Gender Differences in Aerobic and Anaerobic Exercise

Samaria K. Cooper

Ball State University

School of Physical Education, Sport, and Exercise Science

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Dr. Anthony D. Mahon

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Introduction

Aerobic power is the rate at which energy is released using metabolic processes within the cell that are dependent on oxygen. Maximal aerobic power is limited by the ability to deliver and use oxygen and is dependent on cardiovascular, metabolic, and respiratory processes (6). Aerobic power was determined using a Graded Exercise Test (GXT) and it is quantified by the maximal power to transport and utilize oxygen. To assess maximal oxygen uptake (VO$_2$max) measurements of the volume of inspired and expired oxygen must be made. VO$_2$max is important for a couple of reasons. First, it allows for determination of the subject’s cardiorespiratory fitness and whether they had a good or bad aerobic reserve. Second, it is important in determining the athletic performance of the subject (3).

Anaerobic power is the rate at which energy is released using metabolic processes within the cell that function without oxygen. The subject’s anaerobic power was assessed through performing a Wingate Anaerobic Test (WAnT). This test is an all-out performance that the subject gives against a fixed amount of resistance for 30 seconds while measuring peak power (PP), mean power (MP), and fatigue index (FI) (6). It is difficult to determine anaerobic power through tests because no one test is universally accepted. Anaerobic power is used for short, quick bouts of energy such as sprinting. The importance of measuring anaerobic power is to predict athletic performance (6).

There are several factors that affect gender differences using aerobic and anaerobic power, such as body composition, strength, cardiorespiratory function, and metabolic function. Generally during childhood, body composition is relatively the same for males and females. However, later in development females begin to acquire more fat (6). Through muscle biopsies it has been determined that males and females have similar fiber type distributions. The type of
fiber and the fiber’s size has a direct effect on athletic performance both aerobically and anaerobically depending on the activity (2). There are also differences in cardiorespiratory function between males and females that impacts VO₂max. Overall females tend to have lower VO₂max levels due to generally having smaller lungs and hearts than males. The smaller the lungs the less oxygen can be utilized, and the smaller the heart the less blood it pumps which is a factor for stroke volume (SV). Also, lower hemoglobin levels in females reduce oxygen concentration in the blood (6).

In this study the differences in aerobic and anaerobic power were examined by gender. Aerobic power was quantified as the VO₂max assessed during a GXT on a cycle ergometer. Anaerobic power was assessed using a WAnT. It was hypothesized that males will tend to have a higher aerobic and anaerobic power than females. The absolute measure(s) of aerobic power was VO₂max and the absolute measure(s) of anaerobic power were PP, MP, and FI. There are no significant differences found amongst males and females when the results are concerning fat-free mass (FFM). However, there are significant differences concerning absolute values relative to body weight; but these differences are reduced when the absolute values are corrected to the body weight of the subjects (8). It is important to study the differences during aerobic and anaerobic exercise between groups in order to ascertain the absolute factors that determine exercise performance and the subject’s effectiveness during exercise.

Methods

Participants

This study included 15 males and 15 females of college-age. The mean (± standard deviation ‘SD’) age of males was 21.9 ± 1.7; the mean (± SD) age of females was 20.8 ± 0.68.
The participants completed a pre-test screening using the PAR-Q questionnaire. All of the participants were apparently healthy to complete the study.

**Procedures**

Prior to exercise testing, anthropometric measurements were taken. These measurements included height, weight, skinfolds, gender specific equations for body density and body fat, and FFM was calculated from body fat percentage. Height measurements were assessed using a wall mounted stadiometer and measured to the nearest 0.1 cm, and weight was measured using a scale to the nearest 0.1 kg. Skinfold measurements were assessed based on gender. For males the measurement sites included triceps, chest, and subscapular, and for females the measurement sites included triceps, suprailliac, and abdomen. Skinfolds were measured twice, and a third time if the first two measurements were not within 2 mm. Based on skinfold measurement, body density was determined. In order to determine body density the generalized three-site skinfold equation for males and females was calculated (7).

Males: Body density = 1.1125025 - 0.0013125 X (sum of three skinfolds) + 0.0000055 X (sum of three skinfolds)$^2$ – 0.000244 X (age);

Females: Body density = 1.089733 – 0.0009245 X (sum of three skinfolds) + 0.0000025 X (sum of three skinfolds)$^2$ – 0.0000979 X (age).

In order to determine body fat percentage the following equations were used (7).

Males: Body fat % = ((4.95/Body Density) – 4.50) X 100;

Females: Body fat % = ((5.01/Body Density) – 4.57) X 100.

