The cardiorespiratory responses of female obese subjects and normal-weight women during cycle ergometry

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The Cardiorespiratory Responses of Female Obese Subjects and Normal-Weight Women During Cycle Ergometry


Obesity is a major health problem. There is considerable information regarding the association between excessive body fatness and many health risks. The purpose of this study is to compare the cardiorespiratory responses of female obese subjects and normal-weight women during cycle ergometry. The obese group included 23 female subjects with mean age of 39.6±13.2 years (range: 19-57 yrs.). The mean body weight of obese subjects was 71.4±7.0 kg, and the body mass index (BMI) was 29.0±2.0 kg/m². The control group included 23 normal-weight women with matched age and body height. Breath-by-breath measurement of the cardiorespiratory function was obtained during the incremental exercise of leg cycling. The anaerobic threshold (AT) was determined by ventilatory criteria. In the maximal exercise, the oxygen uptake (VO₂ max) of the obese group was significantly higher than respective value of the control group (1.7±0.3 l·min⁻¹ vs 1.4±0.3 l·min⁻¹). However, the VO₂ max per kilogram of body weight of the obese group was lower than that of the control group (13.6±2.1 ml·kg⁻¹·min⁻¹ vs 15.6±3.8 ml·kg⁻¹·min⁻¹). The higher absolute oxygen uptake for the obese subjects may partly be attributed to the increase in lean body mass (LBM). At the anaerobic threshold, the obese group also showed lower VO₂ per kilogram of body weight. It is concluded that the obese group had lower oxygen uptake per unit of body weight in the maximal exercise as well as at the AT, and this result may explain why obese subjects usually experience exercise intolerance during ordinary activities.

Key words: obesity, maximal oxygen uptake, anaerobic threshold, cardiorespiratory function, body mass index

INTRODUCTION

The nutritional status in Taiwan was much improved in the past decades. However, the prevalence of obesity was also gradually increased. From August 1986 to June 1988, a large scale nutritional survey was conducted in Taiwan [1-2]. A total of 20677 persons (10231 males and 10446 females)
were measured for their body height, body weight, triceps skinfold and mid-arm circumference. In this study, obesity was defined as the measured body weight exceeded mean body weight for 20%. According to this definition, the prevalence of obesity was 11.6% for the male and 10.3% for the female subjects in Taiwan area.

Obesity is a long term disease. Until recently, the major cause of obesity was believed to be overeating. In fact, there are obviously other factors operative such as genetic, environmental, social and perhaps racial influences [3]. In addition, lack of physical activity plays a major role for obesity. Obese patients usually experience low work capacity during ordinary activities, and exercise intolerance is universal in this population. From the literature, a lot of studies have focused on the epidemiology, health risks and treatment for the obese patients. However, few study reported the difference of cardiorespiratory function between the obese and the normal-weight subjects. The purpose of this study is to compare the maximal cardiorespiratory responses of female obese subjects and normal-weight women during cycle ergometry. In addition, the ventilatory anaerobic threshold (AT) was compared to determine the cardiorespiratory endurance in the submaximal exercise.

SUBJECTS AND METHODS

Definition of obesity

For clinical purposes, several indices of body adiposity are available. Of these, the body mass index (BMI) best correlates with hydrostatically measured body fat [4]. In addition, BMI values correlate positively with risk factors such as adversely levels of serum total cholesterol, HDL cholesterol and triglyceride [5-6]. It is a useful and easily measured health risk appraisal tool. BMI is calculated by dividing body weight in kilograms by height in meters squared (kg/m²). In western countries, overweight was traditionally defined as those having BMI of 25 to 30 kg/m² and obesity as those having BMI over 30 kg/m² [7]. In the Chinese, according to Huang’s [8] recommended criteria, the BMI of 25 to 28 kg/m² was defined to be overweight, and the BMI exceeded 28 kg/m² was considered as obesity. However, an increase in body weight of 20% or more above desirable body weight constitutes an established health hazard [9]. Therefore, the National Obesity Consensus have denoted obesity with slightly lower values of ≥ 26.4 kg/m² (men) and ≥ 25.8 kg/m² (women) [10-11]. In the present study, all female subjects were included as the measured body weight exceeded their ideal body weight for 20%, and the BMI was greater than 26 kg/m².

