EFFECTS OF 40 % OXYGEN SUPPLEMENTAL DURING RECOVERY PERIOD OF REPEATED EXERCISE BOUTS ON RATE OF RECOVERY

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ABSTRACT

The purpose of this study was to investigate the effect of breathing oxygen gas during the recovery period of repeated exercise bouts on the rate of recovery. Twelve healthy male volunteers, aged 18-23 years, were recruited for the study. The exercise periods consisted of two bouts of 5-min each (R_1, R_2) in which the participants used a cycle ergometer, followed by a single bout to exhaustion (R_3). Intervals of exercise were separated by a 4-min recovery period during which the subject breathed either 1) room air (21% oxygen), or 2) 40% oxygen on two non-consecutive days. The rate of recovery was indicated by blood lactate concentration (BLC), heart rate (HR), hemoglobin oxygen saturation (S_aO_2), and rate of perceived exertion (RPE), which were measured at rest, immediately after exercise, and at two, four, and six minute interval (T2, T4, T6) after exercise cessation. Time to exhaustion (t_{exh}) was also measured

The results showed that there was no significant difference in the BLC and HR when compared between 40% O_2 recovery and room air (21% oxygen) recovery. S_aO_2 at T4 and T6 was significantly higher when 40% O_2 was administered than when room air (21% oxygen) was administered. The RPE at T4 was significantly lower when 40% O_2 was administered than when room air (21% oxygen). Finally, there was no significant difference in the time to exhaustion when compared between 40% O_2 recovery and room air recovery (21% oxygen).

In summary, supplemental oxygen during the recovery period of repeated exercise bouts activity failed to have any effect on physiological variables. Performance was not enhanced, nor was any subjective relief demonstrated. The results of this study indicate there is no scientific basis for the use of supplemental oxygen in speeding up the recovery or improving subsequent performance in healthy individuals.

KEY WORDS : OXYGEN SUPPLEMENTAL / BLOOD LACTATE CONCENTRATION
OXYGEN SATURATION / RECOVERY / EXERCISE

79 pages

ผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว

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บทคัดย่อ

การศึกษาวิจัยครั้งนี้มีวัตถุประสงค์เพื่อศึกษาถึงผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว กลุ่มตัวอย่างในการวิจัยเป็นนักศึกษาเพศชายสุขภาพดีจำนวน 12 คน อายุระหว่าง 18-23 ปี ให้ออกกำลังกายโดยถีบจักรยานวัดงานที่ระดับความหนัก 70% VO_2peak โดยแบ่งเป็น 3 ช่วง คือ ช่วงที่ 1 (Ex_1) และ 2 (Ex_2) เป็นเวลา 5 นาที และช่วงที่ 3 (Ex_3) ปั่นที่ระดับความหนัก 70% VO_2peak และเพิ่มความหนัก 25 วัตต์ ทุกๆ 2 นาที ปั่นจนกระทั่งผู้เข้ารับการทดลองหมดแรงหรือไม่สามารถปั่นต่อได้ โดยในช่วงเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วง กลุ่มตัวอย่างนั่งพักบนจักรยานวัดงาน และมีกิจกรรมขณะพักแบ่งออกเป็น 2 รูปแบบ คือ แบบที่ 1. ให้นั่งพักตามปกติ และแบบที่ 2. ให้หายใจด้วยออกซิเจน 40 % วัดตัวแปรที่เกี่ยวข้องกับอัตราการฟื้นตัว ได้แก่ ความเข้มข้นของกรดแลคติก, อัตราการเต้นของหัวใจ, ความอิ่มตัวออกซิเจนของฮีโมโกลบินและค่าระดับความเหนื่อย วัดทันทีภายหลังการล้า (T0) และในนาทีที่ 2, 4 และ 6 (T2, T4, T6) รวมถึงบันทึกระยะเวลาตั้งแต่เริ่มออกกำลังกายจนหมดแรงโดยเริ่มบันทึกตั้งแต่เริ่มการออกกำลังกายในช่วงที่ 3 (Ex_3) จนกระทั่งผู้เข้ารับการทดลองหมดแรงหรือไม่สามารถปั่นต่อได้

ผลการศึกษาพบว่า เมื่อวิเคราะห์ความเข้มข้นของกรดแลคติกในเลือดและอัตราการเต้นของหัวใจของทั้งสองกลุ่มพบว่าไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ปริมาณออกซิเจนที่ละลายในเลือดในกลุ่ม 40 % ออกซิเจนในนาทีที่ 4 และ 6 มีค่าสูงกว่าอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับกลุ่มนั่งพักตามปกติ ดัชนีความเหนื่อยในกลุ่ม 40 % ออกซิเจน ในนาทีที่ 4 มีค่าต่ำกว่าอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับกลุ่มนั่งพักตามปกติ และระยะเวลาตั้งแต่เริ่มออกกำลังกายจนหมดแรงของทั้งสองกลุ่มพบว่ามีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) จากผลการวิจัยสรุปได้ว่า การให้ออกซิเจนที่ความเข้มข้น 40 % ในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงนั้นไม่มีผลต่อระบบสรีรวิทยาของการฟื้นตัวจากการออกกำลังกายหรือคืนสู่สภาพปกติได้เร็วขึ้น

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LIST OF ABBREVIATIONS

ATP	=	adrenosine triphosphate
ADP	=	adrenosine diphosphate
AT	=	anaerobic threshold
BMI	=	body mass index
bpm	=	beat per minute
cm	=	centrimeter
CaO_2	=	oxygen concentration
CrP	=	creatine phosphate
CO_2	=	carbon dioxide
Ex_1	=	first exercise period
Ex_2	=	second exercise period
Ex_3	=	third exercise period
F_IO_2	=	fractional inspired oxygen content
H_2O	=	hydrogen oxide
HR	=	heart rate
Hb	=	hemoglobin
HR_{max}	=	maximum heart rate
kg	=	kilogram
km	=	kilometer
L	=	liter
LDH	=	lactate dehydrogenase
BLC	=	blood lactate concentration
mmHg	=	millimeter mercury
ml/L	=	milliliter per liter
mmol	=	millimole
$mmol \cdot L^{-1}$	=	millimole per liter
$ml \cdot kg^{-1} \cdot min^{-1}$	=	milliliter per kilogram per minute

LIST OF ABBREVIATIONS (cont.)

NADH	=	nicotinamide adenine dinucleotide
O_2	=	oxygen
P_aO_2	=	arterial partial pressure of oxygen
PC	=	phosphor creatine
RPE	=	rate of perceived exertion
rpm	=	revolution per minute
S_aO_2	=	hemoglobin oxygen saturation
SEM	=	standard error of the mean
sec	=	second
T_{exh}	=	time to exhaustion
VO_2	=	oxygen consumption
VO_{2max}	=	maximal oxygen uptake
W	=	watt
Yr	=	year

CHAPTER I
INTRODUCTION

Introduction

The quest to improve exercise performance has characterized athletic competition throughout history. Improvements in training techniques, clothing, and nutritional practices, as well as new tactics, medical interventions, and used of illegal drugs, all have abetted the drive to win, at what seems to be an eve-increasing cost to tradition, health, moral beliefs, and clear conscience. Not all of these changes are unethical ; for example, the innovations in equipment, such as those seen in cycling, rowing, and skiing, are the result of scientific inventions applied to athletic endeavor to push the limits of human performance.[14]

During short-term intense exercise, muscle contraction largely relies on a high rate of ATP regeneration from the dephosphorylation of creatine phosphate (CrP) and an increased flux of glucose through glycolysis. Potential contributors to muscle fatigue during this type of exercise could be related to muscle energy production, such as decline in the muscle ATP concentration, creatine phosphate depletion, or glycogen depletion. Fatigue could also be related to the production and accumulation of metabolites, such as lactate and acidosis, or it could be related to impaired functioning of the electrochemical events of muscle contraction and relaxation. Finally, there is evidence of a central nervous system contribution to fatigue during intense exercise.[14] Recovery is increasingly recognised as a significant component of athletic training and performance – particularly for elite performers, who expect to engage in very demanding training two or even three times a day. An adequate recovery is known to decrease fatigue, accelerate physiological regeneration, enhance adaptation and (possibly) decrease the risk of injury.

Hyperoxia is defined as an increase in the inspired oxygen (O_2) concentration or excess oxygen in body tissues higher than normal partial pressure of oxygen. Hyperoxia can be administered via autologous blood reinfusion[21,23] , breathing oxygen-rich air (fractional inspired oxygen content (F_IO_2) > (0.2039)[11,15,17,1,26] and exposure to hyperbaria (arterial partial pressure of oxygen (P_aO_2) ~ 500 Torr)[5] However, Oxygen can be harmful at high concentrations. Breathing high concentrations of O_2 (greater than 75%) causes symptoms of hyperoxia which include cramps, nausea, dizziness, hyperthermia, ambylopia, respiratory difficulties, bradycardia, fainting spells, oxygen toxicity and convulsions capable of leading to death[2,24].

Generally athletes have inhaled pure oxygen immediately before an athletic event to better prepare themselves, to improve performance during exercise, and to improve recovery from intense exercise. Pure oxygen is used because of its increased partial pressure relative to oxygen in normal atmospheric air. In many sports, the practical question is whether the breathing of supplemental oxygen during recovery from vigorous exercise hastens recovery or enhances subsequent performance, at least for exhaustive exercise of longer than 1-2 min of duration (Welch, 1982). It is clear that in hypoxia there was a slower response of VO_2 during recovery from exercise (Linnarsson et al, 1974). It is no surprise that research on the use of oxygen during exercise has shown significant increases in VO_2max; oxygen consumption (VO_2) during the initial minutes of intense exercise; and time to exhaustion.[4,7,20] There have been many studies that breathing hyperoxic gas during exercise reduced the burden on the respiratory and circulatory system and prolonged performance[1,9,27]. They discussed that an increase in blood lactate might be delayed or that accumulating speed of blood lactate might be lowered because oxygenation of blood lactate was accelerated by breathing hyperoxic gas more than by breathing air. If blood lactates were effectively reduced by breathing hyperoxic gas during exercise, it could be expected that the same hyperoxic effect could be observed also after exercise. Some studies have indeed detected quicker recovery with post-exercise oxygen intake, but again the subjects knew exactly what they were breathing and might have taken in a psychological boost along with the gas. Overall, it appears that breathing in oxygen after exercise is over has no positive impact on heart rate, ventilation rate, post-exercise oxygen uptake or any known physiological variable associated with recovery. When examined closely, such findings should not be surprising. After all, the post-exercise recovery period is a time frame marked by sub-maximal heart rates and submaximal rates of oxygen consumption. In other words, recovery does not require oxygen delivery to be extremely high, as it is during intense exercise.

Nummela et al. (2001) investigated whether the breathing of hyperoxic gas affects hemoglobin oxygen saturation (S_aO_2) and blood acidosis during intense

intermittent exercise and recovery in sprint runner and founded that hemoglobin oxygen saturation (S_aO_2) occurred during intensive intermittent exercise in normoxia but hyperoxic gas during the exercise prevents S_aO_2 from decreasing. On the other hand, Robbin et al. (1992) to determine whether supplemental oxygen following exercise hastens recovery or enhances subsequent performance and found that breathing 100% oxygen produced no significant difference on the recovery kinetics of minute ventilation or heart rate or improvement in subsequent performance as measured by duration of exercise and peak VO_2. In addition, the perceived magnitude of exertion estimated by the Borg scale was no difference during oxygen breathing.

Maeda and Yasukouchi (1997) investigate effects of breathing hyperoxic gas on blood lactate disappearance after submaximal exercise in two different physical fitness groups and to clarify the most effective oxygen concentration in each group and concluded that the most effective oxygen condition on blood lactate disappearance was obtained over 60% in Higher anaerobic threshold (AT) group and at 30% oxygen in Lower anaerobic threshold (AT) group. Thus, it was especially noteworthy that the beneficial effects of hyperoxic gas in Higher AT group were different from those of Lower AT group.

Supplemental oxygen is frequently used by athletes during recovery from vigorous exercise in the belief that it hastens recovery or enhances subsequent performance. Most previous efforts to determine the efficacy of this practice have been flawed by study designs that neither stimulate intermittent maximal exercise nor control for possible effects. As a result, there have been surprisingly few well-controlled studies evaluating the effect of supplemental oxygen following vigorous exercise upon objective and subjective measures of recovery and subsequent exercise performance.

However, Athletes'test in hyperoxia condition is presently studies in the world according to international widely but there have been only a few studies on the hyperoxia effects during exercise in asia population and previous studies have not provided the evidence that oxygen breathing produces any significant effect on the recovery kinetics it is unclear. Therefore, The hypothesis was that the administration of 40 % oxygen immediately during recovery period of repeated exercise bouts would result in a more rapid recovery, delay blood lactate concentration during the exercise, improved the heart rate recovery after the exercise and prevent S_aO_2 from decreasing. The purpose of present study is to investigate the effect of breathing of oxygen gas

during recovery period of repeated exercise bouts on rate of recovery in healthy male subjects.

Hypothesis

It was hypothesized that the administration of supplemental 40 % oxygen immediately during recovery period of repeated exercise bouts would result in a more rapid recovery from exercise.

Objectives

The objectives of this study are included:

1. To investigate effects of oxygen gas during recovery period on rate of recovery of repeated exercise bouts.

2. To compare the rate of recovery between 40% O_2 and room air during recovery period of repeated exercise bouts.

Advantage of the study

1. To be used as guideline to create appropriate recovery protocol for other exercise using O_2 supplement therapy.

2. To be used as guideline for prospective study in other age group, in athlete or in condition of another exercise during recovery.

The Study designed

This study was designed to investigate the effect of oxygen gas during recovery period on rate of recovery and compare the rate of recovery from different between 40 % O_2 and room air during recovery period of repeated exercise bouts.

The Scope of this study

This experimental study was investigated the healthy male subjects from Sports Science students of Srinakharinwirot University, volunteered for the study. Twelve subjects and age ranging 18-23 years were normal daily activity, all subjects had not difference on age related activities of subjects with relatively normal physical functions.

Paramaters

1. General determinations

1.1. Questionnaires (General health, Physical activities and Exercise)

1.2. The anthropometry and body composition, such as weight (kg), the body mass index (kg. min^{-2}).

1.3. The Physical fitness test : VO_2peak (direct method) for predicted exercise intensity at 70%VO_2peak

2. Specific determinations

2.1. Blood lactate concentration (mmol•L^{-1})

2.2. Heart rate (beat•min^{-1})

2.3. Hemoglobin oxygen saturation (%)

2.4. Rate of perceived exertion (RPE)

2.5. Time to exhaustion (min)

CHAPTER II
LITERATURE REVIEW

The primary concern of this chapter is energy. The sun is the ultimate source of all energy on earth, for it is through solar radiation that carbohydrate are formed in plants. Human and animals eat plants and other animals for food. In the human body, food energy is used to manufacture adenosine triphosphate, or ATP, the chemical compound that, when broken down, supplies energy for muscular contraction and other biological processes.

The production of ATP involves both anaerobic (without oxygen) and aerobic (with oxygen) metabolism (chemical reaction). There are two anaerobic systems: (1) the phosphagen, or ATP-PC system; and (2) anaerobic glycolysis, the lactic acid producing system.

2.1 Energy Sources

2.1.1 Phosphagen system (ATP-PC system)

The phosphagens (ATP+PC, a chemical compound similar to ATP) are stored within the contractile mechanisms of muscle and provide the most rapidly available source of ATP for used by the muscle. Breakdown of ATP to adenosine diphosphate (ADP) release energy for all cellular function, e.g. membrane transport, muscle contraction. PC is broken down to release higher energy, which allows reconstitution of ATP from ADP. Thus, PC can be considered a "reservoir" of high-energy phosphate bonds for cells. Hydrolysis of PC for energy immediately begins at the onset of intense exercise, this process does not require oxygen and reaches a maximum in about 10 seconds (McArdle et al., 2007). This energy system is the major one used for ATP production during high-intensity, short-duration exercise, such as a 40 to 200 meter sprint (Wilmore and Costill, 1994), a 25 m swim, smashing a tennis ball during the serve, or thrusting a heavy weight upward (McArdle et al., 2007). All these short-burst activities utilize ATP and PC from storage pool which will be depleted within 10-20 seconds (Wilmore and Costill, 1994).

2.1.2 Anaerobic glycolysis system

Anaerobic glycolysis releases energy for ATP synthesis through the partial breakdown of carbohydrates (glycogen and glucose) to lactic acid, take place in the cytoplasm (Figure 1). This system can only use glucose, available in blood plasma and stored in both muscle and the liver in term of glycogen. When the amount of oxygen is low, glycogen will be metabolized which produces the end product known as pyruvic acid (also referred to as pyruvate). This acid may be further processed (Figure 2), when oxygen supply to the cell is high, to produce energy in the oxidative pathway (Cerny and Burton, 2001). The major limitation of this energy system is that it produces lactic acid (called lactate in its dissociated form) causes muscular fatigue when it accumulates in the blood and muscles, which is facilitated by a main cytosolic enzyme known as lactate dehydrogenase (LDH). Lactate lowers pH of both the muscle and blood. Once the pH drops below a value of 6.4 to 6.6, enzymes, most of energy producing activities are no longer able to function, and ATP production stops (Willmore and Costill, 1994). Anaerobic glycolysis is the energy system for all-out bouts of exercise lasting from 30 seconds to 2 minutes (Guyton, 1991) and also a major supplier of ATP during high-intensity, short-duration activities, such as sprinting 400 and 800 meters. Activities that depend heavily on the phosphagen system and anaerobic glycolysis are called anaerobic activities (Foss and Keteyian, 1998).

