EFFECTS OF TWO METHODS OF PHYSICAL TRAINING ON BLOOD LACTATE LEVEL AND ATHLETIC PERFORMANCES

PATTARAPONG YINGDAMNUN

A THESIS SUMMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE (SPORTS SCIENCE)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2007

Thesis

Entitled

EFFECTS OF TWO METHODS OF PHYSICAL TRAINING ON BLOOD LACTATE LEVEL AND ATHLETIC PERFORMANCES

…………………………………..
Mr. Pattarapong Yingdamnun
Candidate

………………………………………
Asst. Prof. Opas Sinphurmsukskul,
B.Sc., M.D.
Facharzt fuer Orthopaedic (Germany)
Major-advisor

……………………………………..
Assoc. Prof. Thyon Chentanez,
Ph.D.(Neuroscience)
Co-advisor

…..……………………………….
Asst. Prof. Tavorn Kamutsri,
M.Sc.(Sports science)
Co-advisor

…..………………………………
Prof. M.R. Jisnuson Svasti,
Ph.D.
Dean
Faculty of Graduate Studies

……………………………………….
Clin. Prof. Teerawat Kulthanan,
M.D.
Chair
Master of Sports Programme in
Sports Science
College of Sports Science and Technology

Thesis

Entitled

EFFECTS OF TWO METHODS OF PHYSICAL TRAINING ON BLOOD LACTATE LEVEL AND ATHLETIC PERFORMANCES

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Sports Science)
on
June 12, 2007

…………………………………….
Mr. Pattarapong Yingdamnun
Candidate

……………………………………..
Assoc. Prof. Vichai Vanadurongwan,
M.D.
(Board of Orthopedic Surgery, F.I.M.S.)
Chair

………………………………………
Assoc. Prof. Vijit Kanungsukkasem,
Ed.D.(Physiology of Exercise)
Member

………………………………………
Asst. Prof. Opas Sinphurmsukskul,
B.Sc., M.D.
Facharzt fuer Orthopaedic (Germany)
Member

…..……………………………….
Asst. Prof. Tavorn Kamutsri,
M.Sc.(Sports science)
Member

……………………………………..
Assoc. Prof. Thyon Chentanez,
Ph.D.(Neuroscience)
Member

…..………………………………
Prof. M.R. Jisnuson Svasti,
Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

………………………………………
Clin. Prof. Teerawat Kulthanan,
M.D.
Director
College of Sports Science and Technology
Mahidol University

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and deep appreciation to Assistant Professor Dr. Opas Sinphurmsukskul my advisor for his guidance, excellent supervision and valuable advises. My sincere gratefulness and appreciation are given to Associate Professor Dr. Thyon Chentanez, my co-advisor for his invaluable advice, worthy suggestion, discussion, grammar and consistent use of language. I would also like to express my sincere appreciation to Associate Professor Dr. Vichai Vanadurongwan, Associate Professor Dr. Vijit Kanungsukkasem, and Assistant Professor Thavorn Kamutsri for their kind advice.

I am grateful to all the teachers, Monchai Chottidao, Rittirong Unjana and my friends at the College of Sports Science and Technology, Mahidol University, Salaya Campus, for their support.

Finally, I am extremely grateful to my family for their love, care, understanding, financial support, encouragement and mental support, throughout the study.

Pattarapong Yingdamnun

EFFECTS OF TWO METHODS OF PHYSICAL TRAINING ON BLOOD LACTATE LEVEL AND ATHLETIC PERFORMANCES

PATTARAPONG YINGDAMNUN 4736641 SPSS/M

M.Sc. (SPORTS SCIENCE)

THESIS ADVISORS: OPAS SINPHURMSUKSKUL, M.D., FACHARZT FUR ORTHOPAEDIC,THYON CHENTANEZ, Ph.D. (NEUROSCIENCE), THAVORN KAMUTSRI, M.Sc.(SPORTS SCIENCE)

ABSTRACT

The purpose of this study was to compare the effects of interval training and weight training on blood lactate level and athletic performances. Twenty male subjects were Sports Science students of Mahidol University, aged 18-22 years. Statistical method of simple random sampling was used in this study. Subjects were divided into three groups: control group (n=7), interval training group (n=7) and weight training group (n=6). Both training groups were trained at the same duration (40-50 min) and frequency (3 times/week) for 6 weeks. The intensity of interval training was set at 70% maxHR during high intensity exercise and 50% maxHR during low intensity exercise. The intensity of weight training was set at 70% RM using weight machines. Data collected including body weight, height, body mass index, resting heart rate, blood pressure, maximum oxygen consumption (VO_2max), leg strength, flexibility, percent of body fat, lung vital capacity, anaerobic capacity, running time test and blood lactate level (by Bruce's protocol) before and after each exercise training program. Paired t-test and one-way ANOVA were used to analyze the data. The level for statistical difference was set at $p<0.05$.

The results showed that maximum oxygen consumption, leg strength, flexibility, lung vital capacity, anaerobic capacity of the post-training in interval training group and weight training group were significantly ($p<0.05$) higher than pre-training, percent of body fat did not change. It was found that two exercise training programs had influence on blood lactate level. Interval training program significantly decreased lactate level in blood capillary more than the weight training program. This finding suggested that two training exercise programs were beneficial to develop strength, anaerobic power and delay muscle fatigue. Moreover, higher intensity training may improve running time performance in 400 meters distance. A longer exercise training period and higher intensity training in other methods are recommended for future research.

KEY WORDS: INTERVAL TRAINING / WEIGHT TRAINING /
BLOOD LACTATE LEVEL / ANAEROBIC CAPACITY

81 pp

ผลของสองรูปแบบการฝึกสมรรถภาพทางกายต่อระดับกรดแลคติคในเลือดและสมรรถภาพนักกีฬา
(EFFECTS OF TWO METHODS OF PHYSICAL TRAINING ON BLOOD LACTATE LEVEL AND ATHLETIC PERFORMANCES)

ภัทรพงษ์ ยิ่งดำนุ่น 4736641 SPSS/M

วท.ม. (วิทยาศาสตร์การกีฬา)

คณะกรรมการควบคุมวิทยานิพนธ์: โอภาส สินเพิ่มสุขสกุล พ.บ., Facharzt Fur Orthopaedic,
ไถ้ออน ชินธเนศ Ph.D. (Neuroscience), ถาวร กมุทศรี วท.ม. (วิทยาศาสตร์การกีฬา)

บทคัดย่อ

การศึกษาวิจัยครั้งนี้มีวัตถุประสงค์เพื่อศึกษาเปรียบเทียบผลของการฝึกแบบหนักสลับเบาและการฝึกแบบใช้แรงต้านด้วยน้ำหนักที่มีต่อระดับกรดแลคติคในเลือดและสมรรถภาพนักกีฬา กลุ่มตัวอย่างเป็นนักศึกษาชาย จากวิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล จำนวน 20 คน มีอายุระหว่าง 18-22 ปี ใช้วิธีการสุ่มอย่างง่ายและแบ่งออกเป็น 3 กลุ่ม ได้แก่ กลุ่มควบคุม, กลุ่มการฝึกแบบหนักสลับเบา และกลุ่มการฝึกแบบใช้แรงต้านทานด้วยน้ำหนัก ซึ่งกลุ่มการฝึกแบบหนักสลับเบาและกลุ่มการฝึกแบบใช้แรงต้านทานด้วยน้ำหนักจะเข้าร่วมโปรแกรมการฝึกที่ใช้ช่วงเวลาเท่ากัน (40-50 นาที), ความบ่อย (3วัน/สัปดาห์) เป็นเวลา 6 สัปดาห์ ความหนักของการฝึกของการฝึกแบบหนักสลับเบานั้นแบ่งออกเป็นช่วงหนักสุดอยู่ที่ 70% ของอัตราการเต้นหัวใจสูงสุด ช่วงเบาอยู่ที่ 50% ของอัตราการเต้นหัวใจสูงสุด และการฝึกแบบใช้แรงต้านทานด้วยน้ำหนักอยู่ที่ 70% ของน้ำหนักที่ยกได้เต็มที่ครั้งเดียว ก่อนวันที่เริ่มต้นและหลังวันที่สิ้นสุดการฝึก จะทำการวัดอัตราชีพจรขณะพัก, วัดความดันโลหิต, สมรรถภาพการจับออกซิเจนสูงสุด, ความแข็งแรงของกล้ามเนื้อขา, ความอ่อนตัว, เปอร์เซ็นต์ไขมันของร่างกาย, ความจุปอด, ทดสอบสมรรถภาพการออกกำลังกายแบบไม่ใช้ออกซิเจนเป็นเวลา 30 วินาที, ทดสอบวิ่งจับเวลาที่ระยะทาง 100, 400 เมตร และวัดปริมาณกรดแลคติคที่เกิดขึ้นด้วยโปรแกรม Bruce's protocol การวิเคราะห์ข้อมูลทางสถิติใช้ค่า " ที " (Paired t-test) และการวิเคราะห์ความแปรปรวนทางเดียว (one-way ANOVA)

ผลจากการศึกษาครั้งนี้การฝึกแบบหนักสลับเบาและการฝึกแบบใช้แรงต้านทานด้วยน้ำหนักนั้นส่งผลให้สมรรถภาพทางกายดีขึ้นคือ สมรรถภาพการจับออกซิเจนสูงสุด, ความแข็งแรงของกล้ามเนื้อขา, ความอ่อนตัว, ความจุปอด, และทดสอบสมรรถภาพการออกกำลังกายแบบไม่ใช้ออกซิเจนเป็นเวลา 30 วินาที มีค่าเพิ่มขึ้นอย่างมีนัยสำคัญเมื่อเปรียบเทียบกับกลุ่มการควบคุมและช่วงก่อนทำการฝึก แต่ไม่มีผลต่อเปอร์เซ็นต์ไขมันของร่างกาย นอกจากนี้การฝึกทั้งสองรูปแบบยังส่งผลถึงการลดลงของระดับกรดแลคติคในเลือดอย่างมีนัยสำคัญ($p<0.05$) โดยที่การฝึกแบบหนักสลับเบาจะให้ผลการลดระดับกรดแลคติคได้ชัดเจนกว่าการฝึกแบบใช้แรงต้านทานด้วยน้ำหนัก สรุปได้ว่าการฝึกทั้งสองรูปแบบทำให้เกิดการพัฒนาความแข็งแรง, เพิ่มสมรรถภาพการออกกำลังกายแบบไม่ใช้ออกซิเจนเป็นเวลา 30 วินาทีและยืดระยะเวลาการล้าของกล้ามเนื้อ นอกจากนี้ผลของการฝึกฝนรูปแบบหนักสลับเบาทำให้เวลาในการวิ่งระยะทาง 400 เมตรลดลง สำหรับงานวิจัยในครั้งต่อไปน่าจะเพิ่มระยะเวลาการฝึก เพิ่มความหนักให้มากขึ้นในวิธีการฝึกรูปแบบอื่นๆ เป็นต้น

81 หน้า

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF ABBREVIATIONS

bpm	=	beat per minute
cm	=	centimeter
kg	=	kilogram
kg/m^2	=	kilogram per square meter
m	=	meter
min	=	minute
ml/kg/min	=	millilitre per kilogram per minute
mmHg	=	millimeters mercury
mmol/l	=	milimole per litre
n	=	number
s	=	seconds
wk	=	week
yrs	=	years
ATP	=	adenosine triphosphate
BMI	=	body mass index
CP	=	creatine phosphate
CT	=	control group
DBP	=	diastolic blood pressure
HR	=	heart rate
IT	=	interval training group
L	=	litre
SBP	=	systolic blood pressure
SEM	=	standard error of the means
VC	=	vital capacity
VO_2max	=	maximum oxygen consumption
WT	=	weight training group

CHAPTER I
INTRODUCTION

Physical fitness is important in running performance; including running velocity, muscle strength and power which release major energy metabolism. The ATP is predominantly supplied to the working muscles by way of anaerobic or aerobic metabolic pathways, the rate of ATP utilization depends on the intensity and duration of the activity performed (Foss and Keteyian, 1998). During high intensity exercise, the aerobic energy system is often unable to replenish ATP at the required rate. By additional anaerobically glycogen breaking down, the muscle cell is able to synthesize ATP at a greater rate than is possible via aerobic mechanism alone. However, one of the by products of glycolysis was lactic acid ($C_3H_6O_3$). This, in turn, immediately dissociates into the lactate ion and hydrogen ion (H^+). Several studies reported the hydrogen ion (H^+) and lactic acid have been implicated as one of the causes of fatigue, either through interfering with muscle contractile function or inhibiting cellular energy production (Robert et al., 2004; Falkel & Cipriani, 1996). Previous studies investigated that the relation between weight training program and accumulate blood lactate level on physical fitness. Izquierdo et al. (2005) studied the effects of combined resistance and cardiovascular training in middle-aged men for 16-week. They indicated that no significantly different between groups (resistance training program, endurance training program, combined the resistance training program and endurance training program) in submaximal blood lactate accumulation during exercise. Izquierdo et al. (2003) studied the effects of strength training on performance in middle-aged and older men, after the first 8 weeks of training, submaximal blood lactate accumulate in both groups was decreased but did not change in the subsequent 6 weeks of all groups. Marcinik and co-workers (2003) presented the effects of 12 weeks of strength training on lactate threshold (LT) and endurance performance. The results showed that improvement of performance appeared to be related to both increases in lactate threshold and leg strength. Edge et al. (2006) investigated the effects of exercise training on muscle buffer capacity and H regulation. They concluded that the high-repetition, short-rest, resistance training did not improve muscle buffer capacity in active female, but it did reduce H^+ accumulation during high intensity exercise. Coelho and co-workers (2003) compared physiological responses in 2 high-speed resistance training protocols in untrained adults. The two different protocols (12 repetitions per set and 6 repetitions per 2 set) had significantly value of accumulated blood lactate (5.7±0.5 and 6.7±0.3 mmol/l, respectively) between both training programs.

Burke, Thayer and Belcamino (1994) compared the effects of two interval training programs on lactate and ventilatory threshold. They concluded that both formats of high intensity aerobic interval training produced similar changes in VO_2max, lactate threshold and ventilatory threshold and that these changes appeared to be independent of the length of the work interval. Poole and Gaesser (1985) studied the response of lactate thresholds to continuous training and interval training. They concluded that continuous training and interval training were equally effective in increasing lactate threshold. Favier et al. (1986) studied the effect of endurance training on accumulate lactate production. They suggested that the lactate produced was reduced by muscle during contractile activity. Hurley et al. (1984) studied the effect of training on blood lactate levels during submaximal exercise. This result showed that lactate concentrations at 55-75% of VO_2max were significantly lower in blood after training. Seiler and Sjursen (2004) presented the effect of duration on physiological and rating scale of perceived exertion (RPE) response during self-paced interval training. Their data suggested that RPE increased by 2-4 U during an interval training session, the mean lactate concentration was similar across session. Alexandre and co-workers (2001) reported that the decrease of O_2 deficit was a potential factor in increasing time to exhaustion after specific endurance training. It also showed that, for the same absolute supralactate threshold adaptation concerning the VO_2 kinetics may lead to performance improvements in well-trained subjects. Nilsson et al. (2004) studied the effects of 20-s and 180-s double poling interval training in cross-country skiers. They concluded that different work load durations at 180-s had significantly reduced blood lactate concentration at submaximal workloads, on the other hand, nothing was changed at 20 s. Gottlieb-Vedi (1995) studied the metabolic effects of interval training at the velocity producing a lactate level of 4 mmol/l (VLA4). Their results indicated that training program at VLA4 was sufficient to cause adaptation changes in exercise tolerance related parameters. In 1989, Gladden et al. reported that the sprint-power athletes who performed maximal short-term exercise had their blood lactate level 20% to 30% higher than untrained subject who performed similar exercise. The mechanism for this response was unknown, but it may be partly a result of difference in motivation accompanying the trained state, as well as an approximate 20% increased in enzymes that regulate glycolysis, specifically phosphofructokinase, which accompanies anaerobic training in the athletes. Since the blood lactic acid measured at a particular time during recovery may not likely to give the full picture of individual's capacity for anaerobic metabolism. However, effect of immediate post exercise blood lactate concentration generally related to exercise intensity, exercise duration and also depend on the number of bouts and rest period of short-duration high-intensity exercise (Brinkert et al., 1999; Foss and Keteyian, 1998).

Since, the relative importance of training programs and blood lactate had systematically investigated in athletes; the present study sought to investigate more about the effects of different exercise programs with weight training and interval training and to compare the blood lactate level, VO_2max, anaerobic capacity and peak power between two training programs in more details.

Hypothesis

It was hypothesized that different physical training programs may enhance the decrease of blood lactate level and running time.

Objective

1. To investigate effects of weight training program and interval training program on blood lactate level.

2. To study the effects and compare between weight training program and interval training program on physical fitness.

3. To compare the running time in 100, 400 meter distance before and after training program.

CHAPTER II
LITERATURE REVIEW

1. Energy system for exercise

The individual's fitness was the combined result of the coordinated exertion and integration of variety of functions. It was impossible to present one formula that takes into account all aspects of a person's maximal performance. Fitness was highly task specific. Energy transducer well fitted to one pattern of working was quite inappropriate for an activity that requires some other pattern of energy release. Distinction must thus be drawn between tasks that require, respectively, a high degree of coordination and psychomotor skill, explosives force, muscular endurance, cardio-respiratory endurance, and so on.

Cardio-respiratory fitness has been defined as "the ability of a man to maintain the various processes involved in metabolic exchange as close to the resting state as, is mutually possible during the performance of a strenuous and fully learnt task for moderate time (1-60 minutes), with a capacity to reach a higher steady rate of working than the unfit, and to restore promptly after exercise all equilibrium which are disturbed".

