to the body and time-efficient and result in improvements in oxidative capacity and microvascularization of the muscles.¹¹ Another series of exercises include resistance training (RT) that increases muscle strength by applying tensile force and helps reduce fat tissue.¹² Although it was thought that these exercises might be harmful because of the effect they

have on the child's growth, more recent investigations show that if trainers accurately monitor the workouts in children, they can greatly reduce the probability of the injury. Therefore, the use of RT programs to prevent and treat obesity and overweight in children seems to be beneficial.^{12,13} Therefore, considering the importance of the mentioned cases and the limited number of studies in this field, the purpose of this study was to evaluate the effects of aerobic, resistance, combined training, and healthy eating recommendations on lipid profile and BMI in overweight and obese children and adolescents.

Materials and Methods

This randomized, single-blinded, clinical trial was conducted on 120 children and adolescents, with overweight or obesity and 10-19 years of age, referred to the Clinic of the Pediatric Cardiovascular Research Center in the Cardiovascular Research Institute of Isfahan, Iran, in 2017-2018.

The study inclusion criteria included children and adolescents aged 10 to 19 years with overweight (BMI of more than one standard deviation from the specific BMI according to age and sex) and obesity (BMI of more than two standard deviations from the particular BMI according to age and sex based on the WHO criteria).^{14,15} The exclusion criteria were certain diseases such as thyroid dysfunction, diabetes, or hypertension, history of taking drugs, BMI of less than one standard deviation of BMI according to age and sex, and reluctance to participate in the study.

We selected our participants using simple random sampling method with random allocation software from among eligible cases with overweight and obesity who had a health record at the Clinic of the Pediatric Cardiovascular Research Center.

Finally, 120 participants, using randomized block design, were randomized into 4 groups (30 children and adolescents in each group), 3 intervention groups (including RT, HIIT, and RT + HIIT groups) and 1 control group. Before the beginning of the study, verbal consent was obtained from children and adolescents and written informed consent was received from one of their parents. The ethics committee of Isfahan University of Medical Sciences, Iran, (No. 446755) approved this study. In addition, this study was registered in the Iranian Registry of Clinical Trials (www.irct.ir; IRCT20150428021987N4).

Preliminary data before and after the intervention were obtained by filling out a checklist, measuring anthropometric indices including weight, hip circumference, waist circumference, and BMI, and receiving blood tests. Before the beginning of

the study, anthropometric parameters (weight, height, waist circumference, and hip circumference) were obtained and blood samples were collected from the 4 groups for evaluation of lipid profiles (including triglyceride, cholesterol, HDL, and LDL). The researchers were blinded and allocated to the interventions.

Anthropometric parameters were measured using standard tools before and 8 weeks after the educational intervention. Weight was measured with minimal clothing and without shoes using a Seca scale with an accuracy of 0.1 kg. Height was measured to the nearest 0.5 cm. The waist circumference was measured at the midpoint between the bottom of the rib cage and the top of the iliac crest at the completion of exhalation. The hip circumference was measured in a standing position with a tape measure and on the widest part of the pelvis in a position parallel to the ground.

Blood samples were collected from the 4 groups for evaluation of lipid profiles including at the beginning of and 8 weeks after the study, and sent to a laboratory.

After the data were collected, separate educational intervention (including HIIT as stretch exercises, RT, and combined RT+HIIT program, and healthy eating recommendations) were implemented at different times. The healthy eating recommendations included consumption of vegetables, fruits, whole grains, fat-free or low-fat milk, lean meats, poultry, fish, eggs, beans, and nuts, in addition to lower use of fats, trans fats, cholesterol, salt (sodium), and added sugars. A total of three 60-minute educational sessions of lecture, question and answer, and role-playing were held for the children and adolescents in the intervention groups, and their parents. At the end of the session, participants received educational pamphlets of sports exercises and healthy eating recommendations to continue learning at home. It should be noted that participant in the control group received no training education, but they were provided with healthy eating recommendations in the form of pamphlets.

