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The Effect between Low-Intensity Resistance Training and Maximum Fat Oxidation Intensity Aerobic Exercise on Body Composition of Young Obese Women

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Abstract:

Objectives: Through comparative study on the effect between low-intensity resistance training (RT) and maximum fat oxidation intensity aerobic exercise (FATmax AE) on body composition of young obese women to explore the effect of RT on fat loss.

Methods: Thirty-four young obese women with body fat percentages (BF %) of 30% or more were randomly assigned to FATmax AE group (AEG, control group) and low-intensity resistance training group (RTG, experimental group). The subjects in two groups completed 3*45 min/wk of FATmax AE or RT of 15 maximum repetitions (RM) respectively for 12 weeks. Height, weight, waist and hip circumference (then BMI and WHR were calculated), body fat percentage (BF %), fat mass (FM), muscle mass (MM) were measured at pre-, mid- and post-intervention.

Results: Body weight, BMI, WHR, BF% and FM decreased, and MM increased significantly (all $p<0.05$) in both groups after 12 week of intervention. A greater decrease of body weight and BMI and more MM growth in RTG than those in AEG was found (all $p<0.05$).

Conclusions: Low-intensity RT has the same effect as FATmax AE in reducing BF% and FM in young obese women in 12 weeks of exercise training (3*45 min/wk). Take into account its longer term effects of fat loss due to more MM growth, low-intensity RT should be recommended as one of the fat-loss activities.

Keywords: low-intensity; resistance training; FATmax aerobic exercise; young obese women; fat loss

Introduction:

Obesity is a nutritional metabolic disorder caused by a variety of factors, mainly because of energy intake than energy consumption, then surplus energy into fat accumulation in the body. In 1997, the World Health Organization included overweight and obesity in the global epidemic (WHO,1997). The number of overweight and obese people is expected to reach 1.12 billion by 2030 (Kelly T et al. 2008). It has been proved that obesity can cause many kinds of health problems, and the mortality rate of obese people is rising 3, meanwhile, the quality of life of patients is seriously reduced, resulting in economic burden 4. A large number of studies have confirmed that exercise intervention is one of the effective means to prevent and cure obesity 5-9, then to explore safe and efficient exercise intervention is important. Many studies have shown that traditional continuous aerobic exercise (AE) can rationalize body composition (Schwindling S et al. 2013; Tan S et al. 2016; Tan S et al. 2012). Low-to-moderate intensity continuous AE is considered to safely and efficiently improve body composition and cardiopulmonary function of obese, but its relatively long overall exercise cycle makes it difficult for some participants to adhere to. In 2001, Jeukendrup and Achten (Jeukendrup AE et al. 2001) put forward the term “maximum fat oxidation intensity (Fatmax)” . During an incremental AE, fat oxidation rate will increase to the peak at certain intensity and then begins to decline, that is, the oxidation rate of fat takes an "inverted u" curve, and then exercise intensity at the peak fat oxidation has been defined as FATmax.

The FATmax was influenced by the test program, exercise intensity and the subjects themselves, and the value of the maximum lipid oxidation intensity was also kept in a large range, 22%-77% VO2max（Venables MC et al. 2005）. FATmax AE can maximize fat consumption (Tan S et al. 2016) in theory and it does make fat consumption the most in practice (Schwindling S et al. 2013). Then FATmax as the target intensity reducing fat by exercise has been confirmed.