Endurance in some physical activities such as distance running, swimming, and cycling limited by the capacity of cardio-respiratory system to deliver oxygen to the working muscles and to carry chemical waste products away from them (Lamb, 1984). The degree to which circulation and respiration limit one's performance depends on many factors, chief of which are the intensity of the exercise, the duration of the activity, and the amount of static muscle contraction involved. In general, the lesser the intensity, the longer the duration, the lesser the amount of static contraction involved, the more that performance in the activity limited by the functioning of the cardio-respiratory system. Distance running, for example, was a relatively low intensity, long duration activity consisting mostly of rhythmic, non static muscle contractions and limited mainly by aerobic capacity. Some events, such as middle distance running are not limited so much by endurance of a few muscle groups or by oxygen transport capacity and capacity for anaerobic ATP production in large muscle groups.

Thus, all endurance activities have both aerobic and anaerobic components. Table I shows one way of classifying some activities based on the degree to which the energy for these activities derived from anaerobic sources within the transport of oxygen to the muscles.

Table 1. Aerobic and anaerobic energy production in various activities.

Activity	%Anaerobic Energy	%Aerobic Energy	Activity Classification
50 m. sprint	95	5	Anaerobic power
100 m. sprint	85	15	Anaerobic power
200 m. sprint	80	20	Anaerobic power Anaerobic capacity
400 m. sprint	70	30	Anaerobic power Anaerobic capacity
800 m. run	60	40	Anaerobic capacity Aerobic capacity Anaerobic power
1500 m. run	40	60	Aerobic capacity Anaerobic capacity
3000 m. run	15	85	Aerobic capacity Anaerobic capacity
42 km. run	<1	>99	Aerobic capacity

Lamb DR. Physiology of Exercise. New York: Macmillan Publishing Company, 1984.

There are three common energy processes for the production of ATP (Table 2):

1) ATP-PC (Phosphagen system)
2) Anaerobic glycolysis (lactic acid system)
3) Aerobic system (oxygen system)

Table 2. General characteristics of the three systems by which ATP is formed

System	Fuel	O2 required	Speed	Relative ATP production
Anaerobic				
ATP-CP system	Phosphocreatine	No	Fastest	Few; limited
Lactic acid system	Glycogen (glucose)	No	Fast	Few; limited
Aerobic System	Glycogen, Fat, Protein	Yes	Slow	Many; unlimited

Edward Fox, Richard Bowers, Merle Foss; The Physiological Basic for Exercise and Sport; 5th edition; 31, 1993

Two of three metabolic systems involved in ATP re-synthesis, the ATP-PC (phosphagen system) and anaerobic glycolysis (lactic acid system) are anaerobic. Anaerobic means without oxygen and metabolism refers to the various series of chemical reactions that take place within the body. The ATP-PC (phosphagen system) include adenosine triphosphate (ATP) and phosphocreatine (PC) that both of it contain phosphate groups. The end products of this breakdown are creatine (C) and inorganic phosphate (Pi). The energy is immediately available and biochemical coupled to the synthesis of ATP. As rapid as ATP is broken down during muscular contraction, it is continuously re-form from ADP and Pi by the energy liberated during breakdown of the stored PC. The importance of the phosphagen system found in the powerful, quick start of sprinters, high jumper and by similar activities that require only a few seconds to complete. The phosphagen system represents the most rapidly available source of ATP for use by the muscle. Some of the reason for this is 1) it does not depend on long series of chemical reactions. 2) It does not depend on transporting the oxygen we breathe to the working muscle. 3) Both ATP and PC are stored directly within the contractile mechanism of the muscle. The other anaerobic system in which ATP is re-synthesized within the muscle, anaerobic glycolysis; involves an incomplete breakdown of carbohydrate to lactic acid. In the body, all carbohydrates are converted to the simple sugar glucose, which can either be immediately used in that form or stored in the liver and muscle as glycogen for later use. Lactic acid is a product of anaerobic glycolysis. Glycogen is chemically broken down into lactic acid by a series of reaction. During this breakdown, energy is released and, though coupled reaction, it is used to re-synthesize ATP. Anaerobic glycolysis, like the phosphagen system, is extremely important to us during exercise primarily because it also provides a relatively rapid supply of ATP. Lactic acid is produced and tolerated so that a precious few additional ATPs can generate. However, not many, but a few more until the cells become so acidic that they cannot effectively function. This ability to continue to generate some ATP and tolerate the buildup of lactic acid and compromised muscle function may have important implications for survival in life threatening situations. The most rapidly accumulated and highest lactic acid levels reach during exercise that can be sustained for 60-80 seconds.

Another one common energy processes is aerobic system (oxygen system). In the presence of oxygen, When 1 mole of glucose from glycogen is completely broken down to carbon dioxide (CO_2) and water, releasing sufficient energy to re-synthesized 39 moles of ATP. There are many steps of reactions of the aerobic system which can be divided into three main series: First, aerobic glycolysis; the first series of reaction involved in the aerobic break down of glycogen to CO_2 and H_2O is glycolysis. Oxygen then divert the majority of the lactic acid precursor (pyruvic acid), into the aerobic system. Second, the Krebs cycle; the pyruvic acid formed during aerobic glycolysis passes into the mitochondria and continues to be broken down in a series of reactions. A number of significant events occur during the cycle, carbon dioxide and ATP are produced, oxidation occurs. Last continuing in the breakdown of glycogen, the end product, H_2O, is formed from the hydrogen ions and electron that it is removed in the Krebs cycle. In this reaction 39 moles of ATP are generated per 1 mole of glucose.

2. Exercise

2.1 Aerobic training

There is important factor in formulating an aerobic training program. The training must be geared to provide a sufficient cardiovascular overload to stimulate increase in stroke volume and cardiac output. This central overload should be accomplished with the appropriate muscle groups to concurrently enhance the local circulation and metabolic machinery within the specific muscle. The essentially embodies the specific principle as applied to aerobic training. Simply stated, runners should run, cyclist should cycling, and swimmers should swim. Brief bouts of repeated exercise (interval training) as well as continuous, long-duration work (continuous training) enhance aerobic capacity, if the exercise is sufficiently intense to overload aerobic system. Interval training, continuous training, and Fartlek training are three common methods to improve aerobic fitness (McArdle and co-workers, 1994).

2.1.1 Continuous training

Continuous or long slow distance training involves steady-paced exercise performed at either moderate or high aerobic intensity (60 to 80 % VO_2 max) for sustain duration. The exact pace can vary, but it must be sufficient threshold intensity to ensure physiology adaptation. Continuous training for an hour or longer is popular among joggers and other fitness enthusiasts as well as competitive endurance athletes. It is not common for distance runners to train twice a day on a yearly basis and run between 160 to 240 km each week. By its nature, continuous exercise training is sub maximum and, therefore, can be engaged in for considerable time to relative comfort. Because of the potential hazards of high intensity interval training for coronary-prone individuals, continuous training is particularly suitable for those just beginning an exercise program (American College of Sports Medicine, 1995). When applied in athletic training, continuous training is really over distance training, with most athletes covering between two to five times the actual distances of their racing event. It believes that over-distance training produces the largest aerobic adaptations in both the central circulation and peripheral tissues. Overload is generally accomplished by increase exercise duration, although the work rate increase progressively as training improvements are achieved. One of the advantages of continuous training is that it permits training at near the same intensity as actual competition. Because the recruitment of appropriate motor units depends on work rate, continuous training may be best suited for the endurance athlete in term of adaptations at the cellular level (Fouriner et al., 1982).

2.1.2 Fartlek training

Fartlek or speed play training is a relatively unscientific adaptation of interval and continuous training that is well suited for exercising in out doors over natural terrain. With this system, alternate running is done at both fast and slow speeds on both a level and hilly course. In contrast, to the precise exercise prescription in interval training, fartlek training dose not require systematic manipulation of the work and relief intervals. Instead, the performers determine the training scheme based on "how it feels" at the time. If done properly, this system develops one or all of the energy system. An added advantage is the flexibility it affords in determining the extent of training. Although lacking the systematic and quantified base of interval and continuous training, fartlek training is ideally suited for general conditioning or off-season training and for maintaining a certain freedom and variety in workouts (McArdle and Co-workers, 1994).

2.1.3 Interval training

The interval training prescription can be modified in terms of intensity and duration of the exercise interval, the length and type of relief interval, the number of work intervals (repetition), and the number of repetition blocks (sets) per workout. Many elite athletes attribute their success to interval training (Fox et al., 1975). With the correct spacing of exercise and rest periods, a tremendous amount of work can be accomplished that would not normally be completed in a workout in which the exercise was performed continuously. Repeated exercise bouts (with rest periods or relief intervals) can vary from a few seconds to several minutes or more depending on the desired outcome. Adjustment of any or all of these can easily be made to meet the specific requirements for different performance. This offers flexible options for developing the anaerobic and aerobic energy transfer systems. A longer work interval engages the aerobic system, whereas shorter exercise interval place greater overload on the anaerobic energy system. One value of interval training is that it permits high intensity, intermittent exercise for a relatively long period. In essence, a person can reach max VO_2 repeatedly in training session. For example, few people can maintain a 4 minute mile pace for longer than a minute; let along complete a mile within 4 minutes. If running interval, however, is limited to only 15 seconds followed by 30 seconds of recovery, it would not be exceedingly difficult to maintain these exercise-rest intervals and complete the mile in 4 minutes of actual running. Although this do not suggest a world class performance, the point is that a significant quantity of normally exhausting work at high levels of both aerobic and anaerobic metabolism can be achieved with the proper spacing of rest and work interval (McArdle and Co-workers, 1991).

In the example of a continuous run at a 4-mile pace, a large portion of energy would be supplied through anaerobic glycolysis. Within a minute or two, lactic acid levels would rise precipitously and the runner would become exhausted. With interval training, repeated work bouts of about 15 seconds would permit a severe load to be imposed on the aerobic energy system of specific muscles without an appreciable buildup of lactic acid. Fatigue incurred during the work interval would be minor and recovery could take place quickly. The work interval could then begin after only brief rest period, and a high level of aerobic metabolism would be sustained. For training the long-term aerobic energy system, the work-recovery interval ration is usually 1 to 1 or 1 to 1.5. During a 60 to 90 second exercise interval, for example, oxygen consumption is insufficient to meet the energy requirements of the exercise. The recommended recovery interval enables the succeeding exercise interval to begin before recovery was complete. This ensures that the circulatory an aerobic metabolism stress reach near peak levels even though the exercise were interval relatively short. With longer periods of intermittent exercise there is sufficient time for metabolic and circulatory adjustments, thus, the duration of the rest interval are not as crucial (McArdle and Coworkers, 1991).

2.2 Anaerobic training

The capacity to perform and maintain in all out exercise for brief periods of time up to 60 seconds is largely dependent on ATP generated by the immediate and short term anaerobic energy system. Methods of anaerobic training have common objective to develop phosphagen used to generate energy in athletes.

The phosphate pool: sports such as weightlifting and various other brief sprint activities rely almost exclusively on energy derived from the muscle's phosphate pool. The phosphate pool can be overloaded by engaging specific muscle in repeated maximum bursts of effort for 5 to 10 seconds. Because the high-energy phosphate supply energy for intense, intermittent exercise, only small amounts of lactic acid are produced and recovery is rapid. Thus, a subsequent exercise bout can begin after a 30 to 60 second rest period. This use of brief all out work periods interspersed with recovery represents a specific application of interval training, a technique useful for anaerobic conditioning. In training to enhance the ATP-CP energy capacity of specific muscle, the activities selected must engage the muscle at appropriate speed of movement for which the athlete desires improved anaerobic power. Not only enhance the anaerobic metabolic capacity of the specifically trained muscle fibers, but it also facilitates the recruitment of the appropriate motor units used in the actual movement

2.2.1 Anaerobic mechanism

At the beginning of muscular exercise, oxygen consumption and lactic acid production cannot contribute significantly the energy requirement of the working muscles, as these two mechanisms are relatively sluggish in comparison with the mechanical events of the contraction. As a consequence, during the first few seconds of exercise, the energetic of muscular contraction reduces to:

$$ATP = CP$$

These conditions where both lactic acid and oxygen consumption = 0, here defined as "anaerobic alactic" characterize those situations in which no steady state can be attained; a continuous breakdown of creatine phosphate (CP) must then take place, until the exercise comes to an end.

2.2.2 Anaerobic power and capacity

Many sports and every activity have energy demands which must be met through the anaerobic breakdown of ATP, creatine phosphate, and muscle glycogen.

a) Anaerobic power is defined as "the maximal rate at which energy can be produced or work can be done without a significant contribution of aerobic energy production".

b) Anaerobic capacity is defined as "the ability to persist at the maintenance or repetition of strenuous muscular contractions that rely upon anaerobic mechanisms of energy supply" (Lamb, 1994).

2.3 The lactic mechanism

As the duration of all out effort extends beyond 10 seconds, dependence of anaerobic energy from the phosphate decreases, while the quantity of anaerobic energy generate in the reactions of glucose to lactic acid increases, a substantial accumulation of lactic acid in blood take place. Under these conditions the exercise comes to an end when the blood lactic has reached a concentration of the order of 16-17 mmol/l of blood in non-athletic subjects (Lehninger, 1982; Sahlin et al, 1981; Sahlin et al., 1976).

It has also been observed that the time required to reach this critical level, and thus exhaustion, is shorter when the work is higher intensity. These exercise conditions will be defined as "anaerobic lactic" (di Prampero, 1981).

2.3.1 Physical of lactate removal

a) Excretion via urine and sweat

Lactate is excreted via urine and sweat (Astrand, 1963). However, the amount of lactate removed in this process during recovery from exercise is negligible since blood flow to this organ is remarkably diminished (Powers and Howley, 2001). Furthermore, blood Flow to a specific organ or organ system can increase or decrease, depending on its metabolic demands. During exercise recovery, more blood is sent to the active skeletal muscles, and, as body temperature increase, more blood is sent to the skin. This process is accomplished both by the increase in cardiac output and by the redistribution of blood flow away from areas of low demand, such as the splanchnic organs: kidney, stomach (Rowell, 1986).

b) Conversion to protein

Carbohydrates, including lactate, are oxidized to pyruvic acid and subsequent transamination to from amino acid (e.g. Alanine). Alanine enters the blood and it transported to the liver, where it is converted to glycogen for storage or to glucose, which enters the blood and becomes available as substrate. However, only a relative small amount of lactate is converted to protein during the immediate recovery period following exercise (Foss and Keteyian, 1998).

c) Conversion to glucose and/or glycogen

Because lactate is a byproduct of carbohydrate metabolism (glucose and glycogen) during anaerobic work, it can be reconverted to these glycogen and glucose in the liver and glycogen in muscle. However, glycogen re-synthesis in muscle and liver is extremely slow compared with lactate degradation/removal. In addition, the magnitude of the change in the blood glucose concentration during recovery is also minimal. Therefore, conversion of lactate to glucose and glycogen accounts for only a small portion of the total lactate remove (Brook et al., 1973; Brook and Gaesser, 1980).

d) Oxidation/conversion to CO_2 and H_2O

Lactate is also a metabolic fuel, principally for skeletal muscle (Hermansen and Stensvold, 1972; Hubbard, 1973; Hermansen et al., 1975), but several organs such as heart muscle, brain (Nemoto et al., 1974) and kidney (Yudkin and Cohen, 1974) tissues are also capable of oxidizing lactate. According to the studies of

Rowell et al in 1966, approximately 50% of the liver is the main site of lactate removal during exercise. Furthermore, it is also known that lactate is metabolized in myocardium and resting skeletal muscle (Rowell, 1971). In the presence of oxygen, lactate is first converted to pyruvate (Freund et al., 1980) and then to CO_2 and H_2O in the Krebs cycle and the electron transport system, respectively. ATP is re-synthesized in coupled reactions in the electron transport system.

2.4 Disadvantageous effects of lactate acid

High lactate concentrations cause an acidosis on and around muscle cells. This acid environment may seriously interfere with various mechanisms in the muscle cells. The aerobic enzymes system in the muscle cell may be seen as a factory plant where aerobic energy supply takes place. This enzyme system was sabotaged by acidosis and as a result aerobic endurance capacity was reduced. It may be day before this system has sufficiently recovered and aerobic capacity was at its old level again (Stanley et al., 1985).

When the workload was repeatedly too intense, i.e. without sufficient time to recover, a considerable decrease in aerobic endurance capacity is inevitable. These overly intensive exercise bouts can lead to a complex of complaints known as overtraining. Further, acidosis can cause damage to the muscle cell wall. This causes leakage from the muscle cells into the blood, e.g. increased urea and CK.

It may be 24-96 hours before these values returned to normal again. Recovery of the muscle damage may take a long time. When choosing a form of workout these factors should be considered. Work-loads should be light in this situation: The so-called recovery or regeneration work-out. Whenever training is too intensive, recovery will be prolonged.

1. High lactate values disturb co-ordination: Intense workouts with high lactate values can also interfere with co-ordination capacity. Co-ordination capacity is of overall importance in sports requiring highly technical skills, i.e. soccer, tennis and judo. Training should not take place with lactate above 6-8 mmol/l, because when co-ordination is disturbed training could have negative effects on these skills.

2. High lactate values enhance injury risks: Acidosis in the muscles can lead to microruptures in the muscular tissues. This minor damage may, if insufficiently healed, result in more serious injuries.

3. The phosphate system is disturbed by high lactate values: The reformation of ATP is also delayed in acid muscles. Therefore, it is best to avoid high lactate values during sprint training.

4. Fat oxidation is inhibited at high lactate values: When glycogen reserves are depleted energy supply is endangered at high lactate values because fat oxidation is inhibited.

