THE EFFECTS OF EXERCISE RECOVERY PATTERNS

ON LACTATE REMOVAL AND SUBSEQUENT

MAXIMUM ANAEROBIC PERFORMANCE

A Thesis

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Fern A. Cowen

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APPROVED BY:

Vaughn K. Christian
Vaughn K. Christian, Associate Professor, HPER

Roger Thomas
Roger Thomas, Professor, HPER

Robert Johnson
Robert Johnson, Assistant Professor, HPER

E. Ole Larson
E. Ole Larson, Chairperson, HPER

Joyce U. Lawrence
Joyce Lawrence, Dean of the Graduate School

ABSTRACT

The primary purpose of the study was to investigate the effects of recovery patterns upon blood lactate concentrations following supramaximal anaerobic arm ergometric work. A second purpose was to investigate the effects of blood lactate concentrations upon subsequent supramaximal anaerobic arm ergometric work. A third purpose of the study was to investigate the effects of recovery patterns upon subsequent supramaximal anaerobic ergometric work.

Nine females at Appalachian State University volunteered as subjects to complete four experimental conditions. Each subject completed two tests of supramaximal arm ergometric work. During each experimental condition one of four recovery patterns was utilized in the procedure. Blood samples for the purpose of determining lactate concentrations, were taken four times during each experimental condition. Heart rate and cumulative pedal revolutions were recorded by ten-second intervals during all experimental conditions.

Findings were illustrated through the use of scatter plot graphs to analyze mean values for blood lactate concentrations and cumulative pedal revolutions

during the four experimental conditions. A trend appeared favoring passive recovery of a shorter duration for dissipating lactic acid; however, another trend emerged favoring active recovery patterns of longer duration as being equal or slightly better for the purpose of dissipating lactic acid. There was not a noticeable trend favoring any one recovery pattern for increasing work performance on a subsequent anaerobic test. There appeared to be a trend that indicates increased levels of lactic acid in the body would not necessarily be detrimental to subsequent anaerobic exercise performed with the arms.

ACKNOWLEDGEMENTS

The writer of this thesis is indebted to Mr. Roger Thomas, Dr. Robert Johnson, and especially Dr. Vaughn Christian, for their scholarly advice and help throughout the study.

Special thanks go to Dr. Deanna Bowman of the Computer Center, Dr. William Haag of the Chemistry Department, Dr. Thomas Rokoske of the Physics Department, Miss Beth Dunn, and Miss Lynn Ealing for their medical supervision during the testing, and especially the nine willing subjects who did not have to undergo the inconveniences they did.

DEDICATION

The writer would like to extend her gratitude to her typists and graduate colleagues for their help, understanding, and perserverance, and to her family for their encouragement and sacrifice.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In total carbohydrate combustion, there is an
initial anaerobic sequence followed by an aerobic
phase. It is the availability of oxygen in the cell
which determines the extent to which the metabolic
processes can proceed aerobically and anaerobically
(2: 18-19).

At the commencement of exercise, even if the
intensity was below 60 to 70 percent of maximal oxygen
uptake, some anaerobic metabolism would occur during
the first 45 to 60 seconds, while the cardiac output
would be adjusted from a resting condition to the level
required by the work load. The increasing severity of
exercise would cause adenosine diphosphate accumulation.
The breakdown of glycogen would be accelerated and an
increase in the reduction of nicotinamide adenine
dinucleotide.

At a critical intensity, the oxygen transporting
system would not provide sufficient oxygen to the cells,
and a portion of the pyruvic acid which was formed, in
addition to the oxygen, would act as a hydrogen
acceptor. Under such conditions some of the co-enzyme

1

nicotinamide adenine dinucleotide (reduced), would be reoxidized anaerobically by pyruvate which would be transformed to lactic acid, and the remainder reoxidized in the mitochondria aerobically. If the work were further intensified, a larger accumulation of lactic acid would be formed (2: 30-31).

High intensity exercise has resulted in the production of lactic acid (15, 25), which inhibits the mobilization of free fatty acids or the activity of glycolytic enzymes such as lactate dehydrogenase and phosphofructokinase (4: 932-6). Astrand and Rodahl (1977) recommended that at least one hour was needed between high intensity events to permit lactate removal from the body to be completed (2: 312-3). The removal of lactic acid after intense exercise, through a successful recovery technique, may therefore, be critical for the resumption of subsequent anaerobic exercise, particularly during athletic competition (40: 786-95).

Training has often been reported to increase an athlete's capacity to produce lactic acid during maximal exercise. This greater production of lactic acid has been associated with increased maximal work capacity and a delayed onset of fatigue. It could therefore be deduced that lactic acid may not be the cause of fatigue (3: 184-7).

However, untrained subjects in studies that showed a training effect on maximal lactic acid accumulation were inadequately motivated to continue working, and the training effect was due to an improved motivation to continue in the face of increasing discomfort. Accordingly, there are two explanations to any training effect on maximal lactic acid accumulation. First, training either improved motivation, or a tolerance to lactic acid, or secondly, more lactic acid can be produced in a conditioned athlete as a result of the greater stores of glycogen available during anaerobic breakdown (2: 598-602).

It has been shown that blood lactate levels are reduced faster if moderate aerobic exercise were performed during the recovery period (3, 9, 10, 23, 32, 40). Proponents of active recovery believed that this augmented "total recovery," because of the increased heart rate and oxygen uptake (28: 153-61).

Sharkey (36: 26-30) has stated that the total anaerobic system was essential to the competitive nature of sport in society today. Weltman et al (1977) have investigated the effects of different recovery patterns on lactate removal and subsequent performance (40: 786-95). It appears that little is known about recovery from maximal intensity

anaerobic activity utilizing arm work as the criterion exercise.

