Research Paper

Effects of Skipping Rope Training and Running on Cardiovascular Risk Indicators in Overweight and Obese Girls

Roya Gharaeinejad[1] , Amir Hossein Haghighi[1]* , Roya Askari[1] , Hadi Shahrabadi[1]

1. Department of Exercise Physiology, Faculty of Sport Sciences, Hakim Sabzevari University, Sabzevar, Iran.

ABSTRACT

Background and Purpose: The prevalence of overweight and obesity among adolescents is high. It is necessary to find the methods to reduce the complications of obesity. This study aims to investigate the effect of skipping rope training (SRT) compared to running training (RT) on some cardiovascular risk indicators in overweight/obese girls.

Materials and Methods: In this quasi-experimental study that was conducted in 2020 in Neyshabur, Iran, 30 overweight/obese girls were randomly divided into two training groups (SRT and RT) and one control group. The training programs were performed for 8 weeks at three sessions per week. RT program consisted of running with one-minute intervals and an intensity of 70-75% HRmax. The SRT program was performed with one-minute intervals and an intensity of 45 jumps per minute. The data were analyzed using repeated measures ANOVA and Bonferroni's post hoc test in SPSS software, version 23. The significance level was set at 0.05.

Results: There was no significant difference between the two groups of SRT and RT in the indices (P>0.05); however, body weight (-5.13%), body mass index (BMI) (-8.16%), maximum oxygen uptake (VO_{2max}; 18.18%), triglyceride (-27.45%) and apolipoprotein A1 (apoA1; 2.53%) had a significant improvement in the SRT group compared to the control group (P<0.05). In the RT group, only the VO_{2max} (18.83%) had a significant improvement compared to the control group (P<0.01).

Conclusion: Both SRT and RT seem to have a role in improving cardiovascular risk indicators.

Keywords: Aerobic exercise, Interval training, Cholesterol, Cardiovascular, Obesity

* Corresponding Author:
Amir Hossein Haghighi, Professor.
Address: *Department of Exercise Physiology, Faculty of Sport Sciences, Hakim Sabzevari University, Sabzevar, Iran.*
Tel: *+98 (915) 1702885*
E-mail: *ah.haghighi@hsu.ac.ir*

Introduction

All countries in the world experience overweight and obesity in their adolescent population [1]. The overweight/obesity prevalence in Iran is estimated at 35.09%, of which 56.55% is for people over 18 years old and 21.11% is for people under 18 years old [2]. Overweight and obesity result from a chronic imbalance between energy intake and energy expenditure [3]. In adolescents, obesity is associated with cardiovascular diseases (CVDs), type 2 diabetes, dyslipidemia, non-alcoholic fatty liver disease, obstructive sleep apnea, polycystic ovary syndrome, and psychiatric problems [4]. Identifying cardiovascular risk indicators associated with adolescence overweight/obesity is vital to design preventive interventions for cardiovascular diseases [5].

Maximum oxygen uptake (VO_{2max}) is an important and widely used indicator of an individual's aerobic capacity, which is closely related to body weight and body composition. It improves with the reduction of fat mass and the increase of lean mass [6]. There is also a close relationship between the BMI and the risk of CVDs; for every 5-unit increase in BMI, the risk of CVDs increases by 29% [7]. The amount of VO_{2max} relative to body weight decreases slightly in girls during puberty (i.e. during adolescence) [8]. The increase in BMI in this period is due to the increase in fat mass and bone mineral density. The increase in fat mass is probably due to the release of the estrogen hormone. Therefore, VO_{2max} may decrease more in obese girls [9].

Studies have also shown that lipid profile is an important risk indicator of CVDs. The association of high cholesterol with increased risk of CVDs is mainly related to the low-density lipoprotein (LDL) level. On the other hand, high-density lipoprotein (HDL) level is inversely related to mortality from coronary heart disease [10]. Apolipoprotein A1 (apoA1) is the main protein component of HDL, and it plays a key role in reverse cholesterol transport, the regulation of inflammatory response, and the antioxidant process. In contrast, apolipoprotein B (apoB) is the major protein component of LDL, which represents atherogenic particles. Therefore, it is believed that the increase in the concentration of apoB and the decrease in apoA1 have a strong relationship with CVDs and metabolic syndrome triglycerides (TG) [11].