Subjects

The obese females were recruited from a hospital-based weight reduction program. Sedentary normal-weight subjects were matched from our laboratory’s database to serve as a control group. Because obese individuals were inclined to have some chronic diseases, the recruitment process included two steps. First, subjects who had history of significant cardiovascular, pulmonary, metabolic, and musculoskeletal diseases were excluded. Afterwards, an incremental bicycle exercise test was arranged for each subject. Subject who had significant ECG abnormalities during exercise or was unable to attain the maximal exercise would be excluded from this study.

Exercise test protocol

Exercise testing was conducted no sooner than two hours after a breakfast. Cigarette smoking and consumption of caffeinated beverages were forbidden on the morning of the test. The procedures were fully explained before the test, and informed consent was obtained. The resting heart rate and blood pressure were recorded after sitting quietly for 5 minutes. Afterwards, each subject performed a continuous incremental bicycle exercise test with a pedaling rate of 60±10 rpm until intolerable dyspnea or muscular fatigue occurred. The workload was
10 watt for the first 3 minutes (familiarization period), and then was increased by 10 watts every minute. During the exercise, an electrocardiographic lead (CM5) was continuously monitored for early evidence of any myocardial ischemic changes or cardiac arrhythmias. Blood pressure was measured before the test and upon termination of the exercise. A blood sample was drawn from the antecubital vein five minutes after the exercise test for quantitation of lactate.

**Equipment and Measurement**

An electromagnetic braked cycle ergometer (Erich Jaeger, Ergotest) was used for the test. The expired air was measured and analyzed breath-by-breath by an automated system (Medical Graphics, system 2000). The exercise test was conducted in an air-conditioned laboratory with atmosphere temperature of 22 to 26°C, barometric pressure of 756 to 772 Torr, and relative humidity of 54 to 70%. Exercise cardiorespiratory parameters including heart rate (HR), oxygen uptake (\(\dot{V}O_2\)), carbon dioxide production (\(\dot{V}CO_2\)), oxygen pulse, minute ventilation (\(\dot{V}\)), tidal volume (\(V_t\)), respiratory exchange ratio (R), ventilatory equivalent for O\(_2\) (\(\dot{V}O_2/\dot{V}O_2\)), ventilatory equivalent for CO\(_2\) (\(\dot{V}CO_2/\dot{V}CO_2\)), end tidal PO\(_2\) (P\(_{ET}\)O\(_2\)), end tidal PCO\(_2\) (P\(_{ET}\)CO\(_2\)), and work rate (WR). The data were averaged every minute for further analysis. Blood samples were immediately analyzed by a lactate analyzer (Analog Instruments Ltd.) using an enzymatic method that employs oxidation of lactate to pyruvate.

The \(\dot{V}O_2\)\(_{max}\) was defined as the peak attained oxygen uptake by at least three of the following criteria: (1) the increase of \(\dot{V}O_2\) was less than 2 ml \(\cdot\) kg\(^{-1}\) \(\cdot\) min\(^{-1}\) in the last two minutes, (2) HR exceeded the maximal predicted HR, (3) respiratory exchange ratio exceeded 1.10, and (4) venous lactate concentration 5 minutes after the exercise test exceeded 50 mg/dl.

The anaerobic threshold (AT) was determined by at least two of the following criteria: (1) the \(\dot{V}E/\dot{V}CO_2\) began to increase systematically without a corresponding increase in the \(\dot{V}E/\dot{V}CO_2\), (2) the P\(_{ET}\)O\(_2\) began to increase without a decrease in the P\(_{ET}\)CO\(_2\) [12], (3) departure from linearity for minute ventilation [13]. The determination of the AT was reviewed by two independent observers who were experienced in cardiopulmonary exercise testing. AT with large interobserver variations were reviewed by third observer and then determined by the three observers in discussion.

