Comparison the cardiovascular, metabolical and hematological responses to two type of upper and lower body exercises

Hovanloo Fariborz1*, Ahmadizad Sajad1, Mardani Amene2, Sahami Mina3, Khoramipour Kaivan2

1- Associate of professor in sport and exercise physiology, faculty of physical education and sport sciences, Beheshti University G.C, Tehran, Iran
2- MSc student in sport and exercise physiology, Beheshti University G.C, Tehran, Iran
3- PhD student in sport and exercise physiology, Beheshti University G.C, Tehran, Iran

*Corresponding Author, Email: F_Hovanloo@sbu.ac.ir

Abstract

The aim of this study was the comparison the effect two types of exercise on arm cranking and leg cycling on cardiovascular, metabolical and hematological factors. After obtaining informed consent, 10 sedentary female (age: 25± 2.69 year, height: 161.75± 5.5 cm and weight: 56.35 ± 6.1 kg) participated in this study. They completed four experimental testing sessions (two maximal oxygen consumption tests on a cycle ergometer and arm cranking to assess ergometer cycling and arm cranking VO2max, and two sub-maximal exercises). The maximal tests were performed before the sub-maximal one by at least one week interval between sessions. For sub-maximal testing, subjects performed 30 minutes test at the relative work loads of 70% of VO2max (75-80 % HRmax) and 30 minutes recovery. Before, after and after 30 minutes of recovery, heart rate, blood pressure were recorded and samples of blood were collected for the determination of blood lactate concentration, and red blood cell indices. The data were analyzed using two way repeated measures ANOVA and Bonferroni post hoc test with a significant value of (p<0.05). No differences were found between two type of exercises in the heart rate, red blood cell indices and lactate, but blood pressure was higher for the arm than for the leg (P=0.013 \( F_{1,9} =9.385 \)) and mean corpuscular hemoglobin was higher for the leg than for the arm (\( F_{1,9}=5.372 \) \( P=0.046 \)). The results indicated that arm or leg exercise at the same relative sub-maximal exercise intensity produces a similar degree of physiological strain in two types of exercise in most of the factors except higher blood pressure in arm and higher mean corpuscular hemoglobin in leg exercise.

Key words: arm cranking; cardiovascular factors; ergometer cycling; hematological factors; red blood cell indices.

Introduction

The complexity of responses of cardiovascular system to different body activities in both athletes and non-athletes are important. During exercise some factors such as heart rate, VO2max, the volume of blood pumped per beat are increased (Meyer and Sterling, 2000). In addition exercise results in increase of stroke volume because of diastolic volume increments and systolic volume reduction because of stronger contraction of heart muscles. VO2max increase is mainly due to increase in cardiac output and slight increase in arteriovenous oxygen difference (a-Vo2 diff) (Stephen et al, 2004). Several studies indicate that metabolism increased during exercise and caused changes in blood composition; for example RBC indices including number of red blood cells, hemoglobin (Hgb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) altered (Amir Sasan and Saraf, 2000). The amount of these changes during exercise can be varying in different organs. Dynamic exercise in upper body, which include fewer muscle mass compared with lower body, cause particular cardiorespiratory responses, whilst studies indicated that during exercise with arm cranking oxygen consumption during
Materials and Methods

Subjects:
Following informed written consent ten healthy females (age 25 ± 2.69 year, height 161.75 ± 5.5 cm, weight 56.35 ± 6.1 kg, mean ±SD) participated in the study. The study was approved by the ShahidBeheshtiUniversity Ethics Committee. All of the participants had no history of cardiovascular or respiratory disease and not engaged in physical activity classes for the recent year. The type of research is semi-experimental with pretest-posttest design.

Determination of Vo2max on arm-crank and cycle ergometer:
Subjects in two spate days performed incremental cranking and cycling tests to volitional exhaustion. The arm cranking protocol was consisted of warm-up without any resistance for 3 minutes, and then the load increased 15 watts every 2 minutes with a speed of 85 rpm. Bicycle ergometer protocol was 3 minutes warm-up with 25 watts resistance and then load increased 25 watts every 2 minutes for 3 steps, afterwards 50 watts was added with 60 rpm speed every 2 minutes until subjects unable to continue. Changes in respiratory gases and heart rate were recorded by gas analyzer.

Sub-maximal exercise for arm cranking and bicycle ergometer:
Subjects became familiar with testing protocol and rhythm of exercise with metronome. Then they performed cycling and stretching as warm-up. Exercise protocol for both arm cranking and cycling set at 70 percent of Vo2max and last for 30 minutes. The rate of exercise was 70 and 80 rpm for arm and leg respectively. During exercise resistance increased gradually to reach the defined level (70% Vo2max).

