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Research article

Exercise Training at Maximal Fat Oxidation Intensity for Overweight or Obese Older Women: A Randomized Study

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Abstract
The purpose was to study the therapeutic effects of 12 weeks of supervised exercise training at maximal fat oxidation intensity (FATmax) on body composition, lipid profile, cardiovascular function, and physical fitness in overweight or obese older women. Thirty women (64.2 ± 5.1 years old; BMI 27.1 ± 2.3 kg/m^2; body fat 41.3 ± 4.6%) were randomly allocated into the Exercise or Control groups. Participants in the Exercise group were trained at their individualized FATmax intensity (aerobic training), three days/week for one hour/day for 12 weeks. The Exercise group 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 VO_2max, left ventricular ejection fraction, and sit-and-reach performance. There were no changes in the measured variables of the Control group. These outcomes indicate that FATmax is an effective exercise intensity to improve body composition and functional capacity for older women with overweight or obesity.

Key words: Obesity; exercise; maximal fat oxidation rate; older women.

Introduction

Worldwide prevalence of overweight and obesity has been epidemic (Ng et al., 2014; Stein and Colditz, 2004). Obesity prevalence has increased in all age groups, in particular, the 2015 global data showed that nearly 20% of older women aged 60-64 years were obese, while the obesity rate for men of the same age group was about 10% (Chooi et al., 2019). Obesity amongst older adults may cause the development of type 2 diabetes, cardiovascular disease, Alzheimer's disease, osteoarthritis and other diseases (Cetin and Nase, 2014; Osher and Stern, 2009). Among the different interventions, aerobic exercise training has been recognized as an effective means of prevention and treatment for overweight and obesity (Donnelly et al., 2009; Jakicic and Otto, 2005). Previous aerobic exercise training studies in older people with overweight and obesity have typically designed the exercise intensity at 50% to 85% of the heart rate reserve (Christ et al., 2004; Ortmeyer et al., 2017; Ryan et al., 2006) or at 40% to 80% of maximal oxygen uptake (VO_2max) (Slentz et al., 2004; Solomon et al., 2008). In practice, this intensity range is too broad to determine a precise exercise intensity for an individual. Furthermore, there is little evidence in the literature justifying the exercise intensities mentioned above and which energy substrates were used at those intensities. Therefore, designing and evaluating an individualized aerobic exercise training program on the basis of the pattern of energy substrate utilization for treating or preventing overweight and obesity in older people remains a critical task for exercise scientists.

During graded exercise tests, studies of energy substrate utilization have indicated that fat oxidation rate increases with a gradual increase in exercise intensity. This oxidation rate reaches a peak at a certain intensity and then begins to decrease (Brooks and Mercier, 1994; Hultman, 1995). The exercise intensity at which the peak fat oxidation is observed is defined as the maximal fat oxidation rate (FATmax) (Jeukendrup and Achten, 2001). FATmax is a low-to-moderate exercise intensity. Our team has reported that overweight middle-aged women (51 ± 6 years) reached their FATmax at 52% VO_2max (Tan et al., 2016). Some researchers have applied the FATmax exercise training to adults with metabolic diseases (Botero et al., 2014; Dumortier et al., 2003; Lanzi et al., 2015; Tan et al., 2018; Tan et al., 2016; Tan et al., 2012; Venables and Jeukendrup, 2008). The main outcomes have included decreased body fat (Tan et al., 2016) or improved ability to oxidise lipids during exercise (Dumortier et al., 2003) in middle-aged overweight or obese individuals. Our team also reported that FATmax exercise training can promote glucose metabolism and adipokines regulation in older women with type 2 diabetes (Tan et al., 2018). However, to date there have been no studies that have applied FATmax exercise training in older women who are overweight or obese. FATmax is a low-to-moderate exercise intensity and with a higher fat oxidation rate than other aerobic exercise intensities. Hence, it is logical to expect FATmax would be a suitable exercise intensity for overweight or obese older people who want to decrease their body fat, as well as improve functional capacity. Therefore, the purpose of the present study was to investigate the effects of FATmax exercise training on body composition, lipid profile, cardiovascular function, muscle strength, and body flexibility in older women with overweight or obesity. We hypothesized that FATmax training would improve the measured variables in the trained participants, compared to the non-exercise (control) participants.

