Time-dependent Effects of High Intensity Interval Training on Oxygen Kinetics in Females

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ABSTRACT

Background. Because VO2max doesn’t provide any detailed information about aerobic examinations Oxygen Kinetic is used for more accuracy. Long intensive and repetitive exercises with sufficient time lead to increase in aerobic parameters like kinetic absorption of oxygen.

Objectives. The purpose of this study was to determine time dependent effects of short-time high intensity interval training (HIIT) on oxygen kinetics in females.

Methods. Forty active and healthy students (age: 25.5±5yr) were randomly allocated to one of four groups: H1, which performed one session HIIT (with 120% Vo2 max intensity for 1 minutes and 1 minutes active break for 8 times); H2, which performed two session HIIT; H3, which performed four session HIIT; and a control group (CON). Both exercise and control groups performed the incremental test (initially the work load was 50 watts and after every 4 minutes adding 30 watts and 1 minute active break for recovery) on the ergometer bicycle. After 2 days of pretesting, training groups participated in 1, 2 and 4 session HIIT (with 120% of their Vo2max intensity for 1 minutes and 3 minute active breaks for 8 times). Two days after the completion of the exercise protocol, post-test accordingly pretest was used by control and exercise groups. Result was measured by gas analyzer to breath-by-breath method.

Results. The findings showed that 1 session HIIT had no significant effect on oxygen kinetic factors (Vo2max, oxygen deficit, time constant 1 and 2) (p>0.05). Two sessions HIIT significantly improved some of oxygen kinetic factors (Vo2max, oxygen deficit, time constant 2) (p<0.05), but had not significant effect on time constant 1 (p>0.05). In addition, 4 sessions HIIT, significantly associated with improvement in all of oxygen kinetic factors (Vo2max, oxygen deficit, time constant 1 and 2) (p<0.05).

Conclusion. It seems that 4 sessions HIIT is the at least time for improvement of all oxygen kinetic factors.

KEY WORDS: High Intensity Interval Training, Oxygen Uptake Kinetic, Aerobic Fitness.

INTRODUCTION

Physical inactivity increases the risk of cardiovascular disease, diabetes, osteoporosis, obesity and psychological problems. Regular physical activity leads to cardiovascular-respiratory health and reduces risk of cardiovascular diseases like heart attacks. Physical fitness is one of the key factors in healthy human life that can be one of the strongest predictors of health status in the future. Because cardio-respiratory strength is considered as an essential part of physical fitness (10). Physical and motor preparedness are significant whether for normal individuals or athletes. Physical activity is beneficial in preventing and
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Measuring maximum oxygen consumption (VO\textsubscript{2max}) is a simple method to determine aerobic preparedness (19). Moreover, VO\textsubscript{2max} is the most important success in endurance trainings (26). Because VO\textsubscript{2max} doesn’t provide any detailed information about aerobic examinations. Oxygen Kinetic is used for more accuracy. Training and exercising can be used for improving maximum consumed oxygen (VO\textsubscript{2max}) and life quality by people who have heart failure disease (28). Long intensive and repetitive exercises with sufficient time lead to increase in aerobic parameters like VO\textsubscript{2max}, exercise economy, Lactate threshold and kinetic absorption of oxygen (22). In this study the importance of kinetic or kinetics of oxygen consumption (pattern of abrupt increase of consumed oxygen in beginning of activity until it reaches the uniform level) in comparison with other aerobic parameters for determining differences of athletic performance—especially in postponing muscle fatigue—is surveyed. Because quick access to needed oxygen for competition especially for endurance athletes not only reduces accumulation of metabolites (reduce in oxygen volume fraction) but also because of limited anaerobic energy for later use in competition (at the end of sprint running race) is considered as an important factor (2). Volume of consumed oxygen in a direct measurement of cellular respiration and energy cost is essentially produced by heart output and oxygen absorption in cellular level. Change in VO\textsubscript{2} when moving from rest to exercise is defined as kinetic oxygen absorption (23). Oxygen kinetic response to exercise provides thorough information about cardio-respiratory responses to metabolic changing (24). The oxygen absorption kinetic measures time needed for adaption with metabolic load changes (for example, change from rest to maximum exercise). Also, oxygen absorption kinetic describes changes in related to exercise VO\textsubscript{2} response and is an indicator for measuring cardiorespiratory fitness (25). The oxygen kinetic can be measured by breath to breath VO\textsubscript{2}. On the other hand, traditional methods report basic VO\textsubscript{2} average and essential details. In addition, oxygen kinetic lets gas samples to be measured faster than 20m/s (meter per second) and their volume to be measured exactly. In general, oxygen cost is linearly related to exercise intenseness (24). By the way, oxygen kinetic may change in response to different exercises (23, 24, 27). High-Intensity Interval Training (HIIT) is a kind of exercise that can be used by elite athletes as well as untrained people (21). HIIT is consists of high intensity exercises with time intervals between levels. Therefore, exercises with small duration are tools that can be accompanied by training protocols in order to improve compatibility time procedure for untrained people (21). One of HIIT advantages is that it results in useful results as well as time saving (31). Studies show that intense exercises in small duration are strong exciter for increasing mitochondrial metabolic enzymes, buffering capacity of muscle, fat oxidation in the body and aerobic capacity (6). Moreover, comparing low intensity endurance training and HIIT shows similar adaptation in oxidation potential and oxygen kinetic (30). In addition, evidences proof that HIIT exercises probably leads to oxygen absorption kinetic and aerobic metabolisms (8, 11). Thus, HIIT exercises in a small period of time increases muscle oxidation enzymes (citrate synthase and pyruvate dehydrogenase) (5). All in all, knowing time procedure of initial adaptation may give us a better understanding of relation between biochemical and physiological responses to exercise which possibly can be effective in exercise programming and scheduling. Despite the importance of HIIT in improving aerobic capacity and athletes preparation, changes in oxygen kinetic in response to repetitive high-intensive training are not yet determined based our knowledge about time course (time procedure). Therefore, the present study aimed to determine effects of time-dependent oxygen absorption kinetic to HIIT in females.