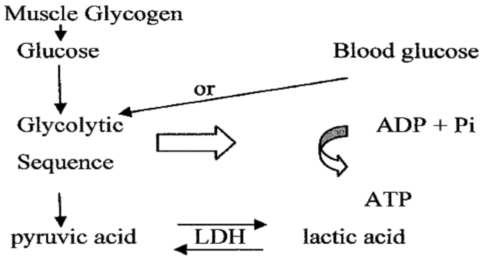

Figure 2.1 Anaerobic glycolysis. Glycogen is chemically broken down by a series of reaction into lactic acid. During this breakdown, energy is released and through couple reactions, is used to resynthesis ATP (Fox et al., 1993).

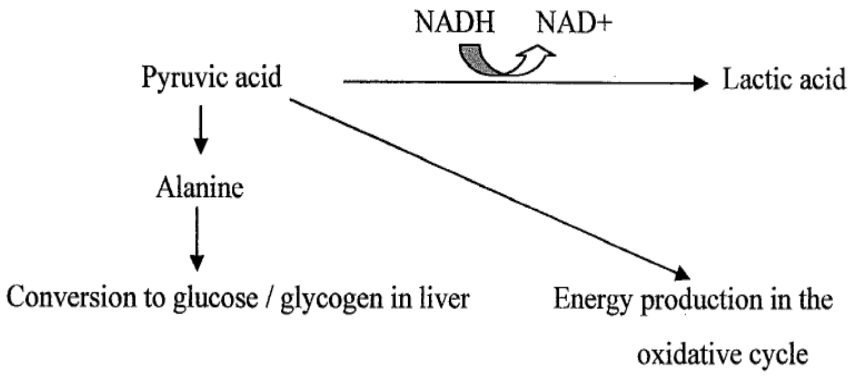

Figure 2.2 The process of pyruvate convertion (Fox et al., 1993).

2.1.3 Aerobic energy system (Oxidative glycolysis system)

The aerobic, or oxygen utilizing system releases energy for ATP production from the breakdown mainly of carbohydrates and fats and sometimes of protein, to carbon dioxide and water. Although the aerobic system yields by far the most ATP, it requires several series of complex chemical reactions. With carbohydrate, in the first series of reactions, called aerobic glycolysis, glycogen is broken down to pyruvic acid; then in the Krebs Cycle, carbon dioxide is produced and electrons, in the form of hydrogen atoms, are removed. In the final series of reactions, hydrogen atoms (electrons) are transported to the mitrocondria, where they combine with the oxygen we breathe; water is formed, and ATP is synthesized. With fats as the fuel, the reactions are the same with the exception of the first series, which is called beta-oxidation and prepares 2-carbon acyl groups to enter the Krebs Cycle. The oxygen system is used during rest and predominates during low intensity, long-duration exercise, such as the marathon. Such activities are called aerobic exercises (Foss and Keteyian, 1998).

2.2 Type of exercise and metabolisms

2.2.1 High intensity, short-duration

This is a type of exercise can be performed for only short periods of time but requires maximal or near-maximal effort. In these types of exercises, the major source of ATP is supplied by the phosphagen (ATP-PC) and anaerobic glycolysis systems (Foss and Keteyian, 1988). Inadequate O_2 delivery generally occurs at the onset of exercise, when the demand foe energy increases remarkable but increased blood flow to the working muscle is delayed (Cerny and Burton, 2001).

During intense exercise to volitional fatigue, blood glucose concentrations are elevated, muscle blood flow is up to near maximal, several substrates of glycolysis have accumulated in muscle, muscle lactate could have increase from 1 to 30 mmol/kg wet weight (Spriet et al., 1989, Medbo and tabata, 1993), whereas blood lactate could have increased from 1-25 mmol/L (Belcastro and Bonen, 1975; Dodd et al., 1984).

2.2.2 Low intensity, long-duration (Prolong exercise)

This exercise, which requires sub-maximal effort, can be performed for relatively long periods of time. In these types of exercises, the major source of ATP is supplied, mainly, by the aerobic system. The anaerobic glycolysis and phosphagen (ATP-PC) systems also contribute, but only at the beginning of the exercise, before oxygen consumption reaches a new steady-state level (Foss and Keteyian, 1998).

2.2.3 The others (energy continuum) High intensity, long-duration exercise

This exercise is not possible to classify such activities as strictly either anaerobic or aerobic. Rather, It is requiring a blend of both anaerobic or aerobic metabolism. Take, for example, the 1500-meter and 2-mile runs. In these activities, the anaerobic systems supply the major portion of ATP during the sprint at both the start and finish of the race, with the aerobic system predominating during the middle, or steady-state, period of the run. Overall, these runs demand about half of the required ATP from anaerobic sources and half from aerobic sources. These latter activities are often the most difficult for the athlete to perform because all the energy systems are involved to a large extent. This exercise is useful when developing training programs.

2.3 Lactic acid and energy production

At rest, a constant low level of lactate is formed (about 2.5mmol.L) due to cellular respiration of the mitochondrial-free red blood cells and their associated glycolytic energy drive. Rate of lactate production and rate of elimination are well-regulated under resting condition. However, there are many circumstances in which these rates are affected, e.g. genetic defect in mitochondrial function, exercise etc.
When energy demand is raised, increasing exercise stress, the respiratory chain fails to process all the hydrogen adjoined to NADH (Nicotinamide adenine dinucleotide) due to the lack of availability of sufficient oxygen. Thus in order for the rapid pace of glycolysis to continue NAD+ needs to shed the H+ to return for pick up of more H+ and to oxidize phosphoglyceraldehyde. In anaerobic glycolsis the H+ are catalysed by the enzyme lactate dehydrogenase and combined and temporarily stored with pyruvate to form lactate. Larger quantities are formed during exercise under condition in which the production of pyruvic acid exceeds the ability of the mitochondria to process those amounts or when O_2 delivery is insufficient to meet the demands for energy production through the oxidative cycle (Foss and Keteyian, 1998). Blood lactate begins to increase exponentially at about 55% of the healthy, untrained person's maximal capacity for aerobic activity. The usual explanation for increase blood lactate in heavy exercise assumes a relative tissue hypoxia, lack of oxygen. The lactate produced within the muscles was traditionally assumed to disperse in the blood and if such activity was to continue the accumulation of lactate was believed to impair performance due to fatiguing metabolic activity (McArdle et al., 2002).

Lactate accumulate have been directly related to exercise intensity. Previous studies documented that immediately after pedaled a cycle ergometer at various intensities and durations showed that the lowest blood lactate concentrations initially occurred in low intensity and short duration (50% VO_2max, 5 minutes) at high intensity and long duration (80% VO_2max, 20 minutes) the higher blood lactate concentration was observed (Hagberg et al., 1980). Subjects, who completed a 20 second high intensity cycle ergometer test at friction about 75 gm per kilogram of body weight, showed increasing in blood lactate concentration (Baker et al., 2002).

Blood lactate is related to mode of exercise. Hermansen and Saltin in 1969 showed that the blood lactate concentration was lower during treadmill exercise than during bicycle exercise at the same sub-maximal metabolic rate. Similar results have been obtained when lactate production during exercise with large muscle groups (i.e. leg exercise) and small muscle groups (i.e. arm exercise) was compared (Asmussen and Nielsen, 1946; Sternberg et al., 1967). Furthermore, it was shown by Hermansen and Saltin in 1967 that well-trained subjects elicited lower blood lactate concentrations than untrained subjects, not only at the same absolute workload, but also at the same relative workload (Hermansen and Stensvold, 1972).

In summary, the immediate post-exercise blood lactate concentration generally relates to exercise intensity but also is influenced by exercise duration, types of exercise, the level and nature of training (Geasser and Brooks, 1984; Rontoyannis, 1988). Lactate accumulation also depends on the number of repeat bouts of short duration, high intensity exercise that was performed and on the length of the rest period between bouts (Foss and Keteyian, 1998).

However lactate is not only a waste product but can act as a store of energy during prolonged and strenuous exercise. This is source of energy occurs when NAD rescavenges the lactate holding H^+ and oxidizes them for ATP. A second energy source is considered when the liver uptakes and recycles lactate and pyruvate to glucose and replenishes liver/muscle glycogen stores and circulating blood glucose via the Cori Cycle (McArdle et al., 2000).

2.4 The Recovery Process

The processes occurring during recovery from exercise are just as important as those occurring during exercise itself. For example, incomplete recovery between exercise bouts or athletic contests will ultimately lead to a decrement in performance.

The process of recovery from exercise involves restoration of the muscle and the rest of the body to their pre-exercise condition. During recovery from exercise, Oxygen consumption remains elevated above the resting level for varying lengths of time. The additional oxygen consumed above rest is termed the recovery oxygen. During the first two or three minutes or recovery, there is a high rate of oxygen consumption followed by a gradual decline to near-resting level. The initial three to six minutes of recovery has been name the fast component, whereas the slower phase has been named the slow component of recovery. In contemporary literature, the terminology of recovery events is in an evolutionary stage, and some sources continue to use the expression oxygen debt for recovery oxygen. Several other important factors in the recovery process also will be discussed, including: (1) restoration of the muscular stores of phosphagen (ATP and PC); (2) replenishment of myoglobin with oxygen; (3) replenishment of muscle glycogen stores; and (4) the removal of lactic acid from the muscles and blood.

2.4.1 The Concept of the Oxygen Debt

The concept of the oxygen debt, as originally developed by Hill, means that the oxygen consumed above the resting level during recovery is primarily used to provide energy for restoring the body to its pre-exercise condition, including replenishing the energy stores that were depleted and removing any lactic acid that was accumulated during exercise. Many erroneously interpret the oxygen debt to mean that the extra oxygen consumed during recovery is being used to replace oxygen that was borrowed from somewhere within the body during exercise. Actually, during maximal exercise, depletion of the oxygen stored in the muscle itself (in combination with myoglobin) and in the venous blood would amount to only about 0.6 L. Oxygen debts, on the other hand, have been found to be nearly 30 times larger than this in athletes during maximal exercise.

As shown in Figure 3, the oxygen debt has two components. The slower portion of the debt, called the lactacid oxygen debt component, is primarily related to the energetics involved in the removal of the lactic acid from the muscles and blood. The fast portion of the oxygen debt is called the alactacid oxygen debt component. The term “alactacid” means not related to lactic acid. The term came about when it was discovered in 1933 that not all of the oxygen debt was related to the removal of lactic acid from the muscles and blood. To name that part of the debt not related to the removal of lactic acid, the word “alactacid” was coined. Although it was not known at the time of naming the alactacid component, it is now known that the alactacid oxygen debt component provides the necessary oxygen for the energy needed for the restoration of the muscle phosphagens. If this had been known earlier, perhaps the term phosphagen debt component would have been used. Both of these oxygen debt components will be discussed later in this chapter as they related to the various recovery processes.

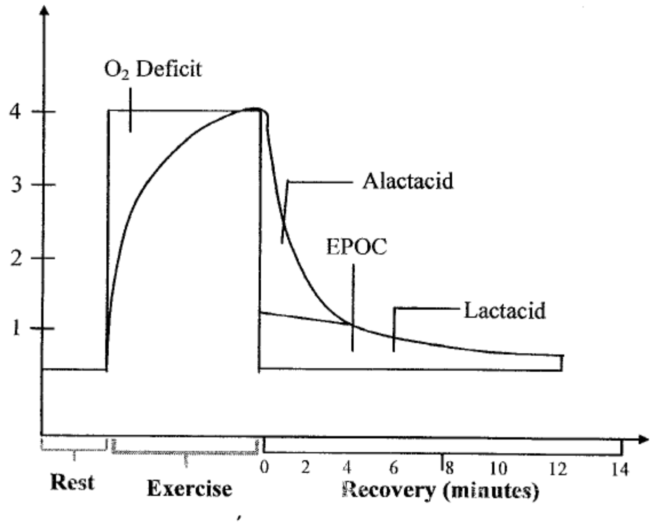

Figure 2.3 The concept of the oxygen debt

2.4.2 Restoration of the muscular stores of phosphagen (ATP and PC)

Much of the muscular ATP and PC store that is depleted during exercise is rapidly restored during the first three to five minutes of the recovery period. The ATP energy required for this process is supplied mainly by the aerobic system through the oxygen consumed during the fast component of recovery. The reduction of the fast component is completed in only a few minutes. The maximum size of the fast component ranges between 2 and 3 liters of oxygen, although a much higher value has been recorded in trained athletes.

2.4.3 Replenishment of myoglobin with oxygen

Oxygen is stored in skeletal muscle in chemical combination with myoglobin. Although the stores are small, they are of importance during intermittent exercise because they are used during the work periods and are restored during the rest periods. Restoration of the O_2-myoglobin stores during recovery is rapid, requiring only a few seconds, and depends on the availability (partial pressure) of oxygen. The oxygen is pare of the fast component of recovery.

2.4.4 Replenishment of muscle glycogen stores

Restoration of the muscle and liver glycogen stores depleted during exercise depends on the type of exercise performed (continuous versus intermittent) and may require several days for completion, during which time dietary intake of carbohydrate is necessary. Following continuous, exhausting exercise, muscle glycogen restoration is 60% completed in 10 hours of recovery and is fully completed within 46 hours. Following intermittent, exhausting exercise, muscle glycogen restoration is 53% completed in five hours and is fully completed within 24 hours. Only small amounts of muscle and liver glycogen are restored within the immediate (one or two hours) recovery period following maximal exercise of either type. The ATP energy for muscle and liver glycogen restoration comes from the aerobic system, but does not involve the oxygen consumed during the slow component of recovery to a great extent.

2.4.5 The removal of lactic acid from the muscles and blood

Lactate, as a metabolic product of glycolysis during exercise, has, as a principle fate, oxidation to CO_2 and H_2O. The concentration of lactate found in the blood at any time during either rest or activity is a function of the rate of production and the rate of degradation of this important metabolite. The lactate accumulated in blood and muscle during exercise is removed during the recovery period. The speed of lactate removal depends on whether a subject rests during recovery (rest-recovery) or performs light exercise (30% to 65% VO_2max) during recovery (exercise recovery). Lactate is removed faster during exercise recovery. Blood lactate is degraded by (1) conversion to glucose and/or glycogen, (2) conversion to protein, and (3) oxidation to CO_2 and H_2O by the aerobic system. The blood lactate's major fate is oxidation to CO_2 and water, which occurs mainly in skeletal muscle, but also occurs in heart, kidney, liver, and brain tissues. Although at least part of the oxygen and ATP energy required for lactate removal probably comes from the slow component of recovery, no quantitative relationship between the two has thus far been determined. The maximal size of the slow component is usually between 5 and 10 liters of oxygen.

Table2.1. Suggested minimum and maximum recovery times following exhaustive exercise

Recovery process	Suggested recovery time	
	Minimum	Maximum
Restoration of muscle phosphagen stores (ATP+PC)	2 minutes	5 minutes
Dissapperance of the fast component of recovery O2	3 minutes	6 minutes
Muscle glycogen replenishment	10 hours (after continuous exercise)	46 hours
	5 hours (after intermittent exercise)	24 hours
Liver glycogen replenishment	unknown	12-24 hours
Reduction of lactic acid in blood and muscle	30 minutes (with exercise-recovery)	1 hours
	1 hours (with rest-recovery)	2 hours
Reduction of the slow component of the recovery O2	30 minutes	1 hours
Restoration of O2 stores (plasma, myoglobin)	10-15 seconds	1 minutes

2.5 Respiratory system

The primary function of respiratory system is to supply the blood with oxygen in order for the blood to deliver oxygen to all parts of the body. The respiratory system does this through breathing. When we breathe, we inhale oxygen and exhale carbon dioxide. This exchange of gases is the respiratory system's means of getting oxygen to the blood. Respiration is achieved through the mouth, nose, trachea, lungs and diaphragm. Oxygen enters the respiratory system through the mouth and the nose. The oxygen then passes through the larynx (where speech sounds are produced) and the trachea, which is a tube that enters the chest cavity. In the chest cavity, the trachea splits into two smaller tubes called the bronchi. Each bronchus then divides again forming the bronchial tubes. The bronchial tubes lead directly into the lungs where they divide into many smaller tubes, which connect to tiny sacs called alveoli. The average adult's lungs contain about 600 million of these spongy, air-filled sacs that are surrounded by capillaries. The inhaled oxygen passes into the alveoli and then diffuses through the capillaries into the arterial blood. Meanwhile, the waste-rich blood from the veins releases its carbon dioxide into the alveoli. The carbon dioxide follows the same path out of the lungs when you exhale (William and Cowerkers, 2000).

2.5.1 Oxygen transport system

2.5.1.1 Oxygen Transport in Blood

Oxygen is transported by the blood either combined with hemoglobin (Hb) in the red blood cells (greater than 98%) or dissolved in the blood plasma (less than 2%). Only about 3 ml of oxygen are dissolved in each liter of plasma. Assuming a total plasma volume of 3 to 5 L, only about 9 to 15 ml of oxygen can be carried in the dissolved state. This limited amount of oxygen cannot adequately meet the needs of even resting body tissues, which generally require more than 250 ml of oxygen per minute (depending on body size). Fortunately, hemoglobin, contained in the body's 4 to 6 billion red blood cells, allows the blood to transport nearly 70 times more oxygen than can be dissolved in plasma (Willmore and Costill, 1999).

