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# Gender differences of anaerobic capabilities in untrained adults

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# 비훈련 성인남여의 무산소성 운동능력 차이

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**Abstract** The purpose of the study was to investigate the gender differences of anaerobic capabilities between anaerobic capacity(AC) from Wingate test and anaerobic work capacity(AWC) from critical power test in untrained male and female adults. Both tests were carried out to 12 male and 13 female subjects on a Monark cycle ergometer. The results of this study demonstrated that men were higher than women in AC for the Wingate test, but no gender difference(J/kg) in AWC for the Critical Power test. There was a significant relationship between AC(J/㎏) and AWC(J/㎏) in women(r=0.61, p<0.05), but no significant relationship in men(r=-0.32, p>0.05). ANCOVA analyses using $VO_{2max}$ and body weight as covariates had significant influence on the AWC gender difference. The study provides preliminary data on gender differences of anaerobic capabilities.

**Key Words :** Gender difference, Anaerobic capability, Anaerobic capacity, Anaerobic work capacity, Untrained

요 약 본 연구의 목적은 윈게이트 검사로부터 측정된 무산소성 운동능력(Anaerobic Capacity, AC)과 임계파워검사로부터 측정된 무산소성 작업능력(Anaerobic Work Capacity, AWC)의 상관관계를 알아보고, 두 가지의 무산소성 능력에서 나타나는 남녀간의 성별 차이를 조사하는데 있었다. 성인 남여 23명을 대상으로 모나크 자전거 에르고미터를 이용하여 두가지 테스트를 수행하였다. 각각의 무산소성 검사에서 AC에서는 남성이 여성보다 높게 나타났으나 AWC에서는 남녀간 차이가 나타나지 않았다. AC와 AWC(J/㎏)사이의 상관관계는 여성에서는 통계적으로 유의하였으나(r=0.61, p<0.05), 남성에서는 유의하지 않았다(r=-0.32, p>0.05). 최대 유산소 능력과 체중을 공변인으로 한 공변량분석 결과에 의하면 두 변인이 AC의 남녀간의 차이에는 유의한 영향을 미치지 않았으나 AWC의 남녀간의 차이에는 통계적으로 유의한 영향을 미친 것으로 나타났다. 또한 본 연구결과는 무산소 운동검사로 평가되는 남녀간의 성별 차이에 대한 기초적인 자료를 제공하고 있다.

주제어 : 성별차이, 무산소성 능력, 무산소성 운동능력, 무산소성 작업능력, 비훈련자

## 1. Introduction

In recent years interests in exercise have been increased because of the realization that health and fitness benefits increase as the amounts of exercise increases[1, 2].

During exercise or physical activity, metabolic processes for energy production are largely classified as aerobic or anaerobic. Aerobic metabolism acts as the main energy system when performing a prolonged period of more than 2-3 minutes and generates energy by using oxygen through Krebs circuit and electron transfer system.

On the other hand, anaerobic metabolism acts to

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utilize the energy source stored in the body without supplying enough oxygen when exercising at high intensity for a short time. The anaerobic metabolism can be further classified into two types. That is, the ATP-PC system that decomposes adenosine triphosphate (ATP) and creatine phosphate (PC), which is already stored in muscle, to generate energy, and the lactate system that decomposes glucose without using oxygen to produce lactic acid.

Since this anaerobic metabolic ability has a high correlation with exercise that can perform effective muscle contraction with high intensity for a short time, studies on appropriate evaluation methods have been tried for a long time.

For example, a 40 yard sprint running, a Sagent jump, a Margaria-Kalamen Power Test, a Wingate test[3], and a treadmill anaerobic power test has been used as a representative method to measure anaerobic exercise capacity.

Among the various tests that can measure anaerobic exercise capacity, Wingate's anaerobic exercise test, which is a power test using a bicycle ergometer, has been widely used because it is objective, valid, reliable and easy to use[4].

This test calculates the total work output over a 30-second period by measuring the work exerted at 5-second intervals at a constant load in order to predict the anaerobic exercise capacity determined by the metabolic ability of ATP-PC system and lactic acid system. On the other hand, a method of indirectly measuring anaerobic exercise capacity by performing a series of high intensity exercises on a bicycle ergometer has been introduced[5].

This method is based on Monod and Scherrer's Critical Power test (CP test), which yields two but simultaneously measurable indices of fitness or physiological performance. Here, the critical power (CP) represents an anaerobic power or anaerobic threshold and the y-intercept represents the anaerobic work capacity (AWC)[6].