After the educational sessions, the intervention groups exercised based on a training program designed in the form of 3 separate programs (HIIT as stretch exercises, RT, and combined RT + HIIT program). The training program was conducted for 8 weeks (a total of 24 training sessions). Each exercise session included 10 minutes of warming up (running in place and stretching movements), performing the main phase of the intervention, and then, 10 minutes of cooling down (performing

stretching movements). The exercises related to the HIIT group are provided in table 1. For the HIIT group, the total training period was 30 minutes and the rest time was 20 seconds between each item.

Table 1. The components of the high-intensity interval training program and its settings

No.	HIIT program component	Settings
1	X-burpee	3 minutes
2	Floor tap squat	3 minutes
3	Side to side burpee	3 minutes
4	Knee lifting exercise	3 minutes
5	Jump squat	3 minutes
6	Lunge	3 minutes
7	Squat jack	3 minutes
8	Controlled burpee	3 minutes
9	Scissor squats	3 minutes

HIIT: High-intensity interval training

In the RT group, interventions were carried out in 3 sets, each containing 3 items, details of which are given in table 2.

Table 2. The components of the resistance training program and its settings

Set	Exercises	Settings
Set 1	Squats	8-10 times
	Push-ups	More than 12 times
	Crunches	30-45 seconds
	Glute bridge	More than 12 times
Set 1	Pull-ups	8-12 times
	Bicycle crunches	30-45 seconds
	Shoulder press	8-12 times
Set 1	Bent-knee bench dip	More than 12 times
	Lying back extension	30-45 seconds

Between each item, 30 seconds, and between each set, 60 seconds was dedicated to resting. For this group, 30 minutes of training was also considered. In the RT+HIIT group, HIIT and RT exercises were performed at 3-minute intervals (in each session). In total, 30 minutes of training was considered for this group. All intervention groups received instructions on the exercise movements at the Clinic of the Pediatric Cardiovascular Research Center, and subsequently, continued their exercises at home. In order to follow the participants' exercise schedule, we made phone calls every week to obtain this information. As no specific sport intervention had been considered for the control group, the participants in this group merely performed routine activities. Other considerations for this group were similar to the other study groups. At the end of the 8 weeks of educational intervention, to observe ethical considerations, effective methods of weight loss such as dietary advice and exercise training were provided to the control group. Figure 1 presents the flowchart of the study participants.