2.5 Lactate curves of athletes

Millimole per liter (mmol/l or mM/l) is unit of the blood lactate concentration measurement. Healthy persons at rest should have values between 1 and 2 mmol/l. The 4 mmol/l threshold is in fact an oversimplification of the relationships between lactate accumulation and relative exercise intensity. Figure 1 indicates the relation between blood lactate concentration and training intensity. The recovery runs should keep lactate concentrations lower than 2 mmol/l. Intense interval workouts give high lactate values (far higher than 4 mmol/l). Under the influence of training values, around 3, 4 and 5 mmol/l lactate.

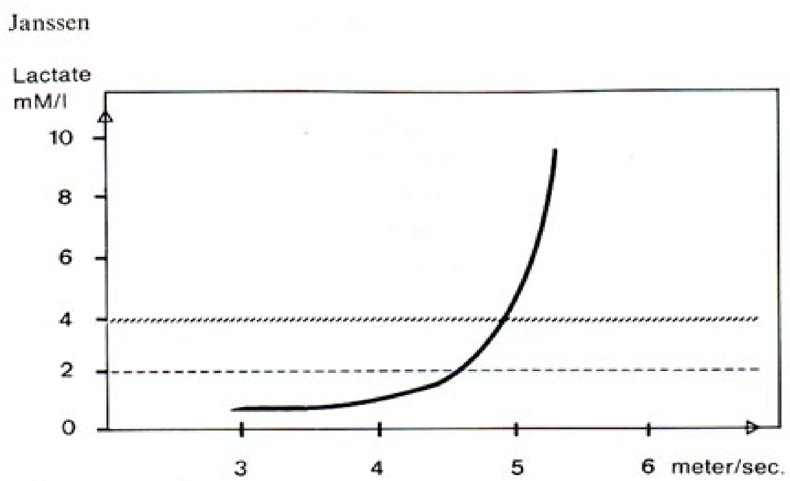

Figure 1. Lactate curves of athlete

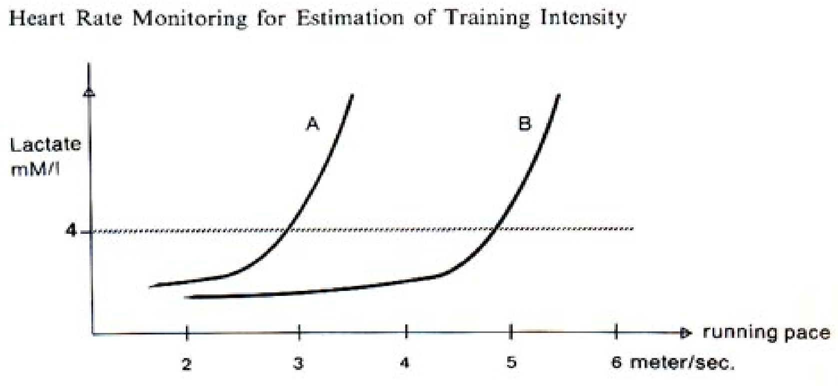

Figure 2. Comparing between pre (A) and post (B) training period

Curves A and B come from the same athlete. Curve A at the beginning of a training period. Curve B at the end of a training period. The curve has shifted to the right. Aerobic capacity has clearly improved. At lactate 4 mmol/l of curve B has decreased accumulate lactate than curve A. (Figure 2)

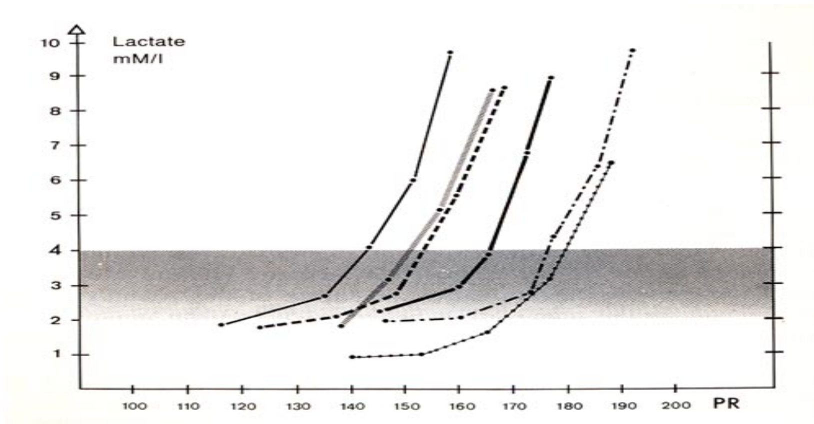

Figure 3. Lactate curves of various athletes

Figure 3 shows lactate curves of various athletes, all of them are well-trained. Every individual has his own curve and the interindividual differences often turn out to be very large. When the athlete with the most right hand curve trains together with the athlete of the left hand curve and the two of them are told to perform at a heart rate of 150 beats per minute, the left hand curve athlete is going through a very intense workout with high lactate values, whereas the right hand curve athlete hardly exerts himself. For this reason training intensity should be set individually. When training in groups the training task has different effects on different athletes.

Various forms of training in relation to lactate concentration and heart-rate. (Karvonen et al., 1992)

1. Recovery or regeneration workout. Intensity of this training is well under 2 mmol/l lactate. In the example HR between 110 and 140 beats/min.

2. Extensive endurance workout. Intensity of this training around 2 mmol/l lactate. In the example HR between 140 and 160 beats/min.

3. Intense endurance workout. Intensity of the training between 3 and 4 mmol/l lactate. In the example HR between 160 and 180 beats/min.

4. Extensive intervals. (Tempo duration): Intensity between 4 and 6 mmol/l lactate. In the example HR over 180 beats/min.

5. Intense intervals. Intensity between 6 and 12 mmol/l lactate. In the example HR over 180 beats/min.

3. Strength Training

Strength is the muscle's ability to exert force. Typically, the term strength is associated with the ability to exert maximum force during a single effort, sometimes referred to as a one-repetition maximum effort (1RM). Strength increases can make major contributions to recreational and competitive sports performances make everyday tasks regardless of age a lot easier. Strength training program usually produce muscle size gains greater than endurance training program but not to the same extent that a body shaping program will. (Thomas and Roger, 1995)

3.1Weight training equipment

Weight training equipment falls into two major categories: machines and free weights. Both types are typically used in schools, colleges, health clubs, and corporate settings; free weight equipment is the most common choice for home training.

3.1.1 Machines

The two most common types of weight training machines are pivot machines (single and multi-unit) and cam machines (Thomas and Roger, 1995).

Pivot Machines (PM)

Pivot machines have one more stacks of weights that are lifted by pulling or pushing a weight arm attached to a pivot point. Single-unit machines are designed to work one muscle, whereas multi-unit machines have various station that let you work many muscle areas by moving from station to station. Pivot machines have both fixed pivot and moving pivot designs, and multi-unit machines use both.

Fixed-resistance pivot machines have one more fixed weight stacks that are lifted by pulling or pushing a weight arm attached to a fixed pivot point. The limitation of this type of equipment is that at some points during result, different positions require more effort than others, as though someone were changing the load during each repetition.

Like the fixed-resistance machine, the variable-resistance pivot machine also has a weight arm attached to a pivot point. But the weight stack moves or rolls back and forth on a weight arm, allowing amore consistent load on muscle. When the weight arm moves to a position that requiring more effort. Conversely, when the weight arm moves to a position that would require more effort, the weight stack moves to a position requiring less effort.

Cam Machines (CM)

A cam machines is a variable-resistance machine that features an elliptically shaped wheel, referred to as a cam. Its shape makes the cam function similarly to a moving weight stack. As the chain (cable or belt) tracks over the peaks and valleys of the cam, the distance between the point of rotation (the axle on which the cam rotates) and the weight stack varies to produce a move consistent on the muscles. (Wayne and Westcott, 2003)

Table 3 Physiological adaptations to resistance training

SYSTEM/VARIABLE	RESPONSE
Muscle Fiber	
Number	Equivocal
Size	Increase
Capillary Density	
In bodybuilders	No change
In powerlifters	Decrease
Mitochondria	
Volume	Decrease
Density	Decrease
Twitch Contraction Time	Decrease
Enzymes	
Creatine phosephokinase	Increase
Myokinase	Increase
Enzymes of Glycolysis	
Phosphofructokinase	Increase
Lactate dehydrogenase	No change
Aerobic Metabolism Enzymes	
Carbohydrate	Increase
Triglyceride	Not know
Intramuscular Fuel Stores	
Adenosine triphosphate	Increase
Phosphocreatine	Increase
Glycogen	Increase

Fleck, S.J., and Kramer, W.J.: Resistance training: physiology responses and adaptations (Part 2 of 4). Phys. Sportsmed., 16:108, 1988.

Adaptations to resistance training

1. Neural adaptations important

Enhanced neural adaptation with resistance training may result from:

a) Increased central nervous system activation
b) Improved motor unit synchronization
c) Lowered neural inhibitory

2. Muscle adaptations

Increases in muscle size (hypertrophy) with resistance training for men and women can be viewed as a fundamental biologic adaptation. Weightlifters' and body builders' extraordinarily large muscle size from enlargement of individual muscle cells, mainly fast-twitch fibers. Growth takes place from one or more of the following adaptations (Vivan, 1997):

a) Increased contractile proteins (actin and myosin)
b) Increased numbers and size of myofibrils
c) Increased enzymes and stored nutrients in Table 3 lists important cellular adaptations in muscle in response to resistance training

Cardiovascular adaptations

Training volume and intensity influence the effect of resistance training on the cardiovascular system. Table 4 lists chronic cardiovascular adaptations from resistance training.

Table 4 Cardiovascular adaptations to resistance training

VARIABLE	ADAPTATION
Rest	
Heart rate	No change
Blood pressure	
Diastolic	Decrease or no change
Systolic	Decrease or no change
Rate-pressure product (HR×SBP)	Decrease or no change
Stroke volume	Increase or no change
Cardiac function	Increase or no change
Left ventricular wall thickness	Increase
Right ventricular wall thickness	No change
Left ventricular chamber volume	No change
Right ventricular chamber volume	No change
Left ventricular mass	Increase
Lipid profile	
Total cholesterol	Decrease
HDL -cholesterol	Increase or no change
LDL -cholesterol	Decrease or no change
During exercise	
Heart rate	No change
Blood pressure	
Diastolic	Decrease
Systolic	Decrease
Rate-pressure product	Decrease
Stroke volume	Increase or no change
Cardiac output	Increase or no change

CHAPTER III
MATERIALS AND METHODS

1. Instrumentation

The following equipments were used in this study:

1. Spirometer (Takei and Company, Japan)
2. Treadmill (Sensormedics 2000 Treadmill)
3. Wingate Ergometer (Ergomedic 894 E)
4. Back and Leg dynamometer (Takei and Company, Japan)
5. Sphygmomanometer (AIL, KII, Japan)
6. Stethoscope (Hico Medical Co.Ltd., Tokyo, Japan)
7. Skinfold caliper
8. Telemetry heart rate monitor (Polar, Finland)
9. Synthetic Track (Mahidol University Salaya Campus)
10. Stopwatch
11. Automatic lactate analyzer (Accutrend ® Lactate)
12. Accu-Chek® Softclix® lancet device.

2. Subjects

Subjects in different training programs.

Twenty male subjects were Sports Science students of Mahidol University, aged 18-22 years old. All of the subjects were divided into 3 groups. Group I (n=6) participated in weight training programs, group II (n=7) participated in interval training program, and group III (n=7) was in control group. The students in the first group and second group were Mahidol University athletes, whereas the third group was non-athlete students.

Subjects were randomly selected by using a specific purpose designation questionnaire to screen their physical activity and excluded from the study if they met any of the following criteria: cigarette smoking, coronary heart disease, hypertension or hypotension, any respiration defects, and epilepsy. Subjects signed informed consent forms before participating in the study after they read all description of the experimental protocol. The protocol was approved by Human Research Ethics Committee of Mahidol University (No. MU 2006-017).

3. Experimental Procedure

3.1 Anthropometrics measurement

3.1.1 Body size measurement

Body weight and height of each subject were measured using weight balance (AND AD-6210: Japan) and a height stadiometer (KYS Co., Ltd., Tokyo, Japan), respectively. All measurements were done with the same equipments and were handled by the same investigator.

3.1.2 Body composition

Subject's skinfold thickness was measured at Biceps brachii, Triceps brachii, Subscapular and Suprailium areas. Subject was instructed to relax during measurement. The thumb and forefinger grasped a double layer of skin and subcutaneous tissue. The caliper was applied about 1.0 centimeter from the skinfold with measurement taken to the nearest 0.1 millimeter, after full spring pressure of the caliper was applied. The percent of body fat was calculated by sum of each value in millimeter (mm), the equations of Durnin and Womersley (1974);

$$Db = 1.1631-0.0632 \log(x_4)$$

Db = Body density

x_4 = Sum of Biceps Brachii, Triceps brachii, Subscapular, Suprailliac

Finally, take in Siri equation, (1961);

$$\%BF = [(4.95 / D_b) - 4.5] \times 100$$

3.2 Physical fitness components

3.2.1 Vital signs

Subject sat quietly for about 10-15 minutes stable vital signs were determined;

a. Resting heart rate was determined by palpating the right radial artery.

b. Blood pressure was determined by sphygmomanometer and stethoscope.

3.2.2 Leg strength

Subjects were asked to stand on the base plate of the Back and Leg dynamometer. Knees were bent to angle of 90 degrees. Back and arms were extended. The handle bar was held in the center (at the level of pubis) with both palms facing downward. The chain was adjusted in a straight line. Subjects were instructed to extend knee vigorously. Two trials were performed. The highest value divided by subject's body weight was recorded in kg.

3.2.3 Sit and Reach (Flexibility)

In order to consider hip and trunk flexibility, trunk forward bending was used. The subject kept both legs in a fully extended posture and placed both feet, in the totally contact fashion, against sit and reach box. Like a scoop position, subject sat on the floor and gradually bended forward as far as possible and, then the distance in centimeters (cm) was recorded. The experiment was repeated and the highest value was record.

3.2.4 Indirect submaximal oxygen consumption (VO_2max)

Treadmill submaximal tests provided to be an estimate of VO_2max and assume a liner increase in rate with successive increases in work rate. The VO_2max was predicted from two (multistage model) submaximal heart rates. For these submaximal run tests, the treadmill maximal test protocol (Table 5) was used to identify the slope of the subject's heart rate response to running (Bruce et al, 1972; Marquette, 1994)

Two submaximal stages of the treadmill test were used. Heart and work rate at each stage measured. The slope (b) of the linear relationship was determined by calculating the two exercise stages and the corresponding change in submaximal heart rates:

$$b = \frac{SM\,(VO_2)_2 - SM\,(VO_2)_1}{HR_2 - HR_1} \quad \text{....... (1)}$$

Where SM (VO_2) = VO_2 at a given submaximal stage by MET

[SM (VO_2) = 3.5 × work each stage (METS)]

HR = Heart rate

1 and 2 = stage 1 and stage 2 of a treadmill test

The VO_2 for each work load is provided, and the VO_2 max is predicted from the equation:

$$VO_2max = SM\,(VO_2) + b\,(HRmax - HR_2) \quad \text{....... (2)}$$

Table 5 Bruce's treadmill protocol (1971)

Stage	**I**	**II**	**III**	**IV**
Minutes	3	6	9	12
Speed (Mph)	1.7	2.5	3.4	4.2
Grade Percent (%)	10	12	14	16
METS	4	6-7	8-9	15-16

*1 MET = 3.5 ml O_2 uptake /kg /min

Figure 4. Treadmill (Sensormedics 2000 Treadmill) in laboratory room

Figure 5. Instrument used in the blood lactate measurement

Figure 6. Anaerobic capacity test by Wingate ergometer (Ergomedic 894 E)

3.2.5 Pulmonary function test

Lung vital capacity (VC) was measured with a spirometer (Takei and Company, Japan). Each subject did two trials with the best effort was recorded.

3.2.6 Wingate Anaerobic Test

The same set up as the work output recording of the continuous progressive non-steady state exercise test was used to measure the pedal revolution during 30 seconds test. The subjects sat on a mechanical-braked bicycle ergometer appropriately adjusted and start to pedal at 50 rpm. The resistance was then increased as quickly as possible to the predetermined resistance which the subject was asked to maintain the speed. When the desired resistance was reached, the subject was asked to speed up as fast as he could for 30 seconds (Patton et al., 1985). At the end of 30 seconds, work load was reduced to zero and the subject was requested to pedal at his ease to taper off. (Green, 1995; Maud & Schultz 1989; Joseph O'Kroy, 2000)

a) Anaerobic capacity (defined as the mean work output over 30-sec period) in watt ($W.kg^{-1}$). = The overall output over 30 sec in kg.m

b) Anaerobic peak power (defined as the highest power output in 5-sec period) in watt ($W.kg^{-1}$) = Resistance Load (kg) × peak number of revolutions (per 5-sec interval) × 6 meters.

c) Power drop in %:

$$\text{Power drop (\%)} = \frac{\text{Peak power} - \text{Lowest 5-sec power}}{\text{Peak power}} \times 100$$

3.3 Blood lactate collection

Finger capillary blood samples were collected into a capillary tube and were analyzed for lactate concentration using an automatic lactate analyzer. The lactate analyzed was calibrated before the tests with several solutions of known lactate concentration (Aunola and Rusko, 1984). The puncture was induced using Accu-Chek® Softclix® lancet device. The result of blood lactate concentration was shown within 1 minute. During blood collection, subject was instructed to relax the hand. Blood sample (~25µl) was collected for each rest time and every 3 minutes (3, 6, 9, and 12 min) on Bruce's protocol.

3.4 Test of the best time on distances 100 and 400 meter

The three groups (control, weight training and interval training) ran the distances of 100 and 400 meters on the synthetic track at Mahidol University, Salaya Campus. Test was employed before and after training programs.

