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# High intensity interval exercise training in overweight young women

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***Aim*. The purpose of this study was intended to evaluate the effects of a high intensity interval training (HIIT) program on the body composition, cardiac function and aerobic capacity in overweight young women.**
***Methods*. Sixty female university students (aged 19-20, BMI≥25kg/m² and percentage body fat ≥ 30%) were chosen and then randomly assigned to each of the HIIT group, the moderate intensity continuous training (MICT) group and the non-training control group. The subjects in both the HIIT and MICT groups underwent exercise training five times per week for 12 weeks. In each of the training sessions, the HIIT group performed interval exercises at the individualized heart rate (HR) of 85% of $VO_{2max}$ and separated by brief periods of low intensity activity (HR at 50% of $VO_{2max}$), while the MICT group did continuous walking and/or jogging at the individualized HR of 50% of $VO_{2max}$.**
***Results*. Both of these exercise training programs produced significant improvements in the subjects' body composition, left ventricular ejection fraction, heart rate at rest, maximal oxygen uptake and ventilatory threshold. However, the HIIT group achieved better results than those in the MICT group, as it was evaluated by the amount of the effect size. The control group did not achieve any change in all of the measured variables.**
***Conclusion*. The tangible results achieved by our relatively large groups of homogeneous subjects have demonstrated that the HIIT program is an effective measure for the treatment of young women who are overweight.**

**Key words:** Overweight - Exercise test - Exercise movement techniques - Heart function tests.

Obesity and overweight are serious hazards to health, which have affected a large proportion of the population in Western countries [1, 2] and increasingly so in the East.[3] These health hazards are linked inseparably with the development and progression of heart disease, hypertension, type 2 diabetes, respiratory disease, certain types of cancer, reproductive abnormalities, and osteoarthritis.[1, 4-7] Many observational studies conducted on the general population have reported that decreased physical activity levels are associated with increased body mass index (BMI) or body weight, as summarized in a review.[8] Therefore, exercise training has been using as one of the key treatments in the management of obesity and overweight. Endurance training at moderate intensity has yielded effective improvements in the body composition of obese or overweight individuals,[9-14] in their aerobic capacity,[9, 10, 12, 15-17] and cardiovascular function.[10, 15, 17]

Previous studies have reported that healthy subjects of normal body weight have been benefited from the high intensity interval training (HIIT) programs. Such programs succeeded in improving their lipid oxidation,[18-21] increased their maximal oxygen uptake ($VO_{2max}$),[18-20,22,23] and decreased the subcutaneous fat in their torsos.[20] In practice, the HIIT programs are usually organized into repeated sessions of high intensity exercises (lasting from 10 seconds to five minutes), which are separated by brief peri-

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ods of low intensity workouts or rests. The repeated stress of the high intensity physical exercises can be effective in pushing the metabolic level of the subjects to a greater extent, which cannot be achieved by the continuous endurance training at moderate intensity.[24]

Some studies have investigated the effects of the HIIT programs on obese or overweight people. A study of the middle-aged obese subjects (BMI 36±1 kg/m$^2$, nearly 80% of whom were female) has found that a 12-week HIIT program (at 85-95% of maximal heart rate) greatly increased their $VO_{2max}$ and decreased body mass, body fat and diastolic blood pressure.[13] As compared with the results of the moderate intensity exercise training, although the HIIT program was shown to be equally beneficial to the body mass, body fat and diastolic blood pressure of the subjects, it helped them to achieve much better improvements on the $VO_2$max. The same researcher team also reported that a 16-week HIIT program assisted some individuals with the metabolic syndrome (55±13 years of age, BMI 29.8±5.5 kg/m$^2$) to markedly reduce their body weight, BMI and blood pressure; while increasing the $VO_{2max}$ significantly.[25] Another study of the middle-aged women with the metabolic syndrome (BMI 34.7±6.8 kg/m$^2$) has reported that a 16-week high intensity exercise training (midway between the lactate threshold and peak $VO_2$) greatly decreased the subjects' body mass, BMI, abdominal fat and subcutaneous fat; while significantly increasing the peak $VO_2$. Furthermore, all of these improvements were better than those of low intensity exercise training program.[26] In summary, these previous studies have suggested that the HIIT program is an effective option of treatment for the middle-aged subjects with obesity or overweight.