MATERIALS AND METHODS

Participants. This study is a quasi-experimental study with pre – pos test outline which its subjects are selected from physical education students of Arak University, Iran. After knowing the essence of research, students gave consent to participate in the study. All subject students were healthy and physically

active and they were not under medication or any special diet. Sampling method was accessible method that based on study history 40 people was selected. Descriptive information about age, height, weight, and body mass index for all of both groups students are provided in Table 1.

Table1. personal specification of research participants (Mean± SD)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Exercise</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>24.8±5.5</td>
<td>24.6±5.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.5±10.234</td>
<td>160.5±10.192</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.3±10.390</td>
<td>47.5±20.124</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>20.10±6.8</td>
<td>21.60±6.87</td>
</tr>
<tr>
<td>Body mass index</td>
<td>24.35±3.05</td>
<td>24.02±4.91</td>
</tr>
</tbody>
</table>

Study Design. The research consists of following steps: 1) two introduction sessions for ergometer, 2) pre-test, 3) one, two, and four sessions of intensive periodic exercise, and 4) post-test.

Maximal Exercise Testing. Subjects were divided into two groups of active and control randomly. Also training groups were divided into three groups of 10 people randomly which each group do one (H1), two (H2), and four (H4) session of interval high-intensity training respectively. In control group there were 10 sample students which they were asked to maintain their normal lifestyle during research period.

In the first test session the participants took part in an exercise accelerating program to maximize ergometer bike (Monark Model 894, is made in Sweden) to exhaustion. During the test run the data was gathered through a spirometer (gas analysis cosmed model made in Italy) and breath to breath method of oxygen kinetic intake variable. Device interpretation was according to calculation of the oxygen consumption and carbon dioxide production using the face mask.

The protocol of increasing sport test was in such a manner that the participants were asked to warm up themselves for 4 minutes with zero watt and 60 rpm speed(figure1). Then the main activity was started at 50 watts that was 4 minutes rest after each training session. This process adds 30 watts workload until exhaustion according to the physical fitness of participants (31).

Training schedule. Training started two days after the initial testing. It included one, two and four intense periodic accelerating training session with one day between training. The exercise protocol was divided into two phases: active rest and exercise at high intensity. At the beginning of each session, the participants warmed up themselves for five minutes. Then, for a minute at 120% of maximum oxygen consumption pedaled.

During the rest phase pedaling continued for three with a very low rate. The cycle of activity and rest repeated for eight times on an electric bicycle ergometer (Monark) (31). During training instructor encouraged participants to improve their performance orally, 48 hours after the exercises, post-test was repeated as pre-test phase.

Data Analysis. Oxygen kinetic response was investigated with a nonlinear exponential parametric formula based on breath to breath method (6).

\[ \text{Vo2b : vo2 baseline} \]
\[ \text{t : time} \]
\[ \text{T: Time constant} \]
\[ \text{a : amplitude} \]
\[ \text{e :2.71} \]

In this way, the pressure gradient pulses of oxygen and carbon dioxide illustrates the oxygen kinetic response data on a two-dimensional diagram of liters per minute (6). The kinetics of oxygen for each subject includes 3 phases, in which the first phase represents anaerobic power. Metabolic needs and oxygen is provided through phosphocreatine. T1 is the first time constant, represents the required time to reach 66 of oxygen kinetic response in the first phase, the less this number the more the aerobic power.
After the first phase, the oxygen kinetics enters the second phase which is regarded as the beginning of the use of aerobic system as a substrate. T2 is the second time constant which represents the required time to reach 66% of oxygen kinetic response in the second phase, the less this number the more the anaerobic power.

