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Effects of High-Intensity Interval Training on Body Composition of Obese Adolescent Girls in China

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Abstract
Objective: The objective of this study is to evaluate the effects of 12 weeks high-intensity interval training(HIIT) on the body composition of obese adolescent girls in China. Methodology: This was a single-center, randomized, multiple repeated-measures controlled trial (RCT), 36 girls aged 12-14 years were randomized into 1 interventional groups (HIIT group) or 1 control group (no training). In the HIIT group, set 100% MAS as the load intensity, and 50% MAS as interval intensity. A 15-second running (intensity of 100% MAS), followed by a 15-second walking (intensity of 50% MAS), which was regarded as 1 bout, each set includes 8 bouts, 4 sets each time, 3 minutes' rest between sets, 25 minutes of interval training time, plus warm-up and cooling time, the total training time was 35 minutes. Intervention period is 12 weeks; the frequency was three times a week. In the dependent variable of this study, there were 9 body composition indicators, including 5 anthropological indexes (height, weight, BMI, waist circumference, and hip circumference) and 4 fat-related indexes (body fat percentage, total fat mass, free fat mass, and visceral adipose tissue). All dependent variables were measured at baseline, 6th weeks and 12th week. To examine the effect of the intervention on the outcomes of interest, Generalized Estimating Equation (GEE) was used. Results: 31 girls completed the 12-week intervention. 15 in the HIIT group and 16 in the control group. Results of GEE showed weight, BMI, WC, hipline, BF%, FM, and VAT in the HIIT group decreased statistically over time, and were significantly different from those in the control group. The FFM showed a statistically significant increase over time in the HIIT group, and was significantly different from the control group. Conclusion: 12 weeks HIIT protocols can improve body composition of obese adolescent girls in China.
Keywords: Childhood and Adolescent Obesity, High Intensity Interval Training, Body Composition.

Introduction

Low levels of physical activity and high participation in sedentary activities have been identified as key contributors to obesity in children and adolescents (Anderson & Butcher, 2006). Obesity in girls is more harmful, leading to a chain of maternal obesity, childhood obesity, adolescent obesity and adult obesity maternal obesity, childhood obesity, adolescent obesity and adult obesity chains (Gupta, 2009). The obese population of China has ranked first in the world, and showing a younger trend. Girls between the ages of 12 and 14 in China are in the middle school stage, and the academic pressure makes obese girls in this age group have no interest and confidence to control their weight through the existing tedious and time-consuming continuous exercise methods (Dong et al., 2018; Zhang et al., 2018; Ito, 2019). Due to providing the same benefits as moderate-intensity continuous training in a shorter period of time Jelleyman et al (2020); Baquet et al (2002); Matusiak (2017), with higher pleasure and lower drop rates Batacan et al (2017); Wewege et al (2017); Malik et al (2018); Thum et al (2017), and possibly more short-term and explosive characteristics of children and adolescents (Baquet et al., 2002), high-intensity interval training (HIIT) is opening new ideas for exercise intervention in obese children. Hence, the objective of this study is to evaluate the effects of 12 weeks HIIT on the body composition of obese adolescent girls in China.

Methods

Study Design

This is a single-center, randomized, multiple repeated measures controlled trial(RCT). The participants were randomized into interventional group (HIIT group) or control group (no training). In the HIIT Group, set 100% MAS as the load intensity of HIIT, and 50% MAS as interval intensity. A 15-second running (intensity of 100% MAS), followed by a 15-second brisk walking (intensity of 50% MAS), which is regarded as 1 bout, each set includes 8 bouts, 4 sets each time, 3 minutes' rest between sets, 25 minutes of interval training time, plus warm-up and cooling time, the total training time is 35 minutes. The duration of the exercise intervention in the HIIT group was 12 weeks, 3 times a week.

Sample Size

The sample power was calculated in the software G*Power (Version 3.1 for Windows, Franz Faul, Germany), using the ANOVA test of repeated measures, within-between interaction(Leite et al., 2022), which was attributed power of 0.80, α of 0.05, ES of 0.22(Batacan et al., 2017). An estimated sample size of 30 participants was seen. To consider the loss of samples and expand the total sample size by 20% to 36 persons. There are 2 groups in this study, 18 people in each group should be recruited to participate. Before enrollment, each participant and their parents signed an informed consent form.