Purpose of the Study

The primary purpose of the study was to investigate the effects of recovery techniques upon the level of blood lactate following supramaximal anaerobic arm ergometric work. A second purpose was to investigate the effects of blood lactate levels upon subsequent supramaximal anaerobic arm ergometric work. A third purpose was to analyze the effects of recovery techniques upon subsequent supramaximal anaerobic arm ergometric work.

Definition of Terms

Anaerobic Metabolism - Anaerobic metabolism referred to the chemical interaction without oxygen, for the production of energy during exercise in the skeletal muscles.

Lactate - Lactate was the fatiguing metabolite of the lactic acid system, resulting from the incomplete breakdown of glucose.

Supramaximal Performance - Supramaximal performance was defined as a maximum voluntary effort of pedaling an arm ergometer for one minute for the purpose of accumulating as many pedal revolutions as possible.

Delimitations

Nine unconditioned female students at Appalachian State University completed four experimental conditions on separate days. During each experimental condition, each subject completed two tests of supramaximal anaerobic arm ergometer work; each test was separated by one of four recovery techniques. Blood samples for the purpose of determining lactic acid were taken four times during each experimental condition. Heart rate and cumulative pedal revolutions were recorded by ten-second intervals during each experimental condition.

Limitations

Due to the unanticipated problem of collapsed blood vessels, three subjects did not complete all four experimental conditions. While maximum effort was asked for during all anaerobic performances, it was possible that some subjects did not give maximum effort.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review of related literature was divided into the following subheadings: studies related to lactate accumulation as the cause of muscular fatigue; studies related to the optimal recovery patterns for lactate removal; studies related to the effects of fiber types upon lactate removal; studies related to lactate release from muscles; studies related to the importance of body organs in lactate removal; and studies related to other factors affecting lactate removal and subsequent performance.

Studies Related to Lactate Accumulation as the Cause of Muscular Fatigue

The theory that lactate acid accumulation in the muscles limits muscular performance has been widely held since 1935 (3, 18, 22, 31). However, there have been recent questions related to this theory.

Lamb (1978) stated that lactic acid accumulation was related to the intensity of the work load and that lactic acid levels were usually high during exhaustion (31: 184-7). However, Hultman et al (1973) showed that the total amount of lactic acid accumulated was

not greatest at the time of fatigue, but at approximately 50 percent of maximal voluntary contraction, which can be held for 90 to 100 seconds (20: 113-25).

Hultman et al (1973) argued that training has been reported to increase a subject's capacity to produce lactic acid during high intensity exercise. As a result, a greater production of lactic acid was associated with an increase in work capacity, and a delayed onset of fatigue. Therefore, lactic acid accumulation may not be the cause of muscular fatigue (20: 113-25).

Lamb (1978) suggested that many young and old subjects experience fatigue earlier in endurance activities than subjects between 20 and 30 years of age who have been shown to have lower lactic acid levels in their blood at exhaustion. Although it may be conceived that there may be some aging effect upon muscular sensitivity to lactic acid, a more practical explanation may be that lactic acid was not the cause of fatigue (31: 184-7).

Studies Related to Optimal Recovery Patterns for Lactate Removal

There have been two studies investigating optimal recovery patterns from maximal exercise (26, 27). Numerous studies have indicated that lactate removal was enhanced during moderate aerobic activity, as

opposed to a passive recovery (4, 6, 9, 10, 16). In
addition, Belcastro and Bonen (1975) stated that when
recovery exercise was intermittent the lactate removal
was faster than at rest, but slower than during
continuous recovery exercise (4: 176-78).

Katch et al (1978) investigated active versus
passive recovery from short term supramaximal exercise.
The analysis of gross VO_2 and heart rate recovery data
for the active and passive conditions revealed statis-
tically significant differences in the analysis of
gross VO_2 with the active recovery scores being higher.
The conclusion was drawn that the more oxygen made
available during active aerobic recovery, the greater
the lactate removal (28: 153-61).

Weltman et al (1977), in a study on the effects
of different recovery patterns from high intensity
short duration exercise on lactate removal and subse-
quent exercise, revealed significant differences. The
20 minute active recovery resulted in significantly
higher post-recovery revolutions (p=.001) and enhanced
rates of lactate removal during recovery (40: 786-95).
Similar observations were concluded by Karlson and
Saltin (27: 598-602).

Studies Related to the Effects of Fiber
Types Upon Lactate Removal

In studies by Bonen and Belcastro (4, 6),
significant differences in lactate removal rates among

subjects have been observed. Bonen and Belcastro (1976) proposed that such differences were related to the slow-twitch fiber composition of skeletal muscles, since slow-twitch fibers have a greater relative activity of the heart specific isozymes of lactate dehydrogenase (6: 176-78). Ivy et al (1980) stated that when there was a greater proportion of slow-twitch fibers the removal of lactate from the blood greatly accelerated, particularly during active recovery exercise (27: 523-7). Similar conclusions were made by Bonen et al (7: 160-62).

Tesch et al (1978), in a study on muscle fatigue and its relation to lactate accumulation and lactate dehyrogenase activity in man, concluded that lactate or associated pH changes primarily in fast-twitch fibers could be one factor responsible for impaired muscle function (38: 413-20). Tesch (1978) found a significant relationship between lactic acid concentrations and performance times (r=.76). The conclusion made suggested that the high ability to form lactate may have been one contributing factor to anaerobic performance capacity (37: 373-4).

Studies Related to Lactate Release From the Muscle

McGrail et al (1978) suggested that the quantity of active muscle controlled the rate of lactate removal

in man (32: 89-97). Belcastro and Bonen (1975)
verified this statement in a study which found the
optimal disappearance of blood lactate was significantly
faster during running than cycling (4: 932-36).
Similar conclusions were made by Hermansen and
Stensvold (16: 191-201).