Procedure:
Subjects performed 4 sessions of Vo2max test and exercise protocol with one week between each session. In 2 sessions Vo2max was determined for both cranking and cycling and the 2 others were performing sub-maximal protocol. The tests orders were randomly designed. At first subjects were familiarized with correct pedaling on arm cranking and cycle ergometer. The subjects were instructed to have the same meals and complete sleep the day before the test and not to perform physical activity 48 hours before the experimental sessions. At the test days they asked to eat breakfast 2 hour before beginning of the session. They were not allowed to drink water or any other drinks throughout the test. It should be noted that measurements were taken in the exercise physiology laboratory of ShahidBeheshti University. The mean temperature of the lab was 21°C. All the subjects were in the lab for the same time period (from 8 to 10 am) in order to perform exercise protocols. Firstly subject's height and weight were measured and they were asked to rest in seated position and then heart rate, body temperature, blood systolic and diastolic pressure were measured and the first blood sample was taken. Before the exercise protocol each subject did warm-up by steady-state, heart rate, ventilation and general blood pressure are higher than cycle ergometer (Miles et al., 1989; Pendergast, 1989 and Toner et al., 1983). Marais et al (2002) studied cardiorespiratory and efficiency responses during exercise with arm-cranking and cycle ergometer (with spontaneously chosen pedal and crank speed) on 12 trained male and compared upper and lower body responses in 20, 40, 60 and 80 percent of maximal power output and passive recovery periods. They found that VO2 and ventilation (VE) were significantly higher but there were no significant difference in HR between two types of exercise (Marais et al, 2002). While Volianitisand Secher (2002) studied arm blood flow and metabolism during arm and combined arm-leg exercise in 10 healthy non-athlete men. Subjects performed arm cranking at 80% of maximum arm work capacity and combined arm cranking with cycling at 60% of maximum leg work capacity. Results showed that VO2, mean arterial blood pressure and arm blood flow during arm cranking and HR and a-v O2 diff during combined exercise were higher (Volianitis and Secher, 2002). Biancotti et al (1992) also measured red blood cell indices (hemoglobin concentration and hematocrit) in a group of male athletes of different sports and found that there is no significant difference in these parameters between groups (Biancotti et al, 1992). Totally in spite of previous work on upper and lower body responses to exercise there is a conflict between findings so there is a need for more research on this issue. Thereupon the aim of this study was to compare the effects of arm and leg exercises on cardiorespiratory and metabolic factors, in other word to identify the different effects of exercise with cycle ergometer and arm cranking on cardiorespiratory and metabolic factors such as blood pressure, heart rate and red blood cell indices (number of red blood cells, Hgb, Hct, MCV, MCH and MCHC).
pedaling and stretching. Afterward subjects performed defined sub-maximal protocol on bicycle ergometer or arm cranking. Immediately after protocol and 30 minutes after passive recovery second and third blood samples were taken. It should be noticed that related data of each subjects recorded.

Statistical analysis: Data analyzed using SPSS software (V.15). At first kolmogorov-smirnov test was used to assess normality of data. ANOVA repeated measure used to compare the effects of two types of exercises and then Bonferroni post hoc test used to determine the differences. Significant level was set at \( P \leq 0.05 \).

**Results**

![Figure 1: blood pressure for cycling ergometer and arm cranking.](image)

* Significant difference between before, after and recovery for each exercise.
£ Significant difference between two type of exercises (\( p \leq 0.05 \))

![Figure 2: mean corpuscular hemoglobin for cycling ergometer and arm cranking](image)

£ Significant difference between two type of exercises (\( p \leq 0.05 \))


Table 1: cardiovascular, hematological and metabolical factors before, after and recovery for both exercises