**Data analysis**

Unpaired Student t-tests were performed to determine the differences between the obese group and the control group. Cardiorespiratory variables in the maximal exercise and at the AT were compared in both groups. A p value less than 0.05 was considered statistically significant. All data are presented as mean \(\pm\) SD.

**RESULTS**

A total of 46 apparently healthy subjects were recruited for this study. The obese group included 23 female subjects with age of 39.6\(\pm\)13.2 yrs (range: 19-57 yrs). Their mean body weight was 71.4\(\pm\)7.0 kg, and the BMI was 29.0\(\pm\)2.0 kg/m\(^2\). The control group included 23 normal-weight women with matched age and body height, and they led a sedentary lifestyle for at least 5 years. The physical characteristics of both groups are listed in Table 1.

**Table 1. Physical Characteristics of the Subjects**

<table>
<thead>
<tr>
<th>Group</th>
<th>Obese</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>39.6(\pm)13.2</td>
<td>36.3(\pm)9.3</td>
</tr>
<tr>
<td>BH (cm)</td>
<td>156.9(\pm) 4.8</td>
<td>158.4(\pm)4.2</td>
</tr>
<tr>
<td>BW (kg)</td>
<td>71.4(\pm) 7.0</td>
<td>52.4(\pm)5.0***</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>29.0(\pm) 2.0</td>
<td>20.9(\pm)1.7***</td>
</tr>
</tbody>
</table>

*** p<0.001.
BH, body height; BW, body weight; BMI, body mass index.
Cardiorespiratory responses of subjects to the maximal exercise are shown in Table 2. In the maximal exercise, the HR and \( \dot{V}_E \) showed no difference between both groups. The mean HRmax was approximately to their age predicted values, and the mean respiratory exchange ratio exceeded 1.10 in both groups. This result showed that these subjects exercised vigorously to achieve their maximal ventilational level. The oxygen uptake (\( \dot{V}_{O_2\text{max}} \)) of the obese group was significantly higher than the respective value of the control group (1.70±0.3 l·min\(^{-1}\) vs 1.4±0.3 l·min\(^{-1}\)). In addition, the obese group showed a significantly higher \( O_2 \) pulse and work rate than that of the control group (p<0.01). However, the \( \dot{V}_{O_2\text{max}} \) per kilogram of body weight of the obese group was lower than that of the control group (23.8±3.9 ml·kg\(^{-1}\)·min\(^{-1}\) vs 26.5±4.1 ml·kg\(^{-1}\)·min\(^{-1}\)). The obese group also had lower blood lactate level than that of the control group.

At the anaerobic threshold, the \( \dot{V}_E \) and work rate showed no difference between both groups (Table 3). The obese group showed a higher \( \dot{V}_{O_2} \) than that of the control group (0.97±0.18 l·min\(^{-1}\) vs 0.82±0.23 l·min\(^{-1}\)). In addition, the obese group also showed a significantly higher \( O_2 \) pulse than that of the control group (p<0.01). However, the \( \dot{V}_{O_2\text{max}} \) per kilogram of body weight of the obese group was lower than that of the control group (13.6±2.1 ml·kg\(^{-1}\)·min\(^{-1}\) vs 15.6±3.8 ml·kg\(^{-1}\)·min\(^{-1}\)).

None of these subjects experienced angina or had major ventricular arrhythmias during the exercise test. The common end point for termination of exercise were leg fatigue or dyspnea. Minor elec-

