THE EFFECTS OF RECOVERY PATTERNS AND BLOOD LACTATE LEVELS ON SUBSEQUENT ANAERObic PERFORMANCES OF FEMALES

A Thesis
by
Katherine Melissa Miller

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Approved by:

Chairperson, Thesis Committee

Member, Thesis Committee

Member, Thesis Committee

Chairperson, Department of Health, Physical Education, and Recreation

Dean of the Graduate School
ABSTRACT

THE EFFECTS OF RECOVERY PATTERNS AND BLOOD LACTATE LEVELS ON SUBSEQUENT ANAEROBIC PERFORMANCES OF FEMALES (May 1983)

Katherine Melissa Miller, B. S., Appalachian State University

M. A., Appalachian State University

Thesis Chairperson: Dr. Vaughn K. Christian

The primary purpose of the study was to analyze the differences among lactic acid levels of females following two supramaximal performances that were separated by either active or passive recovery patterns. A second purpose was to determine the effect of recovery patterns on a subsequent supramaximal performance.

Thirty-seven female subjects were randomly placed into either an active recovery pattern or a passive recovery pattern. During the test, four blood samples were drawn. The differences between the two supramaximal performances were analyzed by One-Way Analysis of Variance. One-Way Analysis of Variance with Repeated Measures determined the differences among the four blood lactate levels.
The findings of the study were as follows:

1. Significant differences were found between the active and passive recovery groups when analyzing the percent decrement in the total cumulative revolutions between the initial and subsequent supramaximal performances in favor of the active recovery group.

2. No significant difference was found in the blood lactate levels between the active and passive recovery groups following the initial supramaximal performance.

3. No significant difference was found in the blood lactate levels between the active recovery group and the passive recovery group following the recovery patterns preceding the subsequent supramaximal anaerobic performance.

4. No significant difference was obtained in the blood lactate between the active recovery group and the passive recovery group following the subsequent supramaximal anaerobic performance.

The following conclusions were deducted from the study:

1. Lactic acid levels are not affected by recovery patterns and are not detrimental to performance.

2. Recovery patterns produced a significant change in the percent decrement of the total cumulative revolutions favoring the active recovery group.
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CHAPTER ONE

INTRODUCTION

The people of the United States are on the run! It appears that more Americans are concerned about health and longevity than ever before. The American public has widely read *Aerobics*, by Kenneth Cooper (1968), which emphasized the importance of oxygen in the muscles during exercise. Aerobics is a familiar concept heard in many conversations, but the concept of anaerobics has been completely overlooked. Few people realize that anaerobic processes precede aerobic processes and provide the immediate supplies of energy for muscular contractions. Exercise physiologists have begun to concentrate on anaerobics since the majority of athletic events are dependent on the anaerobic energy process. Lactic acid, the final product of anaerobics, is one limiting factor to performance since its accumulation in the body inhibits the rate of glycolysis and the mobilization of free fatty acids (3). Recent research has shown that lactic acid may not be the limiting factor to performance. In fact, lactic acid levels have not been necessarily the highest at the onset of fatigue. Athletes have been
able to better previous performances when lactic acid levels were still high within the body (13). Research has viewed anaerobics chemically to investigate whether fatigue varied with muscle fiber types, training effects, or enzymatic reactions.

The anaerobic processes are controlled by enzymatic reactions which form phosphorylated compounds. Although glycolysis, which is the breakdown of glycogen, is the immediate supplier of energy to movement, only a net total of two adenosine triphosphates (ATP) are produced for each glucose molecule. Two ATP liberate an energy equivalent of 55 kilocalories. This small energy yield can support movement for approximately one minute at which time the body will be forced to terminate activity. The breakdown of ATP and phosphocreatine must be continuously replenished so available stores of the high-energy phosphates can be produced.

Anaerobics demands carbohydrates as the preferred energy fuel. Carbohydrates in the form of 6-carbon molecules are metabolized to form pyruvic acid. The anaerobic process precedes from glucose stored in the muscle isomerizing to form glucose-6 phosphate. Fructose 6-phosphate is eventually phosphorylated to form phosphofructokinase (PFK) within the muscle cell's sarcoplasm. Therefore, PFK is the regulator of the anaerobic process. The anaerobic capacity of an
individual is determined by the concentrations of ATP and adenosine diphosphate (ADP) present in the body. ADP presented in high concentrations in the body accelerates the rate of enzymatic reactions forming PFK, and consequently, the anaerobic process is enhanced. However, when ATP is present in high concentrations in the body, PFK becomes inhibited and the anaerobic process is decreased. When the concentration of ADP is high, the anaerobic process continues and forms two triosephosphates which donate hydrogen ions to nicotinanide-adenine-dinucleotide (NAD). NAD, which is reduced to form NADH₂, is a key coenzyme in glycolysis. NADH₂ becomes oxidized to donate the hydrogens to pyruvate. NAD is able to dehydrogenize triosephosphate while lactate becomes the final product by the lactate dehydrogenase reaction (2).

Lactate dehydrogenase (LDH) is present in the muscle tissues of the body in the H form and the M form. The H form of LDH is found primarily in heart muscle and slow twitch muscle fibers which favor aerobic oxidation. The M form of LDH is found primarily in fast twitch muscle fibers and favors anaerobic work (2). Therefore, anaerobic work is dependent upon the fast twitch muscle fibers to produce sudden bursts of power. The fast twitch muscle fibers have a 2 to 2.5 times higher enzyme activity of LDH when compared to the
enzyme activity of LDH of slow twitch muscle fibers. Researchers have sampled muscle types to chemically evaluate the enzymatical potential for influencing performance (2). LDH in slow twitch muscle fibers did not demonstrate a significant correlation with anaerobic power.

The establishment of new records in the world of sport has indicated that the human body has not reached its physiological potential. Enzymes and fiber types must be critically evaluated as to the effect on fatigue and improved performances. Muscle biopsies are needed to further investigate the chemical reactions occurring in both slow and fast twitch muscle fibers. Is lactic acid a deterrent to anaerobic performance? This study was completed to provide additional information to assist in the clarification of the effects of lactic acid on subsequent anaerobic performance.