<table>
<thead>
<tr>
<th></th>
<th>Before exercise</th>
<th>After exercise</th>
<th>recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of red blood cells (ml³)</td>
<td>Bicycle ergometer</td>
<td>4.45±0.34 *</td>
<td>4.55±0.35*</td>
</tr>
<tr>
<td>hemoglobin (Hgb) (g/dl)</td>
<td>Bicycle ergometer</td>
<td>12.64±1.02</td>
<td>12.82±0.91</td>
</tr>
<tr>
<td>hematocrit (Hct) (%)</td>
<td>Bicycle ergometer</td>
<td>38.02±2.49*</td>
<td>38.93±2.85*</td>
</tr>
<tr>
<td>mean corpuscular volume (MCV) (fl)</td>
<td>Bicycle ergometer</td>
<td>88.41±4.24*</td>
<td>88.29±4.36*</td>
</tr>
<tr>
<td>mean corpuscular hemoglobin (MCH) (pg)</td>
<td>Bicycle ergometer</td>
<td>29.03±2.85£</td>
<td>29.05±2.67£</td>
</tr>
<tr>
<td>mean corpuscular hemoglobin concentration (MCHC) (g/dl)</td>
<td>Bicycle ergometer</td>
<td>33.02±2.34</td>
<td>33.00±4.36</td>
</tr>
<tr>
<td>Heart rate (beat/min)</td>
<td>Bicycle ergometer</td>
<td>79.40±7.48*</td>
<td>109.00±12.37*</td>
</tr>
<tr>
<td>Blood pressure (mmHg)</td>
<td>Bicycle ergometer</td>
<td>96.30±8.08£</td>
<td>107.50±1131*</td>
</tr>
<tr>
<td>Lactate (mmol/l)</td>
<td>Bicycle ergometer</td>
<td>2.42±0.42*</td>
<td>3.42±0.59*</td>
</tr>
</tbody>
</table>

* Significant difference between before, after and recovery for each exercise.
£ Significant difference between two type of exercises (p≤0.05)

Results showed that there is a significant difference for heart rate (p=0.59, F₁,₀ =0.306), lactate (p=0.16, F₁,₀ =2.5), red blood cell (p=0.221, F₁,₀ =1.7), hemoglobin (p=0.11, F₁,₀ =3.13), hematocrit (p=0.798, F₁,₀ =0.076), mean corpuscular volume (p=0.59, F₁,₀ =0.315) and mean corpuscular hemoglobin concentration (p=0.075, F₁,₀ =4.05) (table 1).

Cardiovascular and metabolic factors are not significantly different in the same relative intensity of arm and leg exercises but in two parameters significant difference was observed between two types of exercise, blood pressure (p=0.013, F₁,₀ = 9.385) and mean cellular hemoglobin (p=0.046, F₁,₀ =5.372) (graph 1and 2). Results showed that time were an important factor in response of variables (p≤0.05). Therefore Bonferroni post hoc test has been used and significant difference was observed in all parameters before and after exercise except hemoglobin (p=0.06, F₂, 16= 3.18) and mean hemoglobin (p=0.378, F₂, 16=0.909) (table 1).  