To the best of our knowledge, there have been no previous reports on the application of the HIIT program for overweight young women. In our present study, we hypothesized that the HIIT program would produce better effects on the body composition, cardiovascular function and $VO_{2max}$ of the subjects than those of the moderate intensity continuous training (MICT) program. Therefore we specifically focused on the effect of a 12-week HIIT program for improving the body composition, cardiac function, blood pressure, $VO_{2max}$ and ventilatory threshold in a group of overweight young women.

## Materials and methods

### *Subjects*

Sixty (60) female university students aged 19-20 were selected. The criteria for admission were females with BMI>25 kg/m$^2$ and percentage body fat >30%, with normal menstrual cycle at the time of their enrollment. Those students afflicted with heart disease, hypertension, pulmonary ailment, diabetes and those who need orthopedic treatments and had neurological limitations to physical exercise were excluded. The exact details of the study were described to the students before the baseline test, while a written informed consent to the study was obtained from each subject. This study was approved by the Ethics Committee of Tianjin University of Sport, China.

### *Study design*

Subsequent to the baseline test, 20 subjects were randomly assigned to each of the HIIT group, the MICT group and the non-training control group. Those subjects in both the HIIT and MICT groups underwent 12 weeks of supervised exercise training accordingly to the specific requirements. The control group was required to maintain their individual habits of physical activity and refrain from engaging in any other forms of prescribed exercise training during the period of experimentation. Each subject's body mass, height, waist and hip girths, body fat, $VO_{2max}$, ventilatory threshold, stroke volume, left ventricular ejection fraction (LVEF), resting blood pressure and resting heart rate (HR) were measured at the baseline test as well as after 12 weeks of the interventions. All of these measurements and tests were carried out from the early phase up to the mid-follicular phase of each subject's menstrual cycle. The postintervention tests and the last training session were separated by at least two days. All tests and training sessions were conducted in the Exercise Physiology laboratory and the sports grounds of Tianjin University of Sport. Meanwhile, all of the subjects were required to maintain their normal diet during the period of experimentation.

### *Anthropometric measures*

Each subject's body mass was assessed with a balance scale and her height was measured with a stadiometer (without shoes). BMI was calculated by dividing body mass (kg) by height in meters squared ($m^2$). Waist girth was measured at the level of the umbilicus horizontally without clothing. Hip girth was measured at the level of the greatest protrusion of the gluteal muscles with underwear. Waist-hip ratio (WHR) was calculated by dividing the waist girth by the hip girth. All of these measurements were conducted by the same researcher. Each one of these measurements was done three times and the average was reported.

### *Body composition*

After 10-12 hours of fasting, the body composition of each subject was measured by the GE Prodigy direct digital DEXA bone densitometry (GE Healthcare, USA) when the subject was lying supinely. By means of the standard soft tissue analysis provided by that company, the non-bone fat-free tissue, fat tissue and bone mineral content were measured. The total body fat (%) was determined as a portion of the total amount of fat in the entire body mass.

### *Echocardiography*

The M-mode echocardiography was performed by using the Aloka SSC-290 echocardiograph (Aloka, Japan) and transducers with an oscillator frequency of 3.5MHz. The left ventricular internal dimensions were measured at both end-diastole (Dd) and end-systole (Ds). The stroke volume as calculated by using the Teichholz equation, *i.e.* stroke volume =($Dd^3$ –$Ds^3$) x (7.0/2.4 + Dd),[27] while the LVEF was defined as stroke volume divided by $Dd^3$. All of these measurements were carried out by the same radiological technician.

### *Heart rate and blood pressure at rest*

After the subject had remained seated for 10 minutes, her HR was determined from the ECG and her blood pressure was measured at the brachial artery by the auscultatory method. The first Korotkoff sound registered the systolic blood pressure and the last one was considered as the diastolic blood pressure. All of these measurements were carried out by the same researcher.