Purpose of the Study

The primary purpose of the study was to analyze the differences among lactic acid levels of females following two supramaximal performances that were separated by either active or passive recovery patterns. A second purpose was to determine the effect of recovery patterns on a subsequent supramaximal performance.
Definition of Terms

**Anaerobics.** The absence of oxygen available to the muscle cell during exercise.

**Supramaximal Performance.** A maximal effort of pedalling a bicycle ergometer for 50 seconds.

**Active Recovery.** A five minute period following the supramaximal performance in which the subject continued to pedal in a rhythmic pattern at a preferred resistance on the bicycle ergometer.

**Passive Recovery.** A five minute period following the supramaximal performance in which the subject was seated motionless on a table adjacent to the bicycle ergometer.

**Oxidation.** The loss of electrons from an atom or hydrogen molecule that occurs when NADH₂ loses the hydrogens to pyruvate.

**Reduction.** The gain of electrons or hydrogen molecules that occurs when NAD gains two hydrogens to form NADH₂.

**Phosphorylation.** The process of ATP synthesis in the respiratory chain with oxygen as the final hydrogen acceptor.

**Lactic Acid.** The end product of glycolysis which is formed as the result of a lack of oxygen.

**Lactate Dehydrogenase.** The enzyme necessary for the conversion of pyruvic acid to lactic acid.
**Slow Twitch Muscle Fiber.** A muscle fiber with a low activity of myosin ATPase usually associated with relatively slow contraction time, but with a high mitochondrial content for high potential oxidative enzyme activities.

**Fast Twitch Muscle Fiber.** A muscle fiber with a high activity of myosin ATPase usually associated with a relatively fast contraction time, and glycolytic enzyme activities.

**Fatigue.** The accumulation of metabolic waste products which retard the enzymatic reactions necessary to form ATP.

**Basic Assumptions**

The study employed the following assumptions:
1. All subjects were selected randomly.
2. All subjects were tested under identical conditions.
3. All subjects performed on the bicycle ergometer at a maximal effort.
4. All subjects pedalled the ergometer at a resistance of four kiloponds for a duration of 30 seconds.

**Delimitations**

The study was delimited as follows:
1. Thirty-seven subjects from Appalachian State
University were selected as subjects.

2. Each subject was oriented to the procedures of the testing prior to the initial testing. (See Appendix F.)

3. Each subject was tested for maximum aerobic capacity prior to the first experimental session.

4. Each subject had not eaten for three hours prior to testing. (See Appendix E.)

5. Each subject had a systolic blood pressure in the range of 100 to 140 and a diastolic pressure between 60 and 100.

6. Venous blood samples were taken from the antecubital vein prior to exercise, five minutes following the first exercise, immediately following the recovery pattern, and five minutes following the subsequent exercise.

7. Each subject was tested on a supramaximal exercise bout for 30 seconds followed by either an active recovery of five minutes or a passive recovery of five minutes. The recovery pattern was followed by a subsequent supramaximal exercise bout of 50 seconds.

Limitations

The following limitations were noted in the study:

1. Nausea inhibited three of the subjects from producing maximal effort at the start of the subsequent supramaximal performance.
2. Four subjects were eliminated from the study because adequate blood samples could not be drawn by the nurse.
CHAPTER TWO

RELATED LITERATURE

Overview

Research concerning the anaerobic process has not been under extensive investigation until the last decade. The trend for research has been dedicated to two major areas: (1) the relationship of lactic acid and performance, and (2) the relationship of lactic acid and muscle fiber types. This chapter will address the above areas.

Related Literature

Astrand conducted a study on cross-country skiers in 1963 to determine the blood lactate levels following distances ranging from 10 to 85 kilometers. Venous blood was drawn at one to three minutes following the race. Results found that the skiers who raced in the 10-km. event (35 - 36 min.) produced an average lactate accumulation of 139 mg/100 milliliters of blood; skiers who performed in the 30-km. event (1:50 - 1:56) produced an average lactate concentration of 68 mg/100 milliliters of blood; and skiers who participated in the 50-km. event (3:06 - 3:08) produced an average lactate
concentration of 39 mg/100 milliliters of blood. Astrand concluded there was a decrease in the blood lactate concentration with work time (1).

In 1966, Gisolfi tested four physically fit men following exhaustive runs on the treadmill to determine whether active or passive recovery increased the rate of lactate removal. The active recovery consisted of the subjects performing 35 or 50 minutes of aerobic work immediately following the treadmill run. The passive recovery permitted the subjects to rest throughout the recovery. Results indicated that active recovery increased the rate of lactate removal when compared with values observed from the passive recovery. It was also found that the active recovery produced a reduction of one to two liters in oxygen debt. Gisolfi concluded that active recovery assisted in the circulation of lactic acid to the liver for glycogenesis which would form glucose as a fuel (6).

In 1970, Davies measured the aerobic capacity and maximum aerobic power of four subjects before involving the subjects in a series of four experimental sessions. In each session, the subject was required to exercise at 80 percent of maximum aerobic capacity for six minutes on a bicycle ergometer. A 40 minute recovery followed with a workload corresponding to 15, 30, 45, and 60 percent of VO2 max. Three of the four subjects participated in a fifth recovery where no
exercise was performed. Oxygen uptake was measured during the last two minutes of exercise by collecting expired air into a Douglas bag. Venous blood samples from the fingertip were drawn from three to six minutes after cessation of exercise during the preliminary testing. During the four experimental sessions, six to eight blood samples were drawn at exponentially spaced intervals throughout the entire 40 minute recovery period. Results favored the recovery period which approximated 40 percent of the individual's $\dot{V}O_2$ max when considering the rate of lactate removal during recovery (5).