This test consists of a maximum of bike movements over a maximum of several different loads, which determines the total work limit(WL) and the time limit(TL) required to stop the workout. Each WL is calculated by multiplying P by TL (WL = P x TL), where CP and AWC are the slope and y-intercept of the linear correlation of WL and TL, respectively. Unlike the CP, which is a slope index, AWC is not affected by hypoxia and circulatory blockage[7].

The purpose of the study was to investigate the gender differences of anaerobic capabilities between anaerobic capacity(AC) from Wingate test and anaerobic work capacity(AWC) from Critical Power test in untrained male and female adults.

## 2. Methods

Subjects: 25 untrained male and female adults(12 men and 13 women) were volunteered for the study. They agreed to participate in the experiment by listening to the explanation of the contents and the procedures before the experiment. The physical characteristics of the subjects are shown in Table 1.

Table 1. Physical characteristics of subjects

| | | Age (yr) | Height (cm) | Weight (kg) |
|---|---|---|---|---|
| Male(N=12) | X | 25.7 | 176.9 | 73.8 |
| | SD | 3.4 | 4.7 | 4.9 |
| Female(N=13) | X | 23.8 | 162.6 | 58.2 |
| | SD | 3.1 | 6.1 | 7.7 |
| Total(N=25) | X | 24.6 | 169.7 | 65.9 |
| | SD | 3.2 | 9.4 | 9.9 |

**Wingate Test:**

Anaerobic capacity (AC) was determined using a Monarch bicycle ergometer. Before testing, the saddle height of the bicycle was adjusted so that the subject's legs could be fully extended. The subjects warmed up for 2-4 minutes at a sufficient intensity to reach a heart rate of 150-160bpm.

After 2 minutes of rest, the subjects pedalled as fast as possible for a maximum of 30 seconds during exercise given 0.09 kp/body weight for men and 0.075 kp/body weight for women. The bike pedal speed was adjusted within at least 2 seconds. The anaerobic exercise capacity was calculated as the total exercise amount during the 30 second exercise at constant exercise load.

**Critical power test:**

Each subject performed three high intensity exercises with a Monarch bicycle ergometer on the adjusted load(kp) according to the subject's fitness level. In this study, three resistance values were selected according to the subject's ability to cope within the range of 4.5-6.5kp for males and 3.0-5.0kp for females. All subjects stopped exercising within 1 to 10 minutes of exercise due to muscle weakness. The experimenter observed the subject's pedal velocity to maintain a constant power output.

The height of the bicycle saddle before the bike riding exercise was adjusted so that the subject's legs were fully stretched and the bicycle riding was carried out at a resistance of 0.5kp for 2-4 minutes. After this break, we started cycling at 69 rpm (25 km/h) without any exercise load, and soon after the pre-determined load was properly reached, then a stop watch and electronic pedal turn calculator were activated. The subject maintained the required number of revolutions of the pedal until the end of the exercise and considered that the exercise was terminated when the speed of 55 rpm (20 km/h) could no longer be maintained.

The anaerobic work capacity(AWC) was determined by the amount of workout corresponding to the y-intercept of the linear relationship between the Work Limit (the total workout until exhaustion) and the Time Limit (the total time to exhaustion). CP, which is an aerobic exercise capacity, was determined by the power output corresponding to the slope of the linear correlation between WL and TL.

**Maximal aerobic capacity:**

The maximum aerobic capacity was determined by an incremental load method using a Monarch bicycle ergometer. Resistance values started at 25 Watts and were increased until exhaustion. Oxygen uptake was measured using a gas analyzer and $CO_2$ and $O_2$ were adjusted before each test. Maximal aerobic capacity was recorded as the power load or as maximal oxygen consumption when oxygen consumption was plateaued and R was at least 1.2 or greater.

**Statistical Analysis:**

Mean, standard deviation, simple correlation, multiple regression analysis, and independent t-test were calculated using the SPSS 18.0 program.

Stepwise regression analysis was performed to examine the major variables influencing AC and AWC, with the maximum oxygen uptake, body weight, height, age, and gender as independent variables. In order to investigate the effect of body weight and physical fitness on the gender differences, covariance analysis was performed with maximum oxygen uptake and weight as the covariates. P-value less than 0.05 was considered to indicate significance.