### *Maximal oxygen uptake and ventilatory threshold*

Each subject's $VO_{2max}$ was measured by a graded treadmill walking/running test (Pulsar cosmos treadmill, Germany). The initial workload was at the speed of 3.3 km/h on a 0% incline for 3 minutes. The second workload was executed at the speed of 6.3 km/h on a 0% incline for 1 minute; the speed was then increased by 0.8 km/h per minute. When the speed was up to 10 km/h, the incline was simultaneously increased by 1% per minute as the speed was still increased by 0.8 km/h per minute. This procedure continued until the subject has reached exhaustion, at which time the test was terminated. The criteria for measuring $VO_{2max}$ were: a leveling off of $VO_2$ despite increased workload, a respiratory exchange ratio which was equal to or higher than 1.15, and the exercise HR higher than 180 bpm. Ventilatory threshold was defined as the exercise intensity at which the increase in ventilation becomes disproportion to the increase in workload.[28]

$VO_2$ and carbon dioxide production ($VCO_2$) were measured by using an open-circuit indirect gas analyzer (Cortex Metalyzer II gas analyzer, Cortex, Germany), which was calibrated before each test with the standard gas. HR was checked by using a PE-4000 HR monitor (Polar Electro, Finland). The HR at 85% and 50% of $VO_{2max}$ were recorded and utilized as the target intensity for the HIIT and MICT programs.

### *Exercise training programs*

The subjects in both the HIIT and MICT groups underwent five training sessions per week on an outdoor track for 12 weeks. The HIIT program consisted of a 10-minute warm-up period, which included walking and jogging, as well as muscle stretches. This was followed by 5x3-minute interval running at the individualized HR of 85% of $VO_{2max}$, which was intervened by a 3-minute active break in between at the individualized HR of 50% of $VO_{2max}$. There was a 5-minute cool-down period for the subjects by walking slowly and stretching the muscles at the end of session. Each HIIT session lasted about 42 minutes. The MICT group did continuous walking and/or jogging at the individualized HR of 50% of $VO_{2max}$ for 40 minutes. There was also a 10-minute warm-up period as well as a 5-minute cool-down period similar to that of the HIIT group. Each MICT session lasted about 55 minutes. All of these training sessions were fully supervised by the researchers and every subject wore a heart rate monitor during the training so as to maintain the correct training intensity.

*Statistical analysis*

An analysis of variance (ANOVA) with repeated measures (3 groups [*i.e.* the control group *vs.* the HIIT group *vs.* the MICT group] x 2 time points [*i.e.* pretraining *vs.* post-training]) was performed to evaluate the effect of the interventions. When a significant F-ratio was obtained, a post-hoc analysis with Bonferroni adjustment was then used to identify which pair of mean values had significant changes. The effect size (ES) of measured variables following the HIIT and MICT programs was calculated.[29] The statistical significance was set at $P<0.05$. All of these analyses were performed by using the SPSS Version 11.5 for Windows (SPSS Inc. USA).

## Results

The results were based on the observations of 17 subjects in the HIIT group, 16 subjects in the MICT group, and 19 subjects in the control group who completed the study. There were no significant differences among these groups in any of the variables at the baseline (Table I). Eight subjects dropped out of the study: two subjects in the HIIT group and three in the MICT group because of a lack of time for exercise training due to heavy academic requirements; one subject in the HIIT group and one in the control group due to family problems; and one subject in the MICT who sustained accidental injury which was not related to the exercise training program. As for those who successfully completed the exercise training programs, there were no reported physical injuries which were cause by athletic activities during the training sessions. The average HR at 85% of $VO_2$max was 174 bpm for the subjects in the HIIT group; while the average HR at 50% of $VO_2$max was 142 bpm for those in both the HIIT and MICT groups.

The subjects in both the HIIT and MICT groups markedly decreased their body mass, BMI, body fat and WHR. The ES made by the HIIT program on these four variables were 0.52, 0.79, 0.96 and 1.13 respectively. The corresponding ES of the MICT group were 0.49, 0.80, 0.52 and 0.67. All of these variables at the post-test for the two training groups were significantly lower than those of the control group. The body fat of the HIIT group was greatly lower than that of the MICT group at the post-test. The subjects in the HIIT group were benefited by a 9.9% decrease in body fat after the exercise training, while those in the MICT group had a 5.2% decrease. There was no obvious change in these variables for the control group (Table II).