FFM was then determined by taking the fat mass (% body fat X body weight) and subtracting that value from body weight.
A GXT was performed on an electrically braked cycle ergometer. The GXT for males started at 50 watts (W) for 2 minutes and increased by 50W every 2 minutes. As the subjects approached maximal effort, the work rate increased by 25W every minute until the test was terminated. The test for females started at 40W for 2 minutes and increased by 40W every 2 minutes. As the subjects approached maximal effort, the work rate increased by 20W every minute until the test was terminated. A mouthpiece breathing valve with a nose clip was used as a metabolic measuring system. Measurements taken included gas exchange at 30 second intervals, maximal respiratory exchange ratio (RER), and heart rate (HR) based on the highest values. HR was recorded every 30 seconds using a Polar heart monitor. Maximal values for VO₂max (L/min), HR, and RER were defined as the highest values from the test. VO₂max was then calculated relative to body mass and FFM.

On a separate day, a WAnT was completed on a cycle ergometer. Prior to testing a 5 minute warm-up at 100W and several short sprints in the last minute were performed. The subject had a 30 second lead in at 80rpm upon the start of the test. Then resistance (Newton-meter) was set at 0.7 body weight for males and 0.67 body weight for females, both starting at 80rpm. Subjects were instructed to pedal as fast as possible and give an all-out maximal effort for 30 seconds, the duration of the test. During those 30 seconds weight was added to the work load based on the subject’s body weight. This caused greater resistance for the subject to pedal against. Measurements taken included PP (W) defined as the highest 3 second power, MP (W) as an average over 30 seconds, and FI, the rate at which the subject’s power output declined expressed as a percentage. PP (W) and MP (W) were scaled to weight and FFM.
**Statistical Analysis**

The primary dependent variables in the study included body size and composition (height, weight, percent fat and FFM), VO\(_2\)max (L/min, ml/kg/min), VO\(_2\)max (ml/kg FFM/min), PP and MP (W, W/kg, W/kg FFM), and FI. The secondary dependent variables were HR and RER at maximal exercise. The independent variable was gender. Data are presented as mean ± SD. Significance was established if p < 0.05.

**Results**

Table 1 shows the anthropometric measurements for males and females. Males had significantly greater height, weight, and FFM than females. Females had significantly greater body fat percentage.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>180.3 ± 6.8</td>
<td>164.8 ± 4.9 *</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.9 ± 12.7</td>
<td>61.8 ± 7.8 *</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>12.0 ± 5.2</td>
<td>22.6 ± 5.7 *</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>68.1 ± 8.2</td>
<td>47.7 ± 6.2 *</td>
</tr>
</tbody>
</table>

*P < 0.05

Table 2 shows the GXT results based on the subjects maximal responses. Means between males and females were different for VO\(_2\)max (L/min) and VO\(_2\)max (ml/kg/min) with the values in males significantly greater than females. The results for VO\(_2\)max (ml/kg FFM/min) were similar between males and females. Results for maximal HR and RER were not significant between groups.
Table 2 GXT Results at Maximum

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>$VO_2$ (L/min)</td>
<td>3.57 ± 0.51</td>
<td>2.49 ± 0.29*</td>
</tr>
<tr>
<td>$VO_2$ (ml/kg/min)</td>
<td>46.4 ± 7.1</td>
<td>40.6 ± 5.5*</td>
</tr>
<tr>
<td>$VO_2$ (ml/kg FFM/min)</td>
<td>52.8 ± 8.2</td>
<td>52.5 ± 6.7</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>190 ± 9</td>
<td>186 ± 6</td>
</tr>
<tr>
<td>RER</td>
<td>1.25 ± 0.08</td>
<td>1.22 ± 0.06</td>
</tr>
</tbody>
</table>

*P < 0.05

Table 3 shows the WAnT results for males and females. Means between males and females were different for all measurements except FI. Specifically, males had significantly greater power for all measurements.

Table 3 WAnT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP (W)</td>
<td>1194 ± 156</td>
<td>694 ± 133*</td>
</tr>
<tr>
<td>PP (W/kg)</td>
<td>15.4 ± 1.4</td>
<td>11.2 ± 1.8*</td>
</tr>
<tr>
<td>PP (W/kg FFM)</td>
<td>17.6 ± 1.7</td>
<td>14.5 ± 2.2*</td>
</tr>
<tr>
<td>MP (W)</td>
<td>706 ± 129</td>
<td>440 ± 78*</td>
</tr>
<tr>
<td>MP (W/kg FFM)</td>
<td>9.1 ± 0.7</td>
<td>7.1 ± 1.1*</td>
</tr>
<tr>
<td>FI</td>
<td>61.7 ± 4.6</td>
<td>55.9 ± 10.2</td>
</tr>
</tbody>
</table>