Methods

Participants

Thirty overweight or obese women, aged 60-69 years with body mass index (BMI) > 25kg/m^2, were recruited via local

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medical practitioners. None of them had been engaged in regular exercise training over the past two years. Individuals with heart disease, resting blood pressure (BP) greater than 160/95 mmHg, type 2 diabetes, pulmonary diseases, impaired renal or liver function, or who were unable to participate in the exercise training protocol due to orthopedic or neurological limitations were excluded. Before the baseline tests, the exact details of the study were explained to the participants and a written informed consent to the study was obtained from each of them. All methods and procedures of the present study were approved by the Ethics Committee of Tianjin University of Sport, China.

Study design

Participants were randomly allocated into the Exercise or Control groups, 15 in each group. A third party not involved in the present study listed participants in alphabetical order, according to their family name. Odd numbered participants were allocated to the Exercise group and even numbered participants were allocated to the Control group. After the baseline tests, which measured body composition, FATmax rate, predicted VO_2max, lipid profile, cardiovascular variables, hand grip strength, and body flexibility, the Exercise group took part in supervised exercise training at the individualized FATmax intensity for 12 weeks. The Control participants maintained their individual habit of physical activity and did not engage in any prescribed exercise training during the interventions. All variables in the baseline tests were measured again at the end of the experiments. The post-intervention tests were performed at least 48 hours after the last training session of the Exercise group. Under full supervision, all exercise tests and training sessions were conducted in the Exercise Physiology Laboratory and sports grounds of Tianjin University of Sport. There were no diet interventions introduced during the experimental period for either group of participants.

Measurements

Body mass and height of each participant were measured to calculate their BMI by dividing body mass (kg) by height in meters squared (m^2). The waist circumference (WC) was measured at the level of the umbilicus horizontally. After an overnight fast, body composition was measured using a dual-energy X-ray absorptiometry (DXA) (Prodigy Advance, GE Healthcare Lunar, USA). Using the computer program for soft tissue analysis provided by the manufacturer, the total body fat (%) was determined. Fat mass and fat-free mass were calculated. An experienced technician completed all measurements. To assess abdominal obesity, the visceral trunk fat percentage (% in area) was estimated by bioelectrical impedance analysis equipment (Body Composition Analyser Tanita AB-140 Viscan, Tanita Corporation of America, Inc., USA).

FATmax of each participant of the Exercise group was measured at baseline only. Participants refrained from any severe physical activity 24 hours and fasted for at least 10 hours before the test. All FATmax tests were conducted in the morning between 8:00-10:00 to avoid circadian variance. FATmax was measured by a graded treadmill exercise test (Tan et al., 2016). Briefly, there was a warm-up exercise of treadmill walking at 2.5 km/h with an incline of 1% for 3 minutes, followed by 3 minutes of major skeletal muscle and joint stretches on the ground and a 2-minute rest sitting on a chair. The first stage of exercise was set at a speed of 4.0 km/h with an incline of 1% for 3 minutes. The speed was increased to 4.5 km/h for 3 minutes at the second stage, 5.0 km/h for 3 minutes at the third stage, and 5.5 km/h for 3 minutes at the fourth stage until the respiratory exchange ratio (RER) reached 1.0. Oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were measured using an open-circuit indirect gas analyser (Cortex Metalyzer 3B Gas Analyzer, CORTEX Biophysik GmbH, Germany). Average gas values every 15 seconds during the exercise test, before the RER reached 1.0, were recorded to calculate the fat oxidation rate, following the stoichiometric equation with the assumption that the urinary nitrogen excretion rate was negligible:

Total fat oxidation = $1.67 \times VO_2 - 1.67 \times VCO_2$ with VO_2 and VCO_2 in liters per minute. The value of 1.67 is derived from the volume of VO_2 and VCO_2 used in the oxidation of 1 gram of fat (Frayn, 1983).

The exercise intensity at which the highest rate occurred was defined as the FATmax (Jeukendrup and Achten, 2001). HR was recorded continuously during the test by an electrocardiogram. The corresponding HR at the FATmax intensity (FATmax HR) (Tan et al., 2016) was recorded and applied to control the intensity of subsequent exercise training.

VO_2max was estimated using a submaximal exercise test on a bicycle ergometer and VO_2 was measured using the same gas analyser as in the FATmax test. HR and VO_2 at the workloads of 25 and 75 watts were measured to develop the line of best fit for HR and VO_2. VO_2max was then predicted from the estimated maximal HR (220-age) (ACSM, 2006).

A 6-ml fasting blood sample was collected. Concentrations of triglyceride (TG), total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), and high-density lipoprotein-cholesterol (HDL-C) were measured using an Automatic Biochemical Analyser Hitachi 7800 (Hitachi High-Technologies Corporation, Tokyo, Japan).