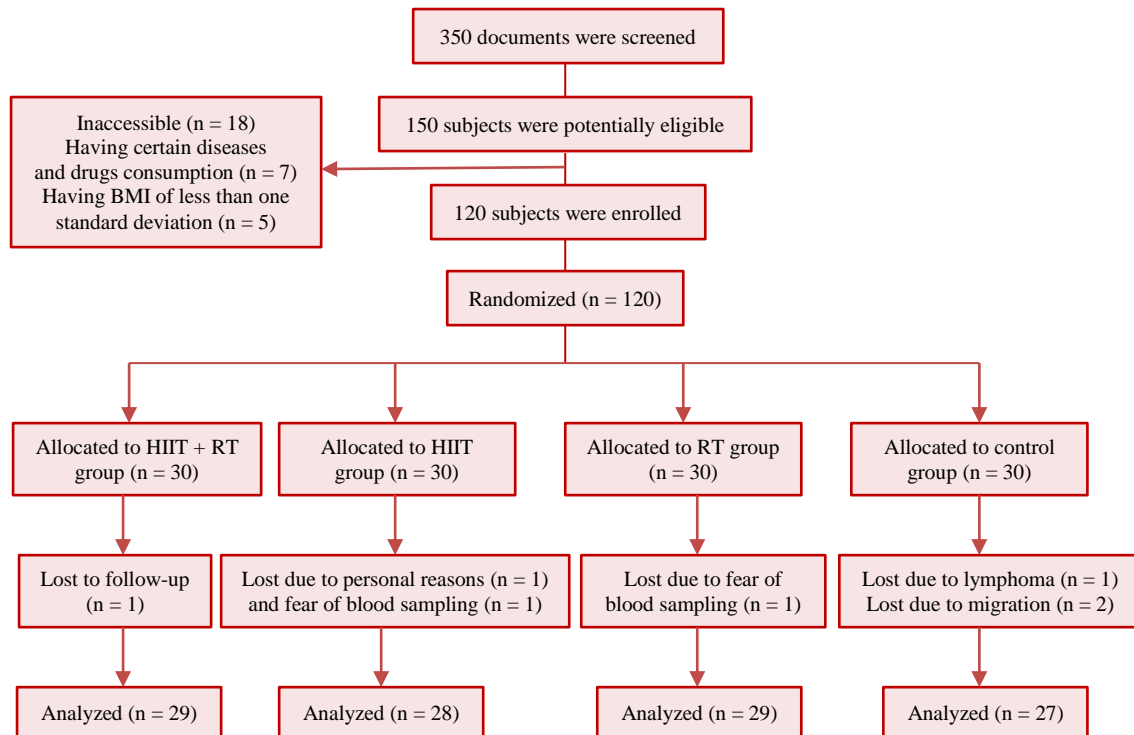


Figure 1. Study flowchart

HIIT: High-intensity interval training TR: Resistance training

The collected data were imported into SPSS Software (version 23.0.; IBM Corporation, Armonk, NY, USA). Quantitative data were expressed as mean and standard deviation (SD), and qualitative data were expressed as numbers and percentages. To determine the normality assumption of the data, Kolmogorov-Smirnov test (K-S test) was used, and a non-parametric test was used for variables that were not normally distributed. The paired t-test was used for intra-group comparisons before and after the intervention. Analysis of covariance (ANCOVA) was used to compare the measured values after the intervention between groups (with initial effect adjustment). The significance level was defined as P -value < 0.050 .

Results

During the study, from among the 120 participants, 1 subject due to lymphoma, 2 subjects due to

migration, and 4 subjects due to unwillingness to participate in the study were excluded. In this study, 113 subjects participated, including 68 (60%) girls and 45 (40%) boys. The mean age of the study subjects was 13.86 ± 2.75 years. The statistical analysis of demographic information showed no significant differences between the groups in terms of age and sex ($P > 0.050$). Details of the demographic information are provided in table 3.

Comparison of physical variables and blood lipid profiles showed that there were no significant differences between the case and control groups before the intervention. However, after the intervention, there was a significant difference between the groups in terms of the levels of HDL; the lowest mean was observed in the control group (37.70 ± 9.45) and the HIIT group displayed the highest mean (43.65 ± 9.09) ($P = 0.040$). Tables 4 and 5 show these results.

Table 3. Demographic characteristics of the participants

Variable	HIIT (n = 28)	RT (n = 29)	RT+HIIT (n = 29)	Control (n = 27)	P*
Sex [n (%)]					0.280
Male	13 (44.8)	8 (28.6)	10 (34.5)	14 (51.9)	
Female	16 (55.2)	20 (71.4)	19 (65.5)	13 (48.1)	
Age (year) (Mean \pm SD)	14.55 \pm 2.55	13.89 \pm 2.80	14.27 \pm 2.77	12.70 \pm 2.64	0.060

*Sex difference assessed via chi-square test and age difference assessed via analysis of variance

$P < 0.050$ was considered significant. HIIT: High-intensity interval training; TR: Resistance training

Table 4. Comparison of physical variables and lipid profiles (Mean \pm SD) before the intervention