In 1970, Karlsson tested three subjects on a maximal bicycle exercise duration of 2, 6, and 16 minutes. During the two minute maximal effort, blood samples were taken immediately following exercise. During the 6 minute and 16 minute maximal exercise, blood samples were drawn after the second and sixth minute, respectively. Muscle biopsies were taken immediately following the work from the quadriceps femoris. The biopsy specimens were tested for ATP, CP, glycogen, G - 6 - P, and lactate. The phosphorylation of ATP and CP was maximal after two minutes in all experiments. The breakdown of the phosphagens averaged 2.7 and 3.6 millimole kg$^{-1}$ wet muscle in ATP and CP, respectively. The lactate in the muscle and blood accumulated continuously until exhaustion. The lactate accumulation
in the muscle during the medium (6 min.) and highest loads (2 min.) averaged 16.1 millimole kg\(^{-1}\) wet muscle and 12.0 millimole kg\(^{-1}\) at the lowest load. Karlsson concluded that low ATP and CP was not the cause of muscular fatigue. However, if the lactate concentration in the muscle was the cause of exhaustion during the two minute and six minute maximal effort, another factor must be present to explain the exhaustion during the 16 minute duration, the lightest load (10).

In 1972, Hermansen conducted a study in which four females and three males participated. In the pretest period, oxygen uptake was measured during at least three submaximal and two maximal workloads. A motor-driven treadmill with an incline of 5.25 percent was used in all experiments. Subjects reported on nine separate days following the pretest period. During the first four days of testing, the subjects performed 30 minutes of continuous walking or running at 30, 60, 70, and 80 percent of the individual's maximal oxygen uptake. On days five through eight, each subject performed a maximal intermittent exercise consisting of three maximal workloads lasting for approximately 60 seconds. Each subject ran at the highest possible speed during each 60 second period. The maximal intermittent exercise period was followed by 30 minutes of continuous treadmill walking or running at 30, 60, 70, and 80 percent of the individual's oxygen uptake.
Each subject rested in a chair for 30 minutes following the maximal intermittent exercise program on the ninth experimental day. Venous blood samples were taken from the fingertip at different time intervals before and during the exercise program, and during the rest periods. Results indicated that during the continuous running experiments, the blood lactate increased minutely up to 60 - 80 percent of the subject's maximal aerobic capacity. Above 60 - 80 percent of the maximal aerobic capacity, a pronounced decrease in the removal rate was observed. During the maximal intermittent exercise period, blood lactate increased to 130 - 220 milligrams per 100 milliliters. The recovery period decreased the lactate levels to resting values.

Hermansen concluded that the rate of lactate removal was affected by the intensity of the workload. A workload of 60 - 80 percent of the individual's maximal aerobic capacity appeared to be a significant level for lactate production and inhibition of lactate removal (8).

In 1972, Klausen tested the leg muscles of four male subjects at supramaximal intensities under two different conditions. Each subject exercised to complete exhaustion within three to six minutes. At the onset of bicycle exercise in the first condition, the subjects averaged a 1.2 millimole in the blood lactate concentration. The arterialized blood sample
was taken from a pre-warmed fingertip following a 30 minute rest period preceding the exercise period. Each subject pedalled a bicycle ergometer at 60 revolutions per minute until complete exhaustion. Expired air was collected throughout exercise and during the first 20 minutes of recovery in supine bed rest. Blood samples were drawn at the second through fifth minute of recovery to determine the blood lactate concentration and the lowest pH level. Another blood sample was taken following recovery. In the second condition, each subject participated in a five minute period of heavy arm exercise following the 30 minute rest period preceding the same maximal exercise on the bicycle ergometer. The lactate concentration following the exercise on the arm ergometer and preceding the bicycle exercise was 10.2 millimoles. Blood samples were drawn four minutes after the arm exercise and then the subjects rested an additional two minutes. The average peak of lactate concentration in blood was 19 percent higher in the second condition, while the increase in blood lactate during exercise was 125 percent greater in the first condition. The existence of high blood lactate prior to maximal exercise did not affect maximal aerobic capacity, but inhibited further lactate production in the working muscles. The hypothesis that lactate was a limiting factor in exercise was not shown (11).
In 1977, Weltman exercised 11 male volunteers in one maximal bicycle test with frictional resistance set at 33.0 kgm x rev. \(^{-1}\). Following supramaximal performance, the subjects recovered either actively or passively, breathing room air or 100 percent oxygen, for 10 or 20 minutes in time duration. The subjects repeated the all-out performance following recovery. Blood samples were collected to measure lactate at minutes 3-4, 9-10, and 19-20. Significant differences were observed for active versus passive recoveries and 10 versus 20 minute recoveries, with active and 20 minute recovery resulting in significantly higher pedal revolutions in the subsequent performance. No significant difference was observed between room air and 100 percent oxygen. However, when analyzing blood lactate levels at the end of recovery and pedal revolutions during the second supramaximal performance, a correlation of \(-.19\) was attained which suggests that factors other than lactate removal were critical for subsequent performances (19).

In 1978, Graham reviewed several studies which investigated the relationships of NAD with hypoxia, muscle fiber types, and muscle water shifts. Graham found that lactate production was not directly related to hypoxia. In 1954 and 1957, Connelly and Chance utilized NAD as an index for hypoxia, but more recent studies have questioned the relationship. In 1965,
Bergmeyer constructed an enzymatic assay for NAD for a muscle biopsy and found no relationship between NAD concentration or NAD level when comparing resting data to either muscle or lactate. Studies concerning NAD have shown that lactate and NAD have different qualitative and quantitative responses to exercise. No direct relationship has been found between hypoxia and muscle lactate production (7).

In 1978, Bonen exercised ten women (age 20.8±0.8 years) at approximately 90 percent of maximal aerobic capacity for six minutes. Each subject immediately followed with a recovery period of 20 minutes at 40 percent of maximal aerobic capacity. Blood samples were drawn from the forearm vein at minutes 5, 10, 15, and 20 during the recovery period. Muscle biopsies from the vastus lateralis were taken several weeks before and after the exercise experiments. The lactate removal was calculated with a first order linear regression and found that the mean rate of lactate removal was 4.77±0.44 milligrams per 100 milliliters per minute. The vastus lateralis was 45.0±3.8 percent slow twitch fibers. A moderate (r=0.544), but statistically significant (p=0.05) relationship was found between the percent of slow twitch and lactate removal rates (4).