Jorfeldt et al (1978) demonstrated that lactate
release by the muscle was impaired at high work loads,
whereas this did not occur during light or moderate
exercise. It was therefore suggested that a similar
relationship might exist in lactic acid uptake by the
blood (25: 350-52). Hermansen and Vaage (1977) did
find significant results which indicated that blood
lactate was impaired during high work loads (17: E422-
E429).

Studies Related to the Importance of
Body Organs in Lactate Removal

Davies et al (1970) demonstrated the importance
of the liver in the elimination of lactate during
exercise (9: 155-61). In addition to the liver the
skeletal muscles and other organs were capable of re-
moving lactate during muscular work (16, 21, 24, 30).

Ahlborg et al (1975) indicated that the resting
muscle exhibited considerable metabolic activity;
therefore, the "resting" muscle could be mimicking an
active recovery (1: 718-23), and according to Bonen

et al (1978), the "resting" muscle takes up a significant proportion of the lactic acid in man (7: 160-62).

Studies Related to Other Factors Affecting Lactate Removal and Subsequent Performance

Hagberg et al (1980) indicated that the most effective rate of lactate removal occurred between 30-70% of the individual's maximum oxygen uptake depending on the condition of the individual (13: 218-24). Previous studies have made similar observations (4, 6, 9, 11, 12, 13, 14, 40).

Weltman et al (1977) stated that the optimal level of active recovery in terms of metabolic load would depend upon the level of conditioning of the individual (40: 786-95). Similar observations were made by Tibes et al (39: 127-40).

Williams et al (1967) stated that the optimal level of recovery would be just below the anaerobic threshold. A conditioned subject has a higher threshold value and should be capable of actively recovering at a higher metabolic load before reaching anaerobic threshold (41: 18-23).

Klausen et al (1972), in a study on the effects of pre-existing high blood lactate concentrations upon maximal exercise performance, proposed that the existence of high blood lactate concentrations prior

to exhaustive exercise did not affect $\dot{V}O_2$ max. However it could inhibit further lactate production in the exercising muscles (29: 415-19).

Astrand and Rodahl (1977) stated that one hour or more was needed for recovery before resting lactate values were reached (2: 313). However, Weltman et al (1977) found that considerable less recovery time was necessary to obtain initial exercise performance values. The data suggested that while active recovery resulted in increased lactate removal, other factors were available to allow for subsequent performance (40: 786-95).

Summary

The primary purpose of the study was to investigate the effects of recovery techniques upon blood lactate levels following supramaximal arm ergometric work. The related literature showed that eight studies found lactate removal could be enhanced by utilizing an active recovery.

The second purpose of the study was to investigate the effects of blood lactate levels upon supramaximal arm ergometric work. The related literature showed that only one study had looked at the effects of blood lactate levels upon subsequent anaerobic exercise. However, thirteen studies stated that other

factors were involved to allow for subsequent performance.

The third purpose of the study was to investigate the effects of recovery techniques upon subsequent supramaximal anaerobic arm ergometric work. The related literature showed that only one study had investigated the effects of recovery techniques upon subsequent anaerobic performance.

CHAPTER III

PROCEDURES

Nine females at Appalachian State University, Boone, North Carolina, volunteered as subjects to complete four experimental conditions during the 1981 Spring Semester. Each subject completed two tests of supramaximal arm ergometric work during each experimental condition which was separated by one of four recovery patterns. Blood samples for the purpose of determining lactate concentrations were taken four times during each experimental condition. Heart rate and cumulative pedal revolutions were recorded in ten second intervals during all anaerobic performances.

Selection of Subjects

A random sampling by computer was initially used to select subjects. However with the lack of numbers, nine females at Appalachian State University volunteered as subjects to complete four experimental conditions. A consent form was signed by each subject prior to testing. (See appendix A).

Orientation

All testing procedures were carried out under medical supervision in the Human Performance Laboratory at Appalachian State University. Subjects were asked to report to the Human Performance Laboratory in loose-fitting clothing and running shoes only. (See appendix B). At the commencement of the first session, data characterizing subjects were recorded, data which included: age, height, weight, and predicted $\dot{V}O_2$ max. (See appendix C).

Equipment

Monark Arm Ergometer

The Monark Arm Ergometer* was used to obtain desired work loads during anaerobic exercise and during the active recovery patterns.

Metronome

A Franz metronome⧸ was used to set the correct revolutions per minute during the active recovery patterns.

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* Monark Arm Ergometer may be purchased from Quinton Instruments, 2121 Terry Avenue, Seattle, Washington 98121.

⧸ Metronome, model no. LM-F3-4, may be purchased from Franz Manufacturing Company, Inc., Printers Lane, South Boulevard, New Haven, Connecticut 06519.

Stopwatch

A stopwatch was used to time specific intervals of work and rest in the study.

Cumulative Revolution Recorder and Microswitch

The Heath Servo Recorder* and the microswitch/ were used to record the number of revolutions made during initial and subsequent anaerobic performance.

Procedure for Preparation of Subject for Collection of Blood Samples

All subjects were prepared for collecting blood samples by two qualified nurses.

1. A surface vein on the anterior side of the forearm was determined as the most suitable site for collecting blood samples.

2. The vein was sought by applying a tourniquet around the upper arm.

3. A butterfly clip was inserted into the vein and secured to the forearm.≠

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* Heath Servo Recorder, model no. EUW-20A, may be purchased from Denton Harbour, Michigan.

/ Microswitch, model no. BZ-2RW82-A2, may be purchased from Brownell Electro, Inc., 5141 Belhaven Blvd., Charlotte, North Carolina 28216.

≠ Venipuncture Procedure Kit, model no. 2687, may be purchased from Abbott Laboratories, N. Chicago, Illinois 60064.