The exercise training programs succeeded in greatly decreasing the resting HR, while a better result was achieved by those in the HIIT group (ES=1.47) as compared with those in the MICT group (ES=0.62). The subjects in both the HIIT and MICT groups had a significantly lower HR than that of the control group at the post-test. The stroke volume of the HIIT group was significantly increased, while no change was observed in the members of the MICT and control groups. The stroke volume at the post-test of the HIIT group was markedly higher than that of the control group. The LVEF of the subjects in both the HIIT and MICT groups increased significantly, but those in the HIIT group obtained a better improvement (ES=0.80) than that of the MICT group (ES=0.28). The LVEF at the post-test of both

Table I.—*Physical characteristics of the subjects at the baseline.*

| Groups | HIIT | MICT | Control |
|---|---|---|---|
| Group size | 17 | 16 | 19 |
| Age (yr) | 19.8±1.0 | 19.3±0.7 | 19.5±0.8 |
| Height (cm) | 160.2±5.1 | 161.6±5.0 | 160.4±5.0 |
| Body mass (kg) | 73.7±7.5 | 74.2±9.0 | 74.0±7.0 |
| BMI (kg/m²) | 27.72±1.88 | 28.32±1.96 | 28.77±1.79 |
| Body fat (%) | 40.57±4.03 | 41.13±4.17 | 40.97±3.99 |
| WHR | 0.83±0.04 | 0.83±0.05 | 0.83±0.03 |

All data are presented in mean±SD. No significant difference among the groups.

TABLE II.—*Changes in body composition before and after the interventions.*

| | HIIT (N.=17) | | MICT (N.=16) | | Control (N.=19) | |
|---|---|---|---|---|---|---|
| | Pretest | Post-test | Pretest | Post-test | Pretest | Post-test |
| Body mass (kg) | 73.7±7.5 | 67.5±7.0**## | 74.2±9.0 | 69.8±9.1**## | 74.0±7.0 | 74.9±8.0 |
| BMI (kg/m²) | 27.72±1.88 | 26.25±1.86**## | 28.32±1.96 | 26.64±2.23**## | 28.77±1.79 | 29.0±2.01 |
| Body fat (%) | 40.57±4.03 | 36.55±4.32**†## | 41.13±4.17 | 38.98±4.04**## | 40.97±3.99 | 41.14±4.07 |
| WHR | 0.83±0.04 | 0.79±0.03**## | 0.83±0.05 | 0.80±0.04*# | 0.83±0.03 | 0.83±0.05 |

All data are presented in mean±SD.
*P<0.05; **P<0.01 between the post-test and the pre-test within the groups.
†P<0.05 between the post-test of the HIIT group and the post-test of the MICT group.
#P<0.05; ##P<0.01 between the post-test of the HIIT and MICT groups and the post-test of the control group.

TABLE III.—*Changes in cardiac function and aerobic capacity before and after the interventions.*

| | HIIT (N.=17) | | MICT (N.=16) | | Control (N.=19) | |
|---|---|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test | Pre-test | Post-test |
| HR (bpm) | 82.3±2.5 | 78.7±2.4**## | 81.9±3.4 | 79.9±3.0*# | 82.0±3.1 | 81.8±4.1 |
| Systolic BP (mmHg) | 116±10 | 115±11 | 115±9 | 114±9 | 119±9 | 118±9 |
| Diastolic BP (mmHg) | 78±4 | 77±4 | 77±4 | 75±5 | 77±5 | 77±5 |
| SV (ml) | 68.73±11.58 | 72.49±12.91*# | 67.34±13.21 | 69.88±12.96 | 67.94±10.34 | 68.59±9.68 |
| LVEF (%) | 64±3 | 67±5**## | 65±4 | 66±3*# | 65±3 | 65±4 |
| $VO_2$max (mL/kg/min) | 33.3±3.9 | 36.1±3.1**†## | 32.9±4.7 | 34.5±3.9*# | 32.8±4.1 | 33.6±3.9 |
| VT (mL/kg/min) | 22.6±4.7 | 25.1±4.0**†## | 22.4±3.5 | 24.0±4.1* | 23.0±4.1 | 23.8±3.9 |