RT is an indispensable part of comprehensive physical exercise by applying a certain amount of load resistance to muscles to achieve muscle growth or strength increase and has long been used as an effective way to increase muscle strength, volume, endurance and maintain fat free mass (Feigenbaum M S et al. 1999; Pollock M L et al. 1997). RT produces different effects on metabolism and endocrine changes by giving different amounts of load to the muscles, performing different repetitions, number of exercise groups, intergroup interval time, and the way and rate of muscle contraction (Chin A P M J M et al. 2006). Olson T P performed one year of moderate intensity (3 sets * 8 to10 RM) RT with whole body muscle group participation in obese women and found that subjects had a significant increase in lean body weight (Olson T P et al. 2006). As shown by Blocquiaux Sara in a 12-week RT training regimen with 2 sets of 65%1-RM (0-4 weeks), increased to 3 sets of 70%1-RM (4-8 weeks), and then to 3 sets of 80%1-RM (8-12 weeks) with increasing intensity, showing significantly increase knee extension strength and power parameters in older men(Blocquiaux Sara et al. 2020). Murphy Chaise performed 5 sets of 5RM RT and controlled calorie intake in young weightlifters, with only 3 days of intervention resulting in a significant reduction in subjects' fat mass and lean body mass, as well as an effect on increasing growth hormone (GH) secretion and reducing insulin-like growth factor-1 (IGF-1) secretion (Murphy Chaise et al. 2020). A literature search of the RT intervention on body composition revealed that RT had significant effect on reducing FM and BF% of overweight, obesity, sedentary and postmenopausal women(Kyu Min Park et al. 2019),and subjects in a high proportion of randomized controlled RT studies with diseases such as type II diabetes (Lee J H et al. 2017), chronic obstructive pulmonary disease (Liao W H et al. 2015), or breast cancer (Cheema B S et al. 2014), as well as in adolescent children (Behringer M et al. 2010), the elderly (Peterson MD et al. 2011), or postmenopausal women (Kelley G A et al. 2004). Meta- analysis showed that RT at lower than traditionally recommended intensities of load may suffice to induce substantial gains in muscle strength in elderly cohorts (R. Csapo et al. 2016). Progressive resistance training can significantly reduce visceral adipose tissue in overweight and obesity (I. Ismail et al. 2012). The duration of exercise interventions spanned 6-60 weeks, most of them between 12 and 24 weeks. The frequency of interventions was essentially 2-to-3 times a week, and the intensity of the exercise intervention is mostly in the range of 8-12 RM (Valéria Bonganha et al. 2012; Phillips M.D. et al. 2012). Fewer studies, however, have used intensity of1-6 RM or 10-15 RM for healthy adults.

A multitude of loading and volume strategies for advanced hypertrophy training were recommended by major health organizations such as the American College of Sports Medicine, the moderate-to-high intensity range (8–12RM) has been regarded as an effective hypertrophy training zone that thought to provide a sufficient balance of mechanical and metabolic stress to the trainee (Ratamess et al.2009). And the RT program as frequency of 2 to 3 times one week, at least 1 set each session, intensity of 8-10RM for ordinary and 10-15RM for elderly and the weak has been recommended (Kraemerw J et al.2002). The moderate RT mostly used for obese with less exercise or only irregular exercise may easily cause improper movement and joint injury (Paw M J M C A et al.2006). Therefore, based on the lack of low-intensity RT intervention on body composition in previous research, this study taking FATmax AE as control group, tried to explore the effect of low-intensity (15 RM *5 sets* 4 muscle groups, 3 sessions*45 min/wk) RT on fat loss in young women with obesity. We hypothesized that low-intensity RT program would prove less efficient at reducing FM than FATmax AE program at the same duration; after all, FATmax AE is considered the most fat consumption exercise.

Subjects and Methods

Subjects

The sample size of the subjects was calculated by using analysis of variance (ANOVA), a large size of effect size of 0.90, a significance level of 0.05 and a power of 0.80 (G*power 3.2.1). The results of sample size per group were calculated as 15 persons. Seventy young obese female volunteers (BF%≥30%) were recruited and screened before participation, to ensure that they were not taking medication or hormone therapy and all functionally independent with no neurological, cardiovascular, metabolic, inflammatory, or musculoskeletal conditions which would preclude their participation to a low- to- moderate-intensity physical exercise program (determined by medical history questionnaire and PAR-Q). Eventually, thirty-six women who did comply with the criteria were included in this study. Each participant was randomly assigned to a control group (AEG, n =18) or experimental group (RTG, n=18). Statistical analysis showed that the groups did not differ with regard to any of the variables applied and evaluated in this study, the details of the subjects shown in Table 1. The study was carried out in conformity with ethical rules and was approved by Southwest University's Human Research Ethical Committee (SWU- 2018-A00057). All the subjects were required to be familiar with the test procedure one week before the experiment and have no strenuous exercise 48 hours before the test. They were also told to keep eating and sleeping normally but without smoke, alcohol and coffee during the whole periods of intervention.