Regular exercise is an effective method for reducing cardiovascular and metabolic diseases, especially in inactive adolescents [12]. It creates a feeling of satisfaction more than drug and treatment regimens that have

side effects [13]. Physical activity can probably reduce cardiovascular risk indicators and mortality through the reduction of inflammatory, body fat, and obesity indicators [14]. The American College of Sports Medicine (ACSM) recommends that, in order to have an optimal effect and durability, it is better to exercise based on interval training [15]. In this regard, studies have shown that 8 weeks of skipping rope training (SRT) increases VO_{2max} and reduces TG and total cholesterol (TC) levels, body fat percentage, and BMI in overweight/obese boys [16], and also increases apoA1 and reduce apoB in overweight/obese girls [17]. There are also studies that reported the effect of running training (RT) on cardiovascular risk indicators in obese people. Song et al. [18] showed that 8 weeks of RT reduced body weight, BMI, body fat percentage, waist circumference, hip circumference, TC level, and LDL level, and increased the HDL level in obese girls. Meng et al. [19] showed that 12 weeks of RT reduced body fat percentage and BMI and increased VO2peak and HDL in obese adolescent boys.

Since inactivity is one of the main causes of obesity [14] and physical activity is considered as an essential component in any training program to reduce or control body weight and treat obesity [16], it is important to know the role of cardiovascular indicators in obese people as well as effective training programs for obesity treatment. Performing SRT in interval mode is more fun and exciting than RT [20], and it may be a suitable alternative to RT because, according to the results of previous studies, overweight/obese people can benefit from it for the health of the cardiovascular system [16, 17]. Considering the low participation of obese people in other exercise programs [21], it may positively affect their participation. Also by reviewing literature, we did not find any research that compares the effect of these two training methods (SRT and RT) on cardiovascular risk indicators in overweight and obese girls. It is necessary to find the best training program according to the condition of obese people in order to improve their cardiovascular indicators. Accordingly, this research aims to compare the effects of SRT and RT on some cardiovascular risk indicators in overweight and obese girls.

Materials and Methods

Study design and participants

This is a quasi-experimental study with a pre-test/post-test design conducted in 2020. The study population consists of overweight and obese girls from Neyshabur city, north-east of Iran. For this purpose, 56 overweight and obese girls referred to health and educational cen-

ters (e.g. schools and universities) in Neyshabur City were assessed for eligibility. The sample size was determined at 23 for repeated measures analysis of variance using G*Power software, version 3.1.9.4 by considering the significance level of 0.05, test power of 0.8, and effect size of 0.6. However, considering the possibility of sample dropout, the sample size was increased to 30.

Inclusion criteria were age 15-20 years, BMI percentile ≥85 (BMI >23.5 kg/m² for girls aged 15 and >25 kg/m² for girls aged 20) [22], not taking drugs (e.g. medications for CVDs, nerve pain, diabetes), no smoking, and no regular participation in any training program in the last 6 months. Exclusion criteria were incidence of heart disease, absence from more than three training sessions, absence in post-test sessions, and unwillingness to complete the training program. After explaining the study objectives and methods, a written consent was obtained from all participants in the study. Then, they were randomly allocated to SRT (n=10), RT (n=10), and control (n=10) groups using the lottery method. During the training period, 7 participants (two from the control group, one from the SRT group, and four from the RT group) were excluded due to reasons such as not regularly participating in the training and post-test sessions.

Finally, data analysis was done on the remaining 23 girls (Figure1).