After the second phase, the oxygen kinetics enters the third phase which and it was not possible to measure the related factors of this phase as well as slow component, Fig 2, (21).

Fig 2. Oxygen kinetic response to training.

**Statistical Analysis.** After confirming normal distribution of data by using Kolmogorov-Smirnov, the effect of the independent variable on the dependent variables (comparison before and after the test in each group) of two-way ANOVA and Tukey's test was applied to differences between research groups. Data are presented as mean ± standard deviation. Statistical analysis was performed by software SPSS20 at significant level P<0.05.

**RESULTS**
Comparing the pre-test and post-test measures oxygen uptake kinetics of training groups is represented in Tables 2, 3 and 4.

At the beginning there was no significant difference in demographic characteristics and indicators of the kinetics of oxygen uptake between groups (P>0.05). It was observed that one day periodic training has no effect on kinetic parameters such as maximal oxygen uptake, the first time constant (T1), the second time constant (T2) oxygen fraction (P>0.05) (Tables 2, 3 and 4). On the other hand it was observed that two session of intense periodic training leads to increased maximal oxygen uptake and decreased the second time constant (T2) and the oxygen fraction (P <0.05) (Tables 2, 3 and 4).

| Table 2. Maximal oxygen uptake (milliliter per minute) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Group           | Pre-test        | Post-test       | Mean Difference | p               |
| H1              | 1603±252        | 1536±258        | 48              | 0.1             |
| H2              | 1840±103        | 2329±101        | 109             | *0.012          |
| H4              | 1848±51         | 2338±42         | 137             | *0.001          |
| p               | 0.78            | 0.012           |                 |                 |

**H1**: One session of intense interval exercise. **H2**: Two session of intense interval exercise. **H4**: Four session of intense interval exercise.

| Table 3. First time constant (seconds) |
|-----------------|-----------------|
| Group           | T2              |
| H1              | 2329±101        |
| H2              | 2338±42         |
| H4              | 2338±42         |

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Table 4. Oxygen fraction (milliliter per second)

<table>
<thead>
<tr>
<th>Index Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Mean Difference</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>5±36.4</td>
<td>35.5±2</td>
<td>0.7</td>
<td>0.78</td>
</tr>
<tr>
<td>H2</td>
<td>35.5±5</td>
<td>29.4±3</td>
<td>3.59</td>
<td>*0.03</td>
</tr>
<tr>
<td>H4</td>
<td>31.4±4</td>
<td>19.7±4</td>
<td>7.8</td>
<td>*0.008</td>
</tr>
<tr>
<td>p</td>
<td>0.84</td>
<td>0.033</td>
<td></td>
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</tr>
</tbody>
</table>


Two intense of interval training session had no significant impact on first time constant (T1) no (P>0.05) (Table 4). In addition, after four intense interval training session there was a significant increase in maximum oxygen consumption (P <0.05) and the fraction of oxygen, the second time constant (T2) and the first time constant (T1) significantly decreased (P <0.05) (Tables 2, 3 and 4). The comparison of the mean difference shows the effectiveness of 4 session intense interval training sessions with respect to the other research groups in all indicators oxygen kinetics (P<0.05) (Tables 2, 3 and 4).

DISCUSSION AND CONCLUSION

The oxygen kinetic response to training provides comprehensive information to about cardiac-breathing mechanism in continue to cardiovascular metabolic. Oxygen kinetic response determination is a non-invasive method and have practical usages for the experts in trainings, including the understanding of the physical fitness of athletes. On the other hand HIIT trainings has been considered by researchers and coaches due to their effectiveness. High intensity interval training (HIIT) are infinitely variable and the compatibility of this practice are determined by numerous factors including the exact nature of sport stimuli (intensity, duration and number of performances interval, duration and recovery time) (43).

Athletes try a lot to achieve good results with the minimal investment and time in this training, so HIIT training can be important in this respect (20). However, few studies have examined the effects of HIIT exercise kinetics of VO2 during transition to sport.

Little and colleagues introduced the effectiveness of HIIT exercise on the oxygen kinetics due to increasing oxidative enzymes such as citrate synthase, protein COX4 (leading to more duplication out of mitochondria) and also activate PGC 1 as the main regulator mitochondrial biogenesis in muscle (32).

Showerman et.al investigated the effect of HIIT exercise on the oxygen kinetics of cyclist. The training exercise compromised of ten repetitive one minute activity (with 110 percent of maximum oxygen consumption) and one minute of active rest. The found that the second time constant and the oxygen fraction of participants is significantly decreased following the interval exercise.