Table 1 Body composition parameters at pre-, and post-intervention for the FATmax AE and RT groups in obese young females (n = 34; mean ± SD)

		Pre-	Post-	F	P
FM(kg)	FATmax AE	21.68±3.08	15.59±2.05	156.96	0.00
	RT	21.66±2.29	15.31±2.72	300.12	0.00
	F	0.06	0.76		
	P	0.91	0.25		
BF (%)	FATmax AE	30.18±0.94	22.76±1.21	621.16	0.00
	RT	30.17±0.89	23.28±1.91	89.23	0.00
	F	0.09	0.45		
	P	0.97	0.53		
MM (kg)	FATmax AE	33.56±4.59	41.70±5.73	131.23	0.00
	RT	33.75±4.74	42.91±4.60	712.79	0.00
	F	0.38	4.38		
	P	0.66	0.04		
BW(kg)	FATmax AE	71.76±9.22	68.52±8.25	34.67	0.00
	RT	71.79±7.02	65.41±6.81	404.57	0.00
	F	0.41	10.05		
	P	0.67	0.00		
BMI	FATmax AE	26.64±3.11	25.44±2.77	36.49	0.00
	RT	27.24±2.80	22.69±1.96	27.95	0.00
	F	1.08	28.86		
	P	0.37	0.00		
WHR	FATmax AE	0.86±0.05	0.76±0.05	508.56	0.00
	RT	0.86±0.02	0.78±0.04	34.7	0.00
	F	1.2	1.5		
	P	0.33	0.21		

Incremental Exercise Test and FATmax Calculation

FATmax and maximal oxygen uptake (VO2max) of each subject were determined through incremental exercise according to Bruce scheme on an exercise treadmill (Run-7410-runner, Italy), with gas analyzer (Cortex Metalyaer II-R2, German) and Polar heart rate monitor (M400, Kempele, Finland) for record of O2 intake, CO2 exhalation and heart rate every 10s during exercise. The subject's Rate of perceptive exhaustion (RPE) was asked at the end of each level of exercise load, and the exercise stopped until subjective exhaustion (RPE reaching to 18).

The VO2 and VCO2 data for the last 30s of each stage of exercise were intercepted and substituted into the fat metabolism calculation formula proposed by Peronnet: 1.6946× VO2 (l/min)-1.7012×VCO2 (l/min), the corresponding heart rate or percentage of maximum oxygen uptake to the maximum value of fat oxidation FATmax (Peronnet F et al. 1991).

Anthropometric Measurements and Body Composition Test

Weight, height, waist and hip were measured to an accuracy of 0.1 kg and 0.5 cm. Waist and hip circumference were measured by means of a flexible tape measure, and BF%, FM and MM were measured with the Body Composition Tester IN BODY7.0 (Model ef-265B, South Korea) at pre-, mid- and post-intervention sessions. The Anthropometric and body composition measurement was taken 2 days before intervention, and 2 days after the mid-session and last intervention session, in a rest fasting state on the morning, at least 3 hours apart from the last energy ingestion.

Exercise Intervention

The intervention on the subjects in each group was 45 min/ time (5-min warm-up exercise + 40-min formal exercise including 5-mincool-down exercise), 3 sessions /wk for 12 weeks. The exercise intervention took place on different locations but at the same time on Monday, Wednesday and Friday afternoons.

Warm-up exercise included 2- min of stretching, and 3- min of power walking at intensity of 30%VO2max related HR.

FATmax AE was continuous walking or running on a treadmill (JOHNSON® T8000EI, USA) with an automatic detection of heart rate, at the intensity of individual FATmax related HR (average at 128±10 bmp).

RT comprised exercises to load the major muscle groups (legs, arms, trunk, and lower back) performed at 15RM (about 45-50% of 1-RM) using a circuit training machine (DVF, USA). Subjects performed 15 repetitions *5 sets * 4 muscle groups in a circuit training each time, 1-minute rest interval between sets. Before training, all subjects were shown the proper technique. According to the individual strength of the subjects, the principal investigator proposed the initial resistance to specific subjects. As for the 15 repetitions, 1 repetition maximum (1-RM) test was not used, but 3-8 attempts were adopted to find the correct resistance (Ploutz-Snyder L L et al. 2001), with a 1-minute recovery period between each attempt.