Measurements

One week before the start of the study and random allocation, the participants were invited to attend Enghelab Sports Complex in Neyshabur city to measure their anthropometric indices, body composition, and aerobic capacity (VO_{2max}). A general physician examined them prior to testing and intervention procedures. The participants were familiarized with the tests, and then measurements were taken by two assessors.

Blood sampling

Blood sampling was done after 12-14 hours of fasting and before and after training to measure the biochemical variables. The participants were asked not to do any strenuous physical activity for two days before blood sampling. The sampling was done at 8-10 AM by taking 5 mL of blood from the vein of right hand at sitting and resting position. A quantitative detection kit for lipid profile indicators in serum with a sensitivity of 1 mg/dL was prepared from Pars Azmoun Co, Iran. The immuno-turbidimetry method and a special kit manufactured by
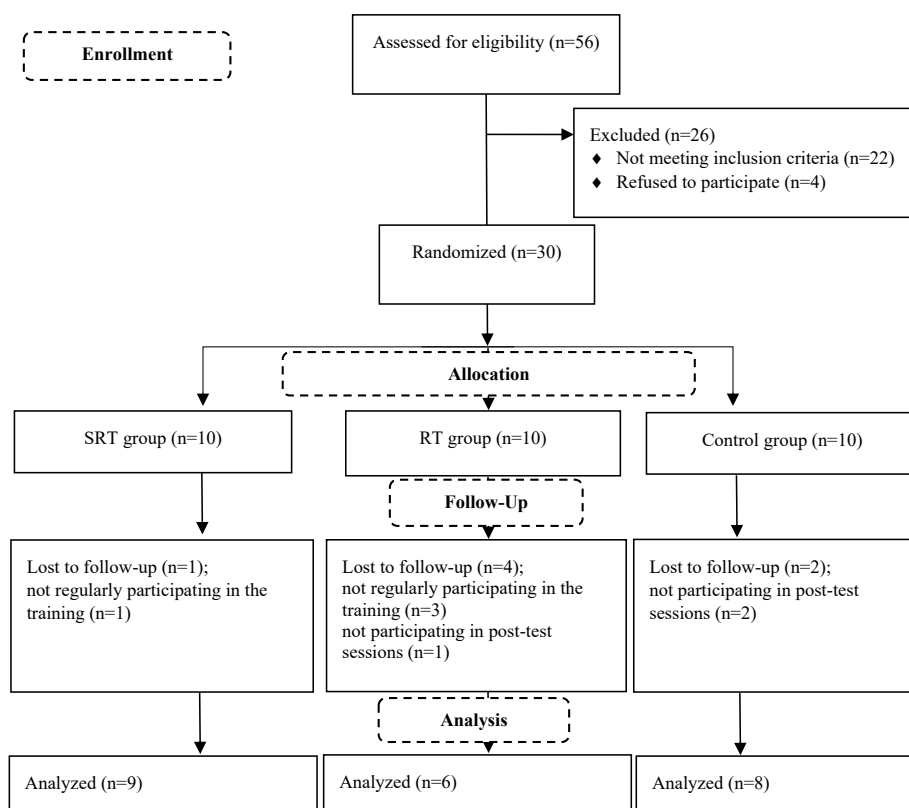

Figure 1. Flow diagram of the sampling and allocation processes

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Biorex Fars Co, Iran, were used to evaluate the level of apolipoproteins.

Anthropometric indices and body composition

Waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference. The body height was measured using a tape (NTT 9650, Nova, Iran) with bare feet and in a standing straight position. BMI was used as an index to determine obesity or body composition. For this purpose, the body weight was measured using a digital scale (EB9460, Camry, China) with bare feet. Then, the BMI was calculated by using the Equation 1:

1. $BMI=Weight\ (kg)/Height\ (m^2)$

Subcutaneous fat was measured using a caliper (MK-60, Yagami, Japan) and Jackson and Pollack's three-site skinfold formula (triceps, thigh, and suprailiac skinfolds) on the right side of the body [23].