4. Exercise training programs

4.1 Weight training

Subject trained to perform resistance exercise by weight machines (Leg press, Bench press, Leg extension and Haft squat) with intensity exercise about 70% of 1 repetition maximum(1-RM); 3 sets per machine, 12 repetition on 1 set, 3 days per week for 6 weeks, with 60 seconds rest between sets (Appendix E). The 1-RM value may indirectly approximate from the submaximum lifting. The computation for 1-RM was derived the number of maximal repetitions (ranged from 2 to 20 repetitions) and that specific submaximal load. The relation was quantified in equation as (Chuanchaiyakul R, 2000);

1-RM = load at which number of maximal repetitions between 2 to 20 can be lifted / [100% - (number of maximal repetitions × 2)]

4.2 Interval training

Interval training program was performed two sessions of intensity work (relief : work ratio = 1:1). Subject trained running at high speed level on 50 meters distance and low speed level on 50 meters distance, total of 3000 meters distance running. The heart rate was analyzed by telemetry heart rate monitor, which detected intensity program. Training was set at 3 days/week, for 6 weeks (Karvonen et al., 1992).

1) At intense endurance workout (high speed) using by heart rate about 170-180 beats/min.

2) Recovery session of continuous training at recovery or regeneration workout (low speed) using by heart rate about 120-130 beats/min.

5. Experimental designs

Subject recruitment (age18-22years)

Pre-training

1. Questionnaires

General health, Physical activity

2. Distribution of groups

Weight training group, Interval training group and Control group

3. Anthropometric and Vital sign measurements

Body weight and height, Heart rate, blood pressure,

Skinfold thickness

4. Physical fitness tests

Lung vital capacity, Strength (leg strength), Flexibility (sit and reach),

Anaerobic test

5. Indirect submaximal oxygen consumption and Blood lactate

6. Running time test on distance 100 and 400 meters

7. Exercise training

↓

8. Anthropometric and Vital sign measurements

Post-training

Body weight and height, Heart rate, Blood Pressure

Skinfold thickness

9. Physical fitness tests

Lung vital capacity, Strength (leg strength), Flexibility (sit and reach),

Anaerobic test

10. Indirect submaximal oxygen consumption and Blood lactate

11. Running time test on distance 100 and 400 meters

6. Experimental protocol

Subject underwent a standardized 6 weeks with exercise training programs. All data were collected at the before and after of the training programs. Data included anthropometrics measurement such as body weight, height, skinfold thickness and physical fitness testing were collected. The experiment process was set at 5 days before and after training program:

Day 1 → Anthropometric, Vital sign and Physical fitness tests

Day 2 → Rest

Day 3 → Indirect submaximal oxygen consumption and Blood lactate

Day 4 → Rest

Day 5 → Running time test on distance 100 and 400 meters

The tests were conducted by the same investigator on all subjects using the same apparatus. Data were collected at the same time of the day at College of Sports Science and Technology, Mahidol University (Salaya Campus). Assistant athletic coach of Mahidol University was controller and trainer for subjects during training programs.

7. Statistical analysis

All data were presented as mean±SEM. Paired simples t-test was used to evaluate significant differences in anthropometrics and physical characteristics between pre-exercise and post-exercise training in the group, which were accepted at P-value less than 0.05. Analysis of variance with repeated measure was used to determine the mean differences within group. Data between group at the same period of time and same variable was analyzed using one-way ANOVA. Significance was set at P-value less than 0.05.

CHAPTER IV
RESULTS

The study was aimed to investigate the effect of different physical training modes; weight training and interval training, on blood lactate levels after a high intensity exercise. The exercise and the determination of VO_2max were parallelly performed on a treadmill by Bruce protocol. The anaerobic capacity of individual subject in each group was determined on the bicycle ergometer using Wingate test. The effect of training on heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) before and after the exercise were also evaluated. All experiments were performed in the laboratory room with an environmental temperature about 25 degrees Celsius.

1. Anthropometrics and Physical fitness characteristics.

The initial data of anthropometrics and physical fitness variables were presented as mean±SEM (Table 6).

Table 6. Initial anthropometrics and physical fitness characteristics of control, weight training and interval training groups. Data were presented as mean±SEM.

Group	Control	Weight training	Interval training
Age (yrs)	20.14±0.14	19.33±0.42	19.42±0.42
Weight (kg)	64.14±3.05	66.50±2.81	71.42±3.62
Height (cm)	173.85±1.53	174.16±1.07	175.57±1.90
BMI (kg/m^2)	21.19±0.77	21.94±0.93	23.13±0.84
Percent body fat (%)	15.45±1.29	14.03±1.54	17.03±1.47
SBP (mmHg)	118.57±6.01	128.16±3.87	126.57±3.31
DBP (mmHg)	63.71±2.03	66.16±2.58	66.85±2.96
RHR (bpm)	77.42±3.00	74.83±1.92	72.14±3.34
VO_2 (ml/kg/min)	46.00±1.31	46.19±1.83	47.03±1.17
Lung vital capacity (cc)	3,800±194.26	3,925±277.71	3,964±227.49
Sit and reach (cm)	8.85±1.15	15.08±2.27^{c}	11.71±1.33
Leg strength (Kg)	176.72±5.96	208.25±7.57^{c}	180.40±6.76^{b}

^{c} significantly different between weight training group and control group at the same period, $p<0.05$

^{b} significantly different between interval training group and weight training group at the same period, $p<0.05$

All group (control group, weight training group and interval training group, respectively) showed no significant difference ($p>0.05$) in mean age (20.14±0.14 ,19.33±0.42 and 19.42±0.42 years), weight (64.14±3.05, 66.50±2.81 and 71.42±3.62 kg), height (173.85±1.53, 174.16±1.07 and 175.57±1.90 cm), body mass index (21.19±0.77, 21.94±0.93 and 23.13±0.84 kg/m^2), Percent of body fat (15.45±1.29, 14.03±1.54 and 17.03±1.47 %), systolic blood pressure (SBP)

(118.57±6.01, 128.16±3.87 and 126.57±3.31 mmHg), diastolic blood pressure (DBP) (63.71±2.03, 66.16±2.58 and 66.85±2.96 mmHg), resting heart rate (RHR) (77.42±3.00, 74.83±1.92 and 72.14±3.34 beats/min).

Physical fitness characteristics in pre-training were represented as resting heart rate (RHR) and maximum oxygen consumption (VO_2max) (Table 6). The comparison of this physiological function was determined among the groups. There were no significant differences in resting heart rate between training groups and control group ($p>0.05$). In addition, there were no significant differences in the maximum oxygen consumption (VO_2max) of control group, weight training group and interval training group (46.00±1.31, 46.19±1.83 and 47.03±1.17 ml/kg/min) ($p>0.05$).

The lung vital capacity was not significant difference among the control group, weight training group and interval training group (3,800±194.26, 3,925±277.71 and 3,964±227.49 cc) ($p>0.05$). There were significant differences in flexibility among groups ($p<0.05$). The flexibility of the weight training group (15.08±2.27 cm) was significantly higher than the control group (8.85±1.15 cm). However, values of the interval training group (11.71±1.33 cm) was not significantly different from the weight training groups ($p>0.05$). Average leg strength value of weight training (208.25±7.57 kg) was significantly higher than interval training (180.40±6.76 kg) and control group (176.72±5.96 kg) ($p<0.05$).

The anthropometric variables among the control group, weight training group and interval training group during post-training period (Table 7), showed no significant difference ($p>0.05$) in age (20.14±0.14, 19.33±0.42 and 19.42±0.42 yrs), weight (64.71±3.13, 65.83±2.62 and 71.28±3.53 kg), height (173.85±1.53, 174.16±1.07 and 175.57±1.90 cm, respectively), systolic blood pressure (SBP) (120.28±6.98, 119.00±4.61 and 119.85±3.18 mmHg), diastolic blood pressure (DBP) (67.06±2.63, 68.83±1.07 and 64.28±3.54 mmHg), body mass index (BMI) (21.39±0.82, 21.62±0.94 and 23.09±0.84 kg/m^2) and resting heart rate (RHR) (73.85±2.49, 72.33±1.85 and 67.42±2.93 beats/min). There were significant difference in the VO_2max among the groups ($p<0.05$). The interval training group (51.97±1.49 ml/min/kg) was significantly higher than the weight training group (46.65±0.86 ml/min/kg) and control group (41.67±1.14 ml/min/kg). There were significant differences in the lung vital capacity among three groups. The control group (3,492±101.43 cc) was significantly lower than the weight training group (3,958±218.86 cc) and interval training group (4,171±217.08 cc) ($p<0.05$).

In addition, there was significant differences in the value of flexibility (sit and reach) among the groups ($p<0.05$). The control group (9.07±0.87 cm) was significantly lower than weight training group and interval training group (16.25±2.16 and 14.00±1.25 cm).

Table 7. The post training anthropometric and physical fitness characteristics of control, weight training and interval training group. Data were presented as mean±SEM.

Group	Control	Weight training	Interval training
Age (yrs)	20.14±0.14	19.33±0.42	19.42±0.42
Weight (kg)	64.71±3.13	65.83±2.62	71.28±3.53
BMI ($kg.m^2$)	21.39±0.82	21.62±0.94	23.09±0.84
Height (cm)	173.85±1.53	174.16±1.07	175.57±1.90
Percent body fat (%)	15.73±1.23	14.26±1.55	16.72±1.36
SBP (mmHg)	120.28±6.98	119.00±4.61	119.85±3.18
DBP (mmHg)	67.06±2.63	68.83±1.07	64.28±3.54
RHR (bpm)	73.85±2.49	72.33±1.85	67.42±2.93
VO_2 (ml/kg/min)	41.67±1.14	46.65±0.86[c]	51.97±1.49[a b]
Lung vital capacity (cc)	3,492±101.43	3,958±218.86 [c]	4,171±217.08 [a]
Sit and reach (cm)	9.07±0.87	16.25±2.16 [c]	14.00±1.25[a]
Leg strength (Kg)	169.00±4.12	224.60±11.71 [c]	205.50±15.5 [a]

[a] significantly different between interval training group and control group at the same period, $p<0.05$

[b] significantly different between interval training group and weight training group at the same period, $p<0.05$

[c] significantly different between weight training group and control group at the same period, $p<0.05$

There were significant differences in leg strength among three groups, the control group (169.00±4.12 kg) was significantly lower than weight training group and interval training group (224.60±11.71 and 205.50±15.5 kg) ($p<0.05$). However, the leg strength of weight training group was not significantly different from the interval training group ($p>0.05$).

2. Blood lactate concentration (BLC).

2.1 Blood lactate concentration of subjects at rest before-training period in control group, weight training group and interval training group were 1.65±0.15, 2.03±0.24 and 1.62±0.22 mmol/l, respectively. The blood lactate concentration of all groups showed remarkable increase during running on treadmill (Table 8).

Table 8. The appearance of blood lactate concentration (BLC) (mmol/l) in the control and training groups before training protocol.

Group	Rest time (mmol/l)	3 min (mmol/l)	6 min (mmol/l)	9 min (mmol/l)	12 min (mmol/l)
Control	1.65±0.15	2.08±0.05	2.70±0.28	3.82±0.39	5.51±0.57
Weight	2.03±0.24	2.08±0.33	2.28±0.18	3.03±0.21	5.53±0.62
Interval	1.62±0.22	1.77±1.64	2.04±0.24	3.27±0.33	6.05±0.88

No significantly different between groups at same period, $p>0.05$.

There were no significant differences among all groups at rest time when subject ran on treadmill ($p>0.05$). Blood lactate concentration (BLC) in control group, weight training group and interval training group during intense exercise at 3, 6, 9 and 12 minutes showed no significantly different among all groups at the same period ($p>0.05$). At 3 minutes in control group, weight training group and interval training group were 2.08±0.05, 2.08±0.33 and 1.77±1.64 mmol/l, respectively. At 6 minutes in control group, weight training group and interval training group were 2.70±0.28, 2.28±0.18 and 2.04±0.24 mmol/l. At 9 minutes in control group, weight training group and interval training group were 3.82±0.39, 3.03±0.21 and 3.27±0.33 mmol/l. Finally, blood lactate concentration at 12 minutes in control group, weight training group and interval training group were 5.51±0.57, 5.53±0.62 and 6.05±0.88 mmol/l.

2.2 Blood lactate concentration at rest after-training period in the control group, weight training group and interval training group were 1.80±0.19, 1.86±0.91 and 1.27±0.17 mmol/l. Blood lactate concentration of the interval training group was significantly lower than both control group and weight training group ($p<0.05$). (Table 9)

Table 9. The appearance of blood lactate concentration (BLC) (mmol/l) in the control and training groups after training.

Group	Rest time (mmol/l)	3 min (mmol/l)	6 min (mmol/l)	9 min (mmol/l)	12 min (mmol/l)
Control	1.80±0.19	2.18±0.15	2.62±0.26	3.38±0.12	5.82±0.62
Weight	1.86±0.91	1.90±0.15	2.11±0.20	2.61±0.24[c]	4.35±0.34[c]
Interval	1.27±0.17[ab]	1.50±0.18[a]	1.78±0.11[a]	2.87±0.27	4.44±0.35[a]

[a] significantly different between interval training group and control group at the same period, $p<0.05$

[b] significantly different between interval training group and weight training group at the same period, $p<0.05$

[c] significantly different between weight training group and control group at the same period, $p<0.05$

After 6 weeks of training, the level of blood lactate concentration during exercise in control, weight training and interval training group at 3 minutes were 2.18±0.15, 1.90±0.15 and 1.50±0.18 mmol/l. Blood lactate concentration (BLC) at 3 min of the interval training group was significantly lower than control group ($p<0.05$). At 6 minutes, blood lactate of interval training group (1.78±0.11 mmol/l) was significantly lower than both weight training group (2.11±0.20 mmol/l) and control group (2.62±0.26 mmol/l). At 9 minutes, weight training group (2.61±0.24 mmol/l) had blood lactate concentration accumulation significantly lower than control (3.38±0.12 mmol/l) ($p<0.05$). Weight training group was no significantly different to interval training group (2.87±0.27 mmol/l) ($p>0.05$). At 12 minutes, there were significant differences higher blood lactate in control group than weight training group and interval training group (5.82±0.62, 4.35±0.34 and 4.44±0.35 mmol/l).

3. Comparison of physical fitness parameter within and between groups

Resting heart rate was compared between the experimental groups and the control group. The results showed no significant difference among these groups. The resting heart rates of post-training of all groups (control group, weight training group and interval training group) were 73.85±2.49, 72.33±1.85 and 67.42±2.93 beats/min, respectively. However, there was significant difference between within control group (77.42±3.00 and 73.85±2.49 beats/min) and interval training groups (72.14±3.34 and 67.42±2.93 beats/min) ($p<0.05$) (Figure 7). Systolic blood pressure was significantly lower ($p<0.05$) in the weight training group (128.16±3.87 and 119.00±4.61 mmHg) and interval training group (126.57±3.31 and 119.85±3.18 mmHg). Systolic blood pressure of the control group was 118.57±6.01 and 120.28±6.98 mmHg (Figure 8). There was no significant difference in diastolic blood pressure within control group (63.06±2.63 and 67.42±2.65 mmHg), weight training group (66.16±2.58 and 68.83±1.07 mmHg) and interval training group (72.14±3.34 and 67.42±2.93 mmHg) (Figure 9).

Figure 10 compared body mass index (BMI) of the subjects before and after training. Subjects' BMI after-training in control group, weight training group and interval training group were 21.39±0.82, 21.62±0.94 and 23.09±0.84 kg/m^2, respectively. There were no significant differences within the three groups ($p>0.05$). Figure 11 show the maximum oxygen consumption (VO_2max) of the three groups. The VO_2max found in interval training group (47.03±1.17 and 51.97±1.49 ml/kg/min) and weight training group (46.19±1.83 and 46.65±0.86 ml/kg/min) were 10.5 % and 1% higher than initial values. Figure 12 showed the value of percent body fat which was no significant difference within the three groups at before and after training (p>0.05). Nevertheless, there was significant difference between the value of lung vital capacity in the interval training group before and after training (3,964±227.49 and 4,171±217.08 cc) (p<0.05). The lung vital capacity of interval training group increased about 5.2% from the initial value. Figure 14 showed the value of flexibility of two training groups and control group. The flexibility of weight training group (15.08±2.27 and 16.25±2.16 cm) and interval training group (11.71±1.33 and 14.00±1.25 cm) were 7.75% and 19.5% higher than initial values.