4. All blood samples for each experimental condition were taken by insertion of a syringe into the butterfly clip.

Procedure for Supramaximal Anaerobic Testing

Prior to commencement of testing, each subject was seated at the arm ergometer, and adjustments were made to the height of the seat and distance from the ergometer. Subjects were connected to a three-lead electrocardiogram for monitoring heart rate.

1. Each subject completed an initial one-minute all-out anaerobic test on the arm ergometer at a resistance of two kiloponds.

2. At the completion of the initial exercise bout, subjects rested for a five-minute latent period, followed by one of four recovery patterns.

3. After completion of the recovery period, the subjects underwent a subsequent all-out anaerobic test at a resistance of two kiloponds.

Procedures for Passive and Active Recovery Patterns

Upon completion of each initial bout of supramaximal exercise, each subject was involved in one of

the following recovery patterns:

Experimental Condition One: Active Recovery -
The subject pedaled an arm ergometer at 25
revolutions per minute with .5 kiloponds
resistance for ten minutes.

Experimental Condition Two: Active Recovery-
The subject pedaled an arm ergometer at 25
revolutions per minute with .5 kiloponds
resistance for five minutes.

Experimental Condition Three: Passive Recovery-
The subject sat quietly at the arm ergometer
for ten minutes.

Experimental Condition Four: Passive Recovery-
The subject sat quietly at the arm ergometer
for five minutes.

Procedure for Collecting Blood Samples

One milliliter of blood was drawn from a surface
vein on the anterior side of the forearm four times
during each experimental condition undergone by the
subject.

1. The blood samples were drawn at the follow-
   ing intervals:

   (a) prior to the initial exercise bout;

   (b) five minutes following the initial

exercise bout;

(c) immediately after the recovery period;

(d) five minutes following the subsequent

exercise bout.

2. Each blood sample was immediately added to

a test tube containing two milliliters of

seven percent perchloric acid and shaken

vigorously for 30 seconds.*

3. Samples were kept in ice for approximately

two hours before being assayed for lactic

acid.

Procedure for Recording Heart Rates

Heart rate readings were recorded as a precau-
tionary measure every ten seconds during the initial
and subsequent maximal anaerobic performances. Subjects
were prepared for electrocardiogram[1] readings in the
following manner:

1. Subject should be rested in a supine position

prior to preparation for electrode placement.

2. The fifth or sixth rib on both sides of the

chest were marked, as was the sternum.

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* Supermixer, catalogue no. 1290, may be purchased
from Lab-Line Instruments, Inc., Melrose Park, Illinois
60161.

[1] Electrocardiogram, model no. EK4, may be purchased
from Burdick Corporation, Milton, Wisconsin 53563.

3. The surface area was cleaned in a circular motion with cotton wool and Redux paste to remove the first subcutaneous layer of skin.

4. A cleaned lead electrode was attached with an adhesive patch to the prepared surface area.

5. Once electrodes were placed on skin, a pre-amplifier was attached to the subject's back.

6. All electrode connections were brought over subject's shoulders after having been attached to either the sternum or rib cage.

7. Excess wire connections were secured to the body using adhesive tape.

8. An elastic bandage was wrapped around the subject's torso to secure preamplifier and wires.

9. The preamplifier was then connected to the electrocardiogram.

Procedure for Recording Cumulative Pedal Revolutions

Cumulative pedal revolutions were recorded on charted paper every ten seconds during the initial and subsequent maximal anaerobic performances. (See appendix D). Revolutions were monitored by a microswitch activated by each pedal revolution, subsequently

recorded on a revolution counter attached to a
kymograph.

Procedure for Assaying Blood
for Lactic Acid

The samples were chilled for approximately two
hours, then placed in a safety centrifuge equipped
with a sensimicrohead (for 13 x 100 mm test tubes), and
centrifuged at 1000 revolutions per minute for ten
minutes.* A .2 milliliter of clear supernatant was
added to 2.8 milliliters of enzyme solution. The super-
natant was assayed for lactic acid using the commercial
kit described in Sigma Bulletin No. 826-W.U. The
supernatent was incubated at room temperature for one
hour to allow for enzyme activity. Samples were placed
in a spectophotometer, and absorbance values were read
at the A340 level. Readings were computed by comparing
the absorbance values with values for standard lactic
acid solutions utilizing the normal curve, and recorded
in milligrams percent. (See appendix F).

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*   A Flescher Safety Centrifuge, model no. IEC, may
be purchased from International Equipment Co., Heedham
Heights, Maryland 02194.

∕   Refer to Appendix E for preparation of testing
solutions.

⚄   Spectophotometer, model no. Spectronic 21, may
be purchased from Bausch and Lomb Analytical Systems
Division, Rochester, New York 14625.

Analysis of Data

After preliminary investigation the original linear statistical model was found to be inappropriate for the data collected, due to the within variance of the subjects; thus an alternative method utilizing scatter plot graphs was used. The analysis of mean values for blood lactate concentrations during four experimental conditions was illustrated through the use of scatter plot graphs to compare: experimental conditions one and three; experimental conditions two and four; experimental conditions one and two, and experimental conditions three and four.

The analysis of mean values for cumulative pedal revolutions during four experimental conditions was illustrated through the use of scatter plot graphs to compare: initial and subsequent mean performance scores during experimental condition one; initial and subsequent mean performance scores during experimental condition two; initial and subsequent mean performance scores during experimental condition three, and initial and subsequent mean performance scores during experimental condition four.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The purpose of the study was to investigate the effects of recovery patterns upon blood lactate concentrations following supramaximal anaerobic arm ergometric work. A second purpose was to investigate the effects of blood lactate concentrations upon subsequent supramaximal anaerobic arm ergometric work. A third purpose of the study was to investigate the effects of recovery patterns upon subsequent supramaximal anaerobic arm ergometric work.