Variable	Before the intervention (Mean \pm SD)				P*
	HIIT (n = 28)	RT (n = 29)	RT+HIIT (n = 29)	Control (n = 27)	
Physical variables					
Height (cm)	163.12 \pm 12.16	156.30 \pm 12.12	154.98 \pm 14.34	154.98 \pm 14.34	0.050
Weight (kg)	80.60 \pm 20.24	71.33 \pm 17.88	70.66 \pm 25.30	70.66 \pm 25.30	0.240
BMI (kg/m ²)	29.97 \pm 5.15	28.80 \pm 4.83	29.55 \pm 5.60	28.48 \pm 6.00	0.720
WC (cm)	94.14 \pm 13.95	88.55 \pm 12.03	93.68 \pm 14.37	92.18 \pm 14.62	0.410
Hip (cm)	109.36 \pm 13.04	102.82 \pm 12.10	100.24 \pm 14.40	100.24 \pm 14.40	0.600
Blood variables					
Cholesterol (mg/dl)	164.17 \pm 35.54	164.32 \pm 33.92	164.31 \pm 32.23	157.60 \pm 29.42	0.830
TG (mg/dl)	126.03 \pm 59.20	123.60 \pm 48.11	118.68 \pm 54.0	121.85 \pm 43.31	0.950
LDL-C (mg/dl)	88.20 \pm 29.96	85.46 \pm 30.60	93.06 \pm 30.01	87.11 \pm 26.70	0.770
HDL-C (mg/dl)	46.44 \pm 10.16	46.25 \pm 9.55	44.51 \pm 9.93	45.25 \pm 16.49	0.910

* One-way ANOVA or Kruskal–Wallis. P < 0.050 was considered significant.

HIIT: High-intensity interval training; TR: Resistance training; SD: Standard deviation; BMI: Body mass index; WC: Waist circumference; TG: Triglyceride; LDL: Low-density lipoprotein; HDL: High-density lipoprotein

Pre-intervention and post-intervention comparison of physical variables and blood lipid profiles after adjusting for variables showed a significant difference between all groups in terms of waist circumference (P = 0.030), hip circumference (P \leq 0.001), and levels of HDL (P = 0.040).

Height was increased significantly in all group. Moreover, body weight had increased during training in the case and control groups, and this increase was significant in the RT group. BMI decreased significantly only in the HIIT+RT group (P = 0.010) after the intervention.

Waist circumference increased during training in all groups except the HIIT group. Hip circumference increased significantly in the RT and control groups, but decreased significantly in the HIIT group (P = 0.030). Waist/hip ratio differed in all groups after the intervention compared to before the intervention, but this difference was not significant.

Serum cholesterol level decreased in the HIIT and RT groups and increased in the control group, but these differences were not significant. Serum triglyceride level decreased only in the HIIT group; this difference was not significant. LDL levels

decreased only in the RT group, but this reduction was not statistically significant. HDL levels had not increased after the intervention in all groups, but had significantly decreased in the control group (P = 0.020) (Table 6).

Discussion

This study showed that the combined RT+HIIT program had a significant effect on the reduction of participants' BMI. However, the post-intervention weight of the groups did not show any significant changes except for the RT group in which weight was significantly increased after the intervention.

Another finding of our study was that waist and hip circumference increased significantly in the RT group. The highest mean hip circumference was seen in the HIIT group, the RT+HIIT group, and the RT group, respectively, which were significantly different compared to the control group. Similarly, the groups were significantly different regarding hip circumference after the training. Although, hip circumference was considerably higher in the RT and control groups, this factor showed a significant decrease in the HIIT group.

Table 5. Comparison of physical variables (Mean \pm SD) and lipid profiles after the intervention

Variable	Group	HIIT (n = 28)	RT (n = 29)	RT+HIIT (n = 29)	Control (n = 27)	P*
		Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD	
Physical variables						
Height (cm)		164.40 \pm 11.43	157.57 \pm 11.94	161.50 \pm 9.20	155.81 \pm 14.09	0.070
Weight (kg)		80.90 \pm 18.66	72.70 \pm 17.21	76.88 \pm 19.38	71.10 \pm 24.81	0.180
BMI (kg/m ²)		29.55 \pm 5.00	28.87 \pm 4.65	29.05 \pm 5.35	28.41 \pm 5.80	0.670
WC (cm)		93.53 \pm 12.91	92.32 \pm 13.30	94.58 \pm 13.90	93.20 \pm 14.55	0.890
Hip (cm)		107.05 \pm 11.38	105.78 \pm 12.06	103.46 \pm 11.98	102.44 \pm 14.50	0.420
Blood variables						
Cholesterol (mg/dl)		157.62 \pm 23.91	157.71 \pm 40.30	164.51 \pm 35.77	161.70 \pm 43.30	0.440
TG (mg/dl)		118.13 \pm 44.43	127.92 \pm 75.48	125.62 \pm 61.74	137.92 \pm 54.70	0.330
LDL-C (mg/dl)		91.65 \pm 17.30	81.28 \pm 20.19	96.37 \pm 26.36	88.77 \pm 27.71	0.160
HDL-C (mg/dl)		43.65 \pm 9.09 [#]	43.35 \pm 8.85	42.55 \pm 8.53	37.70 \pm 9.45 [#]	0.040