2.5.1.2 Hemoglobin Saturation

Each molecule of hemoglobin can carry four molecules of oxygen. When oxygen binds to hemoglobin, it forms oxyhemoglobin; hemoglobin that is not bound to oxygen is referred to as deoxyhemoglobin. The binding of oxygen to hemoglobin depends on The PO_2 in the blood and the bonding strength, or affinity, between hemoglobin and oxygen. The middle curve in figure 8.5a shows an oxygen-hemoglobin dissociation curve, which reveals the amount of hemoglobin saturation at different PO_2 results in almost complete hemoglobin saturation, which means the maximal amount of oxygen is bound. But as the PO_2 decreases, so does hemoglobin saturation.

Many factors can influence hemoglobin saturation. IF, for example, the blood becomes more acidic, the dissociation curve shift to the right. This indicates that more oxygen is being unloaded from the hemoglobin at the tissue level. The rightward shift of the curve (see figure 4) due to a decline in pH is referred to as the Bohr effect. The pH in the lungs is generally high, so hemoglobin passing through the lungs has a strong affinity for oxygen, encouraging high saturation. At the tissue level, however, the pH is lower, causing oxygen to dissociate from hemoglobin, thereby supplying oxygen to the tissues. With exercise, the ability to unload oxygen to the muscles increases as the muscle pH decreases.

Blood temperature also affects oxygen dissociation. As shown in figure 8.5b, increased blood temperature shifts the dissociation curve to the right, indicating that oxygen is unloaded more efficiently at higher temperatures. Because of this, the hemoglobin unloads more oxygen when blood circulates through the metabolically heated active muscles. In the lungs, where the blood might be a bit cooler, hemoglobin's affinity for oxygen is increased, which encourages oxygen binding (Willmore and Costill, 1999).

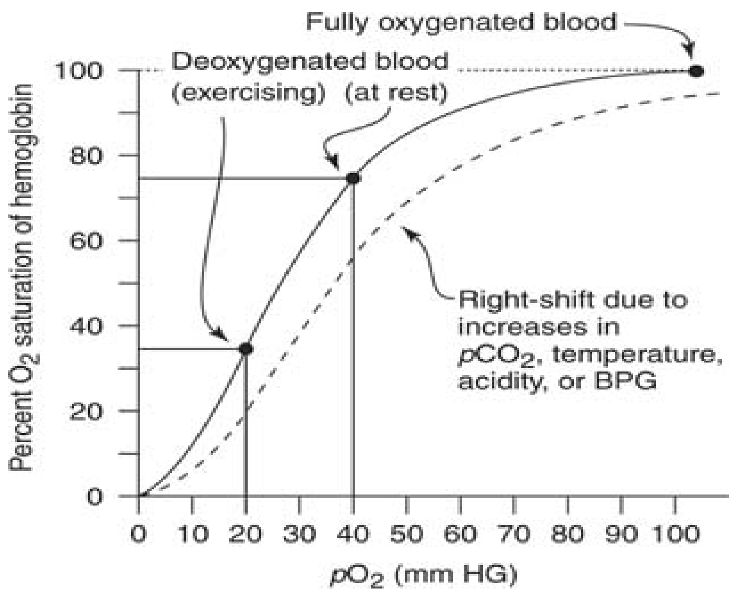

Figure 2.4. Hemoglobin oxygen saturation (S_aO_2) curve

2.5.1.3 Blood Oxygen-Carrying Capacity

Blood oxygen-carrying capacity is the maximal amount of oxygen the blood can transport. It depends primarily on the blood hemoglobin content. Each 100 ml of blood contains an average of 14 to 18 g of hemoglobin in men and 12 to 16 g in women. Each gram of hemoglobin can combine with about 1.34 ml of oxygen, so the blood oxygen-carrying capacity is approximately 16 to 24 ml per 100 ml when blood is fully saturated with oxygen. At rest, as the blood passes through the lungs, it is in contact with the alveolar air for approximately 0.75 s. This is sufficient time for hemoglobin to bind nearly all the oxygen it can hold, resulting in 98% saturation. At high intensities of exercise, the contact time is greatly reduced, which can reduce the binding of hemoglobin to oxygen and decrease the saturation.

People with low hemoglobin contents, such as those with anemia, have reduced oxygen-carrying capacities. Depending on the severity of the condition, these people might feel few effects of anemia while they are at rest because their cardiovascular system can compensate for reduced blood oxygen content by increasing cardiac output. However, during activities in which oxygen delivery can become a limitation, such as highly intense aerobic effort, reduced blood oxygen content limits their energy production and performance (Willmore and Costill, 1999).

2.5.1.4 Oxygen Transport in Muscle

Myoglobin is an oxygen-binding protein found in skeletal muscle fibers and cardiac muscle (not in blood) and acts as a “shuttle” to move O_2 from the muscle cell membrane to the mitochondria. Myoglobin is found in large quantities in slow-twitch fibers (i.e., high aerobic capacity), in smaller amounts in intermediate fibers, and in only limited amounts in fast-twitch fibers. Myoglobin is similar in structure to hemoglobin, but is about one-fourth the weight. The difference in structure between myoglobin and hemoglobin results in a difference in O_2 affinity between the two molecules. This point is illustrated in figure 10.17. Myoglobin has a greater affinity for O_2 than hemoglobin and therefore the myoglobin- O_2 dissociation curve is much steeper than that of hemoglobin’s for P_aO_2 values below 20 mm Hg. The practical implication of the shape of the myoglobin discharges its O_2at very low P_aO_2 values. This is important since the P_aO_2 in the mitochondria of contracting skeletal muscle may be as low as 1- 2 mm Hg.

Myoglobin O_2 stores may serve as an “O_2 reserve” during transition periods from rest to exercise. At the beginning of exercise, there is a time lag between the onset of muscular contraction and increased O_2 delivery to the initiation of exercise serves to buffer the O_2 needs of the muscle until the cardiopulmonary system can meet the new O_2 requirement. At the conclusion of exercise.myoglobin O_2 stores must be replenished and this O_2 consumption above rest contributes to the O_2 debt.

2.5.2 Oxygen's Role in Energy Metabolism

Three prerequisites exist for the continual resynthesis of ATP during coupled oxidative phospholylation. Satisfying these three conditions causes hydrogen and electrons to shuttle uninterrupted down the respiratory chain to oxygen during energy metabolism.

1. Availability of the reducing agent NADH (or $FADH_2$) in the tissues
2. Presence of the oxidizing agent oxygen in the tissues
3. Sufficient concentration of enzymes and mitochondria to ensure that energy transfer reactions proceed at their appropriate rate

In strenuous exercise, inadequacy in oxygen delivery (condition 1) or its rate of use (condition 3) creates a relative imbalance between hydrogen release and its final acceptance by oxygen. If either of these deficiencies exists, electron flow down the respiratory chain "back up" and hydrogens accumulate bound to NAD^+ and FAD. McArdle et al. in 2007 describe how the compound pyruvate, a product of carbohydrate break down, temporarily binds excess hydrogens (electrons) to form lactate. Lactate formation allows electron transport-oxidative phosphorylation to continue to provide energy.

Aerobic metabolism refers to energy generating catabolic reactions in which oxygen severs as the final electron acceptor in the respiratory chain and combines with hydrogen to form water. In one sense, the term aerobic seems misleading because oxygen does not participate directly in ATP synthesis. On the other hand, oxygen's oresence at the "end of the line" largely determines the capacity for aerobic ATP production and sustainability of high-intensity endurance exercise.

2.6 Oxygen supplement (Hyperoxia)

An increased ability to transport O_2 to the muscles and a delay onset of lactate production are related to improved performance. Two ergogenic aids have been used to try to influence O_2 delivery. The breathing of O_2 enriched mixtures.

Since oxygen is the importance of aerobic metabolism in the production of ATP for muscular work, it is not surprising that scientists have been interested in the effect of additional oxygen (hyperoxia) on performance. But in order to discuss this issue we must ask the following question: how and when was the O_2 administered to achieve a higher PO_2 in the blood? In his insightful review of this topic. Welch (64) stressed the difficulty of comparing results from studies in which hyperoxia is achieved by increasing the percent of O_2 in the inspired air with those that use a hyperbaric (high-pressure) chamber with 21% or higher O_2 mixture. It shows that performance improves throughout the range of inspired oxygen pressures when O_2-enriched mixtures are used at a normal pressure of 1 atmosphere (constant pressure), compared to the use of hyperbaric chamber (increasing pressure). The second part of the question is related to the time of administration of the supplemental O_2. Accordingly results obtained from the literature show a variation depending on whether the O_2 is administered prior to during, or following exercise. For that latter reason, this section on oxygen will be organized by those conditions.

2.6.1 Prior to Exercise

The rational for use of supplemental oxygen prior to exercise is to try to "store" additional oxygen in blood so that more will be available at the onset of exercise. It has been estimated that the hemoglobin in arterial blood is about 97% saturated with O_2 at rest (200 ml O_2/ blood). Breathing 100% O_2 would increase the O_2 bound to hemoglobin by only 3% or 6 milliliters. However, the amount of oxygen physically dissolved in solution is proportional to the arterial PO_2, and when the PO_2 increases from about 100 mmHg (21% O_2 at sea level) to about 700 mmHg (100% O_2), the dissolved oxygen increases from 3 ml/L to 21 ml/L. If a person has a total blood volume of 5 liters, approximately 100 milliliters of additional O_2 can be "stored" prior to exercise. However, if the person breathes several times between the times the O_2 breathing stops and the event begins, the O_2 store will return to that associated with air breathing (70).

The focus of attention on the use o oxygen prior to exercise has been on short-term exercise. In general, in runs of 880 yards or less, weightlifting, stair climbing, and swims of 200 yards or less, the O_2 seemed to beneficial (46,70). In addition, evidence suggested that the O_2 breathing needed to take place within 2 minutes prior to the task (70). Some concerns have been expressed about these findings due to the fact that in some cases the subjects knew they were breathing O_2, as factor that could have affected the results (70). Overall, considering the fact that O2 cannot be breathed up to the start of a sprint event in swimming or track, any effect would be lost before the starter's gun is fired. Therefore, unless one participates in a breath-holding event, oxygen breathing prior to exercise will have a little effect on performance.

2.6.2 During Exercise

The rationale for the use of oxygen during exercise to improve performance is based on the proposition that muscle is hypoxic during exercise and additional O_2 in the blood during O_2 breathing should increase the delivery of O_2 to the muscle and improve performance. However, Welch et al. (650 showed that when breathing hyperoxic gas mixtures, the increase in the O_2 content of arterial blood (CaO_2) is balanced by a decrease in blood flow to the working muscles such that O_2 delivery (CaO_2 x flow) was not different from normoxic (21% O_2) conditions. VO_2 max is increased by only 2-5 % with hyperoxia, which is about what would be expected since maximal cardiac output doesn't change and the a-v O2 difference does not increase more than 5-6% (54) ,(VO_2 max = Q max * (CaO_2 - CvO_2)).

In spite of similarities in O_2 delivery during hyperoxia and normoxia, performance has been shown to increase dramatically as a result of an increase in inspired O_2, which presented in the introduction to this section, showed a performance increase 4% while breathing 100% O_2. How could this be if O_2 delivery to muscles is not substantially different? The increased availability of O_2 has been shown to decrease pulmonary ventilation and reduce the work of breathing, a chance that should lead to an increase in performance (64, 71, 72). In addition, those athletes who experience "desaturation" of hemoglobin during maximal work while breathing 21% O_2 could benefit by breathing oxygen-enriched gas mixtures (50). Finally, the high PO_2 slows glycolysis during heavy exercise, resulting in a slower accumulation of lactate and H^+ in the plasma and extending the time to exhaustion (32, 64). Given the impracticality of trying to provide O_2 mixtures to athletes during performance, this research on hyperoxia is more useful as a tool to answer questions related to the age-old question of what factor, O_2 delivery or the muscle's capacity to consume O_2, limits aerobic performance (64).

2.6.3 After Exercise

The rationale associated with the use of supplemental oxygen after exercise is that the subject might recover more quickly following exercise and be ready to go again. Some of the early work showed just that, but because the subjects knew what gas they were breathing the results have to be interpreted with caution (Morris, 1983 and Wilmore, 1972). Willmore summarized the effects of several studies and concluded that there was no benefit of O_2 breathing during recovery on heart rate, ventilation, and post-exercise oxygen uptake. This conclusion was supported by studies showing no effect of O_2 breathing on subsequent performance in all-out exercise (Robbins et al., 1992).

During the last two decades, hyperoxia has been widely used by researchers to examine limitations to maximal oxygen uptake (VO_2max), so it is necessary to summarize these findings. In addition, since much additional research has been completed since the most recent review of hyperoxia and exercise tolerance, cardiovascular function, lactate (La^-) or acid/base balance. Search criteria for this review included all studies in which healthy subjects completed incremental exercise to volitional fatigue under hyperoxic conditions.

Table 2.2 Effect of Hyperoxia on Exercise Performance

Author (yr)	Subjects	% Increase in Ex. Performance	Parameter
Margaria (72)	11 healthy men	19	Time at supramaximal workload
Fagraeus (73)	11 healthy men	15.1*	Time at supramaximal workload
Linnarsson (74)	6 healthy men	20.0*	Peak workload
Davies (74)	5 healthy men	1	Peak workload
Adams (80)	6 male runners	26.4*	Time at 90 %VO2max
Buick (80)	11 track athletes	31	Time at 95 %VO2max
Wilson (80)	10 healthy men	21.8	Time at 8 mph
Hogan (83)	6 healthy men	5.9	Peak workload
Hogan (84)	6 healthy men	22	Time at 90 %VO2max
Powers (89)	7 trained runners	5.3	Peak workload
Plet (92)	11 young men and women	41.0*	Time at 80 %VO2max
Chick (93)	5 healthy men	32.3*	Time at 85 %Wmax
Knight (93)	11 trained cyclists	8.7*	Peak workload
Mateika (94)	8 healthy men	13.0*	Incremental exercise time
Peltonen (95)	6 trained rowers	6.5*	Peak workload
Nielsen (98)	11 trained oarsmen	3.2	Peak workload
Hogan (99)	6 men and women	14.0*	Incremental exercise time
Richardson (99)	5 trained cyclists	12.1	Peak workload
Linossier (00)	5 healthy men	45.0*	Maximal exercise time
Harms (01)	25 female runners	57.0*	Time at peak work rate
Peltonen (01)	6 trained men	5.5	Peak workload
Astorino (01)	20 healthy men	7.4*	Peak workload

* = p<0.05

Table 2.3 Change in VO_2max, Maximal S_aO_2, and HRmax reported in Hyperoxia

Author (yr)	Subjects	Ex. Mode	FIO_2	ΔVO_2max (%)	ΔSaO_2 (%)	ΔHRmax (b.min-1)
Margaria (72)	11 men	TM[1]	1	8.1	N/R	0.8
Ekblom (75)	9 men	TM/CE[2]	0.5	+12.6*	4	2
Buick (80)	11 runners	TM	Blood reinfusion	+5.1*	N/R	N/R
Thomson (82)	4 untrained men	TM	Blood reinfusion	+11.2*	-0.7	1
Byrnes (84)	6 men	CE	0.7	+13.0*	N/R	0
Spriet (86)	4 runners	TM	Blood reinfusion	+6.8*	N/R	-12
Powers (89)	7 runners	CE	0.26	+6.6*	+5.3*	1
Plet (92)	6 men, 5 women	CE	0.55	+3.7, +11.4*	N/R	+2.0, +5.0*
Knight (93)	12 cyclists	CE	1	+8.1*	3.7	0.4
Peltonen (95)	6 rowers	RE[3]	0.62	+11.1*	N/R	11
Cardus (98)	6 men and women	CE	1	16.4	N/R	2
Nielsen (98)	11 oarsmen	RE	0.3	+13.3*	5.4	-4
Richardson (99)	5 cyclists	KE4	1	+18.5*	1.5	-4
Astorino(01)	20 healthy men	CE	0.25	+12.1*	3.1	1.9
Harms (01)	25 trained women	TM	0.26	+6.3*	+5.2*	1
Peltonen(01)	6 trained men	CE	0.32	+14.0*	N/R	N/R

[1] = treadmill, [2] = cycle ergometer, [3] = rowing ergometer, [4] = one-leg knee extension, N/R = not reported, * = significant increase ($p<0.05$) in VO_2max, SaO_2, and HR compared to normoxia

Metabolite Depletion

The Phosphagens (ATP and CP)

Adenocine triphosphate (ATP) is the high-energy intermediate that supports muscle contraction as well as most other cellular endergonic processes. The immediate source of ATP rephosphorylation is creatine phosphate (CP). Because the catalyzing enzyme, creatine kinase, functions so rapidly, the muscle contraction of ATP is little affected until the CP level is significantly depleted, when exercise starts, the ATP and CP level drops rapidly at first, and then slowly. Although CP may continue to decline if exercise intensity is difficult for the subject, ATP levels will be well maintained until CP is exhausted. (Bergstrom, 1967). Therefore, at the fatigue point, both CP and ATP become depleted.