In 1978, McGrail conducted a study of nine untrained men. The maximum oxygen uptake for leg
exercise, arm exercise, and combined arm and leg exercise was obtained for each subject from progressively increased workloads on the bicycle ergometer. Recovery exercise workloads were determined by establishing a VO$_2$ workload relationship for each mode of exercise. Each subject participated in a six minute bout of leg ergometer exercise at 90 percent of the subject's leg maximum aerobic capacity. A 30 minute recovery period followed during which the subject either rested or performed arm or leg or simultaneous arm and leg exercise at 27 percent of maximum aerobic capacity of the muscle groups involved. Blood samples were taken during the first minute following the six minute bout and every five minutes during the recovery. Oxygen uptakes and heart rates were measured during the fifth and sixth minute of the six minute bout and from 11 to 15 minutes during the recovery. Results indicated that lactate removal was slowest at rest (p<.05). Lactate removal occurred faster during leg recovery than arm recovery (p<0.05), but the leg removal was not different from the combined arm and leg recovery (p>0.05). The VO$_2$ cost of the arm, leg, and combined arm and leg differed significantly from each other (p<0.05). The VO$_2$ costs were 0.73±0.04 liters per minute for the arm, 1.04±0.05 liters per minute for the leg, and 1.23±0.10 liters per minute for the combined arm and leg exercise.
A high correlation ($r = 0.92$) was found between VO$_2$ cost and the lactate removal rates of the recovery conditions. Lactate during aerobic activity was found to increase proportionately with the metabolically active mass which indicated the strong influence of skeletal muscle upon the rate of lactate removal (12).

Tesch involved nine physical education students in a study in 1978 to determine lactate concentrations in different muscle fiber types. Muscle biopsies were taken from the vastus lateralis of the left leg while the subjects rested. Each muscle biopsy provided muscle fiber type distribution, total lactate dehydrogenase activity, and isozymes of LDH. Subjects reported twice a week to perform repeated maximal isokinetic knee extensions with the left leg. Each subject was positioned in a seated position with the left leg attached to the lever arm of the Cybex II isokinetic apparatus. The first session consisted of 50 muscle contractions and the second session consisted of 25 contractions. Muscle biopsies were taken three to four seconds following the 50 and 25 repetitions of the knee extensions, respectively. Slow twitch muscle fibers corresponded to better sustained force. Higher lactate concentrations were found in fast twitch muscle fibers after 30 seconds, but no significant difference was found after 60 seconds. The lactate levels and pH changes in fast twitch muscle fibers were concluded to
be a prime factor for fatigue (15).

In 1978, Tesch tested seven males characterized by high aerobic capacity to study the lactate distribution pattern within the fast twitch and slow twitch muscle fibers. Each subject performed a supramaximal exercise at 120 percent of the subject’s maximal aerobic capacity on the bicycle ergometer until exhaustion occurred. Biopsy samples were taken three minutes following the exercise. A positive relationship was found between the maximal aerobic capacity and percent of slow twitch fibers. Lactate concentration in the fast twitch muscles averaged 25.8 mmol x kg\(^{-1}\) wet muscle and the slow twitch muscles averaged 18.7 mmol x kg\(^{-1}\) wet muscle (p > 0.05). The mean fast twitch to slow twitch lactate ratio was 1.4. A significant relationship (r = .76, p < 0.05) was found between lactate concentration and performance time. The results indicated subjects who had predominately fast twitch fibers possessed higher anaerobic power and capacity. In addition, Tesch concluded fast twitch fibers form more lactate when compared to slow twitch fibers (16).

Jacobs tested 19 male runners from the 1979 Stockholm Marathon. Each subject performed a treadmill test to determine the running velocity where a blood concentration of 4 millimole x l\(^{-1}\), Onset of Blood Lactate Accumulation, (OBLA), occurred. Muscle biopsies
were taken from the vastus lateralis to determine muscle composition, capillary density, activities of phosphofructokinase (PFK), citrate synthetase (CS), and lactate dehydrogenase (LDH). Results indicated that a high correlation \((r=.96)\) existed between onset of blood lactate accumulation and marathon running velocity \((V_m)\). A positive relationship was found between percent of slow twitch muscle fibers and capillary density to \(V_m\) and \(V_{OBLA}\) \((r=.45, \ p<0.05)\). Marathon running performance and \(V_{OBLA}\) which were closely related were in turn significantly related to percent slow twitch, capillary density, and muscle enzyme activities (9).

Tesch examined the muscle lactate concentration at the onset of blood lactate accumulation on ten subjects. The maximal oxygen uptake of the subjects during cycling ranged from 37 to 59 ml·kg\(^{-1}\)·min\(^{-1}\). Each subject pedalled a bike ergometer during four constant workloads which increased every fourth minute by 25 watts. Blood samples were collected during the last minute of each of the four workloads. Also, oxygen consumption and heart rate were determined during each workload for the pretesting. The subjects were tested a second time with exercise ceasing when the onset of blood lactate accumulation was reached and maintained for four minutes. Muscle biopsies were taken from the vastus lateralis at rest and immediately after each exercise. Results found that the OBLA was
reached at 65 percent of the maximum aerobic capacity. The muscle lactate concentration varied 2.1 to 12.6 mmol/kg^-1 v.w. at the OBLA. No consistent relationship existed between the blood and muscle lactate accumulation (17).

Sjodin tested eight well-trained middle and long distance runners to determine the effects of training on onset of blood lactate accumulation and muscle enzyme activities. Each subject ran on a treadmill for 20 minutes at a velocity where onset of blood lactate accumulation occurred. The subjects trained once a week for 14 weeks. A muscle biopsy was taken from the vastus lateralis during each training session. Biopsies were analyzed for phosphofructokinase (PFK), lactate dehydrogenase (LDH), and citrate synthetase (CS) activities. After the 14 weeks of training, the VO_{2BLA} increased significantly from 4.69±0.25 to 4.89 M x s^-1 0.27 (p<0.01). The PFK decreased significantly from 7.7±2.0 to 5.4±0.5 mmoles x 10^-6 (p<0.05). The activity of LDH and CS remained unchanged. The ratio of PFK/CS activity decreased significantly from 1.4±3 to 0.9±1 moles x g x min^-1 x 10^-6 (p<0.001). Sjodin concluded that a more balanced activity ratio existed between the glycolytic enzymes, PFK and LDH, to the oxidative enzyme, CS, following training (14).