Nine females at Appalachian State University volunteered as subjects to complete four experimental conditions. Each subject completed two tests of supramaximal arm ergometric work during each experimental condition, separated by one of four recovery patterns. Blood samples for the purpose of determining lactate concentrations were taken four times during each experimental condition. Heart rate and cumulative pedal revolutions were recorded by ten second intervals during all anaerobic performances.

Analysis of Mean Values for Blood Lactate
Levels During Four Experimental
Conditions

An Analysis of Blood Lactate
Levels During Experimental
Conditions One and Three

In comparing blood lactate levels during experi-
mental condition one (a ten-minute active recovery
pattern) and experimental condition three (a ten-minute
passive recovery pattern) it was observed that prior
to exercise, lactate levels were 11.49 milligram percent
and 14.08 milligram percent respectively. After the
initial exercise bout, blood lactate levels rose to
92.09 milligram percent for subjects performing experi-
mental condition one, and 77.33 milligram percent for
subjects performing experimental condition three.
Following the recovery period, blood lactate levels
dropped to 65.04 milligram percent for subjects per-
forming experimental condition one, and 55.86 milligram
percent for subjects performing experimental condition
three. After the subsequent exercise bout, blood lactate
levels rose to 97.12 milligram percent for subjects
performing experimental condition one, and 127.48
milligram percent for subjects performing experimental
condition three. It was observed that an interaction
occurred between the two experimental conditions, after
the subsequent anaerobic exercise bout, as can be seen
in Figure 1.

Fig. 1. The Mean Values for Blood Lactate Concentrations During Experimental Conditions One and Three
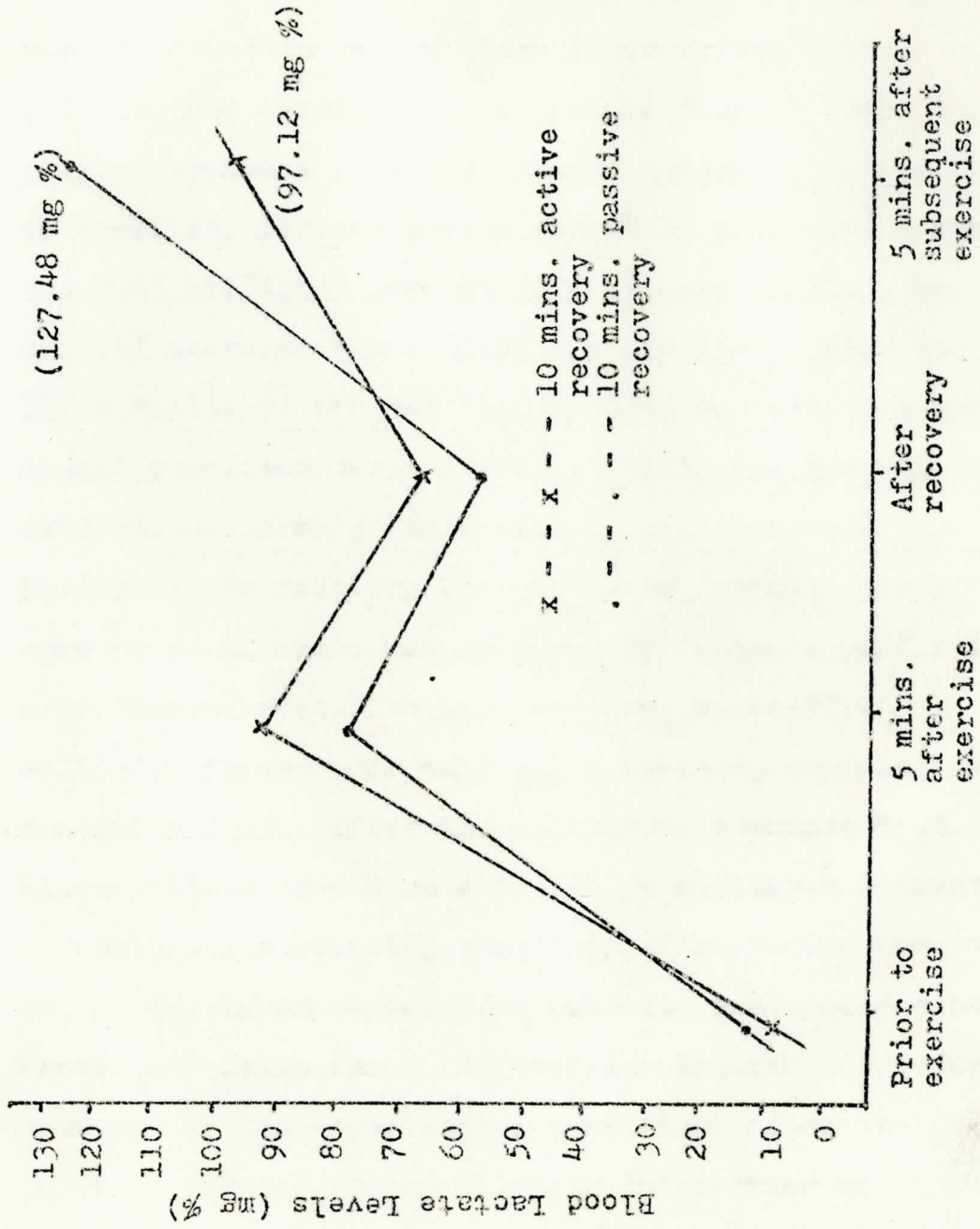
An Analysis of Blood Lactate
Levels During Experimental
Conditions Two and Four