## 3. Results

The physical characteristics of the male and female subjects are shown in Table 1. Female subjects showed significantly lower values in height, weight, and oxygen uptake than male subjects. The results of this study showed a linear correlation between the work limit and the time limit, ranging from 0.98 to 1.00, through the critical power test of all subjects.

The correlation between the test and retest of AWC was $r=0.81$ ($n=6$, $P<0.05$). The mean AWC of test-retest was 12459±2650J and 12517±2305J, ($t=-0.09$, $P<0.05$). The test-retest correlation for CP, which is a slope variable, was $r=0.89$ ($n=6$, $P<0.05$). The mean CP values of the test-retest were 187±38 W and 183±46W, respectively. There was no significant difference between the mean values ($t= 0.39$, $P>0.05$). In addition, there was no statistically significant correlation between AWC and CP (r=0.07, P<0.05), indicating that the two measurement indices are mutually independent and can not be used interchangeably.

As shown in Table 2, there was no significant correlation between AC (240.2±30.5 J/kg) and AWC (184.0±51.2 J/kg). When AC and AWC were expressed as units of Joules and not adjusted by body weight factor, they showed a significant moderate correlation (r=0.41, P<0.05). The AWC, an anaerobic estimate obtained in the critical power test, was 33, 15, and 24% lower than the value obtained from the Wingate test for male, female, or total(P<0.05).

In each anaerobic test, when comparing performance between male and female, Wingate test showed that male subjects were 20% (J/kg) higher than female subjects in AC, and AWC values were higher in male subjects 6% (J/kg) higher than female subjects. As shown in Table 2, there was a significant correlation between AC and AWC (J/kg) in female subjects (r=0.61, P<0.05) (r=0.27, P>0.05) between the two groups.

When the correlation between AC and AWC was compared with absolute values without body weight factor, the correlation in female subjects was somewhat lower and statistically not significant (r=0.32, p>0.05). Also, the correlation in male subjects was not statistically significant (r=-0.22, p>0.05).

Table 2. Relationship between Anaerobic Capacity and Anaerobic Work Capacity in men and women.

| Variables | Total (n=25) | Men (n=12) | Women (n=13) |
|---|---|---|---|
| AC vs AWC (Joules) | r=0.57* | r=-0.22 | r=0.32 |
| AC vs AWC (Joules/kg) | r=0.19 | r=0.27 | r=0.61* |

*P < .05

Covariance analysis using maximal oxygen uptake and body weight as covariates showed that maximal oxygen uptake and body weight did not significantly affect gender differences in AC, but significant differences were found in AWC. The results of the stepwise regression analysis with the AWC as the dependent variable and the height, weight, sex, maximum oxygen uptake, and age as independent variables were statistically significant only in the AWC(F=4.72, p<0.05), but all other independent variables did not (p>0.05). Table 3 shows the comparison of the maximum aerobic capacity, AC, AWC, and CP according to gender in the Wingate and critical power test.

Table 3. Maximal Oxygen uptake, Anaerobic Capacity, Anaerobic Work Capacity, and Critical Power.

| Variables | Total (N=25) | Men (N=12) | Women (N=13) |
|---|---|---|---|
| $VO_2$.max | | | |
| ($LO_2$/min) | 2.71 ±0.32 | 3.29 ±0.22** | 2.24 ±0.31 |
| (ml/kg/min) | 39.4 ±1.7 | 42.1 ±3.4* | * 36.1 ±2.8 |
| AC | | | |
| (kJ) | 15.9 ±1.1 | 19.7 ±1.3** | 13.0 ±0.7 |
| (J/kg) | 237.9 ±7.6 | 255.6 ±8.5** | * 219.5 ±7.3 |
| AWC | | | |
| (kJ) | 12.2 ±1.3 | 13.9 ±1.7* | * 10.5 ±1.2 |
| (J/kg) | 182.3 ±14.3 | 188.7 ±13.4 | 177.1 ±15.4 |
| CP | | | |
| (W) | 171.7 ±11.5 | 206.1 ±9.5** | 142.0 ±12.6 |
| (W/kg) | 2.51 ±0.12 | 2.71 ±0.15 | * 2.37 ±0.13 |

*P<0.05 **P<0.01

# 4. Discussion

Reserchers reported that the y-intercept, which is calculated from the linear relationship between the work limit and the time limit, has an anaerobic work capacity (AWC) and is specific to the muscles performing the exercise[8]. The test methods used in this study are reliable and well comparable to those reported in similar studies[9, 10]. Previous study reported that the AWC can effectively track or measure changes in AC[11].