This study had the following inclusion and exclusion criteria for participants. Inclusion criteria: (1) BMI is obese according to age and gender standards. The obesity criterion for participates is BMI ≥ 95th percentile (according to age and gender), referring to the overweight and obesity screening criteria for children and adolescents issued by the Chinese Health and Family Planning Commission in 2018 Ji et al (2018) (Table 3.1). (2) 12-14 years old, female. (3) Willing to participate in this study, and both myself and the guardian have signed informed consent. Exclusion criteria: (1) Those with severe organic diseases such as heart, brain, lung, kidney and motor system. (2) Those who are taking medication for chronic diseases. (3) Those who have a history of mental illness.

Measurement and Instrument

Dependent Variables

There are 9 body composition indicators involved in this study, 5 anthropological indexes and 4 fat-related indexes. The 5 anthropological indicators were height, weight, BMI, waist circumference, and hip circumference. The 4 fat-related indicators were body fat percentage (BF%), total fat mass (FM), free fat mass (FFM), and visceral adipose tissue (VAT), which were measured by Dual Energy X-ray absorptiometry(DEXA). All dependent variables of two groups were tested at baseline, 6^{th} week and 12^{th} week.

Covariates

Habitual physical activity and daily dietary intake were the main potential covariates in this study. Referring to the experience of other researchers, in this experiment, participants were required to try their best to maintain habitual physical activity and daily dietary intake throughout the intervention period. Detailed, 3-day records (2 weekdays and 1 weekend day) of weighed food and beverage intake are collected from each participant at baseline, 4^{th} week, 8^{th} week and 12^{th} week. Energy intake and diet compositionCasperson et al (2015) were analyzed by an experienced dietitian using a food diary (ESHA Food Processor SQL version 10.7). Participants were also required to complete the Chinese version of Physical Activity Questionnaire for Older Children (PAQ-C) (Wang et al., 2016; Erdim et al., 2019). A pedometer (Tanita PD-637, Tokyo, Japan) was also required to be worn one week out of every four weeks. Experimenters collected PAQ-C scores and pedometer data at baseline, fourth, eighth and twelfth weeks.

Statistical Analysis

SPSS27.0 software (v 27.0; SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis on the data. Descriptive characteristics were summarized as mean values ± standard deviations(SD). Categorical data were summarized as frequency and percentage. To examine baseline group differences, T-test was used for continuous variables and chi-square test was used for categorical variables. The Shapiro–Wilk was used to evaluate the normality of the data distribution. Levene's test was performed for equality of variances to evaluate the homogeneity of variances. To examine the effect of the intervention on the outcomes of interest, the generalized estimating equation (GEE) was used. The result was a two-tailed test. The test result $P < 0.05$ was set as significant. When the group × time interaction was significant, analysis of covariance (ANCOVA) was used to accurately find out the effects of habitual physical activity and dietary intake on the experimental results.

Results

36 people completed all components of the baseline test, but only 31 girls ended up completing the 12-week experiment, with a retention rate of 86%. 5 girls failed to complete the training program due to personal reasons, including 3 in the HIIT group and 2 in the CONT group, their data were therefore excluded from all analyses other than baseline.

(1) Socio-Demographic Characteristics of Participants

The demographic characteristics of all participants before the intervention was shown in Table 1. The results of the chi-square test show there were no baseline differences in socio-demographic characteristics of participants between HIIT group and CONT group ($P>0.3$).

Therefore, these variables were considered as covariates for the all analysis to remove their probable effect on research variables.

Table 1
Socio-Demographic characteristics of participants

Variables	**HIIT (N=18)**		**MICT (N=18)**		**Total (N=36)**		**χ2**	**P**
	n	**%**	**n**	**%**	**n**	**%**		
Age (years)							1.205	0.877
12	5	27.8	6	33.3	11	30.6		
13	7	38.9	5	27.8	12	33.3		
14	6	33.3	7	38.9	13	36.1		
Grade							5.613	0.691
5	4	22.2	3	16.7	7	19.4		
6	4	22.2	8	44.4	12	33.3		
7	5	27.8	4	22.2	9	25.0		
8	4	22.2	2	11.1	6	16.7		
9	1	5.6	1	5.6	2	0.6		
Ethnicity							2.038	0.361
Han	18	100	17	94.4	35	97.2		
Minority	0	0	1	5.6	1	1.9		
Degree of obesity							0.263	0.992
Mild	4	22.2	4	22.2	8	22.2		
Moderate	10	55.6	11	61.1	21	58.3		
Severe	4	22.2	3	16.7	7	19.4		

(2) Comparison of Baseline Values of Dependent Variables
Table 2 reflects the baseline values of each variable before intervention in HIIT and control groups. The results of T-test showed that there was no significant difference between the three groups in the selected variables of body composition and cardiopulmonary fitness (P > 0.05).