### Table 2. Selected Variables of the Obese group and the Control Group in the Maximal Exercise

<table>
<thead>
<tr>
<th>Group</th>
<th>Obese</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal oxygen uptake  (l·min(^{-1}))</td>
<td>1.70±0.3</td>
<td>1.39±0.26*</td>
</tr>
<tr>
<td>Maximal oxygen uptake  (ml·kg(^{-1})·min(^{-1}))</td>
<td>23.8±3.9</td>
<td>26.5±4.1**</td>
</tr>
<tr>
<td>Maximal heart rate (beats/min)</td>
<td>176±12</td>
<td>182±11</td>
</tr>
<tr>
<td>Maximal ( O_2 ) pulse (ml/beat)</td>
<td>9.7±1.6</td>
<td>7.7±1.4***</td>
</tr>
<tr>
<td>Maximal ventilation (l/min)</td>
<td>60.7±12.0</td>
<td>56.7±11.4</td>
</tr>
<tr>
<td>Respiratory exchange ratio (R)</td>
<td>1.12±0.08</td>
<td>1.24±0.10***</td>
</tr>
<tr>
<td>Maximal work rate (watt)</td>
<td>129±19</td>
<td>117±13*</td>
</tr>
<tr>
<td>Lactate (mg/dl)</td>
<td>53.9±11.2</td>
<td>63.1±14.7*</td>
</tr>
</tbody>
</table>

* p<0.05, ** p<0.001, data are listed as means ± S.D.

### Table 3. Selected Variables of the Obese Group and the Control Group at the Anaerobic Threshold

<table>
<thead>
<tr>
<th>Group</th>
<th>Obese</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen uptake (l·min(^{-1}))</td>
<td>0.97±0.18</td>
<td>0.82±0.23*</td>
</tr>
<tr>
<td>Oxygen uptake (ml·kg(^{-1})·min(^{-1}))</td>
<td>13.6±2.1</td>
<td>15.6±3.8*</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>126±12</td>
<td>136±13*</td>
</tr>
<tr>
<td>( O_2 ) pulse (ml/beat)</td>
<td>7.7±1.1</td>
<td>6.0±1.3***</td>
</tr>
<tr>
<td>Ventilation (l/min)</td>
<td>25.5±3.7</td>
<td>24.4±5.9</td>
</tr>
<tr>
<td>Work rate (watt)</td>
<td>63±11</td>
<td>58±18</td>
</tr>
</tbody>
</table>

* p<0.05, ** p<0.001, data are listed as means ± S.D.
trocardiographic abnormalities including occasional APC/VPC or nonspecific ST segment displacement were noted in 5 obese and 4 control subjects.

**DISCUSSION**

Obesity is a major health problem. Although there is little agreement as to the exact causes of obesity, there is considerable information regarding the association between excessive body fatness and a number of health risks. Obesity is associated with an increased risk of coronary artery disease [14], hypertension [15], diabetes [16], hypercholesterolemia [17] and certain types of cancer [18]. What is not clear is whether obesity causes the risks or simply is a by-product of particular medical conditions. Clearly, obesity is associated with multiple atherogenic traits, and an excessive fat accumulation contributes to an increased risk of disease. Therefore, the impact of obesity on health should serve as an impetus for physicians to prescribe weight reduction program for overweight patients [19].

The causes of obesity are multifactorial. Mayor and Thomas [20] have pointed out, obesity is often the result of too little physical activity rather than overeating. For both young and middle-aged who exercised regularly, the time spent in activity was inversely related to their fat level [21]. Surprisingly, no relationship emerged between body fat and caloric intake. In the present study, none of the obese subject had participated in regular exercise program. Consequently, a sedentary normal-weight group was selected to compare their cardiorespiratory responses during cycle ergometry.

The maximal oxygen uptake, which is normally determined by the capacity of the cardiovascular system to deliver oxygen to the working muscles, has been used as an index of overall maximal cardiovascular functional capacity [22]. The maximal oxygen uptake score was influenced by many factors, such as age, sex, heredity, body composition, mode of exercise and state of training [23]. In the present study, the obese group and the control group were well matched for age, sex, body height and activity level. In addition, they were tested by the same exercise mode and were all highly motivated to reach maximal volitional level.