Resting BP was measured by the auscultatory method after 10 minutes of resting. Resting stroke volume (SV) and left ventricular ejection fraction were measured by M-mode echocardiography (Aloka SSC-290 echocardiograph, Aloka, Japan) with an oscillator frequency of 3.5MHz. One experienced technician performed all echocardiography measurements. Cardiac output (CO) was calculated as SV x HR.

Right hand grip strength was tested three times using a hand-grip dynamometer and the average was reported. Sit-and-reach test was conducted on a gym mattress. In a sitting position with the knee joint extended, the distance between the middle finger and the feet was measured. The average of three tests was reported as the body flexibility.

Exercise training program

The Exercise group undertook 12 weeks of FATmax exercise training, one hour per day for three times per week.

The training session consisted of a 10-minute warm-up period, which included walking and jogging, as well as skeletal muscle stretches; this was followed by 20-40 minutes of walking or jogging with the intensity controlled at the individualized FATmax HR. The exercise time was 20 minutes in week 1, 30 minutes in weeks 2-4, and 40 minutes in weeks 5-12. Short breaks of 1-2 minutes were allowed; and finally, there was a 10-minute cool-down period which involved slow walking and skeletal muscle stretches. The researchers supervised all the training sessions. Every participant wore a HR monitor (Polar Electro, Finland) during the training. An alarm on the HR monitor was set at ±5 beats of the target HR to judge the exercise intensity.

Dietary records

All participants recorded a five-weekday dietary diary at the beginning and the end of the experimental period, respectively. The food weight and percentages of carbohydrate, fat, and protein in the food were estimated. Daily energy intake was calculated by multiplying the weight of carbohydrate, fat, and protein consumed by their energy values (carbohydrate provides 4 kcal/g of energy, fat 9 kcal/g, and protein 4 kcal/g). After removing the highest and lowest values, the average of the other three days was reported as the daily energy intake.

Statistical analyses

All values are presented as mean ± SD. The independent samples t-test was applied at baseline to determine any possible differences in measured variables between the groups. Effects of FATmax training on measured variables were detected using 2 times (before and after intervention) x 2 groups (Exercise and Control) factorial design, split plot analysis of variance (SPANOVA). A $p < 0.05$ was regarded as statistically significant. All analyses were performed using SPSS Version 22 for Windows (SPSS Inc. USA).

Results

Thirteen participants of the Exercise group completed the training program. Five of them missed one to three training sessions, but no make-up sessions were added. Due to time constraints, two participants from the Exercise group dropped out of the study. Therefore, the data of 13 participants of the Exercise group and 15 of the Control group were reported in the present study. There was no difference in all of the measured variables between the groups at baseline. The FATmax of the Exercise group was 0.36 ± 0.10 g/min (range 0.19-0.51 g/min), occurring at the VO_2 of 12.6 ± 3.4 ml/kg/min and at 34.5 ± 8.0% VO_2max (range 24.4-46.8% VO_2max). Estimated VO_2max was 36.6 ± 5.6 ml/kg/min. Average FATmax HR was 101 ± 9 bpm.

There was no physical injury caused by the training. Dietary data did not indicate significant changes in daily energy and macronutrient intakes before and after the experimental period within and between the groups. Average energy intakes of the Exercise group were 2217 ± 101 kcal/day at baseline and 2234 ± 99 kcal/day at the end of intervention ($p > 0.05$); the corresponding data of the Control group was 2209 ± 96 kcal/day and 2224 ± 102 kcal/day ($p > 0.05$). Carbohydrate provided approximately 39%; fat approximately 48%; and protein approximately 13% of participants' daily energy intake in both groups. These percentages did not change before and after the experiment ($p >0.05$).

The FATmax training significantly decreased body mass, BMI, body fat%, fat mass, visceral trunk fat (% in area), and WC; meanwhile, there were no significant changes in fat-free mass (Table 1). Following the FATmax exercise training, concentrations of TG, TC, and LDL-C were not changed, while that of HDL-C was increased ($p < 0.01$). There was a significant decrease in diastolic BP, but not in systolic BP in the Exercise group. Left ventricle ejection fraction of the Exercise group increased ($p <0.05$), and there were no changes in SV and CO. Predicted VO_2max increased in the Exercise group compared to that of the Control ($p < 0.05$). The sit and reach performance in the Exercise group improved ($p < 0.001$); meanwhile, there was no significant change in hand grip strength. In the Control group, these variables did not change significantly during the 12-week experimental period (Table 2).