Once the identified resistance was found, a set of 15 repetitions with maximal volitional effort with a similar rest period between sets was performed. Cool-down exercise included 2- min of power walking at intensity of 30% VO2max related HR and 3-min of stretching.

Statistical Analysis

Statistical analyses were performed using SPSS 25.0 for windows software. Continuous data were expressed as mean ± standard deviation according to statistical distribution. The normality of the residuals of these models was studied by using the Shapiro-Wilk test. The training effect of the two groups was compared by two way ANOVA. The tests were two-sided, with a Type I error set at $\alpha = 0.05$.

Results

In total, 34 participants completed the study. Two in RT group dropped out for family reasons, then n=16 in RTG, and n=18 in AEG. As shown in Table 1, there were no significant differences in body weight, BMI, WHR, MM, FM, BF% (all $P>0.05$) between two groups before training. Concerning the primary outcome, FM and BF% significantly decreased in both AEG (21.68±3.08 vs.15.59±2.05; 30.18±0.94 vs. 22.76±1.21) and RTG (21.66±2.29 vs.15.31±2.72; 30.17±0.89 vs.23.28±1.91), MM increased in AEG (33.56±4.59 vs.41.70±5.73) and RTG (33.75±4.74 vs. 42.91±4.60) after training compared to pre-training, with a significantly greater increase（27.1% vs. 24.3%）in the RTG than the AEG ($P <0.05$; Figure 1).