*P < 0.05

Discussion

The purpose of this study was to examine the differences in aerobic and anaerobic power in males and females. College-aged subjects participated in a GXT to assess aerobic power and a WAnT test to assess anaerobic power. Males had a greater absolute $VO_2$max and $VO_2$max relative to body mass than females. However, $VO_2$max relative to FFM was similar. Males also had greater PP and MP for all measurements than females. However, FI was not significant.
There were some differences between genders that were relative to body size and composition. Males had greater overall mass and FFM than females, whereas females were found to have a significantly higher percentage of body fat than males. A study done by Durnin and Womersley (4) suggests that this is due to females carrying more subcutaneous fat as they age. Hormonal factors play a key role in the body composition differences between males and females. Following puberty males secrete more testosterone while females secret more estrogen. The testosterone increases bone formation which leads to larger bones and increased synthesis of protein, ultimately increasing muscle mass. Larger bones and increased muscle mass increases FFM in males. The estrogen, which is produced more by females, also influences body growth and fat formation (6). Body size and composition will have an effect on aerobic and anaerobic power (9).

Absolute VO$_2$max (L/min) was greater in males than females. These finding are comparative to a study by Hermansen (5). Hermansen reports that VO$_2$max is expressed on a basis of height and weight of the subjects. Males are generally taller and weigh more than females, while also having greater muscle mass (5). A hormonal factor that could play a role in these results is that testosterone stimulates more production of erythropoietin by the kidneys, which leads to increased red blood cell production (6). We measure VO$_2$max to show the differences in cardiovascular and respiratory factors between males and females. The limiting factor for VO$_2$max is cardiac output, which is greatly affected by body size. The cardiac output is determined by the HR and SV. The SV could be different between genders due to heart size or blood volume. Collectively this increases the blood flow to the muscles. Females have less hemoglobin so this makes them transport less oxygen per unit of blood (6).
VO$_2$\textsubscript{max} in ml/kg/min also was significantly higher in males than in females. However, VO$_2$\textsubscript{max} in ml/kg FFM/min was similar between groups. These results were comparative to results found by McLester et al. (9). Adjusting by mass reduced differences but did not eliminate them, but adjusting by FFM did eliminate differences. Adjusting by mass alone does not take into account the differences in fat content. Fat is a metabolically inactive tissue in comparison to muscle. Thus, by adjusting to FFM fat differences are eliminated (6).

Absolute PP (W) and MP (W) were greater in males than females. These results differed from a study reported by Baker et al. (1). In the Baker et al. study the comparisons of average MP (W) values were reported higher.

Results from other studies compared to the results obtained from this study show that the female values obtained were relatively close in range, and the male values obtained had a larger difference. The primary reason for these differences is due to variations in metabolism and cardiovascular and respiratory regulation. This would demonstrate why males showed greater results and more improvements. Males also have greater muscle mass. The more muscle mass the higher the power output will be (6).

The WAnt test results for PP and MP (W/kg) and (W/kg FFM) were all significantly higher in males than females. These results do not compare with the Maud and Schultz study (8). Maud and Schultz found no significant differences between males and females, providing that results were expressed relative to FFM. However, significant differences were found when reported as absolute values or relative to body mass. When absolute values were corrected for body weight percentages they were found to be reduced. When data is reported as absolutes, significant differences are found. These differences, however, are reduced when data is adjusted according to body mass, and when it is corrected for FFM (8).
Adjustments made based on body size between males and females does not eliminate differences in performance due to neuromuscular or fiber type differences between groups. It could be said that there are neuromuscular differences between groups; however, there is not significant research supporting this. A study done by Suetta et al. (11) in elderly males and females showed a slight difference in neuromuscular activation between groups but nothing significant. There were a limited number of subjects participating so the results presented were not feasible to make gender comparisons. As for fiber type differences, it has been shown in athletes that males and females have similar fiber type distribution. However, a study done by Saltin et al. (10) showed male athletes, compared to female athletes, achieving greater percentages (> 90%) of Type I and Type II fibers. Furthermore, biopsies have shown male athletes, particularly runners, differing from female athletes in Type I fiber distribution by about 10%. It was also concluded from the Saltin et al. study that females had a smaller fiber area for Type I and Type II fibers.

The FI between males and females was not different. These results do not compare with another study performed by Baker et al. (1). Baker et al. reports male values being higher for PP (W) and MP (W). This could result in an increased FI because FI is related to higher PP values. A higher FI could also be partly due to differences in anaerobic power or in muscle mass between subjects.

This study examined the differences between genders in absolute and relative aerobic and anaerobic power. The absolute differences were largely due to body composition; differences between males and females decreased when scaled to body mass and FFM. All of these would explain why males achieved greater results. It is important to understand the differences in males
and females during aerobic and anaerobic exercise to better understand the absolute factors in determining exercise performance and their effectiveness during exercise bouts.
Reference List