Table 2
List of Baseline Values of Dependent Variables

Variables	HIIT(N=15)	CONT(N=16)	t	P value
Height (cm)	152.3±7.2	152.4±4.9	-0.029	0.977
Weight (kg)	56.5±6.0	55.3±4.1	0.634	0.532
BMI (kg/m2)	24.5±1.1	23.8±0.7	1.289	0.208
WC (cm)	79±7	77±7	0.728	0.472
Hipline (cm)	90±7	88±7	0.316	0.754
BF（%）	38.4±4.0	37.9±2.3	0.582	0.567
FM（kg）	21.7±2.2	20.9±2.3	1.364	0.183
FFM（kg）	30.2±3.6	29.6±3.5	0.537	0.595
VAT（g）	348±55	356±65	-0.255	0.801

(3) Analysis of Main Potential Covariates

The Results of GEE Analysis of Habitual Physical Activity and daily diet intake showed (Table 3) that the time effect(P>0.08), group effect(P>0.4) and time*group interaction(P>0.1) were not statistically significant, that is, both habitual physical activity and daily diet intake did not differ within and between groups in the HIIT, MICT, and CONT groups. This suggested to us that participants were strictly instructed to maintain their habitual physical activity and daily diet intake during the intervention period. Hence, this outcome removed the possibility that then act as covariates affecting the analysis of the results.

Table 3
Results of GEE Analysis of Habitual Physical Activity

		Group (df=1)		Time (df=3)		Group*Time (df=3)	
		Waldχ^2	P value	Waldχ^2	P value	Waldχ^2	P value
Physical activity	PAC-C	1.392	0.499	2.379	0.497	7.550	0.273
	Steps	0.296	0.862	6.425	0.093	2.597	0.857
Dietary intake	Energy	0.615	0.735	4.099	0.251	25.427	0.060
	Protein	1.026	0.599	11.894	0.080	3.880	0.693
	Fat	1.539	0.463	5.076	0.166	10.002	0.125
	Carb	0.212	0.899	1.281	0.515	2.010	0.919

(4) Effects of HIIT on Body Composition

Table 4 presents the descriptive statistics of the three measurements of each dependent variable in the two groups, and Table 5 shows the results of the generalized estimating equation analysis of each dependent variable.

Table 4
Means and Standard Deviations of dependent variables for two Groups

Variable	Group	Baseline	6th week	12th week
Height(cm)	HIIT	152.3±7.2	152.4±7.2	152.8±7.0
	CONT	152.3±4.9	152.4±4.9	152.6±4.9
Weight (kg)	HIIT	56.47±5.98	55.47±5.98	53.83±5.72
	CONT	55.30±4.07	56.30±4.07	58.45±3.95
BMI (kg)	HIIT	24.56±1.25	23.76±1.22	22.72±1.23
	CONT	23.78±1.61	24.30±1.61	24.66±1.62
WC (cm)	HIIT	79±6	76±5	74±5
	CONT	77±5	78±5	79±6
Hipline (cm)	HIIT	90±6	86±5	83±5
	CONT	88±5	89±5	89±5
BF%	HIIT	38.43±3.26	37.55±3.15	36.22±3.01
	CONT	37.88±1.75	39.98±1.79	39.88±1.83
FM (kg)	HIIT	21.73±1.49	20.74±1.36	19.27±1.25
	CONT	20.90±1.85	22.16±1.82	23.19±1.82
FFM (kg)	HIIT	30.17±2.88	31.32±3.01	32.09±3.11
	CONT	29.61±2.92	29.81±2.93	29.97±2.95
VAT (g)	HIIT	349.47±45.20	317.11±45.46	295.53±45.93
	CONT	353.81±49.49	373.13±50.64	387.19±52.34