In comparing blood lactate levels during experimental condition two (a five-minute active recovery pattern) and experimental condition four (a five-minute passive recovery pattern), it was observed that prior to exercise, lactate levels were 8.91 milligram percent and 9.66 milligram percent respectively. After the initial exercise bout, blood lactate levels rose to 98.49 milligram percent for subjects performing experimental condition two, and 101.04 milligram percent for subjects performing experimental condition four. Following the recovery period, blood lactate levels rose to 99.21 milligram percent for subjects performing experimental condition two, and dropped to 90.40 milligram percent for subjects performing experimental condition four. After the subsequent exercise bout, blood lactate levels rose to 110.79 milligram percent for subjects performing experimental condition two, and 138.08 milligram percent for subjects performing experimental condition four. An observed interaction occurred between the two experimental conditions after the recovery period. An even larger interaction occurred after the subsequent anaerobic exercise bout, as can be seen in Figure 2.
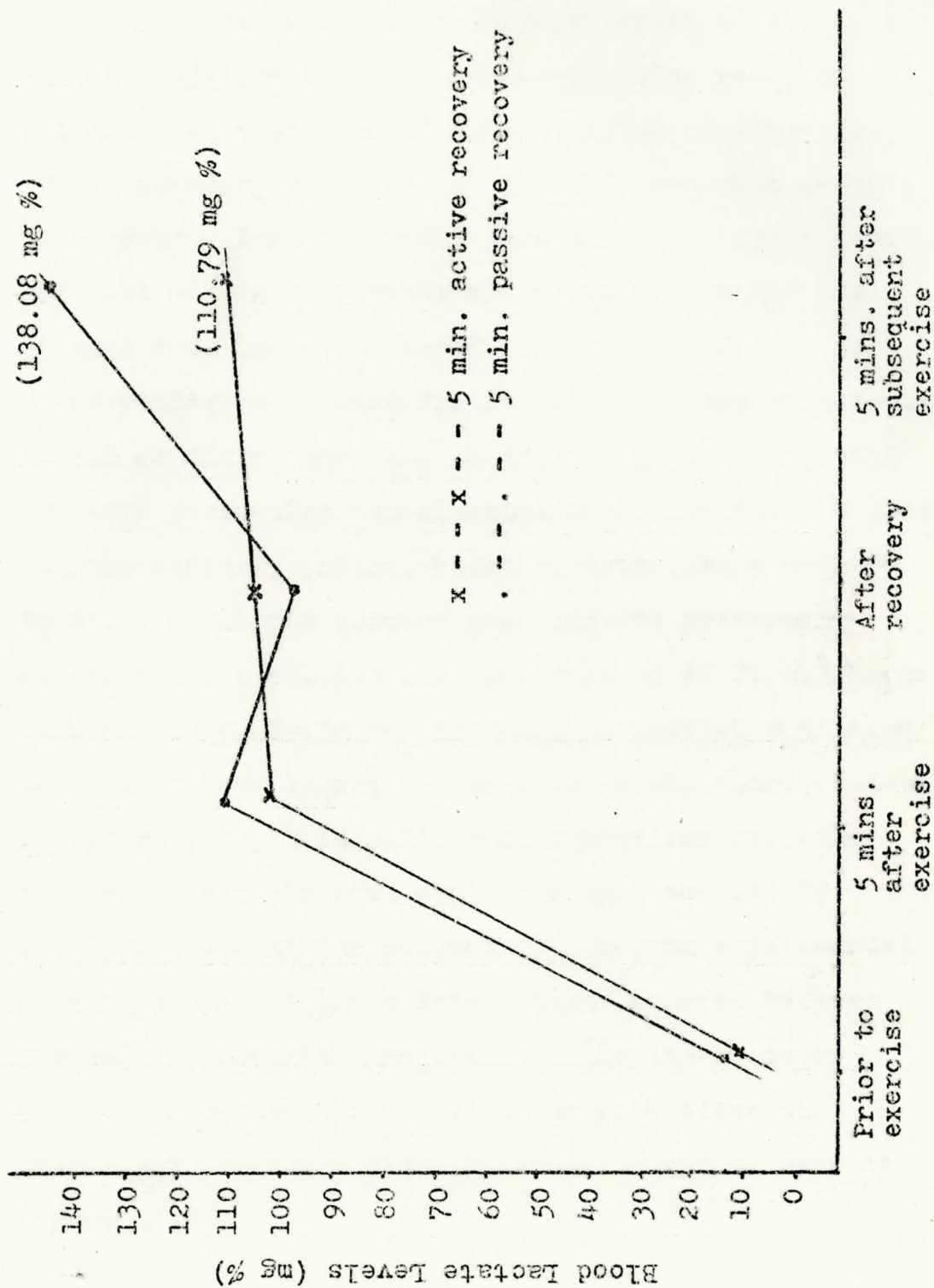
Fig. 2.   The Mean Values for Blood Lactate Concentrations
          During Experimental Conditions Two and Four

An Analysis of Blood Lactate
Levels During Experimental
Conditions One and Two

In comparing blood lactate levels during experimental condition one (a ten-minute active recovery pattern) and experimental condition two (a five-minute active recovery pattern), it was observed that prior to exercise, lactate levels were 11.49 milligram percent and 8.91 milligram percent respectively. After the initial exercise bout, blood lactate levels rose to 92.09 milligram percent for subjects performing experimental condition one, and 98.49 milligram percent for subjects performing experimental condition two. Following the recovery period, blood lactate levels dropped to 65.04 milligram percent for subjects performing experimental condition one, and rose to 99.21 milligram percent for subjects performing experimental condition two. After the subsequent exercise bout, blood lactate levels rose to 97.12 milligram percent for subjects performing experimental condition one, and 110.79 milligram percent for subjects performing experimental condition two. A large interaction occurred between the two experimental conditions after the recovery period. A smaller interaction occurred after the subsequent anaerobic exercise bout, as can be seen in Figure 3.