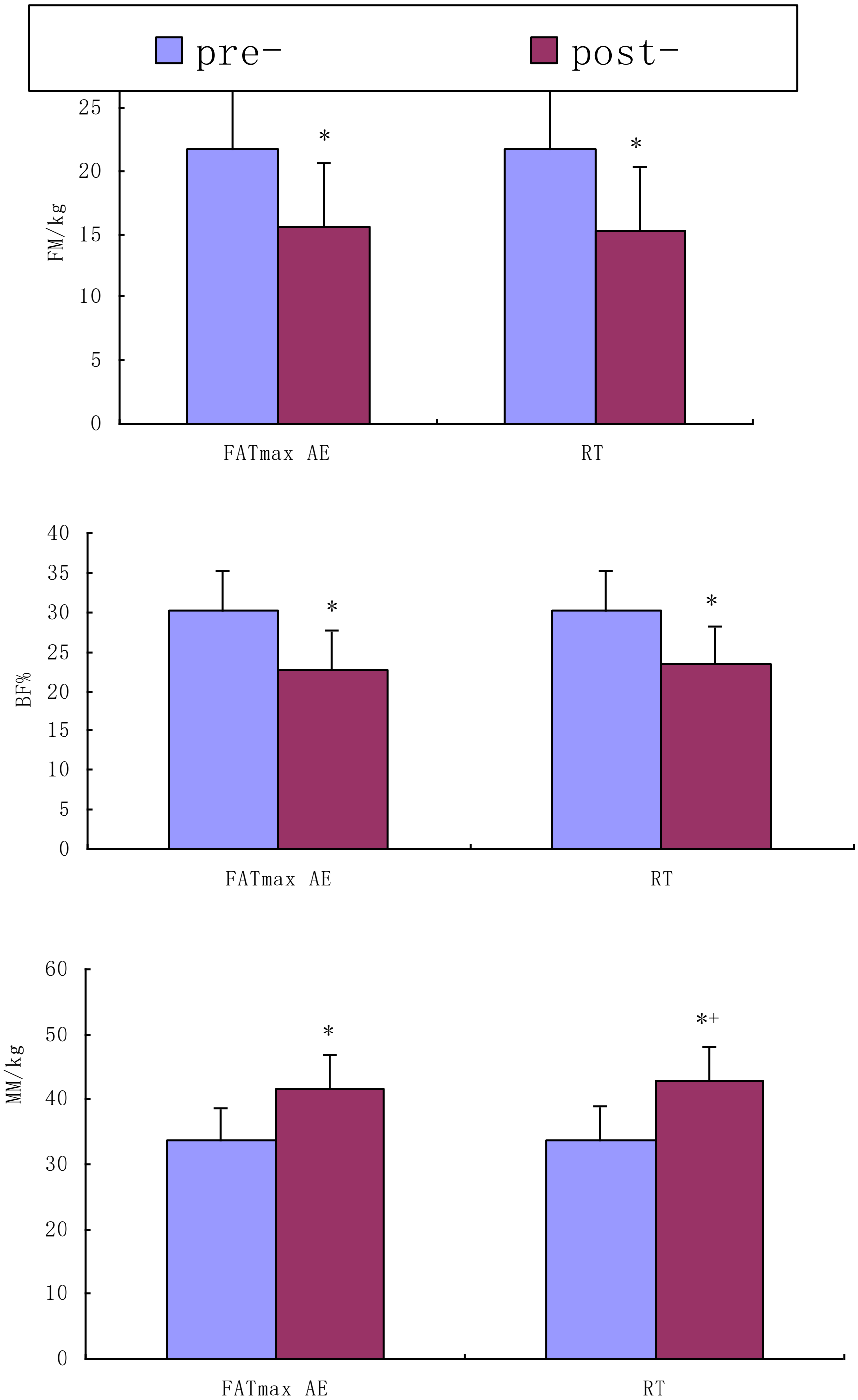

Figure 1 Comparison of FM,BF% and MM before and after 12-wk training for RT and FATmax AE groups in young women with obesity
(n = 34; mean ± SD).
Note:* significant difference between pre- and post- training session in the same group,
+ significant difference between two groups after training.

Body weight, BMI and WHR were significantly lower after 12-wk training compared to pre-training both in AEG (weight： 71.76±9.22 vs. 68.52±8.25, BMI： 26.64±3.11 vs. 25.44±2.77, WHR: 0.86±0.05vs. 0.76±0.05) and RTG (weight: 71.79±7.02 vs. 65.41±6.81, BMI: 27.24±2.80 vs.22.69±1.96, WHR: 0.86±0.02 vs.0.78±0.04, all $P<0.05$）, and the body weight and BMI of RTG with greater decrease than those of AEG（both $P<0.05$）（Figure 2）.