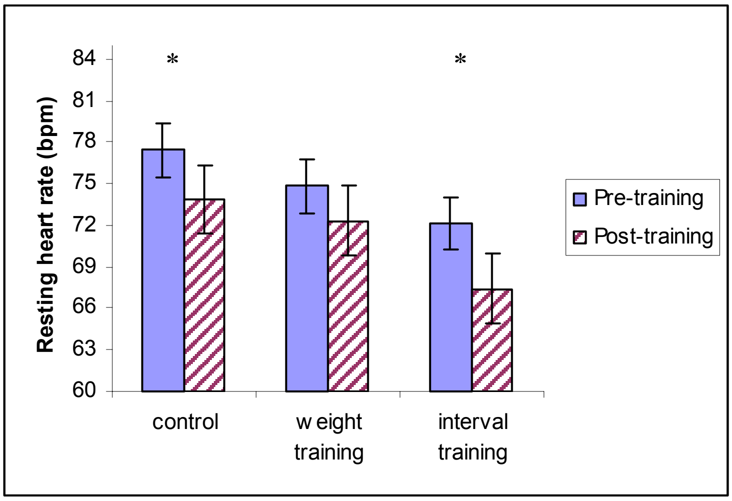

Figure 7. Comparison of means (±SEMs) values of resting heart rate (beat/min) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group (p<0.05)

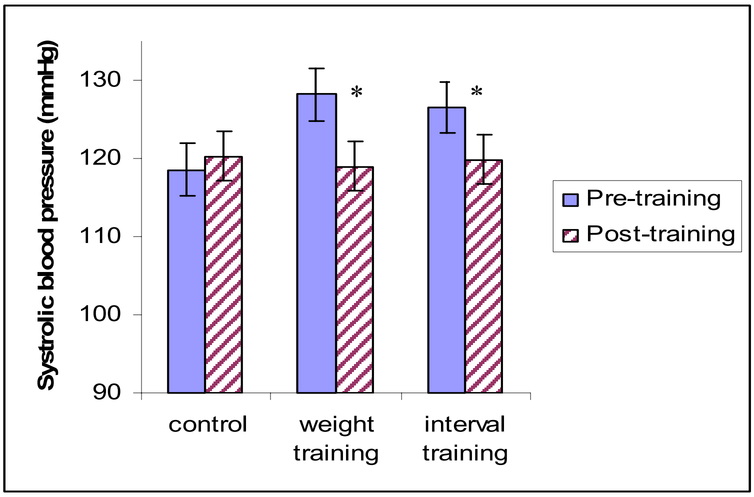

Figure 8. Comparison of means (±SEMs) values of systolic blood pressure (mmHg) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$)

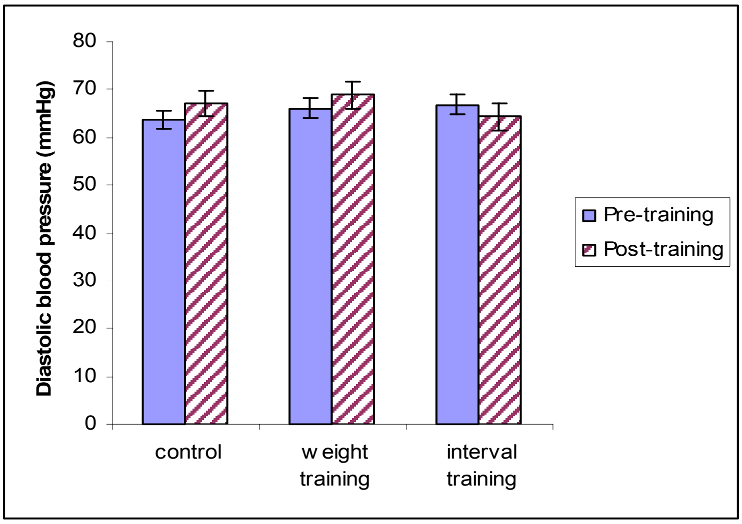

Figure 9. Comparison of means (±SEMs) values of diastolic blood pressure (mmHg) among control, weight training, and interval training groups pre and post each mode of training.

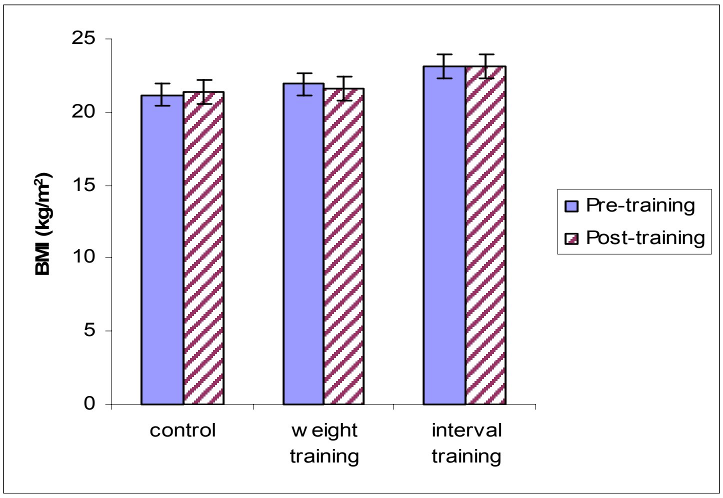

Figure 10. Comparison of means (±SEMs) values of BMI (kg/m^2) among control, weight training, and interval training groups pre and post each mode of training.

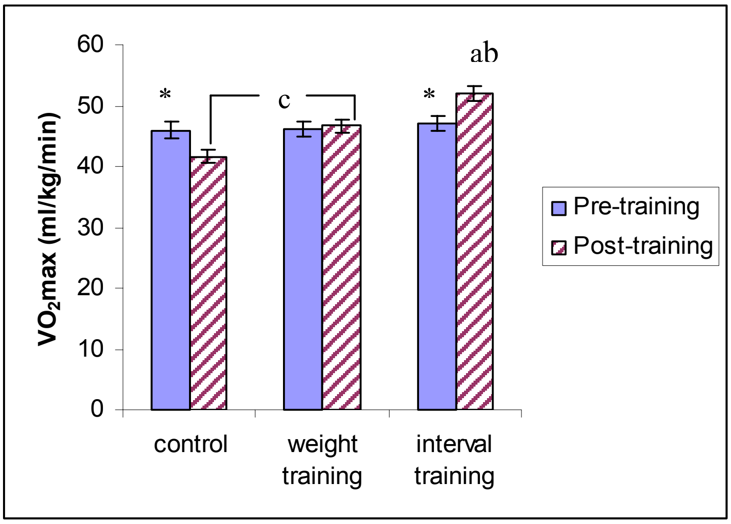

Figure 11. Comparison of means (±SEMs) values of maximum oxygen consumption or VO_2max (ml/kg/min) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$

[c] significantly different between weight training group and control group at the same period, $p<0.05$

[b] significantly different between interval training group and weight training group at the same period, $p<0.05$

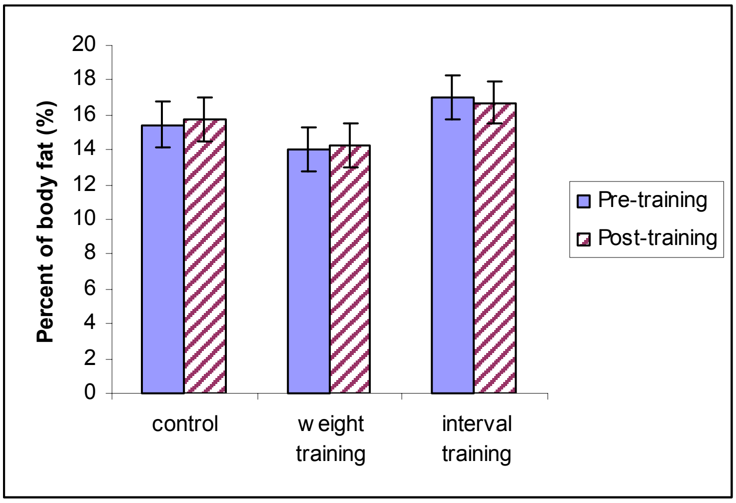

Figure 12. Comparison of means (±SEMs) values of percent body fat (%) among control, weight training, and interval training groups pre and post each mode of training.

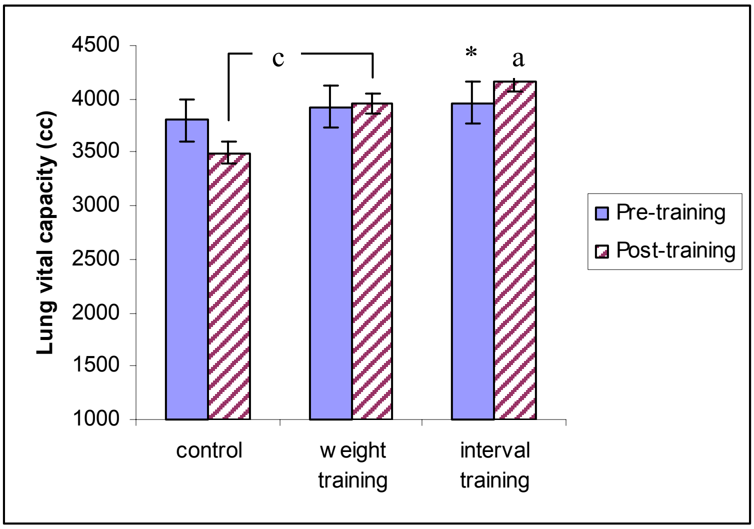

Figure 13. Comparison of means (±SEMs) values of lung vital capacity (cc) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$,

[c] significantly different between weight training group and control group at the same period, $p<0.05$

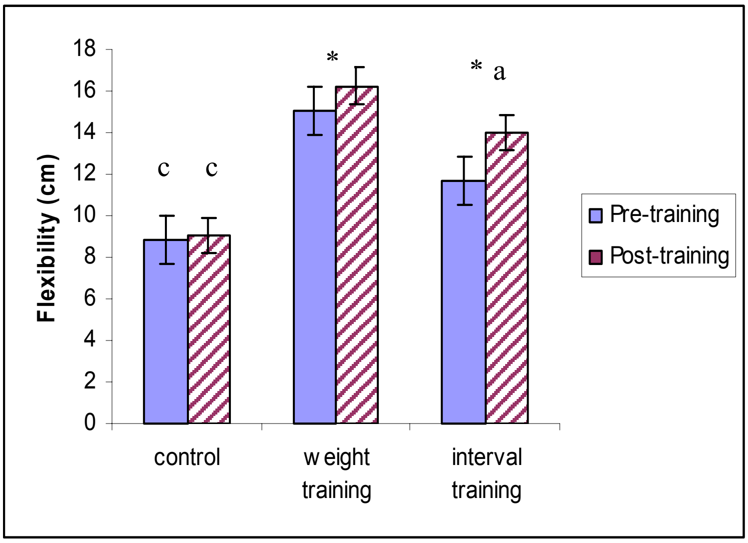

Figure 14. Comparison of means (±SEMs) values of maximum flexibility (cm) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[c] significantly different between weight training group and control group at the same period, $p<0.05$,

[a] significantly different between interval training group and control group at the same period, $p<0.05$

There was significant difference in the value of leg strength within each group (Figure 15). Interval training group significantly increased in the leg strength value (14%) than pre-training ($p<0.05$). The pre-training and post-training of interval training group were 180.14±6.76 and 205.50±15.50 kg, respectively. Leg strength value of the weight training group was significantly higher (10.6%) than post-training ($p<0.05$). The leg strength value pre-training and post-training was 208.25±7.57 and 224.60±11.71 kg, respectively.

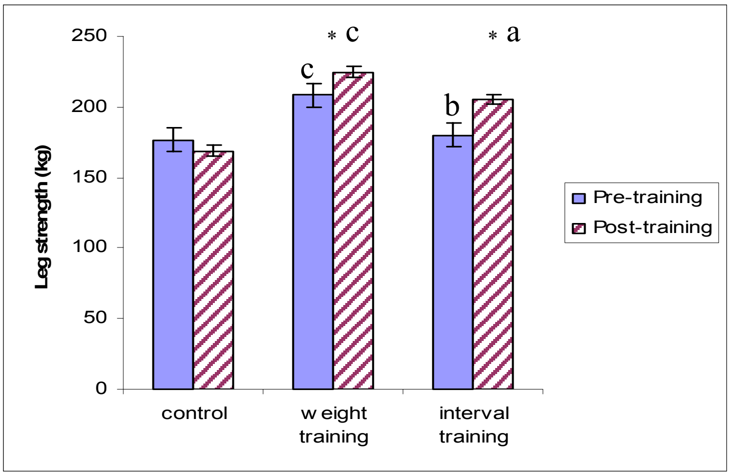

Figure 15. Comparison of means (±SEMs) values of maximum leg strength (kg) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[c] significantly different between weight training group and control group at the same same period $p<0.05$,

[a] significantly different between interval training group and control group at the same period, $p<0.05$,

[b] significantly different between interval training group and weight training group at the same period $p<0.05$

Blood lactate level at all periods showed in Figure16, 17, 18, 19, and 20. There was significant difference within the interval training group at rest (1.62±0.22 and 1.27±0.17 mmol/l), 9 minute (3.27±0.33 and 2.87±0.27 mmol/l) and 12 minutes (6.05±0.88 and 4.44±0.23 mmol/l) ($p<0.05$). The percentages were decreased about 21.6%, 12.23 % and 26.61%, respectively compared between before and after training. There was significant difference within weight training group at 12 minutes (5.53±0.62 and 4.35±0.34 mmol/l). The percentages were decreased about 21.33% between before and after training. There were not significant differences within three groups during 3 and 6 minutes.

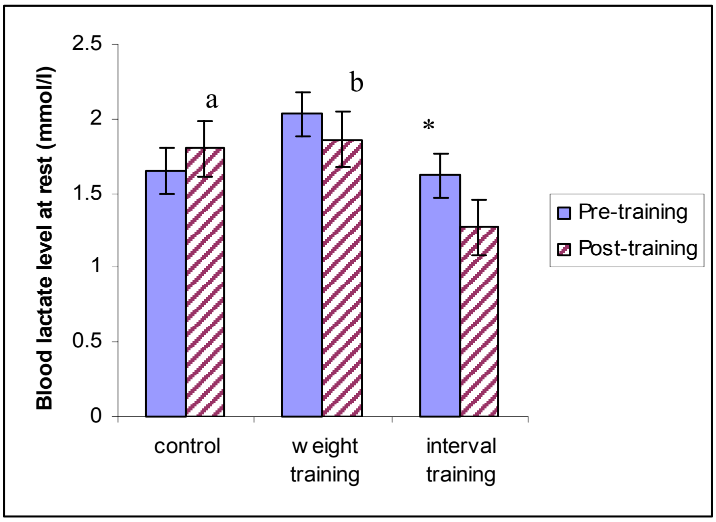

Figure 16. Comparison of means (±SEMs) values of blood lactate level at rest time (mmol/L) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$,

[b] significantly different between interval training group and weight training group at the same period, $p<0.05$

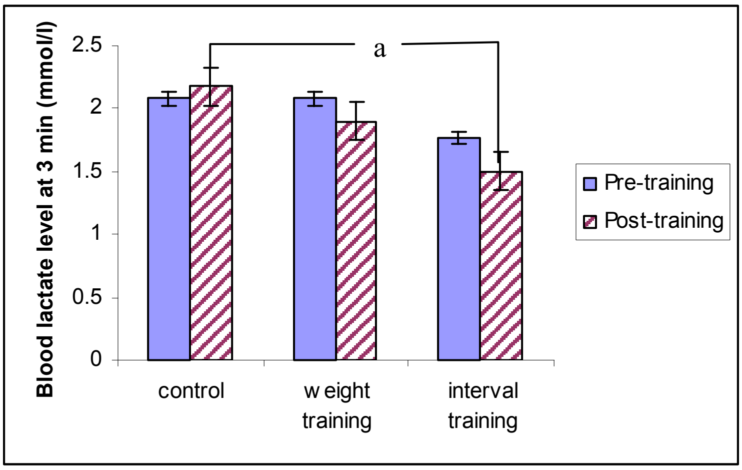

Figure 17. Comparison of means (±SEMs) values of blood lactate level at 3 min (mmol/L) among control, weight training, and interval training groups pre and post each mode of training.

[a] significantly different between interval training group and control group at the same period, $p<0.05$

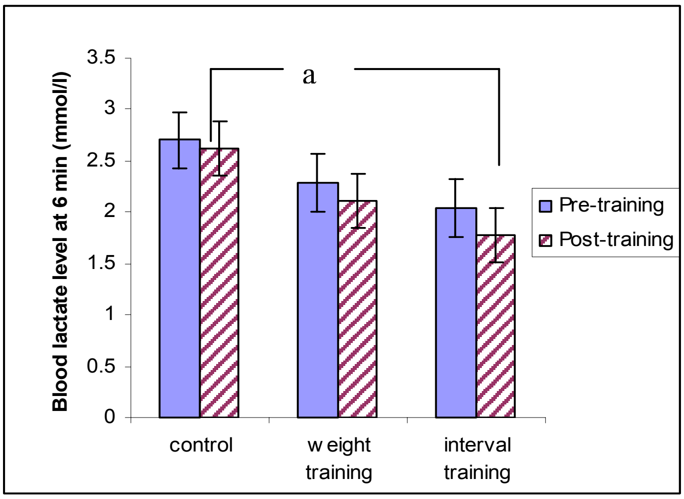

Figure 18. Comparison of means (±SEMs) values of blood lactate level at 6 min (mmol/L) among control, weight training, and interval training groups pre and post each mode of training.

[a] significantly different between interval training group and control group at the same period, $p<0.05$

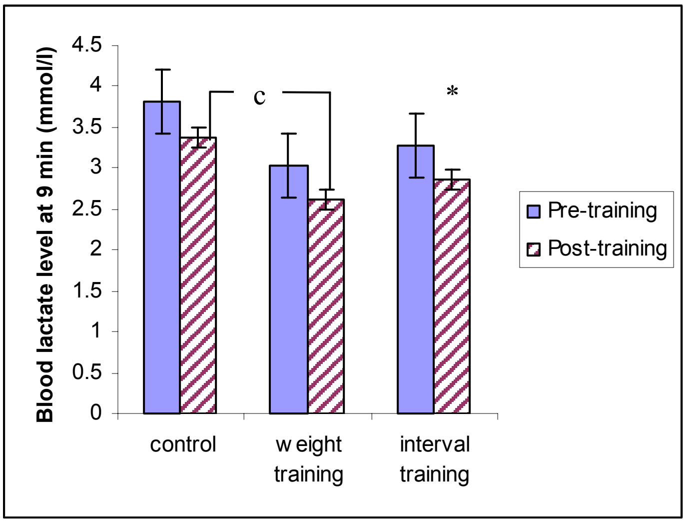

Figure 19. Comparison of means (±SEMs) values of blood lactate level at 9 min (mmol/L) among control, weight training, and interval training groups pre and post each mode of training

* indicates significantly different from the within group ($p<0.05$),

[c] significantly different between weight training group and control group at the same period, $p<0.05$

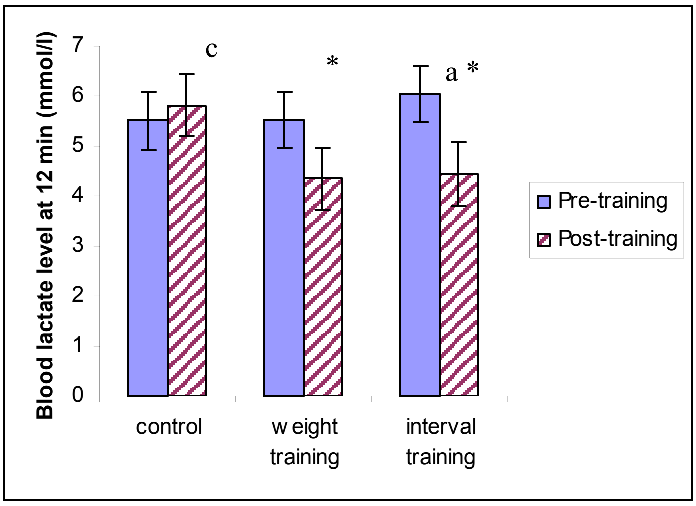

Figure 20. Comparison of means (±SEMs) values of blood lactate level at 12 min (mmol/L) among control, weight training, and interval training groups pre and post each mode of training.

* indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$

[c] significantly different between weight training group and control group at the same period, $p<0.05$

The anaerobic energy system data presented at Figure 21, 22 and 23. There were significant differences within the three groups ($p<0.05$) namely; mean power, peak power and power drop of anaerobic exercise modes. After training, the value of mean power (5.92±0.22 and 6.31±0.23 watt/kg) (+ 6.5%) and peak power (7.64±0.15 and 8.32±0.19 watt/kg) (+8.9%) of the interval training group were higher than the initial value. The mean power of control group was 5.13±0.16 and 5.22±0.14 watt/kg. Mean power of weight training group was not significant difference within group ($p>0.05$) (5.06±0.39 and 5.71±0.22 watt/kg) (+12%). However, the values of peak power was significantly increased in weight training ($p<0.05$) (7.61±0.30 and 8.04±0.31) watt/kg (+6%). The peak power of control group was 6.92±0.32 and 6.93±0.27 watt/kg). Finally, there was significant difference in percentage of power drop within interval training group and weight training group. Interval training group was significantly decreased in post-training (2.40±0.18%) than pre-training program (2.94±0.21 %). There was decrease in the power drop of weight training group (3.68±

0.28 and 2.66±0.22 %) and the value of control group was not significantly different within group (3.03± 0.29 and 3.23± 0.67%) ($p>0.05$).

4. Accumulate blood lactate concentrations with Bruce's protocol

Changes in blood lactate concentration between pre and post-training program of all groups are illustrated in Fig 24, 25 and 26. There were accumulations of blood lactate at all stages. Control group was not significantly different between both pre and post-training program ($p>0.05$). The mean different between pre and post-training of weight training group were found significantly different at 12 min ($p<0.05$). During exercise training period, blood lactate level at rest, 9 and 12 min of interval training group were significantly different within group ($p<0.05$). Blood lactate level within interval training group was lower than pre-training.

5. Running time of athlete in distance 100, 400 meters.

Figure 27 and 28 showed the running time of subjects in distance 100 and 400 meters on the synthetic track. Between before and after training program on distance 100 meter of the two training groups and control group with running performance time, there were no significant differences between training groups and control group of distance 100 meters ($p>0.05$). The running time of interval training (13.15±0.37 and 13.16±0.16 s) was lower than the running time of control group (13.90±0.36 and 14.42±0.34 s). However, there were no significant differences between both interval training group and weight training group (13.63± 0.55 and 13.30± 0.46 s) ($p>0.05$). For running time of distance 400 meters, the interval training group was significantly different from the control group ($p< 0.05$). Interval training group were 67.17±1.67 and 64.52±1.53 s lower running time than control group (70.39±1.67 and 73.55±2.17 s). There was significant difference within weight training group (72.66±3.62 and 69.95±3.19 s) ($p<0.05$) at the same distance.

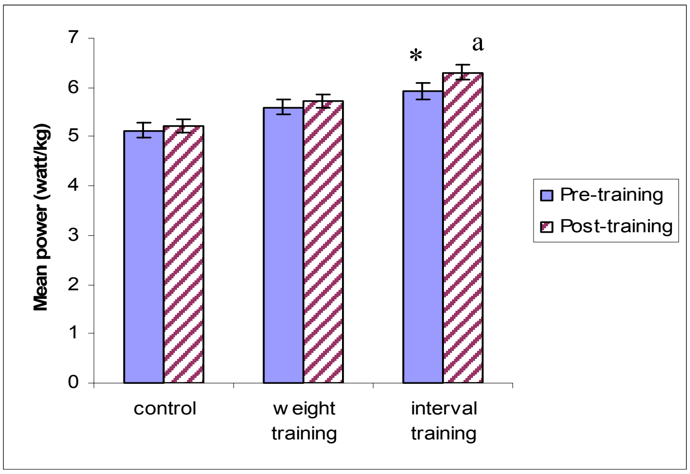

Figure 21. Comparison of means (±SEMs) values of mean power (watt/kg) among control, weight training, and interval training groups pre and post each mode of training.

* Indicates significantly different from the within group ($p<0.05$)

[a] significantly different between interval training group and control group at the same period, $p<0.05$

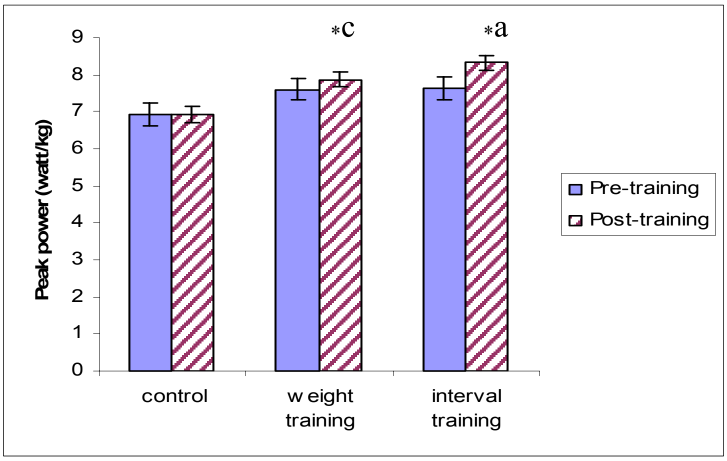

Figure 22. Comparison of means (±SEMs) values of peak power (watt/kg) among control, weight training, and interval training groups pre and post each mode of training.

* Indicates significantly different from the within group ($p<0.05$),

[c] significantly different between weight training group and control group at the same period, $p<0.05$,

[a] significantly different between interval training group and control group at the same period, $p<0.05$

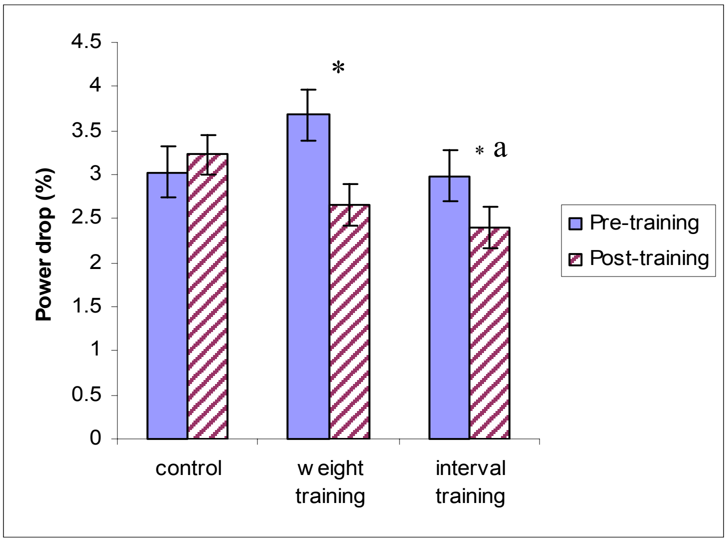

Figure 23. Comparison of means (±SEMs) values of power drop (%) among control, weight training, and interval training groups pre and post each mode of training.

* Indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$.

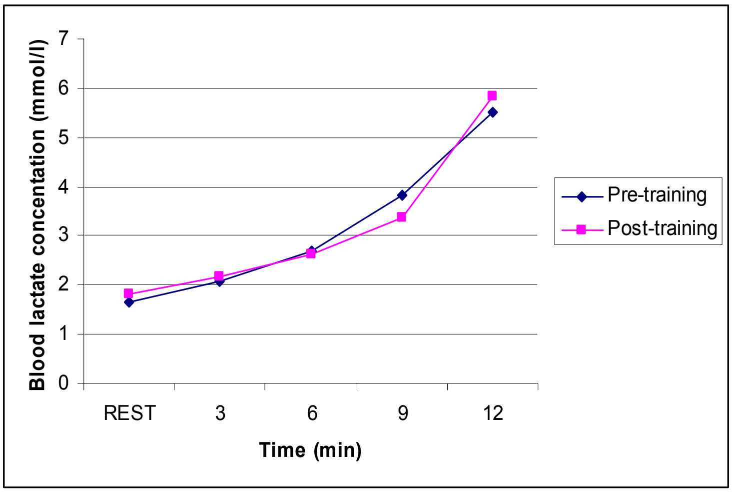

Figure 24. Comparison of means (±SEMs) values of blood lactate concentration (mmol/l) between pre and post training of control group with Bruce test stages.

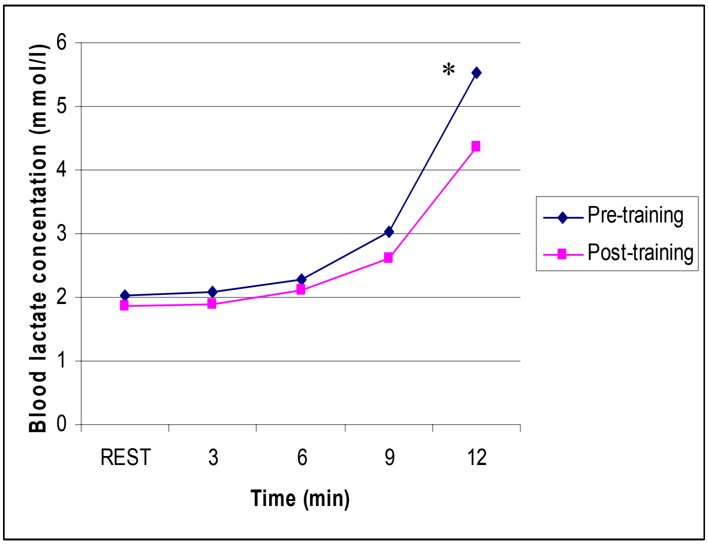

Figure 25. Comparison of means (±SEMs) values of blood lactate concentration (mmol/l) between pre and post training of weight training group with Bruce test stages.

* Indicates significantly different from the within group ($p<0.05$)

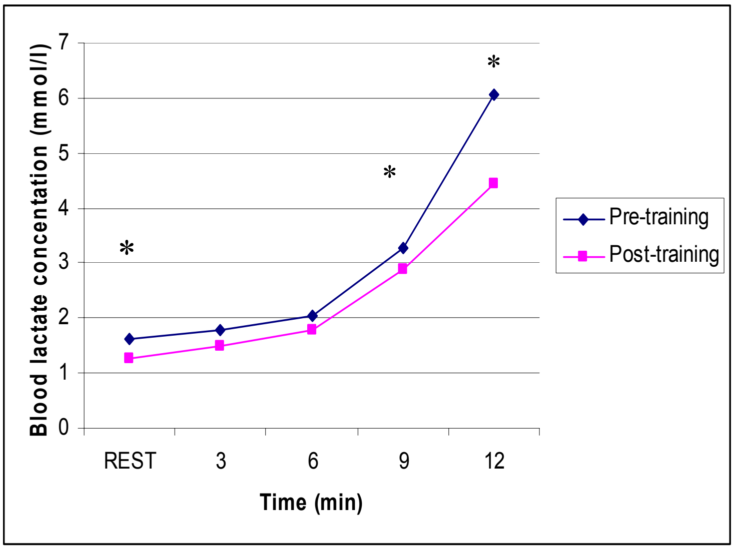

Figure 26. Comparison of means (±SEMs) values of blood lactate concentration (mmol/l) between pre and post training of interval training group with Bruce test stages.

* Indicates significantly different from the within group ($p<0.05$)

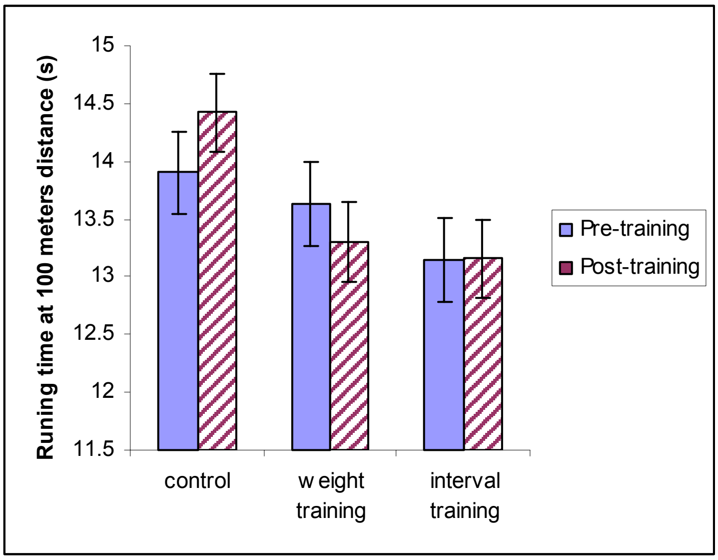

Figure 27. Comparison of means (±SEMs) values of 100 meters running time between pre and post training among control, weight training, and interval training groups.

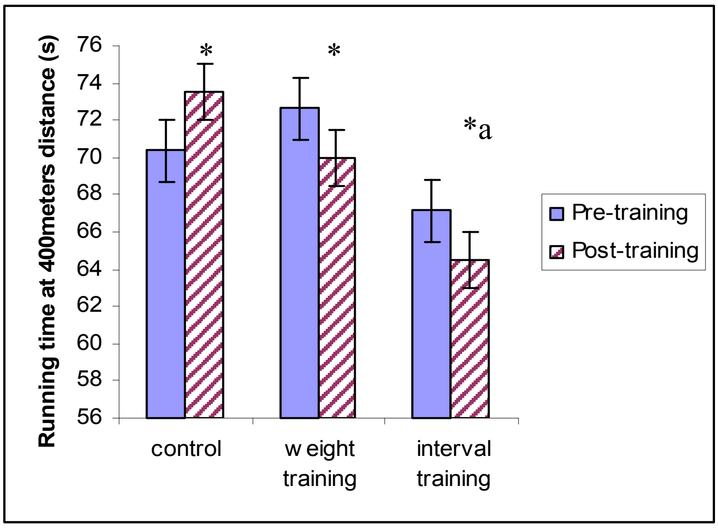

Figure 28. Comparison of means (±SEMs) values of 400 meters running time between pre and post training among control, weight training, and interval training groups.

* Indicates significantly different from the within group ($p<0.05$),

[a] significantly different between interval training group and control group at the same period, $p<0.05$.

Table 10. Summary of physical fitness results between groups during 6 weeks of exercise training.

Period	VO_2	LVC	FLE	LS
Pre-training	WT>CT			WT>CT
Post-training	IT>CT WT>CT IT>WT	WT>CT IT>CT	WT>CT IT>CT	WT>CT IT>CT

Abbreviations VO_2, LVC, FLE, LS, CT, WT, IT and > (maximum oxygen consumption, lung vital capacity, flexibility, leg strength, control group, weight training group, interval training group and significantly different, respectively).

Table 11. Summary of blood lactate level at several periods between groups during 6 weeks of exercise training.

Period	rest	3 min	6 min	9 min	12 min
Pre-training					
Post-training	CT > IT WT > IT	CT > IT	CT > IT	CT > WT	CT > WT CT > IT

CHAPTER V
DISCUSSION

In this study, the measurement of anthropometric characteristic pre and post training for the subjects was body weight and height. This study indicated that the parameters were similar in age, body mass index, resting heart rate, systolic blood pressure and diastolic blood pressure. After training, mean values of systolic blood pressure and resting heart rate of interval training group was significantly lower comparing to initial value ($p<0.05$). This indicated that the training program had induced cardiovascular system leading to increase performance of this system, reducing vascular resistance. This result was supported by Wilmore et al (2001) and Fagard (2006) indicated the small decrease in resting heart rate across groups and small changes in resting systolic blood pressure.

Physical fitness characteristics in pre and post-training were presented as the maximal amount of oxygen consumption (VO_2max) in the weight training group, interval training group and control group. There were significant differences between control group and training groups ($p<0.05$). As expected, the interval training group and weight training group had higher VO_2max than the control group after training. These results indicated that aerobic capacity of the two training groups were effectively improved supported by McMillan et al (2005) who indicated that the aerobic capacity can be improved by the high intensity interval. In 2007, Helgerud et al investigated the effect of high-intensity interval training and moderate training (long distance) on VO_2max. The result indicated that high-intensity interval training was significantly induced higher VO_2 max than moderate training. VO_2max of interval training group was significantly different between pre and post-training ($p<0.05$), while the VO_2max of weight training group did not change. The duration of weight training might be not long enough to induce differences in the VO_2max or the extent of improvement was too small. Mean value of VO_2max in interval training group was significantly higher than the weight training group. This results indicated that there were adaptation of the cardiovascular system (an increased heart size, a decreased heart rate, an increased stroke volume, an increased blood volume, and an increased capillary density) (Foss and Keteyian, 1998; Schantz, 1982). In addition, the weight training program used in this study might be inferior to high-intensity interval training program in stimulating the aerobic capacity of the subjects. However, the effect of resistance training on VO_2 and capillary supply to skeletal muscles had been investigated previously. Those studies indicated that the resistance/strength training can increase capillary supply to skeletal muscle fiber (Hepple et al., 1997; Tesch et al., 1984) and a small increase in VO_2max (4%) (Hickson et al., 1980).