* One-way ANOVA or Kruskal–Wallis test; [#] The difference between the first and fourth group was significant.

HIIT: High-intensity interval training; TR: Resistance training; SD: Standard deviation; BMI: Body mass index; WC: Waist circumference; TG: Triglyceride; LDL: Low-density lipoprotein; HDL: High-density lipoprotein

Table 6. Comparison of physical variables and lipid profiles before and after the intervention after adjusting for variables

Variables		HIIT (n = 28)	RT (n = 29)	RT+HIIT (n = 29)	Control (n = 27)	P**
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Height (cm)	Pre-intervention	163.12 ± 12.16	156.29 ± 12.12	160.05 ± 9.48	154.98 ± 14.34	0.220
	Post-intervention	164.39 ± 11.43	157.57 ± 11.94	161.50 ± 9.20	155.81 ± 14.09	
	P*	0.001	0.001	< 0.001	< 0.001	
Weight (kg)	Pre-intervention	80.60 ± 20.24	71.34 ± 17.89	76.77 ± 20.13	70.67 ± 25.31	0.370
	Post-intervention	80.90 ± 18.66	72.70 ± 17.21	76.88 ± 19.38	71.09 ± 24.82	
	P*	0.617	0.010	0.807	0.251	
BMI (kg/m ²)	Pre-intervention	29.97 ± 5.15	28.79 ± 4.83	29.54 ± 5.60	28.49 ± 6.00	0.170
	Post-intervention	29.56 ± 4.99	28.88 ± 4.65	29.05 ± 5.35	28.41 ± 5.79	
	P*	0.088	0.677	0.011	0.603	
WC (cm)	Pre-intervention	94.14 ± 13.94	88.55 ± 12.03	93.68 ± 14.37	92.18 ± 14.62	0.030
	Post-intervention	93.53 ± 12.91 [¥]	92.32 ± 13.30 [¥]	94.58 ± 13.90	93.20 ± 14.55	
	P*	0.553	0.001	0.311	0.268	
Hip (cm)	Pre-intervention	109.36 ± 13.08	102.82 ± 12.09	104.93 ± 11.86	100.24 ± 14.40	< 0.001
	Post-intervention	107.05 ± 11.38	105.78 ± 12.06 [§]	103.46 ± 11.98 [§]	102.44 ± 14.50	
	P*	109.36 ± 13.08	0.004	0.261	< 0.001	
Waist/hip ratio (cm/cm)	Pre-intervention	0.87 ± 0.08	0.86 ± 0.06	0.90 ± 0.06	0.92 ± 0.05	0.220
	Post-intervention	0.87 ± 0.06	0.87 ± 0.06	0.91 ± 0.10	0.90 ± 0.05	
	P*	0.992	0.282	0.161	0.222	
Cholesterol (mg/dl)	Pre-intervention	164.17 ± 35.54	164.32 ± 33.93	164.31 ± 32.23	157.59 ± 29.43	0.220
	Post-intervention	157.62 ± 23.91	151.71 ± 40.30	164.51 ± 35.77	161.70 ± 43.30	
	P*	0.156	0.073	0.959	0.588	
TG (mg/dl)	Pre-intervention	126.03 ± 59.21	123.60 ± 48.11	118.68 ± 54.00	121.85 ± 43.32	0.350
	Post-intervention	118.13 ± 44.43	127.93 ± 57.48	125.62 ± 61.74	137.93 ± 54.69	
	P*	0.358	0.672	0.411	0.191	
LDL-C (mg/dl)	Pre-intervention	88.21 ± 26.96	85.46 ± 30.60	93.06 ± 30.01	87.11 ± 26.71	0.130
	Post-intervention	91.65 ± 17.29	81.28 ± 20.19	96.37 ± 26.36	88.77 ± 27.70	
	P*	0.462	0.359	0.395	0.757	
HDL-C (mg/dl)	Pre-intervention	46.45 ± 10.17	46.25 ± 9.55	44.51 ± 9.93	45.26 ± 16.49	0.040
	Post-intervention	43.56 ± 9.09 [£]	43.36 ± 8.85	42.55 ± 8.53	37.70 ± 9.46 [£]	
	P*	0.161	0.152	0.246	0.027	