VO$_{2max}$

Cooper's 12-min run test was used to determine VO$_{2max}$. In one study, the validity of this test for female university students was reported to be strong (r=0.88, P<0.001) [24]. In the present study, the intraclass correlation coefficient (ICC) for this test was obtained 0.93 (95% CI, 0.8%, 0.98%). To perform the test, the participants ran for 12 minutes with maximum effort. Then, the distance traveled by each participant was recorded, and the VO$_{2max}$ was calculated using the Equation 2 [25]:

2. $VO_{2max}\ (mL/kg/min)=(Distance\ traveled\ in\ meters-504.9)/44.73$

Exercise protocol

The girls in the intervention groups participated in SRT or RT programs for 8 weeks, three sessions per week, each for 45-60 minutes. In addition to the main exercises (Table 1), there was a 10-min warm-up session using body movements and stretching and a 5-min cool-down session using soft running and stretching movements. The training programs were designed based on the participants' characteristics, recommendations of sports coaches, and previous studies [26]. The training program was implemented under the supervision of two trainers. The maximum heart rate (HRmax) was calculated using the Equation 3:

3. $HRmax=220-Age$

The intensity of RT was controlled using a heart rate monitor (Polar H10, Finland), and the intensity of SRT was controlled based on the number of jumps per minute. The participants in the control group did not perform any exercise during this period, and their daily activities were the same as before.

Statistical analysis

Levene's test was used to evaluate the homogeneity of variances, and the Shapiro-Wilk test was used to test the normality of data distribution. Due to the normality of distribution and the homogeneity of variances, repeated measures analysis of variance (ANOVA) was used for the comparison of physiological and biochemical variables, followed by Bonferroni's post hoc test for pairwise comparison. All statistical analyses were performed in SPSS software, version 23, and the significance level was set at P<0.05.

Results

The percentage of compliance with training was calculated by the ratio of attendance sessions to the total number of required sessions, which was reported as 90.67±3.27 and 91.5±3.34 for the RT and SRT groups. The demographic characteristics of the participants are given in Table 2. There was no significant difference among the groups in age (P=0.827), body height (P=0.563), body weight (P=0.920), and BMI (P=0.472) in the pre-test phase.

Descriptive statistics for the anthropometric and body composition indices and VO$_{2max}$ are presented in Table 3. After 8 weeks of training, there was a significant decrease in body weight in the RT (P=0.009) and SRT (P=0.024) groups, a significant decrease in BMI in the RT (P=0.040) and SRT (P=0.009) groups, a significant decrease in waist circumference in the SRT group (P=0.005), a significant decrease in body fat percentage in the RT (P=0.008) and SRT (P=0.001) groups, and a significant increase in VO$_{2max}$ the RT (P=0.002) and SRT (P=0.001) groups (Table 3).

The results of repeated measures ANOVA (Table 3) showed a significant difference in body weight (P=0.023; p_η^2=0.303), BMI (P=0.002; p_η^2=0.462) and VO$_{2max}$ (P=0.001; p_η^2=0.489) among the three groups, but no significant difference was observed in the indicators of waist circumference (P=0.064), hip circumference (P=0.808), ratio of waist to hip circumference (P=0.931) and body fat percentage (P=0.217). Bonferroni's post hoc test results (Table 3) showed that the body weight

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Table 1. The training protocol

Training Program		Sessions							
		1	2	3	4	5	6	7	8
RT	Sets	21	22	23	24	25	26	27	28
	Time (min)	1	1	1	1	1	1	1	1
	Intensity (%HRmax)	70-75	70-75	70-75	70-75	70-75	70-75	70-75	70-75
SRT	Sets	20	21	22	23	24	25	26	27
	Time (min)	1	1	1	1	1	1	1	1
	Intensity (jumps per min)	45	45	45	45	45	45	45	45

Note: There was a 30-s rest interval between the sets.

and BMI in the SRT group were significantly reduced compared to the control group (P=0.031) and the VO_{2max} increased significantly in the SRT and RT groups compared to the control group (P=0.001).