Leg strength mean values of weight training group and interval training group in pre and post training were significantly higher than that of the control group ($p<0.05$). The leg strength of both two training groups were significantly higher after training program. This indicated that the improvement of leg strength of the training groups increased by the training program while subjects of control group showed no improvement due to less physical activity. However, comparing between weight training group and interval training group, there were no significant differences after training for 6 weeks ($p>0.05$). Two training programs enhanced the improvement of the leg strength, because of program of exercise training that put sufficient load on the muscles and, therefore; induce adaptation in number or size of muscles fiber after training program. Several study investigated that the resistance training did increase muscle fiber in type I, type IIa and IIc (McCall et al., 1996; Hather et al., 1991; Kraemer et al., 1995; Costill, 1976; Baldwin et al., 1972; Gollnick et al., 1973) and increase capillaries per fiber (15%) (Frontera et al., 1990). Compos et al. (2002) reported the adaptation of muscles after different resistance training program. The authors suggested that the intermediate repetition resistance training program induced greater muscles hypertrophy comparing to the high repetition regimen. Vogiatzis and co-workers (2005) showed that the interval training can effectively induce skeletal muscle adaptation. This result demonstrated that after exercise training, there was significant increase in the cross-sectional areas of type I and IIa muscle fibers.

The flexibility of weight training group and interval training group in pre and post training were significantly higher than that of control group ($p<0.05$). The flexibility of both training groups were significantly greater after 6 weeks training. It was recommended that muscle stretching should be added to the exercise training program especially at before and after to enhance the flexibility (increase joint range of motion, reduce muscle tension) of training subjects congruent with study experimented by Jackson and Baker (1986). Some studies reported the effect of resistance training can enhance flexibility of upper and lower body in the elderly subjects (Fatouros et al., 2006; Barbosa et al., 2002). In the present study, the flexibility of interval training group and weight training group were not significantly different ($p>0.05$).

The percent of body fat in pre and post training of weight training group, interval training group and control group were similar ($p>0.05$). In addition, the interval training group and weight training group were not significantly changed in percent of body fat before and after training. This study indicated that duration of training program was not long enough to make the adaptation on percent of body fat in subject groups. Previous study in 2005 by Daly et al presented the effect of high-intensity progressive resistance training on weight and fat mass within 6 months. They found increase values of weight and fat mass in the group. Grund et al., (2001) studied different attributes of physical activity and fitness and their relationships to nutritional state in endurance and resistance trained, compared to untrained men. They reported increase fat free mass and muscle mass by resistance training. However, body masses and fat mass endurance training reduced by endurance training. On the other hand, Fredrick et al (1991) reported the high-resistance training program (85%-90% of RM) had significantly decreased percent body fat after training for 16 weeks. In this study, the interval training program was separated into two modes: 1) Fast speed 2) low speed of running on track. Anaerobic was the main energy at fast speed running period. Previous study in 2001 by Mader et al. reported the bouts of high-intensity exercise for 10 weeks did reduce subcutaneous adipose tissue more than low-intensity exercise. The results recommended that the discontinuous (interval training) protocol was not better in reducing subcutaneous adipose tissue.

There were significant differences of lung vital capacity between two training groups and control group for 6 weeks ($p<0.05$). The values of lung vital capacity in both training groups were higher than the control group. However, lung vital capacity of interval training group and weight training group were not significantly different ($p>0.05$). Interval training group was significantly different within group. Weight training did not change in lung vital capacity before and after training. This study indicated that weight training program had not induced to stimulate physiological adaptation for increasing ventilation. High-intensity interval exercise caused the adaptation of neural input to the respiratory center and increasing of ventilation. For this reason, interval training program with endurance training can increase cardiovascular and respiratory fitness, the ability of lung to improve the volume of gas exchange (O_2 and CO_2) between atmospheric air and lung, also to improve respiratory capacity, airway resistance, exercise tolerance, and to reduce work of breathing (Frownfelter, 1978; Levenson, 1992; Cheng et al., 2003).

In the study, the blood lactate level at 9 and 12 minutes post-training program were significantly decreased in weight training group comparing to control group. There was significant differences between interval training and control group ($p<0.05$). Blood lactate of interval training group was significantly lower than that of control group at rest, 3, 6, and 12 minutes. At rest, interval training group was significantly lower in blood lactate than that of weight training group. In addition, at 12 min of weight training group and at rest, 9 and 12 min of interval training group were significantly lower in blood lactate comparing to those of the pre training. This result indicated that the interval training program might delay the onset of blood lactate accumulation level in muscle. Previous study supported that lactate threshold was significantly higher in high-intensity interval training than moderate training (Helgerud et al., 2007; Donvan and Brook, 1983). In 2007, Rozenek et al recommended that interval training appeared to produce responses that may benefit both aerobic and anaerobic energy system development. In addition, Burgomaster et al (2006) reported the effect of interval training on physiological metabolism. Their results indicated that training program did closer matching of glycogenolytic flux and pyruvate oxidation during submaximal exercise. It was benefit for delay lactate accumulation during exercise (Donvan and Brooks, 1983).

The value of anaerobic peak power were significant differences among two training groups and control group ($p<0.05$). However, the statistically significant difference of anaerobic mean power was observed to be different only between interval training group and control group. The value of anaerobic mean power in control group was lower than the interval training group ($p<0.05$). Anaerobic mean and peak power of between both two training groups were similar. These results indicated that two training programs with high intensity exercise could stimulate the anaerobic energy system. Previous study reported the effects of interval training program on anaerobic system in preadolescent boys. The study recommended that training program could enhance the increasing of the anaerobic capacity: mean power by 10% and peak power by 14%, respectively (Rotstein et al., 1986). Even so, Fatouros et al. (2005) reported the effect of strength training on anaerobic power of older man. They reported that high-intensity training improved 17-25% in anaerobic power value. The power drop value of control group was significantly higher than interval training group after training period ($p<0.05$). However, the control group was not significantly different compare to weight training at after training program ($p>0.05$). Weight training group and interval training group were significantly different in power drop before and after training ($p<0.05$). This study indicated that interval training programs may improve lactate oxidation within working muscles, increase expression lactate transporters in muscle sarcolemmal (Pilegaard et al., 1994) and mitochondrial membrane, and maintain glucose homeostasis during exercise (Dubouchaud et al., 2000).

In this study, the running time performance of weight training group, interval training group and control group were significantly different between 400 meters distance before and after training ($p<0.05$). There was significant difference in running time between interval training group and control group at 400 meters distance after training period ($p<0.05$). However, there was no significant difference in running time at 100 meters among three groups before and after training; Control group was higher in running time 100 and 400 meters than that of training groups after training. Exercise training programs did not affect running performance on 100 meters distance. Although effects of two training programs had influence on 400 meters running time, which was stimulated the procedure of anaerobic lactic system. As a result of training, epinephrine is released into the circulatory system which more likely to signal glycolysis and lactate production. Training programs may enhance transfer of lactate turnover into the liver for glucose synthesis and storage (gluconeogenesis or Cori's cycle). Previous studies reported that the interval training program found improving the time-trial performance of cyclists (Laursen, 2002), increasing in muscle strength and power due to improve of muscle mass and neuromuscular activation (Macaluso et al., 2004). Recently, the effects of combination between strength training and endurance training was found to be greater improvement in the 4 km time-trial and aerobic capacity (Chtara et al., 2005; Hickson et al. 1980) than each training programme performed separately (strength circuit training and running endurance training).

Data obtained from this study indicated that interval training and weight training were beneficial to physical fitness. Exercise programs can be individually adapted to meet various needs and abilities. However, to be cautious, the interval training and weight training were high intensity training that may increase risk of injuries. Coaches must understood technical training and prevent injury for athletes.

CHAPTER VI
CONCLUSION

The present study of influences of different methods of training on physical fitness and blood lactate level response during exercise exposure can be concluded as following;

1. The VO_2max of interval training was significantly higher than weight training group and control group after 6 weeks training.

2. The leg strength of training groups were significantly higher than control group ($p<0.05$). In addition, there were significant differences within training groups before and after training.

3. The lung vital capacity and flexibility (Sit and Reach) were significantly higher in training groups than control group ($p<0.05$). However, there were no significant differences between both training groups ($p>0.05$). .

5. Blood lactate level of interval training group at rest time was significantly lower than the weight training group. Nevertheless, at 3-12 minutes of two training program, lactic acid in blood capillary were decreased compare to before training programs.

6. The anaerobic test (mean power, peak power) of training groups were significant higher than the control group ($p<0.05$). Two training programs increased the value of anaerobic test (mean power and peak power) than before training programs. The decrease power drop was found in interval training group.

7. Training programs influenced adaptation for better physical fitness by increasing strength, power and delay muscle fatigue which benefit was placed on running time 400 meters distance.

REFERENCES

1. Alexandre P. Demarle, Jean J. Slawinski, Laurent P. Laffite, Valery G. Bocquet, Jean P. Koralsztein, and Veronique L. Billat. Decrease of O_2 deficitis a potential factor in increased time to exhaustion after specific endurance training. J Appl Physiol. 2001; 90: 947-953.
2. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription: Williams & Wilkins; 1995.
3. Astrand I. Lactate content in sweat. Acta Physiol Scand. 1963; 58: 359-367.
4. Aunola S and Rusko H. Reproducibility of aerobic and anaerobic threshold in 20-50 years old men. Eur J Appl Physical. 1984; 53: 260-266.
5. Baldwin K, Klinerfuss G, Terjung R, Hoolszy. Respiratiory capacity of white red and intermediate muscle: adaptive response to exercise. Am J Physiol. 1972; 222: 373-8.
6. Barbosa AR. Santarem JM, Fillho WJ, Marucc Mde F. Effects of resistance training training on the sit and reach test in elderly women. J Strength Cond Res. 2000; 16(1): 14-8.
7. Brinkert W, Rommes J, Bakker J. Lactate measurements in critically ill patients with a hand-held analyser. Intensive Care Med. 1999; 25: 966-969.
8. Brooks G.A., and Gaesser G.A. End points of lactate and glucose metabolism after exhausting work. J Appl Physiol. 1980; 49: 1057-1069.
9. Brooks G.A., Brauner K.E. and Cassens R.G. Glycogen synthesis and metabolism of lactic acid after exercise. Am J Phsiol. 1973; 224: 1162-1166.
10. Bruce RL, Kusumi F, Hosmer D: Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J. 1972; 85: 545-562.
11. Burgomaster K.A., Heigenhauser G.J.F., Gibala M.J. Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. J Appl Physiol. 2006; 100(6): 2041-7.

12. Burke J, Thayer R and Belcomino M. Comparison of effects two interval-training programs on lactate and ventilatory threshold. British Journal of sports Medicine, Vol 28, Issue 1. 1994; 18-21.

13. Campos GE, Luecke TJ, Wendeln HK, Toma K, Hagerman FC, Murray TF, Ragg KE, Ratamess NA, Kraemer WJ, Staron RS. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. Eur J Appl Physiol. 2002; 88(1-2): 50-60.

14. Cheng YJ, Macera CA, Addy CL, Sy FS, Wieland D, Blair S N. Effects of physical activity on exercise tests and respiratory function. Br J Sports Med. 2003; 37: 521-528.

15. Chtara M, Chamari K, Chaouachi M, Chaouachi A, Koubaa D, Feki Y, Millet GP, Amri M. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. Br J Sports Med. 2005; 39(8): 555-60.

16. Chuanchaiyakul R, editor. Exercise physiology laboratory techniques. Department of physiology faculty of science, Mahidol University. Bangkok. 2000; 5-6.

17. Coelho CW, Hamer D, de Araujo CG, Physiogical responses using 2 high-speed resistance training protocols. J Strength Cond Res. 2003; 17(2): 334-7.

18. Costill DL, Danieds J, Evans W, Fink W, Krahenbuhl G, Saltin B. Skeletal muscle enzymes and fiber composition in male and female track athletes. J Appl Physiol 1976; 40(2): 149-54.

19. Daly RM. Dunstan DW, Owen N, Jolley D, Shaw JE, Zimmet PZ. Does high intensity resistance training maintain bone mass during moderate weight loss in older overweight adults with type 2 diabetes? Osteoporos Int. 2005; 16(12): 1703-12.

20. Danieals J and Scardinia N. Interval training and performance. Sports Medicine. 1984; 1: 327-334.

21. Di Prampero PE. Energetic of muscle exercise. Rev Physiol Biochem Pharmacol. 1981; 89:143-222.

22. Donovan CM, Brooks GA. Endurance braining affects lactate clearance, not lactate production. Am J Physiol. 1983; 244: e83-e92.

23. Dubochaud H., Butterfier G.E., Wolfel E.E., Bergman B.C., and Brooks G.A. Endurance training, expression and physiology of LDH, MCT1 and MCT4 in human skeletal muscle. Am J Physiol Endocrinol Metab. 2000; 278: E571-E579.

24. Durnin J.V.G.A and Womersley J. Body fat assessed from total body density and it estimation from skinflod thickness. Br. J. Nutr. 1974; 32: 77.

25. Edge J, Hill-Haas S, Goodman C, Bishop D. Effects of resistance on H^+ regulation, buffer capacity, and repeated sprints. Med Sci Sport Exerc. 2006; 38(11): 2004-11.

26. Edward Fox, Richard Bower, Marle Foss; The physiological basic for exercise and sport; 5th edition.1993: 16-25.

27. Fagard RH. Exercise is good for you blood pressure: effects of endurance training and resistance training. Clin Exp Pharmacol Physical. 2006; 33(9): 853-6.

28. Falkel J & Cipriani D :Athletic injury and rehabilitation. In Zachachazeweski, J. & Magec, D. & Quillen, W. (Eds.), Athletic injury and rehabilitation. Pennsylvania: W.B. Saunders Company. 1996; pp.206-228.

29. Fatouros IG, Kambas A, Katrabasas I, Leontsini D, Chatzinikolaou A, Jamurtas AZ, Douroudos I, Aggelousis N, Taxildaris K. Resistance training and detraining effects on flexibility performance in the elderly. J Strength Cond Res. 2006; 20(3): 634-42.

30. Fatouros IG, Kambas A, Katrabasas, Nikolaidis K, Chatzinikolaou A, Leontsini D, Taxildaris K. Strength training and detraining effects on muscle strength, anaerobic power, and mobility of inactive older man are intensity dependent. British journal of sports medicine. 2005; 39: 776-780.

31. Favier R. J., Constable S. H., Chen M., Holloszy J.O. Endurance exercise training reduces lactate production. J Appl Physiol. 1986; 61: 885-889.

32. Fleck, S.J., and Kramer, W.J. Resistance training: physiology responses and adaptations (Part 2 of 4). Phys. Sports med. 1988; 16:108.

33. Foss Merle L. and Keteyian Steven J. Fox's physiological basis for exercise and sport 6th edition. McGraw-hill. 1998.

34. Fouriner M., Ricci J, Taylor AW, Ferguson RJ, Montretit RR, Chaitman BR. Skeletal muscle adaptation in adolescent boys: sprint, endurance training and detraining. Med Sci Sport Exerc. 1982; 14: 453.

35. Fox E.L., Bartels R.L, Billings C.E., O'Brien R., Bason R. and Mathew D.K. Frequency and duration of internal training programs and changes in aerobic power. J Appl Physiol. 1975; 38: 481-484.

36. Fredrick C. Hagerman, Seamus J. Walsh, Robert S, Staron, Robert S. Hikida, Roger M. Gilders, Thomas F. Murray, Kumika Toma and Kerry E Ragg: Effects of hight intensity resistance training on untrained older man .I. strength, cardiovascular, and metabolic responses. Med Sci Sports Exerc. 1991; 23(6): 739-43.

37. Freund H., Marbach J., Ott C., Lonsdorfer J., Heitz A., Zouloumian P. and Kehayoff P. Blood pyruvate recovery curves after short heavy submaximal exercise in man. Eur J Appl Physiol. 1980; 43(1): 83-91.

38. Frontera W.R., Meredith C.N., O'Reilly K.P. and Evans W.J. Strength training and determinants of VO_2max in old men. J Appl Physiol. 1990; 68: 329-333.

39. Frownfelter D. Breathing exercise and retraining chest mobilization exercise. In: Chest physical therapy and pulmonary rehabilitation: an interdisciplinary approach, second edition, edited by Frownfelter D. Chicago: Mosby-Yearbook. 1987; p153-178.

40. Gladden, L.B. Lactate uptake by skeletal muscle. Exer Sport Sci Rev. 1989; Vol 17: 115-155.

41. Gollnick R, Armstrong R, Saubert C, Piehl K, Saltin B. Enzyme activity and fiber composition in skeletal muscle of untrained and trained men. J Appl Physiol. 1973; 33(3): 312-9.

42. Gottlieb-Vedi M., Persson S., Erickson H., Korbutiak E. Cardiovascular, respiratory and metabolic effects of interval training at VLA4. Zentralbl Veterinarmed A. 1995; 42(3): 165-175.