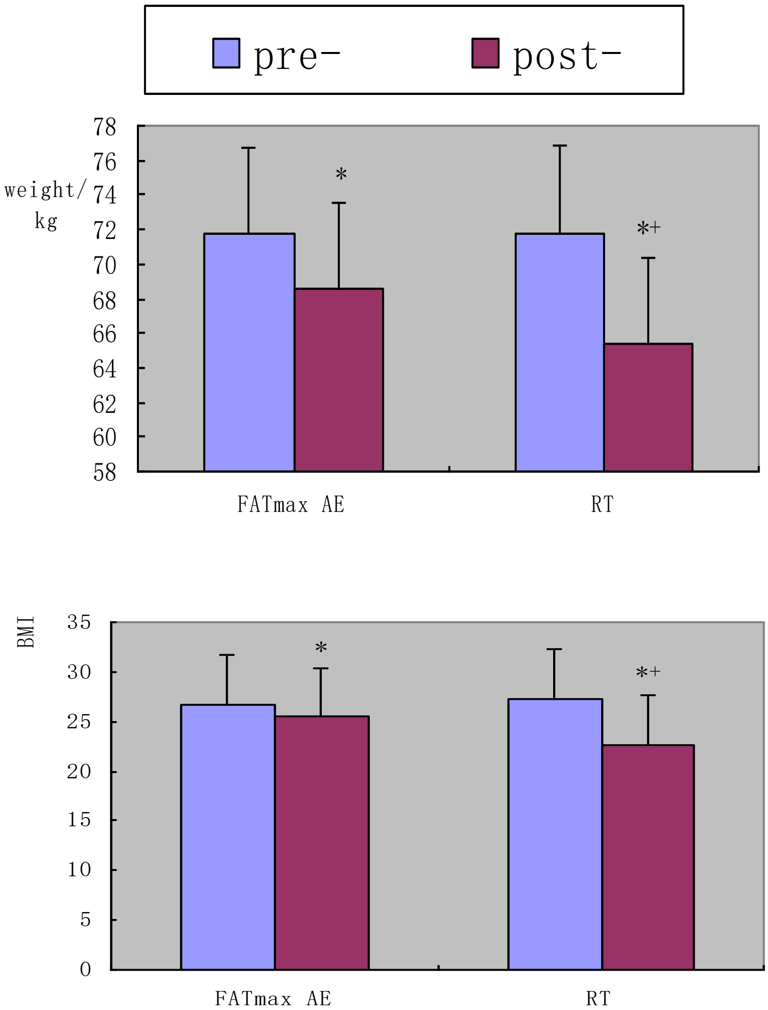

Figure 2. Comparison of body weight, BMI and WHR before and after the 12-wk training for the RT and FATmax AE groups in young women with obesity (n = 34; mean ± SD).

Note:* significant difference between pre- and post- training session in the same group, + significant difference between two groups after training.

Discussion

According to our results, both low intensity RT and FATmax AE interventions improve body composition. The decrease of BF%, FM, BMI and WHR observed in our study after 12-week FATmax training are fully in line with the literature, which has extensively demonstrated its beneficial impact in obese population, for example, overweight or obese older women were trained at their individualized FATmax intensity for 12 weeks, they had significantly decreased body mass, BMI, fat mass, visceral trunk fat, and diastolic blood pressure. Furthermore, there were significant increases in high-density lipoprotein-cholesterol, predicted VO2max, left ventricular ejection fraction, and sit-and-reach performance (Liquan Cao et al. 2019). Another study found that short-term aerobic exercise at FATmax intensity reduced body weight, BMI, WHR, average total carbohydrate oxidation and HDL in sedentary postmenopausal women (Marjan Rostamian et al.2017).FATmax AE can significantly reduce body weight, fat mass and improve the ability of lipid oxidation in overweight or obese patients (Dumortier M et al.2003; Brandou F et al.2003). The ability to oxidize lipids at exercise is increased by training at the level of maximal lipid oxidation, but whether this kind of training is also modifies resting lipid oxidation and making training more effective over 24h remains to be studied (Romain A.J et al. 2012), even though the result from Iwayama (Iwayama.K et al.2015) that 24-h fat oxidation increased only when exercise was performed before breakfast. The significant decrease of BF%, FM, BMI and WHR after 12- wk 15-RM RT intervention in this current study were consistent with results from different duration of low-moderate- intensity RT interventions: FM were significantly decreased and MM was significantly increased by 12-RM RT to intervene systemic muscle group of obese women for 6 weeks (Xie W. J. et al. 2016); a one-year moderate-intensity (8-10RM for 3 sets) RT conducted for obese women, and it was found that the FM decreased (Olson T. P et al. 2006); Willis L h. et al. conducted RT (3 days / week, 3 groups / day, 8-12 repetitions / group) for 8 months in 44 sedentary obese adults, the results showed that there was a significant decrease in BF% before and after RT (Willis Leslie H, 2012).Straight, C. R. et al. also performed RT (2 days / week, 3 groups / day, 8-12 repetitions / group) for 8 weeks in 95 overweight and obese elderly people, BF% of subjects decreased significantly after RT (Straight C R et al. 2012). This main purpose of this study sought to explore the effects of 12-wk 15RM- RT on body composition, taking FATmax AE as control. And the results of this study showed that no significant difference of WHR, BF% and FM decrease between RT and AE intervention groups after exercise intervention, which overturned our previous assumption, and indicated that low-intensity RT had the same significant fat reduction effect as FATmax AE.