Regan tested nine subjects and studied the effects of different recovery patterns following a workload at
approximately 110 percent of the maximum aerobic capacity. Each maximal exertion was followed by a 20 minute recovery and then a second maximal exertion followed. The two recovery patterns consisted of active recovery and passive recovery at 40 percent of each of the subject's maximum aerobic capacity. Results found that blood lactate levels after the first maximal exertion varied significantly across treatments and were significantly higher than prior to the first maximal workload ($p<0.05$). No significant differences were found between the two treatments. Elevated levels of blood lactate were found to exert no demonstrable effect on maximal exertion in males (13).

In 1982, Welshinger determined the workload resistance for women and utilized the Monark bicycle ergometer and the Aim 65 computer for evaluating the anaerobic performance. The study revealed that four kiloponds was the frictional resistance necessary for a time span of at least 40 seconds to be achieved anaerobically by a female. The study concluded that anaerobic performance was time dependent and not work dependent (18).
CHAPTER THREE

PROCEDURES

Overview

The primary purpose of the study was to analyze the differences among lactic acid levels of females following two supramaximal performances that were separated by either active or passive recovery patterns. A second purpose was to determine the effect of recovery patterns on a subsequent supramaximal performance. Blood samples were drawn from the antecubetal artery at rest, following both supramaximal performances, and following the five minute recovery pattern. The blood samples discerned the levels of lactic acid.

The subjects of the study were 37 female volunteers from Appalachian State University. The subjects were randomly placed in either an active recovery group or a passive recovery group.

An orientation session was incorporated where predicted measurements of VO₂ max, resting blood pressure, resting heart rate, and body weight were determined. (See Appendices A and D.) In addition, a pre-test was
performed a month prior to testing to allow the subject to become familiarized with the procedures.

The testing procedure was based on previous research concerning anaerobics, lactic acid, and resistance of work loads for women (3, 4, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19). Each testing session consisted of a subject performing supramaximally on a bicycle ergometer for 50 seconds at four kiloponds (18). A five minute period of no activity followed the conclusion of the supramaximal test. The subjects then proceeded with either a five minute passive or active recovery period. Following the recovery pattern, a second supramaximal performance was completed. Blood lactate levels were measured at rest, five minutes following both of the supramaximal performances, and following the five minute recovery pattern.

**Equipment**

**Monark Bicycle Ergometer** - The bicycle ergometer was pedalled for 50 seconds at a frictional resistance of 4 kiloponds to produce a supramaximal performance.

**Brace** - A piece of wood 11 inches in height and 10 inches in width was used to insure consistency in pedal position at the initiation of each supramaximal performance. The brace was placed under the right foot which

*Manufactured by: Quinton Instruments, 2121 Terry Avenue, Seattle, Washington.*
prevented the left foot from activating the Aim 65 Computer.

**Rockwell Aim Computer** - The computer recorded the time of pedal revolutions during the supramaximal performance.

**Microswitch** - A mechanical switch that was used in conjunction with the Aim 65 computer to count revolutions.

**Stopwatch** - The timing device was used to measure the various time intervals during the testing session.

**Spec 20** - A spectrophotometer measured the levels of lactic acid in milligram percent at 340 nanometers.

**Lactic Acid Kit** - The lactic acid kit was used to activate the conversion of lactate to pyruvate in the presence of NAD⁺.

**Centrifuge** - A centrifuge was used to spin the blood into plasma and hematocrit.

+ Manufactured by: Rockwell Industries, Microelectric Devices, Anaheim, California.

* Manufactured by: Cherry Switch Company, Charlotte, North Carolina.


++ Manufactured by: Bausch and Lomb, Rochester, New York.

### Manufactured by: Sigma Chemical Company, Saint Louis, Missouri.
Procedure for Estimating \( VO_2 \) max

A Monark Bicycle Ergometer was the instrument used to predict \( VO_2 \) max on the 37 female subjects. The height of the seat was adjusted to allow for full extension of the leg to insure mechanical efficiency. A metronome was set for a cadence of 100 beats per minute or 50 revolutions per minute. Each subject pedalled to the sound of the metronome for five to six minutes. The mean value of heart rate for the fifth and sixth minutes was the designated value used to predict the pulse. The carotid pulse was taken during the last fifteen to twenty seconds of each minute. The subject's heart rate was determined by the tester timing the number of seconds required for 30 pulse beats. A stopwatch was begun at the count of zero. The subject's workload was determined by the heart rate. Each subject began with a workload of 450 kiloponds per minute. If the subject's heart rate was below 120 beats, then the resistance was increased to 600 kiloponds per minute. The range of heart rate at the sixth minute was between 120 and 150 beats per minute. The time obtained for 30 beats to occur was converted to maximal oxygen uptake in liters/minute. For maximal oxygen uptake in \( ml/kg \times \text{min.} \) to be obtained, the subject's weight was included.

***Astrand, P. Work tests with the bicycle ergometer. Stockholm, Sweden: Monark - Crescent AB.
**Procedure For Administering**

**Supramaximal Anaerobic Test**

The test was administered with the subject positioned on the seat of the bicycle ergometer with the left leg slightly flexed and the right leg flexed at 90 degrees. The subject's arms were extended to grip the handle bars of the bicycle ergometer. On the command of "Go", the subject began pedalling concurrently, initiating the microswitch that was interfaced with the Aim 65 computer.

The Aim 65 computer was used to determine the number of revolutions completed in 50 seconds. The computer was able to detect the number of revolutions performed every .0082 seconds.

Verbal encouragement was continuously given throughout the activity and information pertaining to the amount of time remaining was given to the subject. At the conclusion of the 50 second activity, a command of "Stop" was given.