43. Green S. Measurement of anaerobic work capacities in humans. Sports Med. 1995; 19(1): 32-42.

44. Grund A, Krause H, Kraus M, Siewers M, Riesckert H, Muller MJ. Association different attributes of physical activity and fat mass in untrained endurance and resistance trained men. Eur J Appl Physiol. 2001; 84: 310-320
45. Hather, Tesch PA, Buchanan P, Dudley GA. Influence of eccentric actions on skeletal muscle adaptations to resistance training. Acta Physiol Scand. 1991; 143: 177-185.
46. Helgerud J, Hoydal K, Wang E, Karlsen T, Berg P, Bjerkaas M, Simonsen T, Helgesen C, Hjorth N, Bach R, Hoff J. Aerobic high-intensity intervals improve VO_2max than moderate training. Med Sci Sports Exerc. 2007; 39(4): 665-671.
47. Hermansen L., and Stensvold. Production and removal of lactate during exercise in man. Acta Physiol. Scand. 1972; 86: 191-201.
48. Hermansen L., Maehlum S., Pruett E.D.R., Vaage O., Waldum H., and Wesellman T. Lactate removal at rest and during exercise. In Howald H. and Poortman J.R. (eds.), Metabolic adaptation to prolonged physical exercise. Basel, Switzerland: Birkhauser-Verlag. 1975; 101-105.
49. Hickson RC, Rosenkoetter MA, Brown MM. Strength training effects on aerobic power and short-term endurance. Med sci Sports Exerc. 1980; 12: 336-339.
50. Hollman W. Historical remarks on the development of the aerobic-anaerobic threshold up to 1966. Int J Sports Med. 1985; 6(3): 109-116.
51. Hubbard JL. The effect of exercise on lactate metabolism. J Physiol. 1973; 231: 1-18.
52. Hurley B.F., Hagberg J.M., Allen W.K., Seals D.R., Young J.C., Cuddihee R.W., Holloszy. Effect of training on blood lactate levels during submaximal exercise. J Appl Physiol. 1984; 56: 1260-1264.
53. Izquierdo M, Hakkinen K, Ibance J, Anton A, Garrues M, Ruesta M, Gorostiaga EM. Effects of strength training on submaximal and maiximal endurance performance capacity in middle-aged and older men. J Strength Cond Res. 2003; 17(1): 129-39.

54. Izquierdo M, Hakkinen K, Ibance J, Ibanez J, Kraemer WJ, Gorostiaga EM, Effects of combined resistance and cardiovascular training on strength, power muscle cross-sectional area, and endurance markers in middle-aged men. Eur J Appl Physiol. 2005; 94(1-2): 70-5.
55. Jackson AW, Landford NJ. The criterion related validity of the sit and reach test: replication and extension of previous findings. Res Quart Exerc Sport. 1989; 60: 384-7.
56. Joseph A. O'kroy. Wingate power output test on a recumbert ergometer. The journal of strength and conditioning research. 2000; 14(4): 405-410.
57. Karvonen I, Lemon PWR, Iliev (eds): Medicine in sports training and coaching. Med Sport Sci. Basal, Karger. 1992; 35: 115-159
58. Lamb DR. Physiology of exercise. Responses & adaptation. 2nd edition. New York: Macmillan Publishing Company, 1984.
59. Lehninger AL. The Principles of Biochemistry (2nd Ed). New York: Worth Publishers, 1982; 721-752.
60. Levenson C. Breathing Exercise. In: Clinics in Physical therapy: Pulmonary management in physical therapy, edited by Zadai C. Edinburgh: Churchill Livingstone, 1992: p135-156.
61. Mader U, Roth P, Furrer J, Brechet P, Boutellier U. Influence of Continuous and Discontinuous training protocols on subcutaneous Adiposetissue and substrates. Int J Sports Med. 2001; 22: 344-399.
62. Marcinik E.J., Potts J., Schlabch G., Will S. Dawson P., Hurley B.F. Effects of strength training on Lactate threshold and endurance performance. Med Sci Sports Exerc. 1991; 23(6): 739-43.
63. Marquette Electronics, Inc. Series 2000 treadmill user instructions, 9th edition. Milwaukee: Marquette Electronics. 1994.
64. Maud&Schultz. Percentile norm and descriptive statistics for fatigue index, Research Quarterly. 1989; 60: pp144-149.
65. McArdle, W.D., and F.I. Katch, and V.L. Katch. Essentials of Exercise physiology. 1994; 342-369.
66. McArdle, W.D., and F.I. Katch, and V.L. Katch. Exercisephysiology energy nutrition and human performance: 3rd edition, 441-444, 1991.

67. McCall GE, Byrnes WC, Dickincon A, Pattany PM, Fleck SJ. Muscle fiber hypertrophy, hyperplasia and capillary density in college man after resistance training. J Appl Physiol. 1996; 81: 2004-2012.

68. McMillan K, Helegerud J, Macdonald R and Hoff J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. J Sports Med. 2005; 39: 273-277.

69. Nemoto E.M., Hoff J.T., and Severringhaus J.W. Lactate uptake and metabolism by brain during hyperlactacidemia and hypoglycemia. Stroke. 1974; 5: 48-53.

70. Nilsson J.E., Holmberq H.C., Tveit P., Hallen J. Effects of 20-s and 180-s double poling interval training in cross-country skiers. Eur J Appl Physiol. 2004; 92(1-2): 121-7.

71. Patton JF, Murphy MM, Frederick FA. Maximal power outputs during the wingate anaerobic test. Int J Sports Med. 1985; 6: 82-85.

72. Pilegaard H., Bangsbo J., Richter E.A., and Juel C. Lactate transport studied in sarcolemmal giant vesicle from human muscle biopsies: relation to training status. J Appl Physiol. 1994; 77: 1858-1862.

73. Poole D.C. and Gaesser. Response of ventilatory and lactate thresholds to continuous and interval training. Appl Physiol. 1985; 58: 1115-1121.

74. Robert A. Robergs, Farzenah Ghiasvand, and Daryl Parker. Biochemistry of exercise-induced metabolic acidosis. Am J Physiol Regul Integr Comp Physiol. 2004; 287: R502-R516.

75. Rotstein A, Dotan R, Bar-Or O, Tenenbaum G. Effect of training on anaerobic threshold maximal aerobic power and anaerobic performance of preadolescent boy. Int J Sports Med. 1986; 1(5): 281-6.

76. Rowell L.B., Krannig K.K, II, Th. O. Evans, J. Ward Kennedy J.R., Blackmon and Kusumi F. Splanchnic removal of lactate and pyruvate during prolong exercise in man. J Appl Physiol. 1966; 1773-1783.

77. Rowell L.B., The live as an energy source in man during exercise. In muscle metabolism during exercise. Plenum Press, New York. 1971; 127-141.

78. Rozenek R, Funato K, Kubo J, Hoshika M, Matsuo A. Physiological responses to interval training sessions at velocities associated with VO_2max. J Strength Cond Res. 2007; 1: 188-2.

79. Sahlin K, Harris RC, Nylind B, Hultman E. Lactate content and pH in muscle samples obtained after dynamic exercise. Pfluger Arch. 1976; 367: 143-149.

80. Sahlin K, Edstrom L, Sjoholm H, and Hultman E. Effects of lactic acid accumulation and ATP decrease on muscle tension and relaxation. Am J Physiol Cell. 1981; 240: c121-c126.

81. Schantz P. Capillary supply in hypertrophied human skeletal muscle. Acta physiol Scand. 1982; 114: 635-635.

82. Seiler S., Sjursen J.E., Effect of work duration on physiological and rating scale of perceived exertion responses during self-paced interval training. Scand J Med Sci Sports. 2004; 14(5): 318-25.

83. Stanley WC, Gertz EW, Wisneski JA, Lynn Morris D, Neese RA, Brooks GA. Systemic lactate kinetics during graded exercise in man. Am J Physiol. 1985, 249: e595-e602.

84. Tesch PA, Thoresson A, Kaiser P. Muscle capillary supply and fiber type characteristics in weight and power lifter. J Appl Physiol. 1984; 56: 35-38.

85. Thomas R. Baechle, Roger W. Earle. Getting Equipped. Fitness weight training book. 1995; 11-21.

86. Vandewelle H, Peres G, Monod H. Standard anaerobic exercise tests. Sports Med. 1987; 4(4): 268-89.

87. Vivian H. Heyward. Advanced Fitness assessment and exercise prescription 3rd edition; Human kinetics. 1997; 1-332.

88. Vogiatzis I, Terzis G, Nanas S, Stratakos G, Simoes DC, Georgiadou O, Zakynthinos S, Roussos C. Skeletal muscle adaptations to interval training in patients with advanced COPD. Chest. 2005; 128(6): 3838-45.

89. Wayne L. Westcott. Strength training equipment. Building strength & stamina second edition books. 2003; pp 211-219.

90. Wilmore JH, Stanforth PR, Gagnon J, Rice T, Mandel S, Leon AS, Rao DC, Skinner JS, and Bouchard C. Heart rate and blood pressure changes with endurance training: The heritage family study. Med. Sci. Sports Exerc. 2001; 33(1); 107-116.

91. Yudkin J., and Cohen R.D. The contribution of kidney to the removal of a lactic acid load under normal and acidosis conditions in the conscious cat. Clin Sci Mol Med. 1974; 46: 8.

APPENDIX

APPENDIX A
PHYSICAL ACTIVITY QUESTIONANAIRE

แบบสอบถาม

คำชี้แจง : โปรดกรองข้อมูลและตอบคำถามต่อไปนี้ตามความเป็นจริง ข้อมูลทั้งหมดในแบบสอบถามนี้จะถูกเก็บเป็นความลับและใช้ในงานวิจัยเท่านั้น

---

1. ชื่อ – อายุ..ชื่อเล่น........................
2. น้ำหนัก.....................กิโลกรัม ส่วนสูง..............เซนติเมตร
3. วัน เดือน ปีเกิด... อายุ........... ปี
4. ที่อยู่ปัจจุบัน...
   เบอร์โทรติดต่อที่บ้าน........................... มือถือ........................... E-mail: ……………….....…………...............
5. กำลังศึกษาชั้นปีที่........................
6. โรคประจำตัว.. ยาที่ใช้...
7. ประวัติการเจ็บป่วย

   - ○ โรคหลอดเลือดและหัวใจ ระบุ...
   - ○ ความดันโลหิตสูง หรือความดันต่ำ
   - ○ โรคเกี่ยวกับสมองและระบบประสาท ระบุ.....................................
   - ○ โรคเกี่ยวกับทางเดินหายใจ ระบุ..
   - ○ โรคลมบ้าหมู
   - ○ มีประวัติเคยผ่าตัด ระบุ ....
   - ○ ปัญหาเกี่ยวกับกระดูกและข้อ ระบุ..
   - ○ โรคติดเชื้อ โรคติดต่อ ระบุ...
   - ○ โรคเบาหวาน
   - ○ โรคภูมิแพ้ ระบุ...
   - ○ โรคไส้เลื่อน
   - ○ อื่นๆ ระบุ...

8. ประวัติการสูบบุหรี่และดื่มเครื่องดื่มแอลกอฮอล์ และสิ่งเสพติดในปัจจุบัน

○ เคยสูบบุหรี่ ระบุจำนวน..................มวน/วัน

○ ดื่มเครื่องดื่มแอลกอฮอล์ใดๆ เป็นประจำ ระบุ........................วัน/สัปดาห์

○ เสพสิ่งเสพติดให้โทษประเภทอื่นๆ ระบุ...........................ความถี่....................ครั้ง/สัปดาห์

9. ประวัติการออกกำลังกาย

9.1 ใน 1 ครั้งต่อสัปดาห์ ท่านออกกำลังกายหรือเล่นกีฬากี่วัน

○ ไม่เคยออกกำลังกาย

○ 1 วัน/สัปดาห์

○ 2 วัน/สัปดาห์

○ 3 วัน/สัปดาห์

○ 4 วัน/สัปดาห์

○ ตั้งแต่ 5 วันขึ้นไป/สัปดาห์

9.2 ประเภทกีฬาหรือการออกกำลังกายชนิดใดที่ท่านปฏิบัติ

ระบุ...

ใช้เวลาประมาณ............................ชั่วโมง............................นาที

9.3 ท่านเคยบาดเจ็บจากการออกกำลังกายหรือเล่นกีฬาหรือไม่

○ ไม่เคย

○ เคย ระบุ..

APPENDIX B

หนังสือยินยอมให้ทำการวิจัยโดยรับการบอกกล่าวและเต็มใจ

(Informed consent form)

ชื่อโครงการ ผลของสองรูปแบบการฝึกสมรรถภาพทางกายต่อระดับกรดแลคติกในเลือดและสมรรถภาพนักกีฬา

(Effects of two methods of physical training on blood lactate level and athletic performances)

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)

ภัทรพงษ์ ยิ่งดำนุ่น

ผู้วิจัย

APPENDIX C
DATA COLLECTION FORM

เรื่อง "ผลของสองรูปแบบการฝึกสมรรถภาพทางกายต่อระดับกรดแลคติคในเลือดและสมรรถภาพนักกีฬา"

(Effects of two methods of physical training on blood lactate level and athletic performances)

ชื่อ – สกุล.. อายุ.........ปี

น้ำหนัก...........................กิโลกรัม ส่วนสูง............................เซนติเมตร

ความดันโลหิต.............................มิลลิเมตรปรอท ชีพจรขณะพัก.....................ครั้ง/นาที

มีความรู้สึกไม่สบายในวันที่ทดสอบหรือไม่...

เข้าร่วมโครงการวิจัยในกลุ่ม...

1. วัดความหนาไขมันใต้ผิวหนัง (Skinfold thickness)

Trial	1		2		3	
Biceps brachii (mm)						
Triceps brachii (mm)						
Subscapular (mm)						
Suprailiac (mm)						

2. วัดความแข็งแรงของกล้ามเนื้อขา (Legs strength)

Trial	1		2	
Force (kg)				

3. วัดความอ่อนตัว (Sit and reach test)

Trial	1		2	
Length (cm)				

4. วัดปริมาณการใช้ออกซิเจนสูงสุด (VO_2max)

Subject's name	BW (kg)	HRmax (220-age)	Submax Vo2 (ml.kg-1.min-1)		HR		b	VO_{2MAX} ($ml.kg^{-1}. min^{-1}$)
			at SM2	at SM1	atSM2	atSM1		

5. วัดปริมาณกรดแลคติค (Lactic acid)

Condition	Duration (min)	HR (bpm)		Lactate (mmol/l)	
Rest	10				
Grade 10%, 1.7 mph	3				
12% , 2.5 mph	6				
14% , 3.4 mph	9				
16% , 4.2 mph	12				

6. วัดปริมาณงานแบบไม่ใช้ออกซิเจน (Anaerobic Power)

Subject	BW (kg)	Load (kp)	Power (watt/kg)		Power drop (%)
			Mean	Peak	

7. วัดความจุปอด (Lung vital capacity)

Subject	1 (cc)		2 (cc)	

8. วัดสมรรถภาพการจับเวลาในการวิ่ง (Time test)

Group	Running Time 100 m		Running Time 400 m	
	Pre	Post	Pre	Post
Interval training				
Weight training				
Control				

APPENDIX D

วิธีการหาระดับกรดแลคติคในเลือด

การเก็บตัวอย่างในเลือด

1. ใช้แอลกอฮอล์เช็ดทำความสะอาด บริเวณปลายนิ้วมือ
2. ใช้เครื่องเจาะเลือดที่ใช้เข็ม Softclix lancet เจาะที่บริเวณปลายนิ้วมือ โดยปรับความลึกของเข็มที่เจาะลึกประมาณ 1 มิลลิเมตร
3. บีบให้เลือดไหลออกมาเป็นหยดลงบนแผ่นทดสอบ

การหาระดับกรดแลคติกในเลือด

1. เปิดเครื่องวิเคราะห์ ระดับความเข้มข้น ของกรดแลคติคในเลือด
2. เสียบ Barcode ของแผ่นทดสอบที่ใช้ให้สุด แล้วดึงออกทันที รอให้เสียงดัง 1 จังหวะ
3. เสียบแผ่นทดสอบ (strip test) รอให้เสียงดัง 2 จังหวะ
4. เปิดฝาเครื่องวิเคราะห์ หยดลงไปที่แผ่นทดสอบ 1 หยด แล้วปิดฝา
5. ใช้เวลานาน 60 วินาที เครื่องจะประมวลผล และแสดงค่าของระดับกรดแลคติคในเลือด โดยมีหน่วยเป็นมิลลิโมลต่อลิตร (mmol/l)
6. บันทึกค่าที่ได้

APPENDIX E
Weight training program

1. Resistance exercise training by single machine includes;

    1.1 Leg press

    1.2 Bench press

    1.3 Leg extension

    1.4 Half squat

2. Starting at low intensity 40-50% RM, 12 repetitions and rest 1 minute between set in each single machine.

Leg press → Bench press → Leg extension → Half squat

3. Mode of exercise was 70% RM, 12 repetitions per set, 3 set per machine and rest 1 minute between set in each single machine (Leg press, Bench press, Leg extension and half squat, respectively).

4. Finally, subject groups did stretch muscle about 10-15 minutes.

APPENDIX F

No. MU 2006-017

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

Title of Project: Effects of Two Methods of Physical Trainings on Blood Lactate Level and Athletic Performances
(Thesis for Master Degree)

Principle Investigator: Mr. Pattarapong Yingdamnun

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: - 2 FEB 2006

Date of Expiration: - 1 FEB 2007

BIOGRAPHY

NAME	Mr. Pattarapong Yingdamnun
DATE OF BIRTH	11 May, 1981
PLACE OF BIRTH	Uthaithani, Thailand
INSTITUTIONS ATTENDED	Mahidol University, 2000-2004: Bachelor of Science (Sports Science) Mahidol University, 2000-2007: Master of Science (Sports Science)
RESEARCH GRANT	Faculty of Graduate Studies, Mahidol University
HOME ADDRESS	61/1 Sriuthai road, Tumbon Uthaimai, Aumper Mueang, Uthaithani, 61000