* Paired t-test; ** ANOVA test; [¥] The difference between the first and second group was significant; [§] The difference between the second and third group was significant; [£] The difference between the first and fourth group was significant.

HIIT: High-intensity interval training; TR: Resistance training; SD: Standard deviation; BMI: Body mass index; WC: Waist circumference; TG: Triglyceride; LDL: Low-density lipoprotein; HDL: High-density lipoprotein

The evaluation of the lipid profile showed that cholesterol levels in the RT group and HIIT group decreased after the exercise. In the control group, there was also a significant decrease in HDL, and this group had the lowest mean compared to the other groups.

The results of the present study generally show the beneficial role of using the exercise program, especially the combined exercises, in improving the lipid profile status and physical indices; however, some of the parameters did not show much change, and these results are not consistent with some studies.

According to the study conducted by Ramezani and Akbari, after performing the HIIT program, there was no difference between the intervention group and control group in terms of weight, but in the intervention group, BMI showed a significant decrease. This finding is consistent with our study, which may be due to their similar pre-intervention parameters and training programs.¹⁶

McGuigan et al. showed that while participants developed extensive changes in body composition and fat after the 8 weeks of resistance training, these exercises did not lead to a massive change in BMI.¹⁷ Moreover, the weight of participants at the end of their study had increased somewhat, although it was not statistically significant. BMI-related findings were consistent with that of our research, but outcomes related to weight gain were inconsistent with that of our results, although overall, weight gain was observed after the 8-week program in their subjects. The probable reason for these differences might be that the lean body mass increased and replaced the adipose tissue. Furthermore, the exercises used in their study differed from those in our study in terms of the type of movement, timing, and relaxation interval.¹⁷

In a study by Racil et al., HIIT was associated with weight loss, BMI improvements, and body fat reduction, and a significant reduction in waist circumference.¹⁸ In another study, they reported an improvement in total cholesterol, triglyceride, and blood glucose levels after HIIT.¹⁹ Although their findings on BMI are consistent with that in the combined group in our study, the significant reduction in weight, some lipid profile parameters, and waist circumference in the HIIT group in their evaluation was not consistent with our study. One of the reasons for these differences between the results of their studies and our investigation may be that their study was only conducted on adolescent girls, while the present study was performed on

children and adolescents of both sexes. In addition, they considered 12 weeks of exercises and the duration of the training interval per session was on average more than our study. Moreover, the monitoring of activity in their research was done through the evaluation of oxygen uptake and the direct observation of exercises, while in our study, we monitored our patients using phone call follow-up.

According to the results of the study conducted by Zakavi et al., after performing 12 weeks of combined aerobic and RT, weight, BMI and body fat percentage were significantly improved.²⁰ However, in our study, post-intervention weight in the combined group was not significantly different, but our results are consistent with the above study regarding BMI. The probable reason for this difference might be their study sample, since they studied male students with a BMI of more than 30; in addition, they considered 12 weeks of training. In their study, lipolysis following a more extended activity was associated with significant weight loss. Furthermore, the exercises in this study and their monitoring were different from our study, which could explain the difference in the results.²⁰