Table 5
Main effect and interaction effect results of GEE for dependent variables

Variables	Time(df=2)		Group(df=1)		Time * Group(df=2)	
	Waldχ^2	P value	Waldχ^2	P value	Waldχ^2	P value
Height(cm)	0.001	0.975	1.974	0.118	2.596	0.273
Weight (kg)	4.292	.038	3.655	.033	569.233	.000
BMI (kg/m^2)	301.421	.000	3.491	.037	301.421	.000
WC (cm)	105.015	.000	3.221	.040	294.701	.000
Hipline (cm)	279.733	.000	3.616	.035	564.554	.000
BF（%）	1310.263	.000	3.881	.031	1310.263	.000
FM（kg）	612.507	.000	7.413	.006	612.507	.000
FFM（kg）	293.121	.000	3.847	.022	293.121	.000
VAT（g）	47.510	.000	9.226	.002	1029.605	.000

From table 2, it can be found that among the nine dependent variables, only height was not affected by the 12-week exercise intervention, because the main effect of time (χ2=0.001, P=0.975), the main effect of group (χ2=1.974, P=0.118), and the interaction effect of time and group (χ2=744.173, P=0.000) in the GEE results of height were not statistically significant.

For the other 8 variables, their main effect of time, main effect of group, and interaction effect of time and group were all statistically significant (P<0.05). The time effect significantly indicated that the mean value changed with the extension of training time. The main effect of group was significant, indicating that there was a statistical difference between the groups.

A significant interaction means that two groups had a different pattern over time (Baseline, 6th week and 12th week) for the variable.
Combined with the statistical description in Table 1, it can be seen that the values of weight, BMI, WC, hipline, BF%, FM, and VAT in the HIIT group decreased statistically over time under the intervention, and were significantly different from those in the control group. The FFM showed a statistically significant increase over time under the intervention, and was significantly different from the control group.

Discussion

This study showed that 12 weeks of HIIT can effectively improve body composition in obese girls, it significantly reduces their weight(-2.64kg) and BMI (-1.84)). In addition, HIIT had a better effect in reducing abdominal fat, which was reflected in the reduction of WC and VAT, which were reduced by -5.8% (-5.0 cm) and -17.1% (-53.94 g) respectively, which is consistent with the findings of (Lau et al., 2015). When energy expenditure is equal, high-intensity training appears to be a more effective training method for weight loss in adolescents (Gutin et al (2002, 2005) and adults (Gutin et al., 2002).

Potential mechanisms underlying HIIT-induced fat consumption may include an increase in catecholamine, resulting in increased fat oxidation and visceral fat release, decreased exercise appetite, and increased post-exercise excess oxygen consumption. Catecholamine responses have been shown to be significantly elevated after HIIT. Since β-adrenergic receptors are mainly located in adipose tissue Collins & Surwit (2001), β-adrenergic receptor sensitivity in adipose tissue increases after exercise Crampes et al (1986), these factors may explain why HIIT can be effective in reducing body fat in obese individuals. The increased resting metabolic rate caused by excess metabolism following HIIT may also be responsible for the reduction in central adiposity caused by HIIT (Schubert et al., 2017; Chuensiri et al., 2017).
Excess post-exercise oxygen consumption (EPOC) during the post-exercise recovery period helps to restore the metabolic process to a baseline state. During the slow recovery period, EPOC is associated with lactate and H+ removal, increased lung and cardiac function, elevated body temperature, catecholamine effects, and glycogen de novo synthesis (Almuzaini et al., 1998). Some studies suggest that there is an exponential relationship between training intensity and EPOC Laforgia et al (2006), the marked increase in catecholamine and the concomitant glycogen depletion previously described may be the triggers for the marked increase in EPOC after HIIT. Whether the increase in EPOC after training is one of the mechanisms by which HIIT improves body composition in obese children in this study remains to be further verified by subsequent studies.

Conclusion

12 weeks HIIT was effective in improving body composition of obese adolescent girls. This improvement was the result of reduced weight， BMI, waist circumference, hipline , BF%, FM, VAT and increased FFM. HIIT is a time-efficient and effective exercise intervention that can be promoted among obese adolescent girls in China.

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