All data are presented in mean±SD.
*P<0.05; **P<0.01 between the post-test and the pretest within the groups.
†P<0.05 between the post-test of the HIIT group and the post-test of the MICT group.
#P<0.05; ##P<0.01 between the post-test of the HIIT and MICT groups and the post-test of the control group.



the HIIT and MICT groups were much higher than that of the control group. The resting blood pressure of all the subjects remained unchanged after the interventions.

The subjects in the HIIT group had their $VO_{2max}$ increased by 8.4% (P<0.01, ES=0.79). Those in the MICT group obtained a 4.7% increase of $VO_{2max}$ (P<0.05, ES=0.37). Evidently, the $VO_2$max of the HIIT group was much higher than that of the MICT group at the post-test, while the subjects in the HIIT and MICT groups had greatly higher $VO_2$max than that of the control group. The ventilatory threshold of the HIIT group increased by 11.1% (P<0.01, ES=0.57) and that in the MICT group increased by 7.1% (P<0.05, ES=0.42) following the exercise training. The HIIT group had a markedly higher ventilatory threshold than that of the MICT group (P<0.05) and also in the control group (P<0.01) at the post-test. All of the variables of the control group were not changed during the experimental period (Table III).

## Discussion

Based on the physiological investigation of the relatively large group of homogeneous subjects, the major finding of the present study was that the HIIT program can be an effectual measure to improve the body composition, cardiovascular function and aerobic capacity of overweight young women. Further, the HIIT program produced better results than those of the MICT program on most of the improved variables, as shown by the ES calculations. All the variables of the control group remained unchanged during the experimental period. This outcome supported the hypothesis of our present study.

Both the HIIT and MICT programs in this study have succeeded in achieving significant improvements in the body composition of the subjects. We have found, in particular, that the HIIT group evinced a greater decrease of the percentage body fat than that of the MICT group. This result is compatible with the outcome of a recent study [26] in which the effects of 16 weeks of intervening high and low intensity exercise training on body composition were compared within a group of middle-aged women with the metabolic syndrome (BMI 34.7±6.8 kg/m$^2$). The authors found that the high intensity exercise training can be of great help to these obese people by decreasing the accumulation of fat tissue in different parts of the body, while the low intensity exercise training has failed to produce any notable change. Another study has also shown that after eight months of vigorous or moderate intensity exercise training undertaken by some middle-aged overweight subjects (BMI 28.9±2.4 kg/m$^2$), there was a significant decrease in their body fat mass and percentage body fat. However, the higher intensity exercise training has been shown to be more effective in obtaining a greater improvement.[14] The results from these two studies signify that the degree of training intensity may play an important role in the exercise training programs for the reduction of body weight and they are constant with our current result.

By obtaining the measurements of metabolic enzymes (especially hydroxyacyl-CoA dehydrogenase),[20] plasma free fatty acid concentration [21] and intramuscular triacylglycerol content [19] in healthy subjects of normal weight, some previous studies have suggested that the high intensity exercise training can significantly enhance lipid oxidation. Furthermore, the HIIT program has been shown to be more effective for increasing metabolic enzyme activities than the endurance training.[20] These evidences may explicate the mechanism which justifies the result of the present study. Nevertheless, the impact of the high intensity exercise training on lipid oxidation in obese or overweight persons still needs to be investigated in the future.