Khammassi et al. evaluated the effect of a 12-week HIIT program on the lipid profile of young people and reported improvements in weight, BMI, and waist circumference as a result of the program.²¹ Their findings are inconsistent with that of our study because we only found a significant decrease in hip circumference and significant increase in height of the HIIT group. Moreover, in their study, lipid profile parameters did not show significant changes, and these findings are also consistent with the results of the HIIT group in our study. It should be noted that they evaluated young men aged between 18 and 21 years, and had a 12-week training period with a different duration of exercise for each session in different weeks. Furthermore, they monitored their patients through direct observation and oxygen uptake measurement, which helped to improve the accuracy of the measurements and the correctness of the exercises.²¹

Sung et al. reported that an adjusted diet program along with strength training was correlated with improved lipid profiles.²² In addition, Ouerghi et al. studied 24 subjects aged 21 to 26 years, and reported a decrease in LDL, cholesterol, and triglyceride and an increase in HDL in the HIIT group after 12 weeks of training, and an increase in LDL, cholesterol, and triglyceride, and a decrease in HDL in the control group.²³ It should be noted that

the difference between the results of their investigation and the present study might be due to differences in exercise programs, measurement tools, monitoring methods, sample size, and the ages, racial disparities, and gender of the participants, and the varying degrees of obesity.²³

Some studies have shown that BMI might not adequately determine the obesity status in children because there is no measurable test to distinguish body fat mass and body lean mass. Various methods such as measuring anthropometric indices, waist-hip ratio, hydrometry, x-ray absorptiometry, and bioimpedance may help determine the structure of the body better, and thus, estimate the body fat tissue more accurately compared BMI.^{24,25} Considering that an increase in lean body mass can accompany RT, the lack of reduction in BMI and weight gain in the RT group may be justifiable.²⁶

Different sports exercises have been associated with various outcomes on the lipid profile. For example, while in some studies, cholesterol, LDL, triglyceride, and HDL levels improved significantly after conducting HIIT, in some other researches, they did not change significantly.²⁷ Aerobic exercises, RT, or combinations of these exercises can result in the improvement of HDL status, and subsequently, lead to a reduction in the LDL and triglyceride levels, although more training will be needed to achieve these results.²⁸ The mechanism of effect of these exercises is not precisely understood yet. However, evidence suggests that the need for energy that increases through exercise may be related to increased activity of the lipoprotein lipase enzyme, and consequently, changes in the levels of lipid parameters in the blood.²⁸

Additionally, changes in levels of very-low-density lipoprotein (VLDL) secreted from the liver following exercise and an increase in adiponectin secretions, which accompany fat catabolism and intake of glucose by muscle cells, are some of the factors that are considered as a possible mechanism for adjusting lipid profile and blood glucose following the above exercises in some studies.^{19,28}

One of the most important strengths of this study was the attention to exercise at home following a primary education, which can be done with minimal costs and facilities for all overweight and obese children and adolescents in any socioeconomic status. Moreover, at the time of submitting this manuscript, it was the first study to compare the effects of HIIT, RT, and combined HIIT and RT with a control group in children and adolescents.

One of the limitations of the current study was the relatively small sample size, which may complicate the generalization of the results to the

whole society. Another limitation was the lack of appropriate monitoring of home-based training interventions, which will limit the assessment of the correctness of the exercises. Our participants were selected from a single research center, and multicenter sampling facilitates the generalization of results to the community. Measuring body fat is better for evaluating the changes in adipose tissue; however, due to the limited equipment in this study, we could not differentiate lean body mass and fat tissue. Considering the above limitations, it is recommended that more extensive studies with larger sample sizes, increased duration of exercise, a diet based on the number of calories per person, and oxygen uptake monitoring to be conducted in the future to obtain more reliable results.

Conclusion

Our study results demonstrate that the combined training program (RT+HIIT) and HIIT program with nutritional recommendations in overweight and obese children and adolescents significantly reduced BMI and hip circumference, respectively. Further research is required to confirm these findings, as well as the effect of aerobic training, RT, and combined training programs on the reduction of lipid profile and other anthropometric indexes in overweight and obese children and adolescents.

The results of this project can be used to plan for improving overweight and obesity management in children and adolescents, provide suitable training at home and schools, and increase knowledge about controlling obesity and overweight.

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Conflict of Interests

Authors have no conflict of interests.

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