The comparative study of moderate intensity continuous AE and RT intervention in obese people shows that RT is better than moderate intensity continuous aerobic exercise in improving body composition and body shape of obese people, and RT is more effective in protecting lean body weight and improving body metabolism than AE, for example, Harvard University conducted a large-scale investigation on 10500 healthy American men for 12 years, the results showed that after excluding other potential confounding factors, RT was more effective in reducing weight and waist circumference than moderate to vigorous AE (Mekary, R. A et al. 2015). In another study, researchers at the University of Pennsylvania found that twice a week strength training was equally effective in preventing women's body fat and waistline growth (Schmitz,K. H. et al. 2007). The results of this study supports that RT is superior to moderate intensity continuous AE in improving BMI and body weight of obese people, and in protecting lean body weight, but there is no difference in reducing FM, BF% and WHR. However, the effect of AE versus RT on waist circumference (WC)or visceral fat have been conflicting: a meta-analysis (Jozo Grgic et al.2018) showed AE (e.g., bike; elliptical machine; walking) more effective than RT (e.g., sets of machine exercises), another trial showed RT not effective on decreasing abdominal fat (WC) in midlife women (Steven Mann et al.2018). Some studies believe that the intervention effect of AE combined with RT on WHR of obese people is better than that of single type of exercise, but there is no significant difference in weight loss of obese people between AE alone, RT alone or combined exercise of both. Although compared with AE, RT as mainly anaerobic metabolism may not consume more fat during exercise, the effect of RT on lipid oxidation associated with a more oxidative metabolism at interval. The traditional heat measurement method greatly underestimates the heat consumption of strength training. Among them, the heat consumption of push up was underestimated by 50%, belly roll by 40%, lunge squat by 46% and pull up by 62% (Gastin, D. P. B et al. 2001). That is to say, during the intervals of RT, the energy consumption was still much higher than usual. That’s one reason for the fat-loss effect of RT. While the main viewpoint about the effect of RT on weight loss is that RT can increase MM including skeletal muscle mass and muscle strength, increase body metabolic rate and total daily energy consumption, so as to increase the proportion of fat energy supply and reduce the body's fat (Scaglioni G et al. 2002). The results of this study also showed that 12 weeks of low-intensity RT induced more obvious growth rate of MM when compared to FATmax AE (27.1% vs. 24.3%). Strength training is to produce subtle damage to the muscle fibers of the exercise site. The injured muscle tissue will release a substance called cytokines, and the body will repair the minor damage site after receiving the signal. But in the process of repair, there will be "excessive recovery", getting MM growth. The greater MM increase observed in our RT group could be partly explained by a physiological and metabolic hypothesis that RT impacts resting energy expenditure and metabolic substrates. One of metabolic characteristics of subjects predisposed to obesity is a decreased 24-h fat-to-carbohydrate oxidation ratio compared with normal-weight subjects, and training-induced increases in fat oxidation over 24-h have been shown to be a predictor of exercise-induced weight loss (Barwell, N.D et al. 2009).

It has previously been demonstrated that RT can induce a larger increase in post-training resting energy expenditure (Feigenbanm M.S. et al.1999; Jabekk P.T et al.2010). It has likewise been suggested that RT could impact metabolic substrate use, increasing the fat oxidation rate while reducing that of glucose. These explicative mechanisms seem to be emphasized more in patients with overweight and obesity when comparison with lean subjects (Paschalis V et al.2010).
Therefore, the most important finding in this study is 15RM-RT gains the same fat-loss effect as FATmax AE. There was no restriction on diet and no calculation on the balance of energy intake and no plan to result in the same energy expenditure between both groups in the design of the study, then the comparison of the two exercise protocols should be made with cautions. However, what can be concluded from the current experiment is that 45- min 15RM-RT has an equal pronounced effect on fat loss than 45- min FATmax AE, and this finding is likely to be important for obese practice.

Conclusions

The results of this study indicated that even low intensity of RT can gain the same fat-loss effect as FATmax AE in 12 weeks of exercise training (3*45 min/wk). Moreover, RT bore additional effects on MM growth. Therefore, it can be concluded that low intensity RT represents an appropriate modality of training to be recommended to maintain pro-long weight loss and decrease FM in young women with obesity. Additionally, it will be necessary in the future to compare the effectiveness of RT and FATmax AE programs performed in standardized experimental conditions of energy balance.

Disclosure

Author's contribution

Conceptualization: Shishun Sun; methodology: Shishun Sun; check: XiongZhuang XU; datacuration: Shishun Sun; supervision: Li Peng
Authors have read and agreed with the published version of the manuscript.

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Dlinical trial Registration

The trial was approved by Human Research Ethical Committee of Affiliated Hospital of Southwest University (SWU-2018-A00057).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability

The raw data supporting the conclusions of this manuscript will be available by the authors, without any undue reservation, to any qualified researchers.

Conflict of Interest

All authors declare that there is no conflict of interest. The authors alone are responsible for the content and writing of the manuscript.

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