Endurance and its converse, fatigue, can be likened to two opposing and competing forces, those that utilize ATP and those that restore it. Because the Quantities of ATP and CP on hand in a resting muscle are fairly small, any significant utilization must be immediately matched with an equivalent restoration. If the rates of ATP and CP restoration are even a little less than utilization, exercise cannot continue very long.

O_2 Depletion

The depletion of muscle O_2 stores, or rather the inadequacy of circulating O_2 delivery to muscle, can result in fatigue. Those with impaired circulatory or ventilatory function, those engaged in strenuous exercise at sea level can fall short in the balance between muscle respiratory requirement and the actual O_2 supply. Because most of the ATP required to perform any activity lasting 90 seconds or more is from cell respiration, adequate O_2 supply is essential to support maximal aerobic work. The effects of inadequate O_2 supply or utilization can be represented by increased lactate production or decreased CP levels, or both. Thus, inadequate oxygenation of contracting muscle can be result in at least two fatigue-causing effects.

CHAPTER III
MATERIALS AND METHODS

3.1 Subjects

Twelve healthy non-athlete males, aged between 18 and 23 years, were recruited from Sports Science students of Srinakharinwirot University and volunteered for the study. They all generally participated in sports leisure activity but did not join with any heavy training. Subject selection was performed using a specific purpose designed questionnaire (Appendix A) to screen their physical activity. Physical activity level questionnaire was modified from national Heart Foundation's Physical activity questionnaire. Subject were interviewed about their personal and medical history. Physical examination was performed for each individual before entering the experiment. Experimental protocol, procedure, as well as risks and benefits of the test were clearly explained to each individual. Then, Subjects signed informed consent forms before participated in this study after they had read all description of the experimental protocol. The protocol was submitted and approved by the Human Research Ethics Committee of Mahidol University No. MU 2007-231.

The anthropometrics data including weight, height and body mass index were recorded. The inclusion and exclusion criteria were as follow.

3.1.1. Inclusion criteria

3.1.1.1. Body mass index (BMI) between 20-25 kg•m^{-2}.

3.1.1.2. Score obtained from physical activity level Questionnaire equals or more than 24 (high activity level).

3.1.2. Exclusion criteria

3.1.2.1. Having cardiovascular disease, hypertension, or hypotension, any respiratory disease, cigarette smoking, any endocrine dysfunction especially hyperthyroidism, chest injury or operation, epilepsy and any neuro-muscular disease, joint or muscle dysfunction which may affect exercise testing.

3.1.2.2. AIDS or any infectious disease.

3.1.2.3. Unable to sustained high intensity exercise up to specified period.

3.1.2.4. Taking any medicines that affect the cardio-respiratory and metabolic system and level of consciousness within 24 hours before testing.

3.1.2.5. Drinking alcohol or caffeine within 24 hours before testing.

3.2. Instruments

The following equipments were used in this study.

1. Oxygen tank (Figure 5)

Figure 3.1 Oxygen tank (AIRSEP, USA)

2. Simple mask (Figure 6)

Figure 3.2 Simple face mask

3. Flowmeter (Figure 7)

Figure 3.3 Flowmeter

4. Accutrend®lactate portable lactate analyzer (Roche Mannheim, Germany) (Figure 8 / No.1)
5. Softclix®blue kit (Germany) (Figure 8 / No.2)
6. Accu-Chek®Softclix®II Lancet (Germany) (Figure 8 / No.3)
7. BM-Lactate®test strip (Figure 8/ No.4)

Figure 3.4 Set of instrument for determination of blood lactate concentration (Accutrend®lactate portable lactate analyzer (Roche Mannheim, Germany)

8. Cycle ergometer (Monark ergomedic 839E,Sweden) (Figure 9)

Figure 3.5 Cycle ergometer (Monark ergomedic 839E,Sweden)

9. Telemetry heart rate monitor (Polar,Finland) (Figure 10)

Figure 3.6 Telemetry heart rate monitor (Polar Accurex Plus, Finland)

10. Hemoglobin oxygen saturation oximetry (Figure 11)

Figure 3.7 Hemoglobin oxygen saturation analyzer (Sportstat)

11. Oxygen and carbon dioxide analyzers (Figure 12)

Figure 3.8 Oxygen and carbon dioxide analyzers (COSMED Quark PFT ergo)

12.The Borg perceived exertion scale. (Table 4)

Scale	**Verbal expression**
6	
7	Very, very light
8	
9	Very light
10	
11	Fairy light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Table 3.1 The Borg perceived exertion scale (Christopher, 1993)

13.70% Alcohol solution and Cotton ball

14.Plastic adhesive bandages (Tensoplastic®,Pharmacare,Thailand)

15.Disposable glove

16.Stopwatch (Casio HS-30W)

17.Digital weight scale (AND AD-6201, Japan)

18.Height scale (cm)

19. Physical activity questionnaires (National Heart Foundation of Australia)

3.3. Experimental procedures

Data were collected at the same time of the day at The Sports Science Laboratory, College of Sports Science and Technology, Srinakharinwirot University. All subjects were instructed to abstain from smoking, drinking alcohol, wine, coffee, soda, fermented food, avoid or limit any intense physical activity within 24 hour prior to the test. Each subject strictly controlled the amount of fluid intake by drinking 1.5 liters of water provided after 6 p.m. on the day before test. Before the experimental day, subject was asked to visit to the laboratory for familiarized with the experimental protocol and baseline data collection such as weight and height, body mass index (BMI), and physical fitness test including predicted peak oxygen consumption (VO_2peak).

Maximal exercise testing.

The maximal test was used to determine an individual VO_2peak and the percentage of VO_2peak by using Ramp protocol. During the test, subjects began cycling at 80 W for 5 min with kept pedaling constant at 60 rpm, workload was increased by 5 W every 12 sec until met criterias or volitional exhaustion. Rate of perceived exertion were collected before exercise every 10 min and at the end of exercise. The VO_2peak measured during the test was used to establish the exercise intensity (70% VO_2peak) to be employed during the subsequent experimental sessions.

The VO_2peak were identified if the subjects met at least three of the following five criteria (1) an increase in oxygen consumption no greater than 150 ml min^{-1} despite an increase in exercise intensity; (2) a test heart rate reaches 90 % HR_{max} of the age related theoretical maximum (220-Age); (3) a respiratory exchange ratio greater than 1.1; (4) Exhaustion; and (5) The subject is unable to continue pedaling at the prescribed rate.

Submaximal intermittent exercise test.

On the experimental day, subjects arrived at the laboratory at least 2-3 hours after meal. Before the first test, equipments involved in this study was set up and calibrated before the subject's arrival to ensure that the equipment were ready for and could run smoothly during the experiment. In addition, after the subject arrival, the detail of the test were re-explained and was found using of equipment involved was demonstrated in order to reduce anxiety. The questionnaire before testing was requested to re-check subject's condition. Telemetry heart rate monitor (Polar, Finland) was attached on subject's chest to monitor heart rate. Then, subjects sat quietly for about 10-15 minutes until stable vital signs were determined. Hemoglobin oxygen saturation (S_aO_2), heart rate (HR) were recorded. Blood samples were collected before the intermittent exercise test. The intermittent exercise test was performed on cycle ergometer.

Each subject was asked to exercise on two non-consecutive tests in a randomized order on a single-blind fashion. Each subject was cycling on Cycle ergometer at free load for 10 min for light warm-up and familiarization with the apparatus. During the exercise period, they exercised at a workload of 70% VO_2peak and kept pedaling at a constant rate of 60 rpm. Tests 1 and 2 were separated by 2 days, regardless of the F_IO_2 conditions. The protocol for all two tests was graphically illustrated in Figure 13.

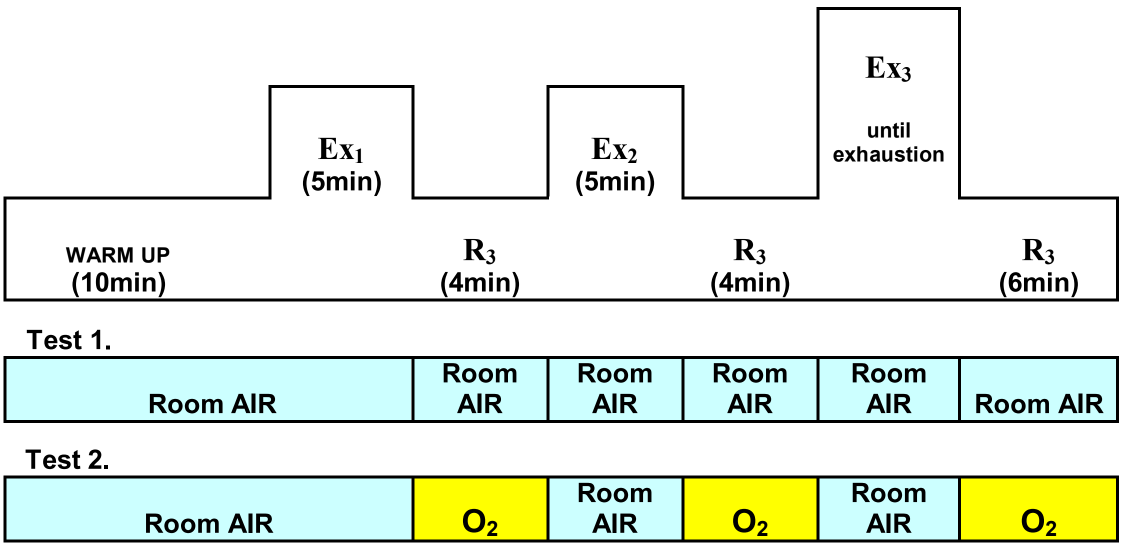

Figure 3.9 A study protocol for the two exercise tests (test 1 and test 2). The top panel shows the duration of warm-up, exercise and rest for the two submaximal period (Ex_1, Ex_2) and the maximal exercise period (Ex_3). The two gas mixture (air, oxygen) are shown in two panels.

The first two exercise period (Ex_1, Ex_2) were 5 min in duration, each was followed by two recovery mode during which the subject stop cycling and seated quietly on the cycle for 4 min and breathed either 1) room air for 4 min, or 2) 40 % oxygen from oxygen tank. Oxygen was led into simple face mask from a gas bottle through a flow controller and breathing controlled valve. The flow controller was set so that the inspired air contained 40% of oxygen (oxygen flow rate of 5 L/min by venturi face mask)[12]. During the first exercise period (Ex_1) and second exercise (Ex_2) each subject began at workload corresponding to exercise intensity at 70% VO_2max for 5 min The two different inspired gas mixture were randomly selected for the two different days. During the third exercise period (Ex_3) each subject began at the same workload as at the end of Ex_2 followed by 2 min increments of 25 Watts until the subject reached exhaustion, indicated by a prearranged hand signal, or the subject could no longer maintain a pedaling frequency $\geq$ 60 rpm. The subjects stop cycling and seated quietly on the cycle for 6 min during the third recovery period (R_3). During R_3 the inspired gas mixture was the same as the first two recovery period. Blood lactate concentration, hemoglobin oxygen saturation (S_aO_2), heart rate (HR) and rate of perceived exertion (RPE) were obtained at the same time periods, (0, 2, 4, 6 min of R_3.). Time to exhaustion were recorded at the beginning of Ex_3 until exhaustion.

Heart rate measurement

HR was measured continuously with a telemetry system (Polar heart rate chest belt transmitter) were collected for each protocol before and immediately at 0, 2, 4, 6 min of R_3 during each test.

Blood lactate concentration (BLC) measurement

Blood sample was obtained from the fingertip using a standard hygienic finger puncture method (Declan et al., 2003) The puncture was induced using Accu-Chek®Softclix®II lancet device (No.3 in Figure 4) that set at optimal penetration depth to reduce discomfort by avoiding contact with nerves. During blood collection, subject was instructed to relax. After puncture, fingertip was cleaned with the alcohol. Drops of blood were placed on lactate test strip and then analyzed immediately using a portable lactate analyzer (Accutrend®lactate, Roche Mannheim, Germany) (Figure 4).

The result of blood lactate concentration was shown within 1 minute. After blood collection, blood was stopped using a brief compression and cover with plastic adhesive bandage. Series of five blood samples were collected for each protocol before and immediately at 0, 2, 4, 6 min of R_3.

Hemoglobin oxygen saturation measurement

Hemoglobin oxygen saturation was determined by a pulse oximeter on the finger. Pulse oximetry is a noninvasive monitoring technique used to estimate the measurement of arterial oxygen saturation (S_aO_2) of hemoglobin. Oxygen saturation is an indicator of the percentage of hemoglobin saturated with oxygen at the time of the measurement. Normal oxygen saturation values are 97% to 99% in the healthy individual. An oxygen saturation value of 95% is clinically accepted in a patient with a normal hemoglobin level. The reading, obtained through pulse oximetry, uses a light sensor containing two sources of light (red and infrared) that are absorbed by hemoglobin and transmitted through tissues to a photodetector. The amount of light transmitted through the tissue is then converted to a digital value representing the percentage of hemoglobin saturated with oxygen. Hemoglobin oxygen saturation (S_aO_2) were recorded before, immediately after the test at 0, 2, 4, 6 min of R_3.

Rating of Perceived Exertion (RPE) measurement

Subjected were instructed to correctly used The Category-Ratio RPE scale for Rating of Perceived Exertion consisted of series of integers from 6 to 20, 15-grade scale, to indicate his total, inner feeling of exertion during recovery. The Category-Ratio RPE scale was clearly shown to the subjects in order to determine his psychological aspects. Each subject read the charts and then informed the scales to the researcher for recording.

Time to exhaustion

Time to exhaustion begin were recorded at the beginning of Ex_3 until exhaustion.

3.4. Statistical analysis

The SPSS 15.0 for Microsoft windows was used for statistical analysis. Data were expressed as mean and standard error of the means (means ± SEM) values otherwise will be stated. GLM-repeated measures analysis of variance was used to determine rate of recovery within the group. Paired-Sample t-test or Wilcoxon Match-Pairs Signed Ranks Test were used to compare effects of difference conditions (between group). Significance level is set at $\alpha < 0.05$.

Summary scheme of the study

Subject recruitment

Questionnaires

(General health, Physical activities and Exercise)

↓

Procedure explained and informed consent signed

↓

Anthropometric measurements

Body weight, Height, Body mass index (BMI)

↓

Physical fitness test

-VO_2peak (direct method)

↓

Submaximal intermittent exercises (70% VO_2max)

↓

Recovery period in two modes

↙ ↘

1. breathing of hyperoxic gas
2. non-breathing of hyperoxic gas

↓

Data collection

BLC, S_aO_2, Heart rate, Rate of perceived exertion, Time to exhaustion

↓

Data analysis

CHAPTER IV
RESULTS

This study was aimed to investigate the effect of oxygen gas supplemental on rate of recovery following exhaustive on maximal exercise and We hypothesized that the administration of supplemental 40 % oxygen immediately during recovery period of repeated exercise bouts would result in a more rapid recovery from exercise. The investigated parameters included blood lactate concentration (BLC), heart rate (HR), hemoglobin oxygen saturation (SaO_2), rate of perceived exertion (RPE) and time to exhaustion (T_{exh}). All experiments were performed in the laboratory at an environmental temperature of 25.40 ± 0.08 degree Celsius and a relative humidity of 58.29 ± 0.67 %.

4.1 Characteristics of Subjects

Twelve male volunteers were recruited from Sports Science students at Srinakharinwirot University. They all were healthy non-athletes and generally participated in leisure physical activity but did not participate in any regular sports training. Baseline characteristics of subjects characteristics for age, height, body mass, BMI, HRmax, predicted max oxygen consumption (VO_{2peak}) and 70 % max oxygen consumption (VO_{2peak}) are shown in Table 5.

Table 4.1 General physical characteristics of all subjects. Values are presented as mean ± SEM. (n = 12)

Variable	Value
Age (years)	20.17 ± 0.24
Body mass (kg)	66.96 ± 2.36
Height (cm)	173.25 ± 1.49
BMI ($kg \cdot m^{-2}$)	22.20 ± 0.47
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$) [1]	32.12 ± 1.56
Predicted 70%VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$) [1]	22.48 ± 1.09
HR_{max} (beats/min)	199.83 ± 0.24
Maximal workload (W)	232.50 ± 6.49
Predicted 70% Max workload (W)	116.25 ± 2.76
Physical activity score[2]	25.83 ± 0.54

[1] Value was indirectly estimated from Ramp test, [2] Value derived from specific design questionnaire for this study (Appendix A).

4.2 Blood lactate concentration (BLC)

The mean value of blood lactate concentration at rest in room air and 40% O_2 supplemented conditioning were 1.79 ± 0.18 and 1.67 ± 0.16 $mmol \cdot L^{-1}$, respectively. Blood lactate concentration of all group showed a remarkable increase in post-exercise recovery.

Peak blood lactate concentration

Levels of immediate post-exercise blood lactate concentration in room air breathing and 40% O_2 breathing modes were 8.63 ± 0.71 and 9.37 ± 0.61 $mmol \cdot L^{-1}$, respectively. In room air breathing, blood lactate concentrations at 2, 4 and 6 min post exercise were 8.93 ± 0.66, 8.10 ± 0.68 and 7.25 ± 0.68 $mmol \cdot L^{-1}$, respectively, Whereas, blood lactate concentrations in 40% O_2 breathing at 2, 4 and 6 min post exercise were 9.78 ± 0.58, 8.55 ± 0.59 and 8.22 ± 1.17 mmol•L^{-1}, respectively, Note that the peak blood lactate concentration was shown at 2 min post-exercise in both conditions.