In the maximal exercise, $\dot{V}O_2$, $O_2$ pulse and work rate of the obese group were significantly higher than the respective values in the control group. At the first glance, the obese group appears to have higher maximal cardiorespiratory function. But, if we explore further, the difference may largely be attributed to different body composition between both groups. Though the increased weight in obese subjects are mainly adipose tissue, their lean body mass (LBM) are also increased. James et al [24] have indicated that obese subjects have an increased LBM, which results in an increase in resting metabolic rate. The higher $\dot{V}O_2$max and $O_2$ pulse for the obese subjects, in a large part, accounted for by an increase in lean body mass (LBM). Obese subjects are known to have greater $\dot{V}O_2$ and lower gross efficiency as compared with lean subjects when cycling a given work rate [25-26]. Anton-Kuchly et al [25] found that approximately 70% of the increased energy cost during cycling in obese subjects was due to the work of moving the legs. In addition, Kamon et al [27] have found that external loading of the ankles during cycle ergometer exercise will increase the $O_2$ cost of the exercise task. In the present study, though the obese subjects had higher gross $\dot{V}O_2$max (1·min⁻¹), their $\dot{V}O_2$ max per kilogram of body weight was significantly lower than the control group. Additionally, the obese may not perform exercise in high intensity because they could not tolerate higher blood lactate level. The results may explain why the obese group had lower physical capacity in comparison with their normal-weight counterpart.

The anaerobic threshold was used initially to assess the exercise tolerance of individuals with cardiorespiratory diseases. In recent years, it has been used to evaluate the individual's aerobic po-
tential and the effect of training [28]. For the clinical application, AT is thought to be a direct measurement of the work load at which the cardiovascular system fails to supply adequate O2 to the tissue. When assessing one's endurance, the AT is considered to be a sensitive indicator of physical performance [29]. In the present study, the obese group also showed a significantly higher VO2 and O2 pulse. However, the VO2 per kilogram of body weight of the obesity group was lower than the control group (13.6 vs 15.6 ml·kg⁻¹·min⁻¹). This result showed that the obese group had lower exercise endurance, and it would be difficult for them to do a prolonged exercise with moderate intensity.

In conclusion, our data demonstrated that obese subjects had high absolute VO2 in the maximal exercise and at the ventilatory threshold. However, their VO2 per kilogram of body weight was significantly lower than the control group. This result may explain why obese subjects usually experience exercise intolerance during activities. Exercise is as important as diet control in a weight-reduction program, and the beneficial effects of exercise go beyond achieving and maintaining weight reduction. Suitable exercise program may facilitate reduction in adipose tissue while preserve the lean body mass. If obese subjects can improve or at least maintain their cardiorespiratory function while reduce their body weight, the VO2 per kilogram of body weight will increase significantly.

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REFERENCES


肥胖患者與正常體重者在踏車運動時之心肺功能反應

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林光華 曾美智** 賴淵蘭*** 連倚南

肥胖與許多健康上的危險因素關係密切。本研究目的是要探討肥胖患者與正常體重的人在踏車運動時之心肺功能反應的差異。肥胖組有23位女性，其平均年齡為39.6±13.2歲，體重為71.4±7.0kg，而身體質量指數(BMI)為29.0±2.0kg/m²。對照組則有23位年齡與身高相匹配而體重正常的女性。受試者除了接受一般性體檢外，均以固定式踏車作一次最大運動測試。在測試進行時，除了作心電圖監視，並逐次分析其呼出氣體，以記錄受試者換氣量、攝氧量和二氧化碳呼出量等生理變數的變化。結果發現最大運動時，肥胖組的最大攝氧量較對照組為高（1.7±0.3 l·min⁻¹ vs 1.4±0.3 l·min⁻¹）。但是，肥胖組的單位體重最大攝氧量卻較對照組顯著為低（13.6±2.1 ml·kg⁻¹·min⁻¹ vs 15.6±3.8 ml·kg⁻¹·min⁻¹）。至於最大換氣量與最大心搏率，兩組均無顯著差異。在無氧閾值時，肥胖組的單位體重換氣量也較對照組為低。由上述結果可知肥胖組的攝氧總量雖較對照組為高，但是其單位體重攝氧量卻較對照組為低。此結果可以解釋肥胖體能較差，且其運動耐力偏低的原因。