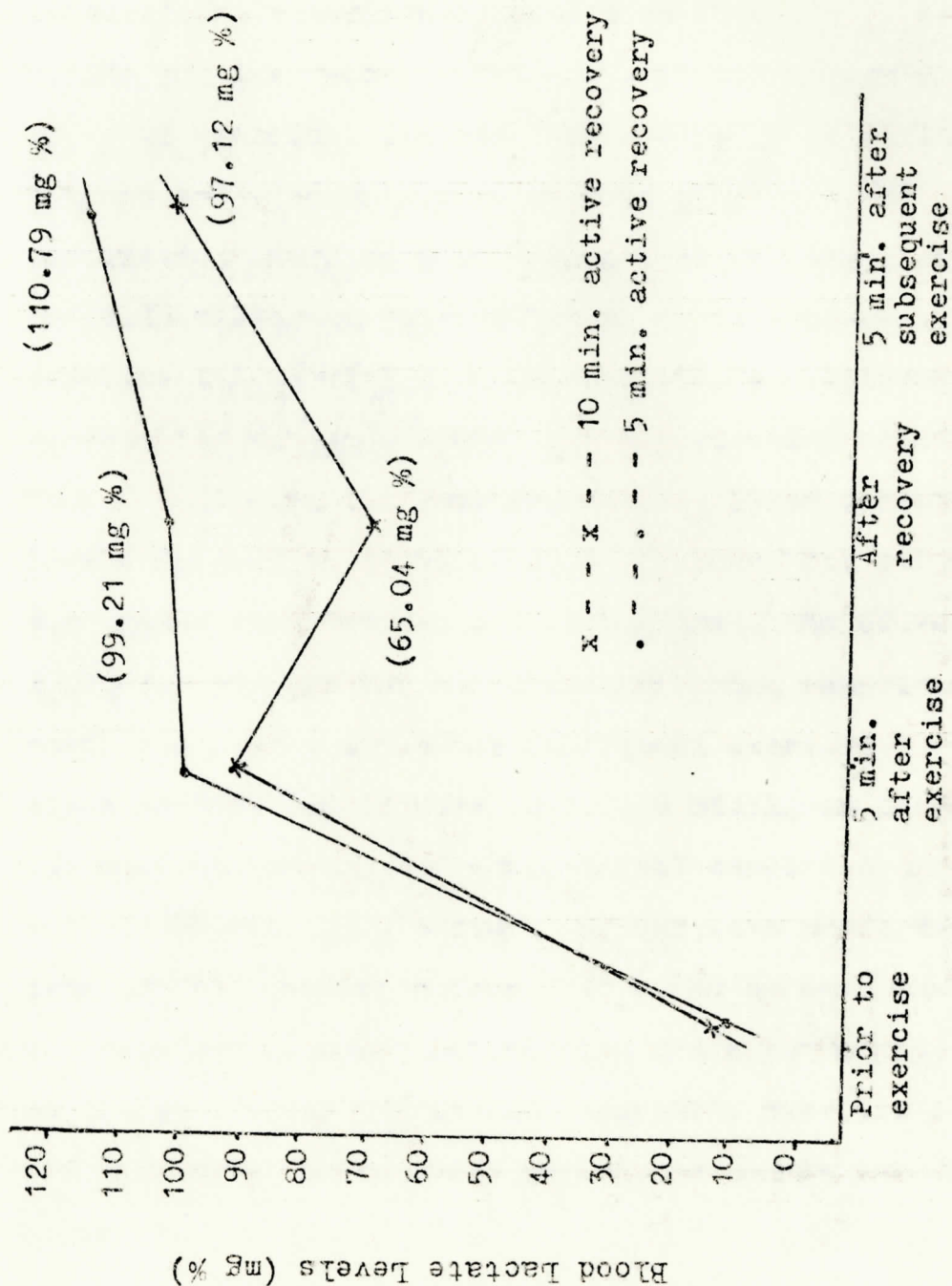Fig. 3.   The Mean Values for Blood Lactate Concentrations
During Experimental Conditions One and Two.

Blood Lactate Levels (mg %)

An Analysis of Blood Lactate
Levels During Experimental
Conditions Three and Four

In comparing blood lactate levels during experi-
mental condition three (a ten-minute passive recovery
pattern) and experimental condition four (a five-
minute passive recovery pattern), it was observed that
prior to exercise, lactate levels were 14.08 milligram
percent and 9.66 milligram percent respectively. After
the initial exercise bout, blood lactate levels rose
to 77.33 milligram percent for subjects performing
experimental condition three, and 101.04 milligram
percent for subjects performing experimental condition
four. Following the recovery period, blood lactate
levels dropped to 55.86 milligram percent for subjects
performing experimental condition three, and 90.40
milligram percent for subjects performing experimental
condition four. After the subsequent exercise bout,
blood lactate levels rose to 127.48 milligram percent
for subjects performing experimental condition three,
and 138.08 milligram percent for subjects performing
experimental condition four. It could be seen that
interactions occurred between the two experimental
conditions, after the initial anaerobic exercise bout,
and following the recovery period, as can be seen in
Figure 4.