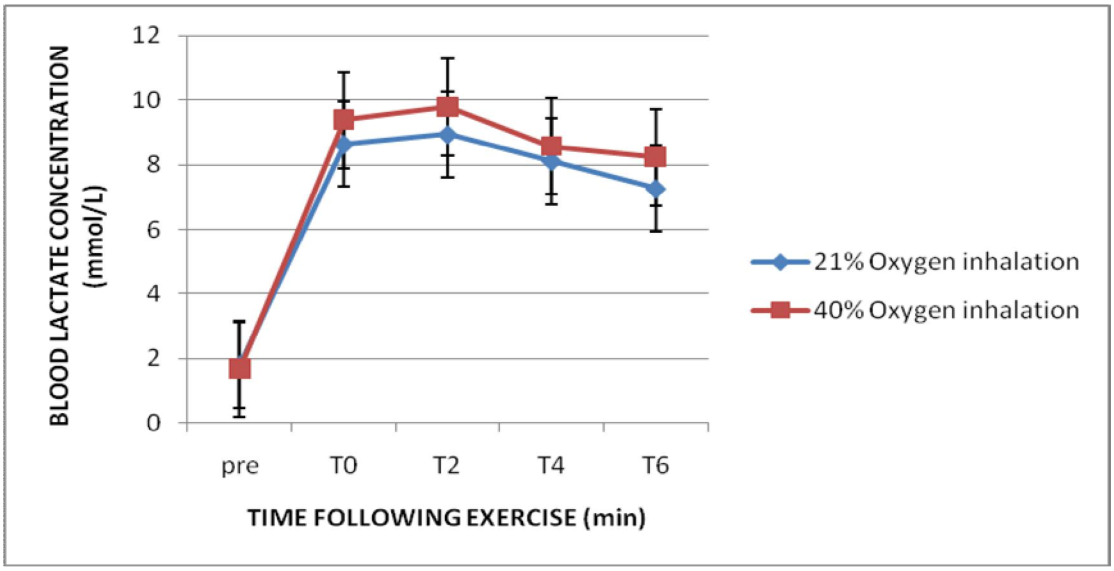

Figure 4.1 Comparison of blood lactate concentration (mmol/l) between room air breathing modes and 40% O_2 breathing modes during the recovery period.

Changes of blood lactate concentration within the group

Comparison within the group revealed that BLC at immediate post-exercise in both room air and 40% O_2 modes were significantly increased from its corresponding initial, resting level ($p < 0.05$). Level of immediate post-exercise BLC in room air breathing and 40% O_2 breathing were 8.63 ± 0.71 mmol•L^{-1} and 9.37 ± 0.61 mmol•L^{1}, respectively. Significant difference of BLC compared with resting level was detected at T2 ($p < 0.05$), T4 ($p < 0.05$), T6 ($p < 0.05$) in all group. No significant differences, compared to immediate post-exercise levels of all groups. BLC at T2, T4 and T6 in all groups were significant difference compared to the corresponding resting levels ($p < 0.05$). BLC at T2, T4 and T6 also showed no significant values compared to the corresponding immediate post-exercise values ($p > 0.05$).

Changes of blood lactate concentration between the group

Comparison between groups showed that BLC at immediate post-exercise was similar ($p > 0.05$). Even though peaks BLC were found at T2, there was no significant difference among two groups ($p > 0.05$).

4.3 Heart rate (HR)

Heart rate of subjects at rest in room air and 40% O_2 were 71.16 ± 3.13 and 71.33 ± 1.33 beat•min^{-1}, respectively. No significant difference of HR at rest, was detected ($p > 0.05$). Heart rate of room air and 40% O_2 modes showed remarkably increase in post-exercise recovery.

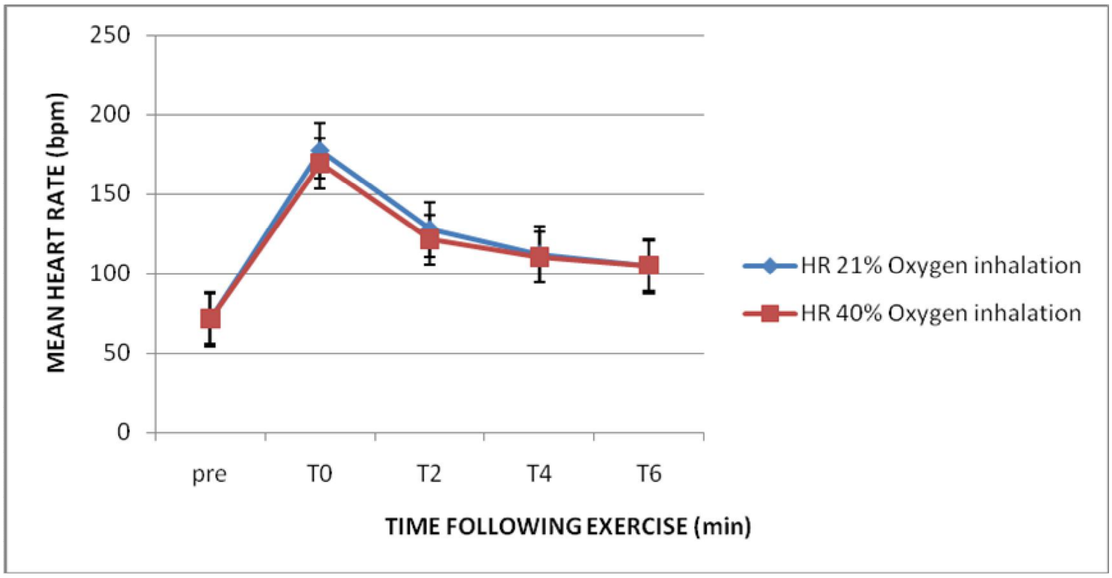

Figure 4.2 Comparison of mean (± SEMs) values of heart rate (bpm) between room air breathing mode and 40% O_2 breathing mode during time following exercise (* significantly different between room air breathing mode and 40% O_2 breathing mode at the same period, $p < 0.05$)

Comparison within the group revealed that HR at immediate post-exercise in both room air and 40% O_2 modes were significantly increased from its corresponding initial, resting level ($p < 0.05$). Heart rates at immediate post-exercise in room air and 40% O_2 were 177.25 ± 4.11 and 169 ± 4.58 beat•min^{-1}, respectively. This increasing pattern in post-exercise HR, compared to initial levels of all groups, was detected in all groups at T4($p < 0.05$). There were sharply declined of HR during the first minute of recovery. During recovery period in room air and 40% O_2 modes, even though HR was gradually declined, data revealed that recovery HR still significantly higher than resting levels ($p > 0.05$).

Comparison between groups showed that HR at immediate post-exercise was similar ($p < 0.05$). there was no significant difference among two groups ($p > 0.05$).

4.4 Hemoglobin oxygen saturation (SaO_2)

Hemoglobin oxygen saturation of subjects at rest in room air and 40% O_2 breathing were 98.33 ± 0.19 and 98.50 ± 0.23 %, respectively. No significant difference in SaO_2, was noted ($p > 0.05$).

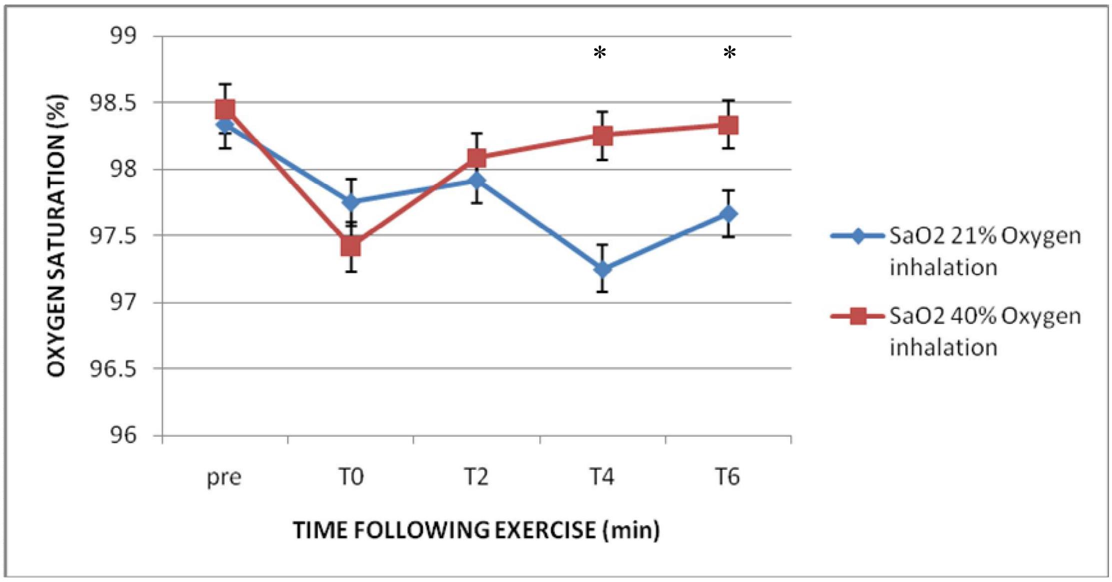

Figure 4.3 Comparison of mean (± SEMs) values of hemoglobin oxygen saturation (%) between room air breathing mode and 40% O_2 breathing mode during time following exercise. (* significantly different between room air breathing mode and 40% O_2 breathing mode at the same period, $p < 0.05$)

Comparison within group revealed that SaO_2 at immediately post-exercise in both room air and 40% O_2 modes were significantly increased from its corresponding initial, resting level ($p < 0.05$). Hemoglobin oxygen saturation at immediate post-exercise in room air and 40% O_2 modes were 97.75 ± 0.28 and 97.42 ± 0.31 %, respectively.

There were no significant differences in between groups. SaO_2 at immediate post-exercise ($p > 0.05$)., there were significant difference in SaO_2 among two groups ($p < 0.05$). At T4 and T6 respectively.

4.5 Rate of perceived exertion (RPE)

Rate of perceived exertion at rest in room air and 40% O_2 were 6.08 ± 0.08 and 6.17 ± 0.11, respectively. No significant difference of RPE at rest was detected ($p > 0.05$).

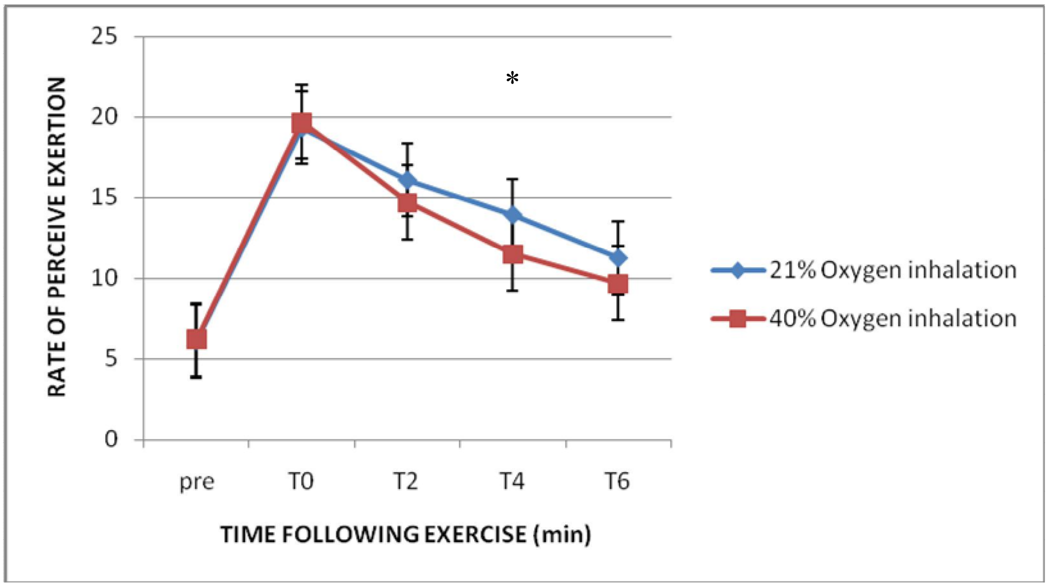

Figure 4.4 Comparison of mean (± SEMs) values of rate of perceived exertion between room air breathing mode and 40% O_2 breathing mode during time following exercise. (* significantly different between room air breathing mode and 40% O_2 breathing mode at the same period, $p < 0.05$)

Comparison within group revealed that RPE at immediately post-exercise in both room air and 40% O_2 modes significantly increased from its corresponding initial, resting level ($p < 0.05$). Levels of immediate post-exercise RPE in room air and 40% O_2 were 19.33 ± 0.14 and 19.67 ± 0.19, respectively. This increasing pattern in post-exercise RPE, compared to initial levels of all modes, was detected at T2 ($p < 0.05$), T4 ($p < 0.05$), T6 ($p < 0.05$). During recovery period, RPE was significantly difference as compared to immediate post-exercise levels of all conditions, (T2, T4, T6).

RPE at immediately post-exercise was similar between two groups. Although RPE at T4 were significantly decreased in all modes, there were no significant difference in RPE among two groups ($p > 0.05$). at T2 and T6.

4.6 Time to exhaustion (T_{exh})

During third exercise period (Ex_3), time to exhaustion (t_{exh}) after inspiring 40% O_2 was significantly increased by 13% when compared to room air breathing, time to exhaustion in room air and 40% O_2 were 9.62 ± 0.57 and 10.88 ± 0.64 min, respectively (Fig. 18).

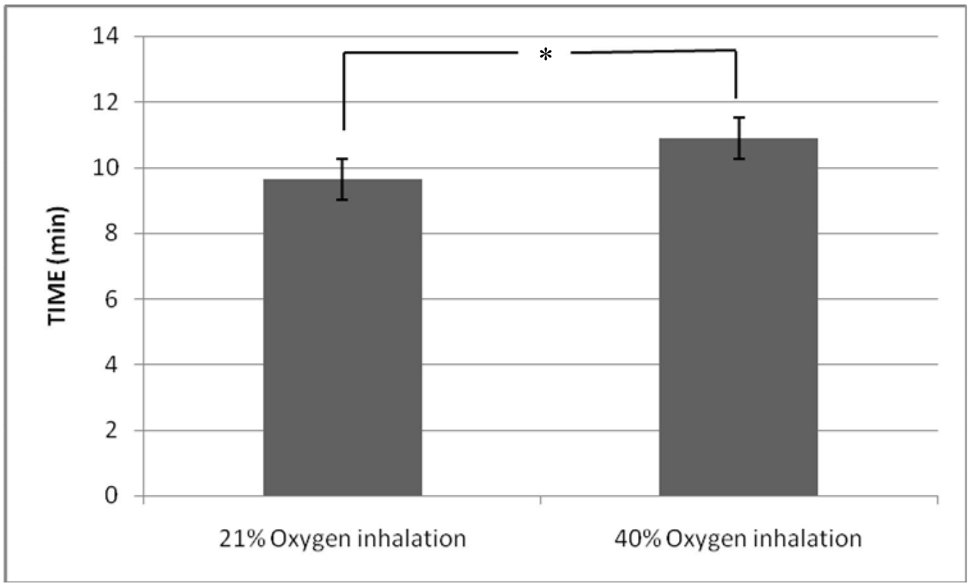

Figure 4.5 Time to exhaustion during the third exercise period (Ex_3) of room air breathing mode and 40% O_2 breathing mode

CHAPTER V
DISCUSSION

5.1 Characteristics of Subjects

Characteristics of subjects were shown in Table 4.1. Anthropometric variables including age, height, body mass, BMI, HRmax, predicted max oxygen consumption (VO_{2peak}) and 70 percent max oxygen consumption (VO_{2peak}) of subjects fall in the normal range of Thai population at this age group (Sports Authority of Thailand, 2543). Therefore, this study successfully recruited a group of normal person for the investigation. Level of physical activity revealed that they were high active male (National Heart Foundation of Australia, 1996). Education background at university level confirmed subject's ability to understand and follow the testing procedure.

5.2 Blood lactate concentration

Resting blood lactate concentrations in all of the two recovery modes were in the normal ranges in human and may be due to cellular respiration of the mitochondria-free red blood cells and their associated glycolytic energy drive. Although at resting condition the most energy supply by the aerobic system, noticed that there is a small but constant of lactic acid present in blood (about 10 mg for every 100 ml of blood). The reason for this relates to the abundance and effectiveness of LDH (lactate dehydrogenase). It is the enzyme that catalyzes the reaction of pyruvic acid to lactic acid and always converting some pyruvate to lactate. (Foss and Keteyian, 1998). It was assumed that at the same exercise intensity, the body should produce similar amount of lactate in the blood. Thus, it was estimated that subjects had the same amount of lactate from repeated exercise bouts but the alteration of lactate during recovery period was due to effect of recovery protocol.

Blood lactate concentration increases greatly during anaerobic exercise when the rate of ATP use exceeds ATP re-synthesis. After ceased of exercise by repeated exercise bouts test, BLC in all subjects were increased (Figure 14) to confirm that exercise in this study was strenuous intensity and induced energy from aerobic system. Supporting that, during intense exercise several substrates of glycolysis have accumulated in muscle, blood lactate could have increased from 1-25 $mmol \cdot L^{-1}$ (Guyton, 1991). The amount of lactic acid in blood at the end of a maximal exercise test reflects 1) the intensity of the exercise for the subject, 2) the degree to which the subject needed to supplement aerobic energy production with anaerobic energy production, 3) the subject's lactic acid tolerance (Foss and Keteyian, 1998; Cerny and Burton, 2001), 4) training condition of the subjects (Ozturk et al., 1998).