Discussion

Following 12 weeks of FATmax training, beneficial effects in body composition, HDL-C level, diastolic BP, left ventricle ejection fraction, predicted VO_2max, and body flexibility were attained in the Exercise group, compared to the Control group. Daily energy intake and the percentages of energy contribution from macronutrients for all participants did not significantly change before and after the experimental period. Therefore, the overall

Table 1. Age and body composition variables.

Variables	Exercise group (n=13)		Control group (n=15)		P for time	P for time*group
	Before	After	Before	After		
Age (years)	63.8 ± 5.9		64.0 ± 4.6			
Body height (cm)	158.2 ± 6.0	158.3 ± 6.2	159.6 ± 3.6	159.4 ± 3.5	0.526	0.069
Body mass (kg)	70.5 ± 11.1	65.9 ± 9.1	67.1 ± 3.8	68.7 ± 4.9	0.019	<0.001
BMI (kg/m^2)	28.0 ± 2.9	26.2 ± 2.5	26.4 ± 1.4	27.1 ± 2.0	0.032	<0.001
Fat%	41.6 ± 5.5	40.1 ± 5.1	41.0 ± 3.8	42.4 ± 4.9	0.956	0.033
Fat mass (kg)	29.7 ± 7.7	26.9 ± 6.4	27.5 ± 3.5	28.9 ± 4.1	0.138	<0.001
Fat-free mass (kg)	40.9 ± 5.2	39.0 ± 4.2	39.6 ± 3.0	39.8 ± 4.5	0.160	0.074
Visceral trunk fat (%)	44.3 ± 4.4	41.8 ± 5.4	40.1 ± 3.9	42.3 ± 5.0	0.710	<0.001
Waist circumstance (cm)	100.6 ± 9.0	99.8 ± 9.9	96.3 ± 4.7	97.4 ± 5.0	0.810	0.045

All data are presented as mean ± SD. BMI, body mass index.

Table 2. Lipid profile, cardiac function, muscle strength, and body flexibility.

Variables	Exercise group (n=13)		Control group (n=15)		P for time	P for time*group
	Before	After	Before	After		
TG (mmol/l)	2.50 ± 1.58	2.05 ± 1.30	2.18 ± 1.32	2.27 ± 1.29	0.216	0.063
TC (mmol/l)	5.29 ± 0.93	5.25 ± 1.11	5.50 ± 0.79	5.61 ± 0.69	0.574	0.215
HDL-C (mmol/l)	1.08 ± 0.16	1.21 ± 0.19	1.19 ± 0.26	1.14 ± 0.24	0.125	0.003
LDL-C (mmol/l)	3.15 ± 0.73	3.11 ± 0.71	3.32 ± 0.89	3.43 ± 0.75	0.545	0.219
Systolic BP(mmHg)	135 ± 16	131 ± 16	136 ± 14	136 ± 14	0.244	0.260
Diastolic BP (mmHg)	83 ± 12	81 ± 10	80 ± 11	84 ± 5	0.488	0.032
Stroke volume (ml)	80 ± 12	84 ± 22	76 ± 11	74 ± 8	0.893	0.115
Cardiac output (L/min)	5.54 ± 0.73	5.78 ± 1.41	5.17 ± 0.60	4.94 ± 0.47	0.977	0.116
Ejection fraction (%)	71.7 ± 12.5	76.5 ± 5.6	73.5 ± 7.2	72.2 ± 5.5	0.218	0.039
VO_2max (ml/kg/min)	32.3 ± 5.4	36.4 ± 6.2	33.4 ± 6.9	32.8 ± 6.0	0.243	0.011
Hand grip strength (kg)	24.1 ± 4.8	26.5 ± 5.4	24.7 ± 5.3	23.6 ± 4.7	0.475	0.081
Sit and reach test (cm)	6.2 ± 9.4	10.8 ± 8.9	9.1 ± 6.8	8.2 ± 6.3	0.010	<0.001

All data are presented as mean ± SD. TG, triglyceride.TC, total cholesterol. HDL-C, high-density lipoprotein-cholesterol. LDL-C, low-density lipoprotein-cholesterol. BP, blood pressure. VO2max, maximal oxygen uptake.

outcome supports the hypothesis that FATmax training is effective in reducing body fat and improving lipid profile and cardiovascular function in older women who are overweight or obese.