**Procedure For Collecting**

**Blood Lactate Samples**

Five milliliters of blood were drawn from the anticubital vein in heparinized test tubes prior to exercise, five minutes following the initial 50 second supramaximal performance, immediately following the active recovery period, and five minutes following the second 50 second anaerobic activity. A portion of each
blood sample was immediately deproteinized in two milliliters of cold eight percent perchloric acid and cooled for five minutes. Blood samples were centrifuged and frozen for one hour. Lactate concentrations were determined enzymatically, via the conversion of lactate to pyruvate in the presence of LDH and NAD$^+$. Five tubes for lactate standard curves were prepared. The blood lactate samples had 2.8 milliliters of enzyme solution added to each tube. Absorbance was determined at 340 nanometers using the Spectrophotometer. Blood samples were compared with the lactate standard curve to determine the results.

Procedure for Administering Active Recovery

Following the five minute rest interval after the supramaximal 50 second anaerobic exertion, the subject began to pedal the bicycle ergometer at the subject's desired resistance. The tester set the resistance at zero kiloponds and informed the subject that an increased resistance was allowed if desired (3). A metronome was utilized to visually and to audibly aid the subject in maintaining a consistent pedal cadence. The tester gave the command of "Stop" after the five minute recovery.
Procedure for Administering Passive Recovery

Following the five minute rest interval after the supramaximal 30 second anaerobic exertion, the subject remained motionless for five minutes while seated on the bicycle.

Interpretation of Data

A One-Way Analysis of Variance was the statistical design used when analyzing the percent decrement in the total cumulative revolutions between the initial and subsequent supramaximal performances of the active and passive recovery pattern. The four blood samples were analyzed to determine if any significant differences existed among the four levels of blood lactate for each subject as related to the active recovery pattern and the passive recovery pattern. The four blood samples of each subject were analyzed utilizing the One-Way Analysis of Variance with Repeated Measures.
Overview

The primary purpose of the study was to analyze the differences among lactic acid levels of females following two supramaximal performances that were separated by either active or passive recovery patterns. The interpretation and preparation of data were performed utilizing two statistical designs. The percent decrement in the total cumulative revolutions between the two supramaximal performances as related to the active recovery pattern and the passive recovery pattern was analyzed by the One-Way Analysis of Variance. One-Way Analysis of Variance with Repeated Measures was the statistical analysis used to determine the differences existing among the four levels of blood lactate for each subject as related to the recovery pattern.

An Analysis of the Effects of Active Recovery Patterns and Passive Recovery Patterns on Subsequent Supramaximal Anaerobic Performance

A significant difference at the .05 level ($F = 4.308$)
was obtained between the active recovery group and the passive recovery group when analyzing the percent decrement in the total cumulative revolutions between the initial and subsequent supramaximal performances. This difference favored the active recovery group which had a 6.95 percent decrement compared to 12.54 percent decrement for the passive recovery group. (See Table 1) (See Appendix C.)

**TABLE I**

**ANALYSIS OF THE EFFECTS OF THE RECOVERY PATTERNS ON THE PERCENT DECREMENT IN TOTAL CUMULATIVE REVOLUTIONS BETWEEN THE INITIAL AND SUBSEQUENT SUPRAMAXIMAL PERFORMANCE**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>0.0297</td>
<td>1</td>
<td>0.0297</td>
<td>4.3080</td>
<td>.05</td>
</tr>
<tr>
<td>Error</td>
<td>0.2482</td>
<td>36</td>
<td>0.0069</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Level of Significance was 4.125 (a=.05)

**An Analysis of the Effects of Active and Passive Recovery Patterns on Blood Lactate Levels**

No significant difference at the .05 level (F=0.80) existed among the four blood lactate samples measured in the active recovery group and the passive recovery group. (See Table 2, Page 32) The mean value for the first lactic acid sample of the active recovery group was 10.52 mg. \( \pm 4.99 \) and the mean value for the
TABLE II

AN ANALYSIS OF THE EFFECTS OF RECOVERY PATTERNS ON BLOOD LACTATE LEVELS

<table>
<thead>
<tr>
<th>Source</th>
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<th>P</th>
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<td>G</td>
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<td>1.60</td>
<td>.05</td>
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<tr>
<td>LA</td>
<td>222581.19283</td>
<td>3</td>
<td>74193.73094</td>
<td>510.70</td>
<td></td>
</tr>
<tr>
<td>LG</td>
<td>347.88136</td>
<td>3</td>
<td>115.96045</td>
<td>0.80</td>
<td>NS</td>
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</tbody>
</table>

Level of Significance was 10.13 (a=.05)
passive recovery group was 7.98 mg ± 3.96. The mean value for the second lactic acid sample for the active recovery group was 98.48 mg ± 20.22 and the mean value for the passive recovery group was 90.80 mg ± 20.56. The mean value for the third lactic acid sample for the active recovery group was 93.33 mg ± 13.88 and the mean value for the passive recovery group was 90.50 mg ± 20.86. The mean value for the fourth lactic acid sample for the active recovery group was 107.54 mg ± 17.57 and the mean value for the passive recovery group was 103.82 mg ± 14.90. (See Figure 1, Page 34.)
(See Appendix B.)
A comparison of the four blood lactate samples in relationship to the blood lactate levels and the means and standard deviations of the lactate samples are presented.

**Figure 1**

- Passive Recovery Group, $\bar{X}$ and SD
- Active Recovery Group, $\bar{X}$ and SD

**BLOOD LACTATE SAMPLES**
CHAPTER FIVE

SUMMARY, FINDINGS, DISCUSSION OF THE FINDINGS, CONCLUSIONS, AND RECOMMENDATION

Overview

The primary purpose of the study was to analyze the differences among lactic acid levels of females following two supramaximal performances that were separated by either active or passive recovery patterns. A second purpose was to determine the effect of recovery patterns on a subsequent supramaximal performance. The 37 female subjects were randomly placed into either an active recovery group or a passive recovery group. Each subject pedalled for a time duration of 50 seconds for each of the two supramaximal performances. The subjects pedalled at a workload of four kiloponds during the supramaximal performances.