After exhaustion, the lactate concentration was no significant differences when compared between 40% O_2 recovery and room air recovery. This can simply conclude that with 21% oxygen inhalation or 40% oxygen inhalation, these two parameter might not cause any increase in O_2 partial pressure within the tissue and the peripheral blood vessel.

5.3 Heart Rate

Resting HR of subjects in all two recovery modes were in the normal of Thai population of their age ranges (Sports Authority of Thailand, 2543). Immediately post-exercise, HR in all group were significantly greater than during resting. It might be the anticipatory response by the activation of motor cortex and higher areas of brain causes increase in sympathetic outflow and reciprocal inhibition of parasympathetic activity. After that, HR in all recovery modes remained elevated above the pre-exercise resting level throughout the recovery which is quite consistent with the reports of other investigators (Miyamoto et al., 1982; Perini et al., 1989; Baum et al., 1992; Yoshida and Whipp, 1994). The elevation of the HR has been reported to be sustained for a relatively long time after the cessation of exercise and far beyond the time required for the restoration of respiratory gas exchange (Miyamoto et al., 1982; Yoshida and Whipp, 1994; Takahashi and Miyamoto, 1998).

This study showed that supplemental 40% oxygen during recovery period of repeated exercise bouts has no discernible effect on the rate of recovery of heart rate. Most previous studies demonstrate conflicting results, Miller in 1952 found supplemental oxygen to have no effect on recovery of minute ventilation or heart rate when administered following submaximal or maximal treadmill exercise in a cohort of athlete. Garner et al. in 1986 found that breathing supplemental oxygen during the recovery period did not alter ventilation or heart rate compared with breathing room air.

At the end of times of recovery in this study, HR in all groups were remained higher than resting level, it has been suggested to be dependent on both the intensity and duration of the exercise. There is no fully recovery in HR within 6 min post-exercise period (Figure 9). Thus the present study indicated that whenever repeated exercise bouts test is performed, the recovery period should be adjusted to further than 6 min.

5.4 Hemoglobin oxygen saturation (S_aO_2)

The results of present study showed there were significant difference in SaO_2 among two groups which was similar to data of Nummela A. et al. 2002; Peltonen et al. 1999, which studied effects of hyperoxia during intermittent exercise. They found mild hyperoxia prevented oxygen saturation from decreasing during exercise. It showed that relationships exist between oxygen saturation and blood pH and lactate, like Adams and Welch (1980) showed that hypoxia and hyperoxia induce significant changes in arterial $[H^+]$ as a result of both respiratory and metabolic responses. They concluded that the $[H^+]$ has an important role in performance and suggested that the effect of hyperoxia on performance is related to the control of $[H^+]$. However in this study showed that oxygen supplemental during the exercise makes significant effect for delaying oxygen saturation during exercise because oxygen breathing increases the alveolar-pulmonary capillary oxygen gradient and thus the driving force to load the blood with oxygen. As a result, oxygen is available to bind with hemoglobin more quickly, producing a more saturated arterial hemoglobin, and improved oxygen transport to exercising muscles.

5.5 Rate of perceived exertion (RPE)

The RPE represent a psychophysiological response generate from a gestalt of many different sensations and feeling related to the work environment (Borg, 1982). Rate of perceived exertion at rest in all modes were showed in normal level due to at rest all subjects were seated comfortably on a cycle ergometer in a quiet laboratory and motionless. After performed high intense exercise RPE increased immediately relate to exercise intensity. There is remarkable diminished of RPE as exercise is being ceased. During recovery,

In this research, the researcher measured RPE for exhaustions from the exercise, by the researcher has hypothesis, that when subjects received 40% oxygen supplement during recovery period of repeated exercise bouts it should delay exhaustions from exercise. But, when compare the RPE between groups; there was no significant difference in RPE at anytime point examined. Except at 4 min during R_3., RPE after 40% oxygen supplement tended to be significantly lower than that of 21% oxygen supplement. From results, indicate when subjects received 40 oxygen supplements during recovery period of repeated exercise bouts had no significant effect for delay exhaustions from the exercise. Although, at 4 min during the exercise meets significant statistics difference but the value from both groups was similar to.

5.6 Time to exhaustion

The time to exhaustion following supplemental O_2 breathing (10.88 ± 0.64 min) tended to be longer compared with room air breathing (9.62 ± 0.57 min), but a statistically insignificant difference was found. In agreement with previous studies (Welch, 1982), results confirmed the beneficial effect of hyperoxia on maximal exercise tolerance as shown by significantly increase time to exhaustion. The improvement in time to exhaustion as a results of a lower lactate accumulation under hyperoxia is in agreement with the findings of Hogan & Welch (1984). In conclusion oxygen breathing during exercise improves time to exhaustion by reduction in the work of breathing and improved oxygen transport to exercising muscles.

There were two limitations that need to be acknowledged and addressed regarding the present study. The first limitation was fixed work load at 70% VO_2peak can't be controlled. The second limitation was no well control studies of gas mixture because have not measured the concentration of oxygen at the simple mass, So no accuracy.

CHAPTER VI
CONCLUSION

The present study was to investigate effects of oxygen gas during recovery period on rate of recovery of repeated exercise bouts It was demonstrated that supplemental oxygen has no discernible effect on the rate of recovery of blood lactate concentration or heart rate. In addition, supplemental oxygen breathing did not alter the perception of the magnitude of exertion as determined by the Borg scale, and the breathing of hyperoxic gas makes no significant effect for delaying oxygen saturation during exercise. Finally the breathing of hyperoxic gas improvement in subsequent performance as measured by duration of exercise.

In summary, supplemental oxygen during recovery period on the rate of recovery of repeated exercise bouts activity failed to have any effect on physiological variables. Performance was not enhanced nor was any subjective relief demonstrated. The researcher can offer no scientific basis for the use of supplemental oxygen in speeding up the recovery or improving subsequent performance in healthy individuals.

Suggestion, it should also investigated. The data may be useful in explaining some of the data found above on adding other variables parameter such as circulating rate of the blood or blood acid-base when receiving oxygen before, during and after exercise with major muscles and in the area that is higher than sea water level.

REFERENCES

1. Adams R.P., Welch H.G. (1980). Oxygen uptake, acid-base status, and performance with varied inspired oxygen fractions. *Journal of Apply Physiology* 49, 863–868.
2. Astorino T.A., Robergs R.A. Effect of hyperoxia on maximal oxygen uptake, blood acid-base balance, and limitations to exercise tolerance. J. Exercise Physiology. 2003;2 (6):9-20.
3. Bannister RG, Cunningham DJC. The effects on the respiration and performance during exercise of adding oxygen to the inspired air. J Physiol. 1954; 125 : 118-137.
4. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14: 377–381.
5. Center for Advanced Microstructures & Devices[online]. Oxygen, Compressed Gas.;2000.Availablefrom:http://www.camd.lsu.edu/msds/o/oxygen.htm [Accessed 2000 jan 3] .
6. Christopher CD. Practical use of rating of perceived exertion in a clinical setting. Sports Med. 1993; 16(4): 221-224.
7. Declan A.J. Connolly, Kevin M. Brennan and Christie D. Lauzon. Effects of active versus passive recovery on power output during repeated bouts of short term, high intensity exercise. Journal of Sports Science and Medicine. 2003; 2: 47-51.
8. Fagraeus L, Hesser C, Linnarsson D. Cardiorespiratory responses to graded exercise at increased ambient air pressures. Acta Physiol Scand 1974; 91:259-74.
9. Forbes GB. The effects of anabolic steroids on lean body mass: the dose response curve. Metabolism 1985; 34: 571-573.
10. Graham T.E., Wilson B.A. (1983). Effects of hypercapnia and hyperoxia on metabolism during exercise. *Med Sci Sports Exerc* 15, 514–519.

11. Hampson NB. Hyperbaric oxygen therapy: 1999 committee report. Kensington, Md.: Undersea and Hyperbaric Medical Society, 1999.

12. Hodges A N H et al. Effect of hyperbaric oxygen on oxygen uptake and measurements in the blood and tissues in a normobaric environment British Journal of Sports Medicine 2003, 37, 516-520.

13. Hogan MC, Cox RH, Welch HG. Lactate accumulation during incremental exercise with varied inspired oxygen fractions. J Appl Physiol Respirat Environ Exercise Physiol. 1983; 55(4) : 1134-1140.

14. Howley E.T., Cox R.H., Welch H.G., Adams R.P. (1983). Effect of hyperoxia on metabolic and catecholamine responses to prolonged exercise. *J Appl Physiol* 54, 59–63

15. Ingjer F, Stromme SB. Effect of active, passive, or no warm-up on the physiological response to heavy exercise, Eur J Appl Physiol. 1979; 40:273-282.

16. Knight D, Schaffartzik W, Poole D, Hogan M, BeBout D, Wagner P. Effects of hyperoxia on maximal leg O_2 supply and utilization in men. J Appl Physiol 1993;75(6):2586-94.

17. Linnarsson, D., J. Karlsson, L. Fagraeus, and B. Saltin. Muscle metabolites and oxygen deficit with exercise in hypoxia and hyperoxia. J. Appl. Physiol. 1974; 36: 399-402.

18. Loretta Y, C. Yam. Clinical applications of oxygen therapy in hospitals and techniques of oxygen administration –a review. J Hong Kong Med Assoc. 1993; 45(4): 318-325.

19. Maeda T, Yasukouchi A. Blood lactate disappearance during breathing hyperoxic gas after exercise in two different physical fitness groups on the work load fixed at 70% VO_2max .Appl Human Sci. 16 (6): 249-255.

20. Maeda T, Yasukouchi A. Blood lactate disappearance during breathing hyperoxic gas after exercise in two different physical fitness groups on the work load fixed at 130% VO_2max .Appl Human Sci. 16 (6): 249-255.

21. Morris A. F. (1983). Oxygen Ergogenic Aids in Sports. *Champaign IL: Human Kinetics.*

22. Nielsen H, Madsen P, Svendsen L, Roach R, Secher N. The influence of P_aO_2, pH, and S_aO_2 on maximal oxygen uptake. Acta Physiol Scand 1998; 164:89-97.
23. Nummela, A., Hämäläine, I. and Rusko, H. Effect of hyperoxia on metabolic responses and recovery in intermittent exercise. Scand. J. Med. Sci. Sports. 2002; 12: 309 -315.
24. Peltonen J.E., Leppavuori A.P., Kyro K.P., Makela P., Rusko H.K. (1999). Arterial hemoglobin saturation is effected by F_iO_2 at submaximal running velocities in elite athletes. *Scan J Med Sci Sports* 9, 265-271.
25. Peltonen J, Rantamaki J, Niitymaki S, Sweins K, Viitasolo J, Rusko H. Effects of oxygen fraction in inspired air on rowing performance. Med Sci Sports Exerc. 1995;27(4):573-9.
26. Powers S, Lawler J, Dempsey J, Dodd S, Landry G. Effects of incomplete pulmonary gas exchange on VO_2max. J Appl Physiol. 1989; 66(6):2491-5.
27. Robert A, Scott O. Exercise Physiology Exercise, Performance, and Clinical Applications.1996: 470.
28. Robbins MK, Gleeson K, Zwillich CW. Effect of oxygen breathing following submaximal and maximal exercise on recovery and performance. Med Sci Sports Exerc. 1992; 24: 720–725.
29. Spriet L, Gledhill N, Froese A, Wilkes D. Effect of graded erythrocythemia on cardiovascular and metabolic responses to exercise. J Appl Physiol. 1986;61(5):1942-8
30. Thoden JS, MacDougall JD, Wilson BA. Testing aerobic power. In: MacDougall JD, Wenger HA, Green HJ (eds). Physiological testing of the elite athlete. Mutual Press, Canada 1982; 39-60.
31. Thomson J, Stone J, Ginsburg A, Hammett P. O_2 transport during exercise following blood reinfusion. J Appl Physiol 1982; 53(5):1213-9.
32. Wadler GI, Hainline B. Drug and the athlete. Philadelphia. 1989, FA Davis.
33. Wikipedia. The free encyclopedia [online]. Oxygen toxicity. 2007, updated 21 June 2007. Available from: http;//www.en.wikipedia.org/wiki/ Oxygen toxicity .[Accessed 2007 jun 21].
34. Welch HG. Hyperoxia and human performance: a brief review. Med Sci Sports Exerc. 1982; 14: 253–262.

35. Welch H. G. (1987). Effect of hypoxia and hyperoxia on human performance. *Exercise and Sports Sciences Reviews* 15, 191-222.

36. Welch H.G., Bonde-Petersen F., Graham T., Klausen K., Secher N. (1977). Effects of hyperoxia on leg blood flow and metabolism during exercise. *J Appl Physiol* 42, 385-390.

37. Welch H.G., Pedersen P.K. (1981). Measurement of metabolic rate in hyperoxia. *J Appl Physiol* 51(3), 725–31.

38. Wilmore J. H. (1972). Oxygen. Ergogenic Aids and Muscular Performance, ed. W.P. Morgan, 321-342. New York : Academic Press.

39. Wilson G. D., Welch H.G. (1975). Effects of hyperoxic gas mixture on exercise tolerance in man. *Medicine and Science in Sports* 7, 48-52.

40. Wilson GD, Welch HG. Effects of hyperoxic gas mixtures on exercise tolerance in man. 1975; 7(1) : 48-52.

APPENDICES

APPENDIX A

PHYSICAL ACTIVITY LEVEL QUESTIONNAIRE

แบบประเมินระดับกิจกรรม

ชื่อ-สกุล...อายุ............................ปี

	สม่ำเสมอ	บ่อย	บางครั้ง	ไม่เคย
	(4)	(3)	(2)	(1)
1. ท่านเลือกที่จะเดินมากกว่านั่งรถ				
2. ท่านออกกำลังกายมากกว่า 1 ครั้ง/สัปดาห์				
3. ท่านออกกำลังกายอย่างหนัก				
4. ท่านเลือกที่จะเดินขึ้นบันไดมากกว่าการใช้ลิฟท์หรือบันไดเลื่อน				
5. ท่านออกกำลังกายเบาๆ				
6. ท่านมักทำกิจกรรมต่างๆด้วยตนเองทุกวัน				
7. ท่านมักทำกิจกรรมต่างๆในวันว่างแทนที่จะนั่งดูโทรทัศน์				
8. ท่านเล่นกีฬาอย่างน้อย 1 ครั้ง/สัปดาห์				

คะแนน กิจกรรม :1)..............+4)................+6)...............+7)..................=..................

การออกกำลังกาย :2)..............+3)................+5)................+8)..................=..................

รวม...คะแนน ระดับกิจกรรม..

≤ 16 low activity 17-23 moderate activity ≥24 high activity

Current Level of Physical Activity

	always	often	sometimes	never
	(4)	(3)	(2)	(1)
a. Dose subject walk rather whenever possible?				
b. Dose subject exercise more than once a week?				
c. Dose subject make time to exercise?				
d. Dose subject use the stairs rather than lifts or escalators?				
e. Dose subject have a formal exercise plan that subject follow?				
f. Dose subject fine time to do something active every day?				
g. After work or during the day, is subject physically active instead of watching television?				
h. Dose subject participate in any sport at least once a week?				

Score: Activity :1)..............+4)...............+6)...............+7)..................=..................

Exercise :2)..............+3)...............+5)...............+8)..................=..................

Total Score………………………Physical Activity Level…………………………..