Discussion and Conclusion  

The results of this study revealed that there is no significant different between two type of exercises for hematological and metabolical factors. These findings are consistent with Martel et al (1999), Marais et al (2002) and Protas et al (1996) studies. But not consistent with results of Toner et al (1983), Leicht et al (2008), Eston et al (1986), Shiomi et al (2000) and Tulppo et al (1999). Various level of physical and physiological fitness of subjects can be the reason for different results in these studies with ours. Subjects in most of the above investigations were athletes and had high level of fitness. Shiomi et al research (2000) showed that since more muscle mass engage during bicycle ergometer compared with arm cranking, thus Vo₂max is higher during exercise on bicycle ergometer but Vo₂ is higher in arm cranking exercise. This difference is prominent in high intensities but slight in low intensities. The reason of this response is related to lower mechanical efficiency of muscle.
contraction in cranking exercise that resulted in higher heart rate (Shiomi et al, 2000). Results of this study about the effect of one session of bicycle ergometer and cranking exercise on blood pressure indicate that there is significant difference between two types of exercises. During exercise on cranking, blood pressure increased much more. Also findings revealed that there is significant difference between time of measurement for blood pressure, which the difference is significant between before and after exercise and after exercise and recovery period. Results of the researches of Miles et al (1989), Pendergast et al (1989), Valiantis et al (2002), Grouke et al (1993) and Miles et al (1993) also demonstrated higher blood pressure during arm cranking compared with bicycle ergometer that is consistent with this study. The possible mechanism for this phenomenon is likely to be sparse vascular network and less muscle mass in hand compared with foot, thereupon there is much more peripheral resistance against blood flow so during such exercises blood flow to arms needs greater peak of systolic pressure. Obviously this kind of exercises (cranking) causes higher pressure on cardiorespiratory system because the heart work increased noticeably. The other result of our research was a significant difference between three times of blood lactate measurement (before, after exercise and recovery period) for both exercises. Also when the effects of both time and type of exercise were analyzed simultaneously there was no significant difference too. From these findings it is concluded that in the same relative intensity lactate level did not differ meaningfully in two types of exercises. Although the results of this study is consistent with the investigations of Scheneider et al (2002) but it has some discrepancy with reports of Aminoff et al (1997), Louherara et al (1990) and Aminoff et al (1998). It can be concluded from previous studies that training which utilized small muscle groups are limited by environmental factors and local fatigue, while training which used large muscle groups are limited by factors related to central circulation and as a result lactate level is higher in exercise with less muscle mass because of less efficiency (Aminoff et al, 1996; Mayo et al, 2001; Secher and Volianitis, 2006). This case show metabolic properties of type Π muscle fibers and the point that these fibers are used more than others in arm exercises compared with leg ones, thus higher lactate during arm cranking is related to type of active muscle mass. Workload during exercise on arm cranking will be apply on smaller number of muscle fiber compared with exercise on bicycle ergometer, so metabolic stress on muscle fibers is higher. It is also possible that increased metabolic and energetic stress prepared through carbohydrate oxidation. So it seems that during exercise with cranking carbohydrate oxidation is higher (Mayo et al, 2001; Secher and Volianitis, 2006). Moreover during exercise with cranking more muscle tension will be produced compared with bicycle ergometer and as a result muscle fibers type Π are used more. Since muscle fiber type Π has more glycolytic and low oxidative capacities, more lactate is produced during exercise with arm cranking (Aminoff et al, 1997). Aminoff et al (1998) showed that physiological stress is higher in similar relative workload during exercise on cranking compared with bicycle ergometer (Aminoff et al, 1998). Thus workload must be lower for arm cranking in order to obtain same results with others in the effects of physical activity, levels of physiological fitness and gender of subjects, because in our study inactive females participated as subjects whereas in the past research usually subjects were active men. Perusing results showed that the number of red blood cells increased significantly as a result of one sub-maximal aerobic exercise session and decreased in recovery period, whilst this result is also true about hematocrit. Whereas mean cellular hemoglobin increased but in recovery period its decrease was not significant. The reduction in mean corpuscular hemoglobin concentration as a result of exercise is negligible but about corpuscular volume it is significant. Finally there is no significant difference in red blood cell indices (except mean cellular hemoglobin) between two types of exercises. Some of researches compared hematological factors in the athletes who trained regularly. Schumacher et al (2002) observed fewer amounts of red blood cells, hemoglobin and hematocrit in endurance athletes compared with resistance group and combined group (Mayo et al, 2001). While Biancotti et al (1992) found no difference in red blood cell indices in seven different sport groups (Biancotti et al, 1992). Also Schmidt and Promer (2008) surveyed the effect of different types of exercises such as treadmill, arm cranking, bicycle ergometer and running in track on blood volume and blood cells and they didn't observed significant difference between different types of exercises (Schmidt and Prommer, 2008). Desgorces et al (2008) surveyed the effect of two types of upper and lower body exercise on several hematological factors and observed that there is no significant difference between two types of exercise on examined factors except mean cellular hemoglobin (Desgorces et al, 2008). It should be noted that this result is similar to the result of this study. Most reports about changes in mean corpuscular volume mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration after exercise is inconsistent. Amir Sasan reported increase in mean corpuscular hemoglobin concentration, decline in mean corpuscular volume, and the amount of red blood cells, hemoglobin and hematocrit which is not consistent with this study (Amir Sasan and Saraf, 1380). The difference between these studies maybe due to some variations such as;
periodization, type, volume and intensity of exercises, body composition, blood sampling time or other factors. For example Amir Sasan's research was accomplished on professional athletes while the subjects of this research were non-active women. It should be noticed that all of the metabolic activity of body and also blood indices were controlled by neural and hormonal factors and it's not possible to adduced just one process as the reason for increase or decrease in factors. One of the important reasons for rise in producing red blood cells is increase in erythropoietin (Epo) hormone from kidneys and small amount from liver. The main stimulus for Epo production is the amount of available oxygen to meet metabolic needs of body tissues and the increase in body need to oxygen is aerobic activities. Moreover for producing optimum Epo normal function of bone marrow precursor cells and availability of some materials for production of red blood cells and hemoglobin (such as iron, folic acid, vitamin B12 etc) is required.

It can be concluded that single-session exercise has some effects on cardiovascular, metabolical and hematological factors. Significant difference was observed in heart rate, blood pressure, number of red blood cells, lactate level and mean corpuscular volume. But type of exercise has no effect on mentioned factors and just in blood pressure and mean cellular hemoglobin significant difference was observed; which blood pressure is higher during exercise on arm cranking and mean cellular hemoglobin is higher during exercise on bicycle ergometer(Schumacher et al, 2002;Wardyn et al, 2008;Saat et al, 2005; Schumacher et al, 2000).

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Conflict of interest: None

References