Descriptive statistics for lipid profile, apoA1, and apoB are presented in Table 4. After 8 weeks of training, there was a significant decrease in TC in the RT (P=0.007) and SRT (P=0.020) groups, a significant decrease in TG in the RT (P=0.010) and SRT (P=0.030) groups, and a significant increase in apoA1 only in the SRT group (P=0.004) (Table 4).

The results of repeated measures ANOVA in Table 4 showed a significant difference in TG (P=0.006; p_η^2=0.399) and apoA1 (P=0.006; p_η^2=0.407) among the three groups; no significant difference was observed in the indicators of TC (P=0.056), HDL (P=0.832), LDL (P=0.471) and apoB (P=0.770). Bonferroni's post hoc test results showed that the level of TG significantly decreased (P=0.003), and the level of apoA1 significantly increased (P=0.005) in the SRT group compared to the control group (Table 4).

Discussion

The present study was conducted with the aim of investigating the effect of two types of training programs (SRT and RT) on some cardiovascular risk indicators in overweight/obese girls. We found a significant improvement in body weight, BMI, VO_{2max}, TG and apoA1 levels in the SRT group after training, while only the VO_{2max} improved significantly in the RT group. There was no significant improvement in waist circumference, hip circumference, waist-to-hip ratio, body fat percentage, TC, HDL, LDL, or apoB levels after 8 weeks of training. Moreover, there was no significant difference between the two groups of SRT and RT in any indicators.

Ghorbanian and Mamaghani [17] showed that SRT did not improve body weight, body fat percentage, and BMI in overweight girls. Nazari et al. [27] stated that 8 weeks of SRT reduced body weight, BMI, and body fat percentage in obese male adolescents. Ghorbanian et al. [16] observed that 8 weeks of SRT reduced body fat percentage and BMI in overweight and obese male adolescents. The intensity of SRT was 40-110 and 60-90 jumps per min in the studies by Nazari et al. [27] and Ghorbanian et al. [16], respectively, but the intensity of

Table 2. Demographic characteristics of overweight and obese girls

Groups	Mean±SD			
	Age (y)	Body Height (cm)	Body Weight (kg)	BMI (kg/m^2)
RT	17.33±1.51	152.15±5.7	74.71±11.1	32.28±5.07
SRT	16.89±1.45	152.41±9.78	75.14±10.77	32.2±2.17
Control	16.87±1.64	156.1±7.07	73.12±9.99	30.1±4.39

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Table 3. Mean levels of anthropometric and body composition indices and VO$_{2max}$ in the study groups

Variables	Groups	Mean±SD		Statistical Test Results		
		Pre-test	Post-test	% Change	F	P
Body weight (kg)	RT	74.71±11.1	72±11.6$^{#}$	-3.62		
	SRT	75.14±10.77	71.28±8.11$^{#†}$	-5.13	4.3	0.023*
	Control	73.12±9.99	72.62±9.6	-0.68		
BMI (kg/m^2)	RT	32.28±5.07	30.6±4.87$^{#}$	-2.17		
	SRT	32.2±2.17	29.57±1.71$^{#†}$	-8.16	8.59	0.002*
	Control	30.1±4.39	29.83±4.66	-0.89		
Waist circumference (cm)	RT	96.71±5.15	94.42±5.88	-2.36		
	SRT	94.14±6.89	90.14±7.6$^{#}$	-4.24	3.092	0.064
	Control	95.87±11.87	94.87±12.54	-1.04		
Hip circumference (cm)	RT	108±11.01	106.57±6.75	-1.32		
	SRT	105.71±9.75	102.85±10.41	-2.7	0.202	0.808
	Control	107.12±6.97	106.62±6.63	-0.46		
Waist-to-hip ratio (cm/cm)	RT	0.9±0.07	0.88±0.05	-2.22		
	SRT	0.89±0.09	0.87±0.06	-2.24	0.063	0.931
	Control	0.89±0.08	0.88±0.95	-1.12		
Body fat (%)	RT	33.12±4.41	32.45±4.28$^{#}$	-2.02		
	SRT	30.19±3.67	29.2±3.7$^{#}$	-3.27	1.596	0.217
	Control	31.24±3.47	30.92±3.11	-1.02		
VO$_{2max}$ (mL/kg/min)	RT	29.04±2.03	34.51±3.94$^{#†}$	18.83		
	SRT	29.69±5.1	35.09±3.24$^{#†}$	18.18	9.584	0.001*
	Control	28.3±6.26	27.93±5.11	-1.3		