≤ 16 low activity 17-23 moderate activity ≥24 high activity

Reference

National Heart Foundation of Australia: Physical activity. National Heart Foundation.1996

แบบสอบถาม

สำหรับคัดเลือกอาสาสมัครเข้าร่วมงานวิจัยวิทยานิพนธ์ สาขา วิทยาศาสตร์การกีฬา

วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล

เรื่อง "ผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว (The effect of 40% oxygen supplemental during recovery period of repeated exercise bouts on rate of recovery) "

คำชี้แจง : โปรดกรอกข้อมูลและตอบคำถามต่อไปนี้ตามความเป็นจริง ข้อมูลทั้งหมดในแบบสอบถามจะถูกเก็บเป็นความลับ และใช้ในงานวิจัยนี้เท่านั้น

ตอนที่ 1 : ข้อมูลทั่วไป

1. ชื่อ – สกุล.. ชื่อเล่น......................
2. เพศ ☐ ชาย ☐ หญิง
3. วัน เดือน ปีเกิด.. อายุ...................... ปี
4. ที่อยู่ปัจจุบัน...
   เบอร์โทรติดต่อที่บ้าน.. มือถือ..
   Email: ……………………………………………………………………………
5. คณะ/สถาบันที่ศึกษา.................................... ชั้นปีที่......... รหัสนักศึกษา.........................
6. น้ำหนัก.............. กิโลกรัม ส่วนสูง................ เซนติเมตร
7. ดัชนีมวลกาย (BMI).......................... กิโลกรัม/เมตร^2

ตอนที่ 2 : ข้อมูลเกี่ยวกับประวัติสุขภาพ

8. ท่านมีโรคประจำตัวหรือไม่
   ☐ ไม่มี ☐ ไม่เคยตรวจ ☐ มี โปรดระบุ............................ เป็นมานาน.........ปี

9. ท่านป่วยเป็นโรคได้แก่ โรคหัวใจ โรคความดันโลหิต โรคเบาหวาน โรคไต หรือไม่
   ☐ ไม่ใช่ ☐ ใช่ โปรดระบุ.. เป็นมานาน.........ปี

10. ท่านป่วยเป็นโรคระบบทางเดินหายใจ เช่น โรคภูมิแพ้ โรคหอบ โรคปอดอุดกั้นเรื้อรัง หรือไม่
    ☐ ไม่ใช่ ☐ ใช่ โปรดระบุ.. เป็นมานาน.........ปี
11. ท่านป่วยเป็นโรคเกี่ยวกับกระดูก ข้อต่อ และกล้ามเนื้อ หรือไม่
    ☐ ไม่ใช่ ☐ ใช่ โปรดระบุ.. เป็นมานาน.........ปี
12. ท่านป่วยเป็นโรคเกี่ยวกับสองและระบบประสาท เช่น โรคลมชัก ลมบ้าหมู หรือไม่
    ☐ ไม่มี ☐ มี โปรดระบุ.. เป็นมานาน.........ปี

13. ท่านเคยได้รับการผ่าตัดที่บริเวณ ทรวงอก ช่องท้อง หลัง และบริเวณอื่นๆ หรือไม่

☐ ไม่เคย ☐ เคย โปรดระบุ.. เป็นมานาน.........ปี

14. ท่านเคยได้รับอุบัติเหตุหรือ บาดเจ็บรุนแรง หรือไม่

☐ ไม่เคย ☐ เคย โปรดระบุ.. เป็นมานาน.........ปี

15. ท่านเคยมีอาการเจ็บหน้าอกอย่างรุนแรง หรือไม่

☐ ไม่เคย ☐ เคย โปรดระบุ.. เป็นมานาน.........ปี

16. ท่านเป็นโรคติดต่อไปนี้ หรือไม่

16.1 ไวรัสตับอักเสบ ☐ ไม่ใช่ ☐ ใช่

16.2 ภูมิคุ้มกันร่างกายบกพร่อง (AIDS) ☐ ไม่ใช่ ☐ ใช่

17. ปัจจุบันท่านต้องรับประทานยาเป็นประจำ หรือไม่

☐ ไม่ใช่ ☐ ใช่ โปรดระบุชื่อยา......................... ระยะเวลาที่ใช้.........ปี

18. การติดต่อกรณีฉุกเฉิน

แพทย์ประจำตัว... เบอร์โทรศัพท์...

19. ประวัติการสูบบุหรี่ และดื่มเครื่องดื่มแอลกอฮอล์

☐ ไม่สูบบุหรี่

☐ สูบบุหรี่เป็นบางครั้ง

☐ สูบบุหรี่เป็นประจำ ระบุ............................ มวน/วัน

☐ ไม่ดื่ม เครื่องดื่มแอลกอฮอล์ใดๆ

☐ ดื่มเครื่องดื่มแอลกอฮอล์ใดๆเป็นบางครั้ง

☐ ดื่มเครื่องดื่มแอลกอฮอล์ใดๆเป็นประจำ ระบุ................ วัน/สัปดาห์

20. ประวัติการออกกำลังกาย (Physical activity history)

20.1 ท่านให้เวลากับการออกกำลังกายมากน้อยเพียงใด

☐ ไม่ได้ออกกำลังกายมาเป็นเวลามากกว่า 3 เดือน (1)

☐ ออกกำลังกายเป็นบางครั้ง เมื่อมีโอกาส (2)

☐ ออกกำลังกายเป็นประจำ ทุกครั้งเมื่อมีโอกาส (3)

☐ ออกกำลังกายสม่ำเสมอ (4)

20.2 โดยเฉลี่ย ท่านออกกำลังกาย หรือ เล่นกีฬากี่วัน/สัปดาห์

☐ น้อยกว่า 1 ครั้ง/สัปดาห์ (1)

☐ 1 ครั้ง / สัปดาห์ (2)

☐ 2-3 มากกว่า / สัปดาห์ (3)

☐ มากกว่า 3 ครั้ง / สัปดาห์ (4)

20.3 ประเภทกีฬา หรือ การออกกำลังกายชนิดใดที่ท่านปฏิบัติอยู่

ระบุ...

20.4 ระยะเวลาของการออกกำลังกาย / เล่นกีฬาที่ท่านปฏิบัติในแต่ละครั้ง

☐ น้อยกว่า 20 นาที (1)

☐ 20-30 นาที (2)

☐ 30-60 นาที (3)

☐ มากกว่า 60 นาที (4)

20.5 ลักษณะของการออกกำลังกาย / เล่นกีฬาที่ท่านปฏิบัติในแต่ละครั้ง

☐ ไม่ต่อเนื่อง (พักนาน มากกว่า 15 นาที)

☐ ไม่ต่อเนื่อง (พักไม่นาน ไม่เกิน 15นาที)

☐ ต่อเนื่อง

20.6 ระดับความหนักของการออกกำลังกาย / เล่นกีฬาที่ท่านปฏิบัติ

☐ เบา (เริ่มรู้สึกเหนื่อย,ไม่มีเหงื่อออก) (1)

☐ ปานกลาง (รู้สึกเหนื่อย,เหงื่อออกเล็กน้อย) (2)

☐ หนัก (รู้สึกเหนื่อยมาก,เหงื่อออกค่อนข้างมาก
,กระหายน้ำมาก) (3)

☐ หนักมาก (รู้สึกเหนื่อยมาก,เหงื่อออกมาก
,กระหายน้ำมาก,ชีพจรเต้นเร็ว, ปวดเมื่อยกล้ามเนื้อ) (4)

ตอนที่ 3: ข้อมูลระดับกิจกรรม

	สม่ำเสมอ	บ่อย	บางครั้ง	ไม่เคย
	4	**3**	**2**	**1**
1. ท่านเลือกที่จะเดินมากกว่านั่งรถ				
2. ท่านออกกำลังกายมากกว่า 1 ครั้ง/ สัปดาห์				
3. ท่านออกกำลังกายอย่างหนัก				
4. ท่านเลือกที่จะเดินขึ้นบันไดมากกว่า การใช้ลิฟต์ หรือบันไดเลื่อน				
5. ท่านออกกำลังกายเบาๆ				
6. ท่านมักทำกิจกรรมต่างๆ ด้วยตนเองทุกวัน				
7. ท่านมักจะทำกิจกรรมต่างๆในวันว่างแทนที่จะนั่งดูโทรทัศน์				
8. ท่านเล่นกีฬาอย่างน้อย 1 ครั้ง / สัปดาห์				

ชื่อ..

วันที่.......เดือน............................... พ.ศ. ....

ผู้วิจัยขอขอบคุณที่ท่านให้ข้อมูลและรายละเอียดข้างต้นตามจริง

เฉพาะผู้วิจัย

<u>คะแนน ตอนที่2</u>

การออกกำลังกาย : 20.1)……… +20.2)……… +20.4) ……… +20.6) ……… = ……………

$\leq$9 low activity 10-13 moderate activity $\geq$ 14 high activity

<u>คะแนน ตอนที่3</u>

คะแนน กิจกรรม : 1)……….+4)………. +6)……….+7)……….= ……………………..

การออกกำลังกาย : 2)……….+3)………. +5)……….+8)……….= ……………………..

รวม.......................... คะแนน ระดับกิจกรรม ....

$\leq$16 low activity 17-23 moderate activity $\geq$ 24 high activity

ความคิดเห็น ผ่าน ไม่ผ่าน

....

....

....

APPENDIX B

หนังสือยินยอมให้ทำการวิจัยโดยรับการบอกกล่าวและเต็มใจ

(Informed consent form)

ชื่อโครงการ ผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว

(EFFECTS OF 40 % OXYGEN SUPPLEMENTAL DURING RECOVERY PERIOD OF REPEATED EXERCISE BOUTS ON RATE OF RECOVERY)

วันให้คำยินยอม วันที่...........เดือน...............................พ.ศ. ....

ก่อนที่จะลงนามในใบยินยอมนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมถึงประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆที่ข้าพเจ้าสงสัยด้วยความเต็มใจ ไม่ปิดบังซ่อนเร้น จนข้าพเจ้าเข้าใจ

ข้าพเจ้าร่วมการวิจัยโดยสมัครใจและมีสิทธิที่จะยกเลิกการเข้าร่วมการวิจัยนี้เมื่อใดก็ได้

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะตัวข้าพเจ้าเป็นความลับและจะเปิดเผยได้เฉพาะในรูปแบบที่เป็นการสรุปผลการวิจัย การเปิดเผยข้อมูลที่เกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆที่เกี่ยวข้อง กระทำได้เฉพาะในกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น

ผู้วิจัยรับรองว่าหากเกิดอันตรายใดๆอันเนื่องมาจากวิจัยดังกล่าว ข้าพเจ้าจะได้รับการรักษาพยาบาลโดยไม่คิดมูลค่าตามมาตรฐานวิชาชีพ และจะได้รับการชดเชยรายได้ที่สูญเสียไประหว่างการรักษาพยาบาลดังกล่าว ตลอดจนเงินทดแทนความพิการที่อาจเกิดขึ้น

ผู้วิจัยรับรองว่าหากมีข้อมูลเพิ่มเติมที่ส่งผลกระทบต่อการวิจัย ข้าพเจ้าจะได้รับการแจ้งให้ทราบโดยไม่ปิดบังซ่อนเร้น

ข้าพเจ้าได้อ่านข้อความข้างต้น และมีความเข้าใจดีทุกประการและได้ลงนามในใบยินยอมนี้

ลงชื่อ..(ผู้ยินยอม)

ลงชื่อ..(พยาน)

ลงชื่อ..(พยาน)

โอภาส อักษรจรรยา

ผู้วิจัย

APPENDIX C
DATA COLLECTION FORM

แบบบันทึกการทดสอบของผู้ของร่วมงานวิจัย (FITNESS TEST)

เรื่อง "ผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว"

(EFFECTS OF 40 % OXYGEN SUPPLEMENTAL DURING RECOVERY PERIOD OF REPEATED EXERCISE BOUTS ON RATE OF RECOVERY)

ชื่อ-สกุล .... เพศ ....

ลำดับที่ ....

วันเกิด : วันที่ .... เดือน .... พ.ศ. .... อายุ .... ปี

วันที่ทำการทดลอง .... อุณหภูมิ .... ความชื้น ....

น้ำหนักตัว .... กก. ส่วนสูง ....ซม.

ดัชนีมวลกาย (BMI) .... Kg/m ระดับที่นั่ง ....

อัตราการเต้นของหัวใจ .... ครั้ง/นาที

ค่าความสามารถในการจับออกซิเจนสูงสุดของร่างกาย

(VO_2max) .... ml/min/Kg

ค่า 70% ความสามารถในการจับออกซิเจนสูงสุดของร่างกาย

(70% VO_2max) .... ml/min/Kg

ค่าความหนักของการปั่นจักรยานที่ปั่นได้สูงสุด

(Maximum Work Load) .... Watt

ระดับความหนัก 70% ของค่าการจับออกซิเจนสูงสุดของร่างกาย

VO_2max .... Watt

เวลาที่เริ่มทำการทดลอง ....

ระยะเวลาที่ปั่นจักรยานรวม .... นาที

ผู้บันทึกผล ....

แบบการบันทึกการทดสอบของผู้เข้าร่วมวิจัย (DATA TEST)

เรื่อง “ผลของการให้ 40 เปอร์เซ็นต์ออกซิเจนในช่วงระยะเวลาพักของการออกกำลังกายแบบแบ่งเป็นช่วงต่ออัตราการฟื้นตัว”

(EFFECTS OF 40 % OXYGEN SUPPLEMENTAL DURING RECOVERY PERIOD OF REPEATED EXERCISE BOUTS ON RATE OF RECOVERY)

ชื่อ-สกุล .... เพศ ....

ลำดับที่ ....

วันเกิด : วันที่ .... เดือน .... พ.ศ. .... อายุ .... ปี

วันที่ทำการทดลอง .... อุณหภูมิ .... ความชื้น ....

น้ำหนักตัว .... กก. ส่วนสูง ....ซม.

ดัชนีมวลกาย (BMI) .... Kg/m ระดับที่นั่ง ....

ค่า 70% ความสามารถในการจับออกซิเจนสูงสุดของร่างกาย

(70% VO_2max) .... ml/min/Kg

ระดับความหนัก 70% ของค่าการจับออกซิเจนสูงสุดของร่างกาย

VO_2max .... Watt

เวลาที่เริ่มทำการทดลอง ....

อัตราการเต้นของหัวใจขณะพัก .... ครั้ง/นาที

Blood lactate concentration (mmol•L^{-1}) ....

Hemoglobin oxygen saturation (%) ....

มีความรู้สึกไม่สบายวันที่ทดสอบหรือไม่..........................

1. วัดความเข้มข้นของกรดแลคติกและค่าระดับความเหนื่อยของ Borg

ช่วงนาทีที่ Time (min)	Blood lactate concentration (mmol•L^{-1})	Rate of perceived exertion (RPE)
0		
2		
4		
6		

2. วัดอัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบิน

ช่วงนาทีที่ Time (min)	Heart rate (beat•min^{-1})	Hemoglobin oxygen saturation (%)
0		
2		
4		
6		

3. วัดระยะเวลาตั้งแต่เริ่มออกกำลังกายจนหมดแรง เริ่มบันทึกตั้งแต่เริ่มการออกกำลังกายในช่วงที่ 3 (Ex_3)

Time to exhaustion .... **min**

40% O_2 Test .... **Room air Test** ....

ผู้บันทึกผล ....

วัดความเข้มข้นของกรดแลคติกในช่วงขณะพัก

ช่วงขณะพัก	Blood lactate concentration ($mmol \cdot L^{-1}$)
ช่วงที่ 1	
ช่วงที่ 2	

อัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบินช่วงขณะพักช่วงที่ 1

ช่วงนาทีที่ Time (min)	Heart rate ($beat \cdot min^{-1}$)	Hemoglobin oxygen saturation (%)
1		
2		
3		
4		

อัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบินช่วงขณะพักช่วงที่ 2

ช่วงนาทีที่ Time (min)	Heart rate ($beat \cdot min^{-1}$)	Hemoglobin oxygen saturation (%)
1		
2		
3		
4		

อัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบินช่วงออกกำลังกายช่วงที่ 1

ช่วงนาทีที่ Time (min)	Heart rate ($beat \cdot min^{-1}$)	Hemoglobin oxygen saturation (%)
1		
2		
3		
4		
5		

อัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบินช่วงออกกำลังกายช่วงที่ 2

ช่วงนาทีที่ Time (min)	Heart rate (beat•min^{-1})	Hemoglobin oxygen saturation (%)
1		
2		
3		
4		
5		

อัตราการเต้นของหัวใจและความอิ่มตัวออกซิเจนของฮีโมโกลบินช่วงออกกำลังกายช่วงที่ 3

ช่วงนาทีที่ Time (min)	Heart rate (beat•min^{-1})	Hemoglobin oxygen saturation (%)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

APPENDIX D
DATA INFORMATION

Blood lactate concentration

- **Room air breathing modes**

ID	BLOOD LACTATE CONCENTRATION (mmol/L) TIME (min)				
	PRE	T0	T2	T4	T6
1	2.8	4.8	6.1	5.7	4.1
2	1.6	6.4	8.2	5.3	5.2
3	2	8.1	7.2	8.5	9
4	0.9	6.6	4.6	6.9	5.2
5	1.1	12.5	10.6	9.6	8.3
6	2.3	6.6	8.2	6.8	8.1
7	2.2	12.9	13.1	14	12.8
8	1.7	8.7	9.2	6.5	7.2
9	1.9	8.6	10.6	7.2	5.6
10	1.5	9.3	8.7	7.7	7
11	0.8	10.8	10.7	10.3	9
12	2.7	8.3	10	8.8	5.6

- **40% O_2 breathing modes**

ID	BLOOD LACTATE CONCENTRATION (mmol/L) TIME (min)				
	PRE	T0	T2	T4	T6
1	1.5	7.8	8.6	6.7	5.2
2	1.5	7.8	10.8	9.2	8.9
3	2	7.2	8.2	6.2	4.9
4	2.4	8.1	9.3	8.1	9.1
5	1	10.5	8.4	10	9.8
6	2.1	12	11.2	10.2	6.7
7	2	10.2	12.2	10	19.7
8	1.2	7.5	8	7.6	7
9	2.6	12.7	13.7	12.3	8.2
10	1.9	11.4	10.3	10.1	9.2
11	1.1	6.6	6.5	5.5	4.6
12	0.8	12.7	10.2	6.8	5.4

Heart rate

- **Room air breathing modes**

ID	HEART RATE (bpm)				
	TIME (min)				
	PRE	T0	T2	T4	T6
1	63	165	124	98	93
2	71	193	147	122	109
3	57	151	115	104	102
4	61	164	123	109	107
5	70	181	125	122	121
6	69	178	119	105	105
7	85	198	126	124	115
8	90	193	154	118	96
9	65	176	126	114	85
10	88	187	124	112	103
11	64	164	115	105	102
12	71	177	132	111	105