The present 12-week FATmax program resulted in favorable changes in body composition in the Exercise group, compared with the outcomes of the Control group. Besides the significant decreases in body mass, BMI, body fat percentage, and body fat mass, a particularly encouraging finding was the decreased visceral trunk fat (% in area) and WC. Such changes confer beneficial changes via decreased abdominal obesity. Indeed, visceral adipose tissue has been described as 'sick fat' (Bays, 2009), as it actively releases non-esterified fatty acids, cytokines, and adipokines, which may cause systemic inflammation and metabolic diseases (Després and Lemieux, 2006; Pedersen, 2009). Decreased abdominal obesity after FATmax was supported by our study in overweight middle-aged women (Tan et al., 2016), as well as other aerobic exercise training but not at the FATmax intensity, in middle-aged and older women with overweight or obesity (Slentz et al., 2004; Solomon et al., 2008). The similar finding of decreased abdominal obesity has also been reported in older women with type 2 diabetes following 12 weeks of FATmax exercise training (Tan et al., 2018). With the lipid profile, the HDL-C levels increased after FATmax training. HDL-C has been recognized as a protective factor against atherosclerosis and other cardiovascular diseases (Boden et al., 2000). The results from other aerobic exercise studies in older women support our finding that HDL-C increased after exercise training (Halverstadt et al., 2007; Kemmler et al., 2009). Resting diastolic BP was decreased after FATmax training, which is supported by an aerobic exercise training study in older adults (Barone et al., 2009). A review also stated that low-to-moderate intensity exercise training may be effective for reducing BP in individuals with hypertension (Hagberg et al., 2000). It is well-known that the risk of hypertension increases with a higher BMI (Bray, 2004; Pi-Sunyer, 2002) and that hypertension may lead to various other cardiovascular diseases (Carretero and Oparil, 2000). Thus, the decreased diastolic BP is a beneficial change for the participants of the present study. Improvement in left ventricle systolic function was shown by the increased ejection fraction after FATmax exercise training. We found similar results in overweight middle-aged women after 10 weeks of FATmax exercise training (Wang et al., 2015). However, the impaired left ventricle ejection fraction is not consistently evident in people with obesity (Tumuklu et al., 2007; Wong et al., 2004). Taken together, the present study contributes a precise exercise intensity to effectively reduce body fat mass and improve cardiovascular function for older women who are overweight or obese.

The 'obesity paradox' is an exceptional point of view in overweight or obese older people. Some studies have reported that a heavier body weight may decrease risk of all-cause mortality (Uretsky et al., 2007; Yamazaki et al., 2017). However, the results of the present study disagree with this view. Improvements in HDL-C, diastolic BP, left ventricle systolic function associated with decreases in body fat should be beneficial to our participants' health status.

There are few studies on FATmax in the current literature. It would be informative to compare the FATmax rate among different age groups of women. Our team has reported FATmax rate of young (FATmax rate 0.43 g/min at 54% of VO_2max) (Tan et al., 2012) and middle-aged overweight women (FATmax rate 0.39 g/min at 52% of VO_2max) (Tan et al., 2016). Compared with the FATmax rate 0.37 g/min at 37% of VO_2max of 60-69 years old women in the present study, the data suggest that FATmax rate decreases with age in women and older women may have a lower ability to utilize fat as energy during aerobic exercise. The mechanism behind this change needs further research.

There are limitations to this study. There was only one exercise training group in the present study, as our hypothesis was to test whether FATmax training provides an effective intensity to reduce body fat and improve cardiovascular function for overweight older women. Therefore, the present result cannot compare with the outcome from other exercise training intensities. Body composition, cardiovascular function, skeletal muscle strength, and body flexibility form a broader picture of health-related physical fitness. In the present study, extensive effort was placed on the former two outcomes, however only preliminary tests on muscle strength and body flexibility were completed. The potential changes in these two components should be studied more in the future.

In this physiological study, the molecular mechanism of the effects of FATmax training on body fat and cardiovascular functions could not be discussed. More research is needed in the future.

Conclusion

The 12-week FATmax exercise training attained improvements in body composition and cardiovascular function of older women who were overweight or obese. These outcomes indicate that FATmax is a precise and effective exercise training intensity for the treatment of overweight and obesity in older women.

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Key points

- Exercise training at maximal fat oxidation (FATmax) intensity is effective and safe for older women with overweight or obesity.
- FATmax exercise training improves body composition and cardiovascular function in older women with overweight or obesity.
- FATmax values decrease with ageing in women who are overweight or obese.

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