*Significant difference among the three study groups (P<0.05), $^{#}$Significant difference compared to the pre-test phase (P<0.05), †Significant difference compared to the control group (P<0.05).

SRT was lower (45 jumps per min) in our study. Kim et al. [13] showed that 12 weeks of SRT reduced body fat percentage and waist circumference in obese female adolescents. In our study, the rate of reduction in these two indicators in the SRT group was lower than in Kim et al.'s study [13], which may be due to the longer duration of the training period.

Karami et al. [28] stated that 8 weeks of regular training reduced body weight, BMI, and waist circumference in obese male adolescents. Meng et al. [19] also showed that 12 weeks of high-intensity interval training (HIIT) reduced body fat percentage and BMI in obese male adolescents. Racil et al. [29] showed that 12 weeks of moderate-intensity interval training (MIIT) reduced body weight and body fat percentage, but not waist circumference. Although these indicators decreased in our study, the intensity and duration of the training were probably not enough to bring the changes to a significant level. In this regard, Abassi et al. [30] showed that HIIT, compared to MIIT, caused more improvement in body composition and physical performance in obese and overweight adolescent girls. They also reported that, despite the improvement of these indicators, the

Table 4. The effect of exercise training on lipid profile indicators, apoA1 and apoB in overweight and obese girls

Variables	Groups	Mean±SD		Statistical Test Results		
		Pre-test	Post-test	% Change	F	P
TC (mg/dL)	RT	152.28±28.34	140.57±27.76[#]	-7.68		
	SRT	158.4±29.68	142.14±21.06[#]	-10.26	3.369	0.056
	Control	162.38±25.37	158±40.37	-2.61		
TG (mg/dL)	RT	97.85±32.62	85±33.14[#]	-13.92		
	SRT	136±93.06	106.71±48.75[#†]	-27.45	6.642	0.006[*]
	Control	123.37±62.14	125.87±58.91	2.02		
HDL (mg/dL)	RT	44.85±8.91	46.28±6.84	3.18		
	SRT	41.28±5.37	43.57±8.01	5.54	0.188	0.832
	Control	45.8±0.34	46.5±6.8	3.33		
LDL (mg/dL)	RT	90.85±27.9	83.71±22.64	-7.85		
	SRT	90±17.6	85.71±18.82	-4.76	0.765	0.471
	Control	99.75±31.23	98.87±28.25	-0.88		
apoA1 (g/L)	RT	1.6±0.82	1.62±0.65	1.25		
	SRT	1.58±0.11	1.62±0.14[#†]	2.53	6.852	0.006[*]
	Control	1.58±0.92	1.57±0.54	-0.63		
apoB (g/L)	RT	0.8±0.05	0.77±0.09	-3.75		
	SRT	0.79±0.15	0.76±0.08	-3.79	0.264	0.77
	Control	0.81±0.59	0.8±0.15	-1.23		

[*]Significant difference among the three study groups (P<0.05), [#]Significant difference compared to the pre-test phase (P<0.05), [†]Significant difference compared to the control group (P<0.05).

MIIT group enjoyed more than the HIIT group during exercise. A study even emphasized that obese people with poor mood status and low self-efficacy should use MIIT [31].