- **40% O_2 breathing modes**

ID	HEART RATE (bpm)				
	TIME (min)				
	PRE	T0	T2	T4	T6
1	66	156	111	102	97
2	68	197	132	133	127
3	66	134	108	104	96
4	80	181	125	94	89
5	71	172	120	114	116
6	71	162	125	115	111
7	80	177	131	122	114
8	70	157	113	108	101
9	71	172	131	110	106
10	74	167	104	102	101
11	69	171	114	94	91
12	70	182	140	124	111

Hemoglobin oxygen saturation

- **Room air breathing modes**

ID	HEMOGLOBIN OXYGEN SATURATION (%) TIME (min)				
	PRE	T0	T2	T4	T6
1	98	98	98	98	98
2	97	98	97	96	98
3	99	96	98	97	97
4	98	99	99	98	98
5	98	97	97	96	97
6	99	99	98	97	98
7	98	98	98	97	97
8	98	98	99	98	98
9	99	98	98	97	98
10	99	98	98	98	97
11	98	96	97	97	97
12	99	98	98	98	99

- **40% O_2 breathing modes**

ID	HEMOGLOBIN OXYGEN SATURATION (%) TIME (min)				
	PRE	T0	T2	T4	T6
1	99	98	98	98	99
2	98	96	98	97	98
3	99	97	98	98	99
4	98	97	97	98	98
5	98	95	98	98	98
6	98	98	98	98	98
7	97	99	99	99	98
8	98	98	98	99	98
9	100	98	98	98	98
10	99	97	98	99	98
11	99	98	98	98	99
12	99	98	99	99	99

Rate of perceive exertion

- **Room air breathing modes**

ID	RATE OF PERCEIVE EXERTION				
	TIME (min)				
	PRE	T0	T2	T4	T6
1	6	19	12	8	6
2	6	19	13	11	7
3	6	19	18	18	18
4	6	19	17	15	15
5	6	20	18	18	15
6	7	20	13	12	10
7	6	19	19	17	15
8	6	19	17	13	12
9	6	19	17	15	7
10	6	20	15	13	9
11	6	20	17	15	13
12	6	19	17	15	13

- **40% O_2 breathing modes**

ID	RATE OF PERCEIVE EXERTION				
	TIME (min)				
	PRE	T0	T2	T4	T6
1	6	19	11	9	8
2	6	20	15	11	9
3	6	18	15	13	10
4	6	20	17	15	13
5	7	20	13	9	7
6	6	19	15	11	9
7	7	20	17	17	15
8	6	20	15	10	8
9	6	20	13	7	7
10	6	20	15	11	8
11	6	20	13	10	9
12	6	20	17	15	13

APPENDIX E

The rate of recovery was indicated by blood lactate concentration (BLC), heart rate (HR), hemoglobin oxygen saturation (S_aO_2) and rate of perceived exertion (RPE), which were measured at rest, immediately after exercise (T0) and 2, 4, and 6 minute (T2, T4, T6) after exercise cessation of R_3 and time to exhaustion (t_{exh}) were measured start Ex_3 until exhaustion. Values are presented as mean ± SEM (n=12)

Table E.1 Blood lactate concentration (mmol•L^{-1})

Time	Blood lactate concentration (mmol•L^{-1}) Room Air Breathing		40% O_2 Breathing		t	P value
	Mean	SEM	Mean	SEM		
Rest	1.79	0.18	1.67	0.16	0.46	0.654
T0	8.63	0.71	9.37	0.6	-0.617	0.55
T2	8.93	0.66	9.78	0.58	-1.241	0.24
T4	8.1	0.68	8.55	0.59	-0.497	0.629
T6	7.25	0.68	8.22	1.17	-1.02	0.33

Table E.2 Heart rate (bpm)

Time	Heart rate (bpm) Room Air Breathing		40% O_2 Breathing		t	P value
	Mean	SEM	Mean	SEM		
Rest	71.17	3.13	71.33	1.33	-0.06	0.956
T0	177.25	4.11	169.00	4.58	1.93	0.080
T2	127.50	3.42	121.17	3.24	1.54	0.151
T4	112.00	2.39	110.17	3.47	0.67	0.518
T6	104.42	2.33	105.00	3.24	-0.21	0.841

Table E.3 Hemoglobin oxygen saturation (%)

Time	Hemoglobin oxygen saturation (%)				t	P value
	Room Air Breathing		40% O_2 Breathing			
	Mean	SEM	Mean	SEM		
Rest	98.33	0.19	98.50	0.23	-0.80	0.438
T0	97.75	0.28	97.42	0.31	0.89	0.394
T120	97.92	0.19	98.08	0.19	-0.56	0.586
T240	97.25	0.22	98.25	0.18	-5.74	0.000*
T360	97.67	0.14	98.33	0.19	-5.00	0.000*

Table E.4 Rate of perceived exertion

Time	Rate of perceived exertion				t	P value
	Room Air Breathing		40% O_2 Breathing			
	Mean	SEM	Mean	SEM		
Rest	6.08	0.09	6.17	0.13	-0.561	0.586
T0	19.33	0.14	19.67	0.19	-1.483	0.166
T2	16.08	0.66	14.67	0.54	2.120	0.058
T4	13.92	0.78	11.50	0.85	2.546	0.027*
T6	11.25	0.96	9.67	0.75	1.929	0.080

APPENDIX F

วิธีการหาระดับกรดแลคติกในเลือด

การเก็บตัวอย่างในเลือด

1. ใช้แอลกอฮอล์เช็ดทำความสะอาดบริเวณปลายนิ้วมือ
2. ใช้เครื่องเจาะเลือดที่ใช้เข็ม Softclix lancet เจาะที่บริเวณปลายนิ้วมือ โดยปรับความลึกของเข็มที่เจาะลึกประมาณ 1 มิลลิเมตร
3. บีบให้เลือดไหลออกมาเป็นหยดลงบนแผ่นทดสอบ

วิธีการใช้เครื่องวัดปริมาณกรดแลคติกในเลือด

1. ใส่แบตเตอรี่ขนาด AAA จำนวน 3 ก้อน ในรางใส่แบตเตอรี่
2. กดปุ่ม ON/OFF เพื่อเปิดเครื่อง ใช้เวลาประมาณ 2 วินาที หน้าจอจะปรากฏ
3. ปรับมาตรฐานเครื่อง (Calibration)
   - สอดแถบรหัส (Code strip) ในช่องสดแถบสำหรับหยดเลือดเพื่อวัดปริมาณกรดแลคติก เมื่อสอดแถบรหัสจนสุดแล้ว ให้ดึงแถบรหัสออกทันที จากนั้นเก็บแถบรหัสไว้ด้านหลังเครื่อง เพื่อใช้ครั้งต่อไป และเปลี่ยนแถบรหัสเมื่อเปิดใช้แถบรหัสกล่องใหม่
   - หากหน้าจอปรากฏข้อความ E-2 ให้เปิดฝาแล้วปิด และทำการปรับมาตรฐานเครื่องใหม่ ทั้งนี้ ให้สอดแถบรหัสเข้าและดึงแถบรหัสออกด้วยความเร็วสม่ำเสมอ
4. วัดปริมาณกรดแลคติกในเลือด
   - กดปุ่ม ON/OFF หน้าจอจะปรากฏรหัสเลข 3 หลัก ซึ่งเป็นรหัสของแถบรหัสที่ใช้ปรับมาตรฐานเครื่อง
   - ตรวจดูรหัสที่หน้าจอกับรหัสของแถบรหัสให้ตรงกัน
   - สอดแถบสำหรับหยดเลือดเพื่อวัดปริมาณกรดแลคติกในเลือด (แถบเปล่า) ในช่องสอดแถบสำหรับหยดเลือดเพื่อวัดปริมาณกรดแลคติก
   - เปิดฝาเครื่อง หน้าจอจะปรากฏข้อความ 60 sec
   - หยดเลือดที่เจาะได้ ประมาณ 15-50 ไมโครลิตร ลงบนส่วนสำหรับหยดเลือด (พื้นที่สีเหลือง) บนแถบสำหรับหยดเลือดเพื่อวัดปริมาณกรดแลคติก การหยดเลือดลงบนส่วนดังกล่าว ควรหยดเลือดให้ครอบคลุมพื้นที่สีเหลืองทั้งหมด
   - ปิดฝาเครื่องทันที ไฟตัวเลข 60 sec จะถอยหลังลงเรื่อยๆ เครื่องจะอ่านค่ากรดแลคติกในเลือดภายใน 60 วินาที

5. เลิกใช้งาน
    - เมื่อใช้งานเครื่องเสร็จแล้ว ให้ปิดเครื่องโดยกดปุ่ม ON/OFF
    - เปิดฝาเครื่องและดึงแถบสำหรับหยดเลือดเพื่อวัดปริมาณกรดแลคติกออกจากเครื่อง
    - เช็ดเครื่องด้วยแอลกอฮอล์ 70 %
    - ปิดฝาเครื่อง
6. การทำ Performance Check

   ใช้ BM-Control Lactate ทำทุกครั้งเมื่อ
    - เมื่อใช้งานเครื่องเสร็จแล้ว ให้ปิดเครื่องโดยกดปุ่ม ON/OFF
    - หลังทำความสะอาดเครื่อง
    - เปลี่ยนแบตเตอรี่
    - หลังการทำ Calibrate
    - เมื่อสงสัยในผลการทดสอบที่ได้

คู่มือการใช้งานภาษาไทย เครื่องวัดปริมาณกรดแลคติกในเลือด Accutrend® lactate portable lactate analyzer (Roche Mannheim, Germany)

APPENDIX G

ความเข้มข้นของออกซิเจนที่ได้จาก low flow oxygen delivery system

	O_2 flow (l/min)	F_iO_2
Nasal canula	1	0.24
	2	0.28
	3	0.32
	4	0.36
	5	0.40
	6	0.44
Simple oxygen mask	6	0.40
	7	0.50
	8	0.60
Mask with bag	6	0.60
	7	0.70
	8	0.80
	9	0.90
	10	0.99

เครื่องมือที่ใช้ในการให้ออกซิเจน

เครื่องมือที่ใช้ในการให้ออกซิเจน แบ่งออกเป็น 2 ประเภทใหญ่ๆ ดังนี้คือ

1. High-flow oxygen system คือ เครื่องมือที่ให้ออกซิเจนโดยที่อัตราไหลของออกซิเจนและความจุของ Reservior เพียงพอกับความต้องการของผู้ป่วยทั้งหมด ทำให้ความเข้มข้นของออกซิเจนที่ได้ค่อนข้างคงที่ และสามารถควบคุมความเข้มข้นของระดับต่ำและระดับสูง ดังนั้นลักษณะเด่นของเครื่องมือชนิดนี้ คือ

สามารถควบคุมความเข้มข้นของออกซิเจนตามความต้องการของผู้ป่วยได้ค่อนข้างคงที่โดยไม่เปลี่ยนแปลงไปตามลักษณะของการหายใจของผู้ป่วย

สามารถควบคุมปริมาณความชื้นและอุณหภูมิของก๊าซที่หายใจเข้าไปได้ค่อนข้างคงที่ เครื่องมือที่ให้ High-flow oxygen system ได้แก่ การให้ O_2 T-piece

2. Low flow oxygen system คือ เครื่องมือที่ให้ออกซิเจนโดยมีลมหายใจเข้าส่วนหนึ่งมาจากบรรยากาศรอบๆ ตัว สามารถให้ความเข้มข้นของออกซิเจนได้ตั้งแต่ 21 ถึง 80 เปอร์เซ็นต์ ซึ่งขึ้นอยู่กับขนาดของ Reservior bag อัตราการไหลเวียนของออกซิเจน ลักษณะการหายใจของผู้ป่วย และปริมาตรของการหายใจของผู้ป่วย การให้ออกซิเจนในระบบนี้เป็นที่นิยมใช้กันโดยทั่วไป เนื่องจากสามารถใช้ได้ง่ายและเป็นที่รู้จักโดยทั่วไป โดยเครื่องมือการให้ O_2 ที่ใช้ในการทำวิจัยเรื่องนี้ ได้แก่

Face mask เป็นวิธีการให้ออกซิเจนที่ให้ FiO_2 สูงกว่าการให้ O_2 ทาง Canula โดย Mask ควรมีขนาดเหมาะสมกับใบหน้าของผู้ป่วย ใช้ครอบเหนือบริเวณจมูกและปากใช้กับอัตราการไหลของ O_2 ตั้งแต่ 5 ลิตรขึ้นไปจนถึง 8 ลิตร/นาที ในกรณีที่อัตราการไหลของ O_2 ต่ำกว่า 5 ลิตร/นาที นั้นจะทำให้เกิดการคั่งของคาร์บอนไดออกไซด์ จากการหายใจเอาลมหายใจออกเข้าไปอีกครั้ง ส่วนในกรณีอัตราการไหลของ O_2 มากกว่า 8 ลิตร/นาที นั้น FiO_2 จะไม่เพิ่มขึ้น เนื่องมาจาก Reservior bag มีปริมาณ O_2 เต็มที่แล้ว การให้ O_2 ด้วยวิธีนี้ ผู้ป่วยจะได้รับความเข้มข้นของ O_2 40-50 % และ 60-80 % ด้วยวิธีใช้ Mask with Reservior bag ข้อควรระวังคือ

- อาจเกิดการสูดสำลักเอาสิ่งแปลกปลอมเข้าไป ทำให้เกิดอาเจียนได้
- Pressure necrosis จากการกดด้วย Face Mask นาน ๆ
- Subcutaneous emphysema
- คาร์บอนไดออกไซด์คั่ง ในกรณีที่อัตราการไหลของออกซิเจนต่ำกว่า 5 ลิตร/นาที

การป้องกันและพยาบาลผู้ป่วยที่ได้รับออกซิเจนเบื้องต้น

1. หมั่นสังเกตและประเมินภาวะ
   - ตรวจวัดสัญญาณชีพ ดูลักษณะและอัตราเร็วของการหายใจ ความดันโลหิต และชีพจร
   - ความผิดปกติของสีผิว ดูลักษณะบริเวณริมฝีปาก เล็บมือ เล็บเท้า
   - ระดับความรู้สึกตัว
   - วัดปริมาณหายใจเข้า-ออกต่อครั้ง (Tidal Volume)
   - กระตุ้นให้ได้รับน้ำอย่างเพียงพอ
2. หมั่นตรวจดูอุปกรณ์ที่ให้ออกซิเจน
   - ตรวจดูสายยาง ให้อยู่ในตำแหน่งที่ถูกต้อง ไม่เลื่อนหลุดจากที่รอยต่อต่างๆ ต้องคงที่ ไม่บิดงอ ไม่อุดตัน

- ขวดทำความชื้นมีน้ำอยู่พอเหมาะ ไม่มากหรือน้อยเกินไป
- ออกซิเจนไม่รั่วจากขวดทำน้ำกลั่นที่ทำความชื้น
- ถ้าเป็นออกซิเจนถัง จะต้องดูให้มีออกซิเจนอยู่เสมอ โดยจากที่หน้าปัดบอกระดับของออกซิเจน
- เปลี่ยนและนำอุปกรณ์การใช้ออกซิเจน ไปทำความสะอาดและทำให้ปลอดเชื้อ ถ้าเป็นอุปกรณ์ชนิดพลาสติก อาจขุ่นมีน้ำขัง หรือมีหยดน้ำเกาะอยู่ ให้เทน้ำแล้วสลัดให้แห้ง เพื่อไม่ให้กีดขวางทางนำออกซิเจนสู่ปอด

ภาวะพิษจากออกซิเจน (oxygen toxicity) ในกรณีที่ผู้ยินยอมตนได้รับออกซิเจนด้วย ความเข้มข้นเกิน 60 % เป็นเวลานาน อาการเริ่มต้น ที่พอสังเกตได้ ก็คือ มีอาการกล้ามเนื้อกระดูก คลื่นเหียน อาเจียน เวียนศีรษะ ย่านการมองเห็นลดลง อึดอัด หายใจลำบาก เหนื่อยง่าย ที่เป็นอันตรายที่สุด คือ การชัก เป็นลมหมดสต แต่เนื่องจากในการทดลองนี้ผู้ยินยอมตนได้รับออกซิเจนเพียง 40 เปอร์เซ็นต์และได้รับในเวลาที่ไม่นานมาก ทำให้เกิดภาวะพิษจากออกซิเจนได้น้อยมาก อีกทั้งทางวิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬานั้นมีบุคลากรทางด้านการแพทย์ พร้อมที่จะให้ความช่วยเหลือในกรณีที่เกิดเหตุฉุกเฉินได้ทุกเมื่อ

APPENDIX H
ETHICAL COMMITTEE APPROVAL

No. MU 2007-231

Documentary Proof of Ethical Clearance
The Committee on Human Rights Related to
Human Experimentation
Mahidol University, Bangkok

Title of Project: Effect of 40% Oxygen Supplemental during Recovery Period of Repeated Exercise Bouts on Rate of Recovery
(Thesis for Master Degree)

Principle Investigator: Mr. Ophas Aksornchanya

Name of Institution: College of Sports Science and Technology

Approved by the Committee on Human Rights Related to Human Experimentation

Signature of Chairman: ....
(Professor Dr.Srisin Khusmith)

Signature of Head of the Institute: ....
(Professor Dr.Pornchai Matangkasombut)

Date of Approval: 22 NOV 2007

Date of Expiration: 21 NOV 2008

BIOGRAPHY

NAME	Mister Ophas Aksornchanya
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