Four blood samples were taken during the testing session to measure the level of lactic acid. The first blood lactate level was taken in the resting state prior to the first supramaximal performance. The second blood lactate level represented the level of blood...
lactate and was taken ten minutes following the first supramaximal performance. Following the recovery period, which occurred after the first supramaximal performance, a third blood sample was drawn. The fourth blood sample was taken five minutes following the subsequent supramaximal anaerobic performance.

A five minute passive period of exercise followed each supramaximal anaerobic performance. The five minutes following exercise was the latent time period which allowed the lactate buildup to diffuse from the muscle into the blood stream. Higher and more accurate readings have resulted when a five minute passive period precedes the drawing of the blood sample (1).

A session was utilized prior to testing to enable the subjects to become familiarized with the procedures and to eliminate any training effects. Measurements of aerobic capacity, resting blood pressure, resting heart rate, and the height of the seat of the bicycle ergometer were recorded.

Two different statistical analyses were used to determine the interrelationship of lactate, recovery patterns, and work output. The work performances affected by the active recovery pattern and the passive recovery pattern were analyzed by a One-Way Analysis of Variance. A One-Way Analysis of Variance with Repeated Measures was used to determine the effects of active
recovery patterns and passive recovery patterns on blood lactate levels.

Findings

The findings of the study were as follows:

1. Significant differences were found between the recovery groups when analyzing the percent decrement in the total cumulative revolutions between the initial and subsequent supramaximal performances in favor of the active recovery group.

2. No significant difference was found in the blood lactate levels between the active and passive recovery groups following the initial supramaximal performance.

3. No significant difference was found in the blood lactate levels between the active recovery group and the passive recovery group following the recovery patterns preceding the subsequent supramaximal anaerobic performance.

4. No significant difference was obtained in the blood lactate between the active recovery group and the passive recovery group following the subsequent supramaximal anaerobic performance.

Discussion of the Findings

Regan's study demonstrated that elevated levels of lactic acid do not exert a significant effect on
performance (13). Klausen reported that high levels of blood lactate prior to exercise inhibited further significant amounts of blood lactate, but that cardiovascular performance was not deterred (11). Earlier research performed by Graham indicated that lactate was not formed from hypoxia during exercise (7).

Research has been devoted to the formation of lactic acid in specific muscle fiber types and several investigators have uncovered pertinent information related to fatigue. Tesch has suggested that fast twitch muscle fibers form higher levels of lactate than the slow twitch fibers (15). Bonen reported that a significant relationship existed between percentage of slow twitch muscle fibers and the rate of lactate removal (4). Research by Tesch has indicated that high lactate levels and pH levels were factors of fatigue, but decreases in performance were not augmented (15).

Recovery patterns which increase the rate of lactate removal have been studied. Gisolfi investigated the most appropriate recovery pattern for reducing the levels of lactic acid and concluded that active recovery was superior to passive recovery patterns. The increased blood flow from active recovery enhanced the rate of glycogenesis in the liver and glucose was able to form at a faster rate (6).
Davies reported that active recovery at 40 percent of the maximum aerobic capacity increased lactate removal during recovery (5). A study by McGrail found that a high correlation existed between VO₂ cost and lactate removal. McGrail's study suggested the importance of skeletal muscle upon the rate of lactate removal following aerobic exercise (12).

Few studies have concentrated on the effects of lactic acid during anaerobic work. Regan's research studied the effects of elevated levels of lactic acid on anaerobic performances and the significance of recovery patterns separating the two supramaximal performances. Regan concluded that the subsequent performance was not hindered by the previous supramaximal performance. The active or passive recovery patterns did not change the subsequent performance significantly (13).

The present study, which concentrated on the effects of lactate on anaerobic performance and the significance of recovery patterns separating the two supramaximal performances, produced contrary results to Regan's. The author found that significant differences did not exist between the levels of lactic acid, but the findings did indicate that significant differences occurred between the active and passive recovery groups. Subsequent anaerobic performance favored the active recovery pattern.
The present study suggested that lactic acid levels did not directly influence the supramaximal performances, but the metabolism of lactate by the aid of the recovery patterns was perhaps the underlying factor. The active recovery pattern allowed increased circulation to occur which enhanced the metabolism of lactate into reusable energy supplies. During the active recovery pattern, the increased levels of pyruvic acid and hydrogens produced during the anaerobic work to form lactate were oxidized during recovery by the needed oxygen from the liver, myocardium, and other skeletal muscles. Oxygen restored ATP and PC so glycogen could be resynthesized for the needed energy to perform the subsequent supramaximal performance. In addition, the significant difference between the active and the passive recovery group might be related to the hypoxia which remained in the muscle groups involved in passive movement, whereas the active recovery allowed the lactate to enter circulation by the active movement of the muscles. During passive recovery, the muscles were deprived of adequate levels of oxygen. Consequently, the lactate was not transformed back into the energy efficient pyruvic acid.

Past research has stated that following anaerobic work, lactate was converted back to pyruvic acid and the citric acid cycle would form ATP. The formation of
ATP would enable pyruvic acid to form glucose. In addition, glucose would be synthesized from amino acids and cortisol. In anaerobic work, the synthesis occurred when carbohydrates fell below normal (2). In active recovery, the combined effects of lowered values of carbohydrates and increased circulation replenished the energy stores of ATP and PC. Passive recovery lacked the increased circulation and the energy stores could not be reloaded.

The present study along with Regan's research have demonstrated that short active recovery periods following anaerobic work are sufficient to allow the energy systems of the body to replenish the depots of oxygen needed for efficient work performance. However, this study, unlike Regan's study, was not able to produce similar results when passive recovery was employed.