Despite the lack of difference in the mentioned indicators between the SRT and RT groups, a significant decrease was observed in body weight and BMI. In the present study, the duration of each training session was almost the same in both training groups, and the training intensity was moderate. The reason for the decrease in body weight and BMI in the SRT group is probably due to the higher energy expenditure in this group, compared to RT, because the training skill level of the SRT group was lower than that of the RT group. Other studies also have stated that body composition improvement can be caused by the increased lipolysis activity in the fat tissue [32].

The results of the present study showed that VO$_{2max}$ improved in both training groups, but no significant difference was observed in this index between the two groups. This result is consistent with the results of Ghorbanian et al. [16], Ghorbanian and Mamaghani [17], Nazari et al. [27], Karami et al. [28], and Meng et al. [19]. Ingul et al. [33] showed that 12 weeks of RT with moderate intensity did not improve VO$_{2max}$ in obese girls. In their study, the intensity of exercise was 60-70% HRmax, which is lower than in our study. The exercise method was also different; in their study, it was a continuous type, while it was interval training in our study. The improvement of VO$_{2max}$ can be due to muscular and cardiovascular adaptations, including increased capil-

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lary density, increased number of mitochondria and mitochondrial enzymes related to the aerobic system, increased cardiac output, and decreased peripheral vascular resistance [34, 35].

The results of the present study showed that, after training, the TG and apoA1 levels improved significantly in the SRT group but not in the RT group. Ghorbanian et al. [16] stated that SRT for 8 weeks, 4 days per week (40 min per day) reduced the TG and TC levels in overweight and obese adolescent boys. Ghorbanian and Mamaghani [17] also stated that SRT for 8 weeks, 4 days a week (45 min per day) increased apoA1 and decreased apoB in overweight and obese girls. They also showed that, due to SRT, the amount of TG decreased and HDL increased significantly, but there was no improvement in TC and LDL. Song et al. [18] showed that 8 weeks of HIIT reduced TC and LDL and increased HDL in obese girls. Ahmadi et al. [36] showed that 8 weeks of RT increased HDL in obese girls, while the TC, TG, and LDL levels remained unchanged. Probably, the low sample size and less energy expenditure in the RT group compared to the SRT group were the reasons for the lack of change in lipid profile indicators, apoA1 and apoB.

Several possible mechanisms that cause an increase in apoA1 due to training include an increase in HDL, lipoprotein lipase (LPL), and lecithin cholesterol acyltransferase, and a decrease in hepatic triglyceride lipase [17]. The increase of the LPL activity causes the release of fatty acids from the triglycerides and generally increases the catabolism of triglycerides and the lipoproteins rich in triglycerides, and facilitates the removal of triglycerides from the bloodstream [37].

Conclusion

The two SRT and RT methods are not superior to each other in improving cardiovascular risk indicators; however, it seems that the SRT improves some health-related components of physical fitness and lipid profile. However, more research is needed to draw a definite conclusion.

Study limitations and recommendations

One of the limitations of the present study was the small sample size. The lack of significant change in most of the measured indicators is probably due to the small sample size. To solve this problem, further studies with a larger sample size are recommended. The non-control of the nutritional status of the participants was another limitation that may affect the results as a confounding factor. Therefore, it is recommended that this variable be controlled in future studies. Moreover, the 8-weeks duration of training might be a short period to show the signs of improvement in overweight and obese girls. Therefore, future studies should consider longer periods of training to achieve better goals. Non-blinding of the participants, personnel, and assessors was another limitation of the current study.

Ethical Considerations

Compliance with ethical guidelines

The procedures in this study were in accordance with the principles of the Declaration of Helsinki. The study was approved by the Ethics Committee of Hakim Sabzevari University, Sabzevar, Iran (Code: IR.HSU.REC.1398.021).

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Authors contributions

Conceptualization and supervision: Amir Hossein Haghighi and Roya Askari; Data collection, analysis, and literature review: Roya Gharaeinejad; Review and editing: Hadi Shahrabadi.

Conflict of interest

The authors declared no conflict of interest.

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