A significant correlation between AWC and AC in this study indicates that the validity of the AWC is limited as a measure of anaerobic exercise capacity. Although the results of this study are in agreement with those of [12], there is room for explanation in physiology. Although this relationship is generally well supported by the literature[6], only 16% of the variance between AWC and AC could be accounted for in this study. Other factors seem to influence this relationship. One of the influencing factors is the aerobic component of the Wingate test, which is estimated to constitute 13-44% of the total energy supply[13].

In this study, the correlation coefficient between the maximum aerobic capacity and AC was $r=0.57(r^2=0.32)$, which accounts for 32% of the unexplained variance between AWC and AC. Another factor is that the Wingate test is too short to consume the anaerobic energy storage, resulting in underestimation of AC. ATP and PC concentrations in muscle during high intensity exercise have been reported to decrease by about 18 mmol/kg wet weight muscle[14]. Assuming a muscle weight of 40%, a high intensity bicycle exercise will produce 7.2 mmol of high energy phosphoric acid. When these values are converted into oxygen consumption, decomposition of PC and ATP contributes 25.6 ml $O_2$/kg. An additional 6.0 ml/kg contributes as oxygen to the blood and myoglobin[9]. The total 31.6 ml $O_2$/kg is in good agreement with the oxygen depletion of 35 ml $O_2$/kg calculated from 184.0 J/kg for the AWC of this study.

The data in this study agree well with the study of [15] which reported that anaerobic exercise capacity can be expressed as the maximum cumulative oxygen deficit when adjusted for body weight and physical fitness. However, these values are 24% lower than the AC measured by the Wingate test. This is due to an overestimation of the Wingate test[12] that is included in the aerobic energy metabolism(15%). Previous study showed that only 5 of 359 white muscle fibers exhibited a 20% decrease in muscle glycogen after 60 seconds of maximum bike ergometer exercise (150% maximum aerobic power, 90-104 rpm)[16]. Therefore, the AWC calculated from the critical power test is expected to be further investigated in order to make a more appropriate interpretation of it as in other non-invasive AC measurement methods.

The average maximum aerobic capacity of the subjects is well known as the maximum oxygen uptake shown in Table 2. As expected, female subjects showed significantly lower aerobic capacity as well as anaerobic capacity than male subjects. However, considering the weight, there was no difference in the anaerobic power (189 vs 177 J/kg, $P>0.05$). This study suggests that anaerobic power is affected by body weight. However, these findings did not appear in the anaerobic capacity obtained from the Wingate test. Because the anaerobic ability that can be expressed per unit body weight of female can be comparable to that of male, it seems that the anaerobic power similar to that of male was found in the critical power test using bicycle ergometer. The reason why these results are not present in the Wingate test but in the critical power test has not yet been clarified. In the Wingate test, aerobic factors contributing to anaerobic capacity were higher in women than in men (male = 20%, female = 25%[17]).

Because the maximum aerobic capacity ($VO_2max$) and body weight were the major factors related to gender difference in AC, covariance analysis was performed to analyze the effects of body weight and $VO_2max$ on gender differences in AC and AWC. Statistical analysis showed that relatively large male AC values were not affected by covariates, body weight and $VO_2max$. That is, even when the body weight and $VO_2max$ were used as covariates, the gender difference in AC still remained. On the other hand, gender differences in AWC were not statistically significant when weight and $VO_2max$ were covariates. It can be seen here that the Wingate test and the critical power test do not evaluate the same anaerobic component.

AWC is limited to energy released from

intramuscular ATP and PC and from blood and muscle oxygen storage, and is related to the amount of energy exhausted by intense anaerobic exercise in about 10-20 seconds. In addition, the estimated AC from the Wingate test will be higher than the AWC estimated from the critical power test because the anaerobic glycolysis process is included and the aerobic process is somewhat involved in Wingate test. These findings are well supported by [11].

This study shows that the maximum oxygen uptake and body weight did not affect the difference between men and women in AC, but did in AWC. This study also provides basic data on gender differences between male and female adults who are evaluated by the critical power test. Future studies are recommended to investigate gender differences of anaerobic capabilities in middle-aged and old-aged people.

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