Some previous studies have illustrated that obesity and overweight were associated the impaired cardiac function. A study of obese women (32±4 years, BMI 37±7 kg/m$^2$) has disclosed that there was no difference in the LVEF (as measured by echocardiography) between obese and non-obese control subjects. However, the authors found that there was a much lower systolic myocardial contractility in the obese subjects when their cardiac function was measured by tissue Doppler imaging, which is a highly sensitive and specific echocardiographic technique.[30] The evidence of the decrease in myocardial peak systolic velocity (by the tissue Doppler imaging) as BMI increased was also observed in a group of healthy participants of both genders across a spectrum of body masses.[31] There was a cross-sectional study which found a decreased LVEF (measured by radionuclide angiocardiography) in overweight or obese subjects (43-45 years, BMI>27.7 kg/m$^2$) as compared with some lean persons, while their LVEF decreased as the duration of overweight or obesity increased.[32] Even though the link between body composition and impaired cardiac function in overweight young women has not been firmly established, any remedial interventions which can improve cardiac function will serve to attenuate the development of this possible association. In our present study, we have found that the HIIT program resulted in a much more beneficial effect on the left ventricular systolic function than that of the MICT program. We were aware of the fact that the higher exercise intensity of our HIIT program could induce a greater stimulus, which in turn would produce more remarkable benefits to the left ventricular systolic function of the subjects.

The current study did not find any change in the resting blood pressure following both the HIIT and MICT programs. This result was supported by a study.[26] However, it was not confirmed by other researchers.[13, 25] The diverging results might have been caused by the different characteristics of the subjects, as ours were young females who had normal blood pressure (average 116/78 mmHg) when they were enrolled. When compared to those subjects in the control group, the trained subjects' resting HR was substantially reduced after both the HIIT and MICT programs, which indicated that they had better cardiac function in general. The improvement gained by the HIIT group, nevertheless, was more substantive than that of the MICT group, as it was shown by the ES of 1.47 for those in the HIIT group *vs.* 0.62 for those in the MICT group. Therefore, the outcome of our study has suggested for the first time that the HIIT program is a valuable option of treating overweight young women by improving their cardiac function.

We have found that both the HIIT and MICT programs were effective measures to increase $VO_2$max. The subjects in the HIIT group, however, obtained a more substantial improvement than those in the MICT group. There have been other studies of the treatment of obesity or overweight by applying the HIIT program, which are substantive to support our results.[13, 25,26] Similar results have also been made by means of the HIIT program for healthy male subjects[22,33] and also for patients with heart failure [34] or coronary artery disease.[35] During the course of our study, we also observed a significant increase in the ventilatory threshold of the subjects following both the HIIT and MICT programs, but with the former again achieving more substantial improvements than the latter program. However, this result was not supported by a study in which the ventilatory threshold of some obese women was measured before and after 16 weeks of supervised low- and high-intensity physical training. They did not find significant changes in the subjects' ventilatory threshold. One of the reasons of their insignificant result was perhaps due to the small group size in that study.[26] As $VO_{2max}$ and ventilatory threshold are the most commonly used variables for measuring aerobic capacity in humans, the improvements in both of them demonstrated that the HIIT program is an effective treatment for young overweight women.

Our present study may be considered as preliminary research in which the aim was focused on whether the HIIT program is a better option, as compared with the MICT program, for providing benefits to young females who are overweight. There are some limitations in the present study. For instance, as the current HIIT and MICT programs were carried out on an outdoor running track, they were not designed as isocaloric exercises. For the cardiac function, we used echocardiography to measure the left ventricular systolic function. We were aware that these data could only reflect a portion of the subjects' cardiac function. Therefore, we believe that more variables to be measured by advanced equipment, such as the tissue Doppler imaging or magnetic resonance imaging (MRI), would show a more precise scope of the effects of the HIIT program on the cardiac function of the subjects. Meanwhile, more effective treatments may be designed by combining the HIIT program with other interventions, such as the HIIT program plus dietary measures. As it was mentioned in a meta-analysis of weight-loss programs,[36] the effectiveness of dietary measures together with exercise training was much higher than that of the programs with merely exercise training. We have decided that will be one of our research orientations in the future.

## Conclusions

The research on finding the optimal mode of exercise training for treatment of obesity and overweight is still a popular topic in exercise physiology. Compared with the moderate intensity continuous training, as well as the non-training control, the outcome of our study demonstrates that the HIIT program is an effective measure for the treatment of excessive body weight which threatens young females.

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