McKee and Associates in 2009 also concluded that 4 session of HIIT significantly increased VO2max and oxygen fraction with 35 percent decline in second time constant. But,
there was no significant change in the first time constant, except the first time constant that it was contrary to the study, the other factor of the study are similar to others (8). Perhaps the discrepancies between time constants in the results of differences between sexes, races of the genome (29) or the training procedure and evaluation of the kinetics of oxygen (including testing on a bicycle ergometer or treadmill) (16) . Evidence believe that intense interval training is to improve the anaerobic system (7).

In the oxygen kinetic curve the first time constant represents the anaerobic system and release of energy from phosphocreatine. At the beginning of aerobic exercise the required oxygen of muscles cannot be provided through aerobic. So this time featured the anaerobic system (7). HIIT training can increase the anaerobic enzymes such as myosin kinase and creatine kinase (the synthesis of creatine phosphate) (12). HIIT training leads to significant reduction in lactate accumulation, H+ and an increase monocarboxilat and decrease in acidity and improve in the recovery process (17). Taken together, these factors are associated with a decrease in the first time constant (12).

The findings of this study suggest that the 4 session of intense interval training is the minimum required time to recover all the kinetic parameters of oxygen (aerobic and anaerobic) and 2 intense interval training session is the minimum required time to improve the effective indices in the in the oxygen kinetics of aerobic systems (including VO2max, the second time constant and oxygen fraction) and 1 intense interval training session has no effect on the kinetics of oxygen.

In these studies, the effects of HIIT training to improve aerobic capacity and increase oxidative enzymes and fat burning is supported (4, 7, 8, 9, 15). But based on our knowledge of (time course) and the minimum time interval changes the kinetics of oxygen in response to intense exercise is not yet known. In this study, it was found that one session of intense interval training increases maximal oxygen uptake, but this increase is not significant, while has no effect on the indices of kinetics of oxygen including oxygen fraction, the first time constant of the and second time constant. As the effect of one session training is not investigated in oxygen kinetics (VO2Max, Oxygen Fraction and the first and second time constant) of the girls, the finding of this research cannot be compared with the findings of same researches. But is in line with the researches done on boys.

In this regard, Zenotca and colleagues have shown that interval training session with an intensity of 110% of maximum oxygen consumption (8 repetitions in one minute) has no significant effect on maximal oxygen uptake and oxygen deficit (13), which is consistent with the findings of the present study.

On the other hand, following two session of interval exercise in this study, the maximum consumed oxygen increased and the oxygen fraction and second time constant decreased, but there was no effect on the first time constant. In the research of Carselli and Melinda in 2005 two session of interval training had significant effect on the oxygen kinetics of the girls with no significant effect on the first time constant.

McKee et al (2009) investigated the effect of intense interval training on the kinetics of oxygen for 20 active men and the training protocol was quite similar to this study. Their most important finding was that after 2 exercise session, the second time constant and oxygen fraction all decreases 20 percentage with respect to previous one, while maximum oxygen consumption goes up. In addition, after 2 sessions, there was no significant change in the first time constant (31). In fact, the findings of this research are similar to that of the present study.

In addition, in this study we found that intense interval training sessions to improve significantly the kinetics of oxygen (VO2max, the first and second time constant oxygen fraction). Because the effects of interval training sessions is not yet investigated of the oxygen kinetics(VO2Max, the first and second time constant oxygen fraction) of the girls, the results of this study in this part cannot be compared with other similar studies. In this connection Habistryt and colleagues in 1998 investigated the effects of HIIT training with an intensity of 100% VO2max effect on children. After 4 sessions of training, participants experienced a significant decrease in the fraction of oxygen and the second time constant (approximately
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30%) and a significant increase in VO2max (about 15%) (20).

Then, in 2000, Baron and colleagues studied the effect of HIIT exercise on oxygen deficit. The results showed that after 4 sessions of exercise at 110% VO2max, the oxygen fraction is reduced by 35%, in which the related mechanism was attributed to a decrease in lactate and better in the muscle buffering (31). It is suggested that following the HIIT training and secretion of adrenaline, fat burning become greater and faster, anaerobic glycolysis and carbohydrate substrate is delayed and the time to reach the same stage is reduced and all reducing the oxygen fraction.

APPLICABLE REMARKS
- Probably 4 session of intense periodic training is the minimum required time necessary to improve all indices of kinetics of oxygen.
- Two intense interval training session is the minimum required time to improve the kinetics of oxygen in the aerobic system (VO2max, oxygen deficit, the second time constant) of the girls.
- One intense interval training session has no effect on the kinetics of oxygen.

REFERENCES

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