Conclusions

The following conclusions were deducted from the study:

1. Lactic acid levels are not affected by recovery patterns and are not detrimental to anaerobic performance.

2. Recovery patterns produced a significant change in the percent decrement of the total cumulative revolutions favoring the active recovery group.
Recommendation

Further research is needed in the area of anaerobic exercise as related to the muscle fiber type's influence on successive bouts of supramaximal performance.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY


APPENDIX A

The Physical Characteristics of the
Active and Passive Recovery Group
## APPENDIX A

### THE PHYSICAL CHARACTERISTICS OF THE ACTIVE AND PASSIVE RECOVERY GROUP

<table>
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<td>43.11</td>
<td>6.96</td>
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APPENDIX B

The Lactate Levels of the Active and Passive Recovery Groups for the Four Blood Lactate Samples
### APPENDIX B

**THE LACTATE LEVELS OF THE ACTIVE AND PASSIVE RECOVERY GROUPS FOR THE FOUR BLOOD LACTATE SAMPLES**

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<td>Passive</td>
<td>18</td>
<td>103.82</td>
<td>14.90</td>
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APPENDIX C

Total Cumulative Revolutions of the Active and the Passive Recovery Groups
# APPENDIX C

**TOTAL CUMULATIVE REVOLUTIONS OF THE ACTIVE AND THE PASSIVE RECOVERY GROUPS**

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<td><strong>SUBSEQUENT SUPRAMAXIMAL PERFORMANCE</strong></td>
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<td>18</td>
<td>62.89</td>
<td>9.64</td>
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</table>
APPENDIX D

MODEL DATA SHEET

RECOVERY PATTERN

NAME ____________________

DATE ____________________

BASELINE MEASUREMENTS:

RESTING HEART RATE _____

RESTING BLOOD PRESSURE _____

HEIGHT _____

WEIGHT _____

LEVEL OF LACTATE (mg%):

READING: 1) _____

2) _____

3) _____

4) _____

CUMULATIVE REVOLUTIONS:

SUPRAMAXIMAL PERFORMANCE I _____

SUPRAMAXIMAL PERFORMANCE II _____

MAXIMAL AEROBIC CAPACITY _____ ML/KG XMIN.

REMARKS:

SUGGESTIONS:
APPENDIX E

Guidelines to Testing
APPENDIX E

GUIDELINES TO TESTING

Subjects participating in this study must heed to the following guidelines before testing:

1) Receive a minimum of eight hours sleep during the night preceding the day of testing.

2) Must not eat any food nor drink caffeinated, carbonated, or alcoholic beverage preceding three hours prior to testing.

3) Do not eat foods loaded with excessive sugar or fats during the day of testing. A meal high in carbohydrates should be eaten for breakfast, but a light lunch should be eaten.

4) Restrict strenuous exercise during the day of testing.

The investigator of this research appreciates your interest and enthusiasm in this study!

THANK YOU!!   THANK YOU!!   THANK YOU!!
APPENDIX F

Subject Consent to Procedure
APPENDIX F

SUBJECT CONSENT TO PROCEDURE

1. I, __________________ (print name of subject), hereby authorize members of the Appalachian State University Department of H.P.E.R., and assistants selected by them, to administer to me the physical exercise and medical tests for analysis as described in the following procedure:

   Each subject will complete a test session consisting of:
   1) A ten-minute relaxation session prior to exercise;
   2) A fifty second supramaximal performance on the bicycle ergometer;
   3) A recovery pattern (active or passive) for ten minutes; and
   4) A subsequent supramaximal performance on the bicycle ergometer for fifty seconds.

   During each session, blood samples will be taken by a qualified nurse, before the initial test, after the initial test, after recovery, and after the subsequent test. The nurse will be present during all procedures. In order to monitor heart rate during exercise, each subject will be checked on the carotid artery prior to and immediately following each supramaximal performance.

2. I have been made aware of certain discomforts and consequences with the procedures described. These are the pain of the insertion of the needle for drawing blood, and soreness associated with these procedures and exercises.

3. I have been informed that maximal exercise may constitute a risk of harm to persons with medical or health problems. I certify that I am in good health and have no known medical or health problems causing me to limit my physical activities.

4. I have understood the explanation of the procedures and voluntarily agree to participate in this study, and I understand the following:
Each subject will need to be available to report to the Human Performance Laboratory for one session over a period of three weeks during the month of January. Subjects will be needed for a maximum of thirty minutes per session, Monday thru Friday, 3:00 to 6:00.

Signature of Subject
VITA

Katherine Melissa Miller

BORN: November 29, 1957 in Greenville, South Carolina

EDUCATION:

High School: Wade Hampton High
Greenville, South Carolina
1972-1976

College: Appalachian State University
Boone, North Carolina
1976-1980

HONORS: Alpha Chi
Cum Laude
Who’s Who Among American College Students
Honor Teaching Award, Appalachian State University, 1980
Most Valuable Player in Women's Varsity Tennis, Appalachian State University, 1979
Most Valuable Offensive Player in Women's Field Hockey, Appalachian State University, 1979, 1980

PROFESSIONAL EXPERIENCE: Exercise Physiologist:
Presently employed at the Aerobic Performance Center, Charlotte, North Carolina. Experience consisted of:
(1) conducting graded exercise tests for cardias and adult fitness programs; (2) prescribing exercise programs; (3) hydrostatic weighing; (4) percent body fat measurements; (5) pulmonary function assessments; (6) consultations with patients concerning results of above evaluations; and (7) educational presentations
concerning topics of weight modification, smoking, and coronary heart disease, and blood lipid levels.

Presentation:
"The Physiological Parameters of Fourteen Corporate Executives Following Six Months of Aerobic Training", State AAHPERD Convention, Greensboro, North Carolina, October, 1982

Teaching:
Student taught at Parkland Senior High School, Winston-Salem, North Carolina, Fall, 1980.
Subject Taught: Physical Education

Coaching:
Assistant field hockey coach to Dr. Jan Watson, Appalachian State University, Fall, 1981
Assistant tennis coach to Miss Norma Freeman, Parkland Senior High School, Winston-Salem, North Carolina, Fall, 1980.

Certified:
Cardio-Pulmonary Resuscitation
Water Safety Instructor

MEMBER OF ORGANIZATIONS: American Alliance of Health, Physical Education, Recreation, and Health American College of Sports Medicine