Fig. 4.   The Mean Values for Blood Lactate Concentrations
During Experimental Conditions Three and Four.
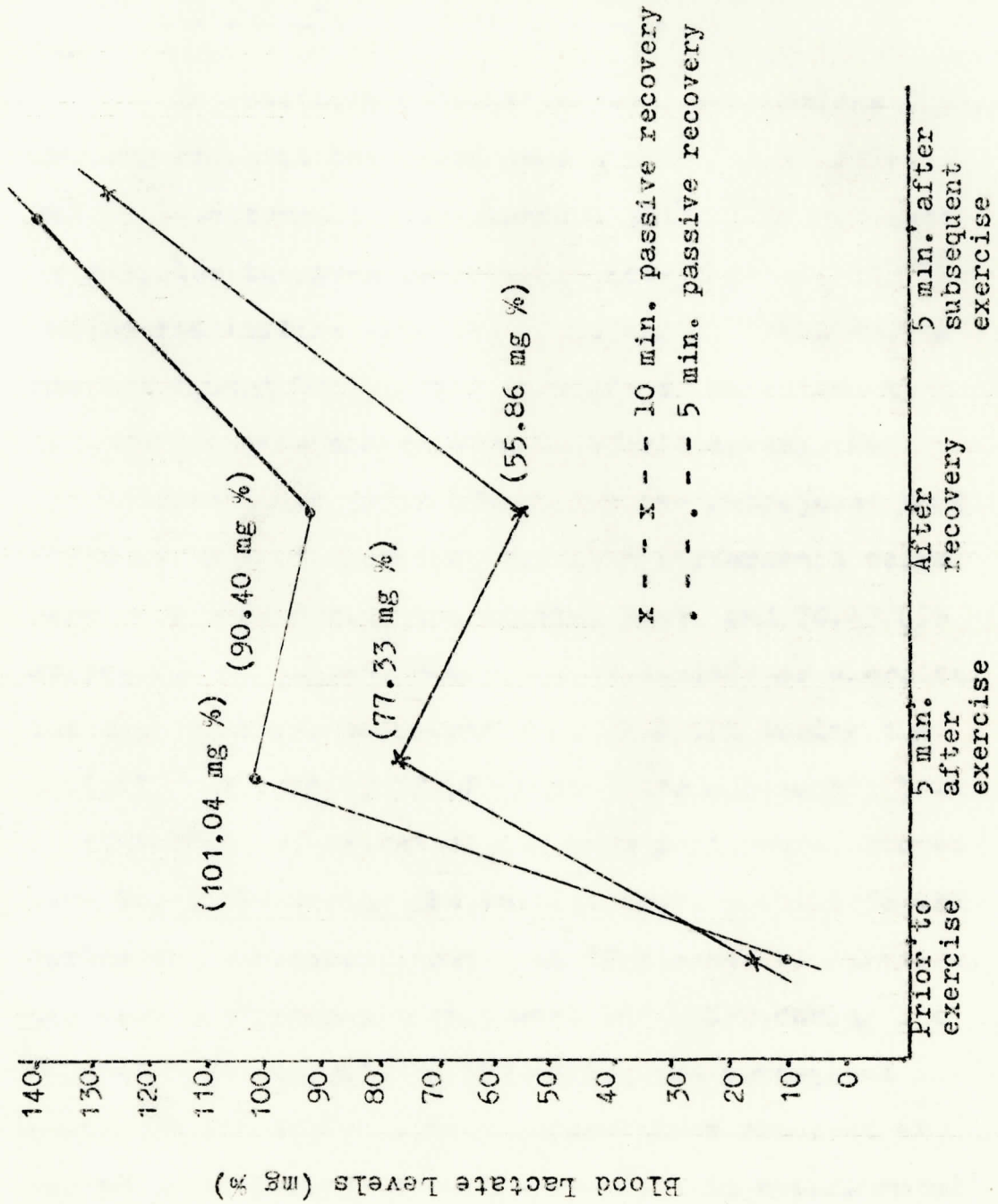
Analysis of Mean Values for Cumulative Pedal
Revolutions During Four Experimental
Conditions

An Analysis of Initial and
Subsequent Performance Scores
During Experimental Condition
One

In analyzing cumulative pedal revolutions (CPR)
for experimental condition one, a ten-minute active
recovery pattern, it was observed that at ten seconds
of exercise the mean performance scores were 27.33 CPR
during the initial exercise bout, and 27.0 CPR during
the subsequent bout. At 20 seconds of exercise, the
mean performance scores were 49.43 CPR during the
initial bout, and 50.57 CPR during the subsequent bout.
At 30 seconds of exercise, the mean performance scores
were 67.86 CPR during the initial bout, and 70.43 CPR
during the subsequent bout. At 40 seconds of exercise,
the mean performance scores were 83.0 CPR during the
initial bout, and 87.57 CPR during the subsequent bout.
At 50 seconds of exercise, the mean performance scores
were 96.28 CPR during the initial bout, and 102.58 CPR
during the subsequent bout. At 60 seconds of exercise,
the mean performance scores were 108.0 CPR during the
initial bout, and 115.86 CPR during the subsequent
bout. It was observed that interactions occurred at
40, 50, and 60 seconds during exercise in experimental
condition one, as can be seen in Figure 5.

Fig. 5.   The Mean Values for Cumulative Pedal
          Revolutions During Experimental Condition One.

An Analysis of Initial and
Subsequent Performance Scores
During Experimental Condition
Two

In analyzing cumulative pedal revolutions for
experimental condition two, a five-minute active
recovery pattern, it was observed that at ten seconds
of exercise the mean performance scores were 28.85 CPR
during the initial bout, and 24.71 CPR during the
subsequent bout. At 20 seconds of exercise, the mean
performance scores were 47.71 CPR during the initial
bout, and 46.63 CPR during the subsequent bout. At
30 seconds of exercise, the mean performance scores
were 65.71 CPR during the initial bout, and 65.0 CPR
during the subsequent bout. At 40 seconds of exercise,
the mean performance scores were 81.41 CPR during the
initial bout, and 80.86 CPR during the subsequent
bout. At 50 seconds of exercise, the mean performance
scores were 95.43 CPR during the initial bout, and 95.0
CPR during the subsequent bout. At 60 seconds of
exercise, the mean performance scores were 108.14 CPR
during the initial bout, and 107.86 CPR during the
subsequent bout. It appeared that no interactions
occurred during exercise in experimental condition two,
as can be seen in Figure 6.

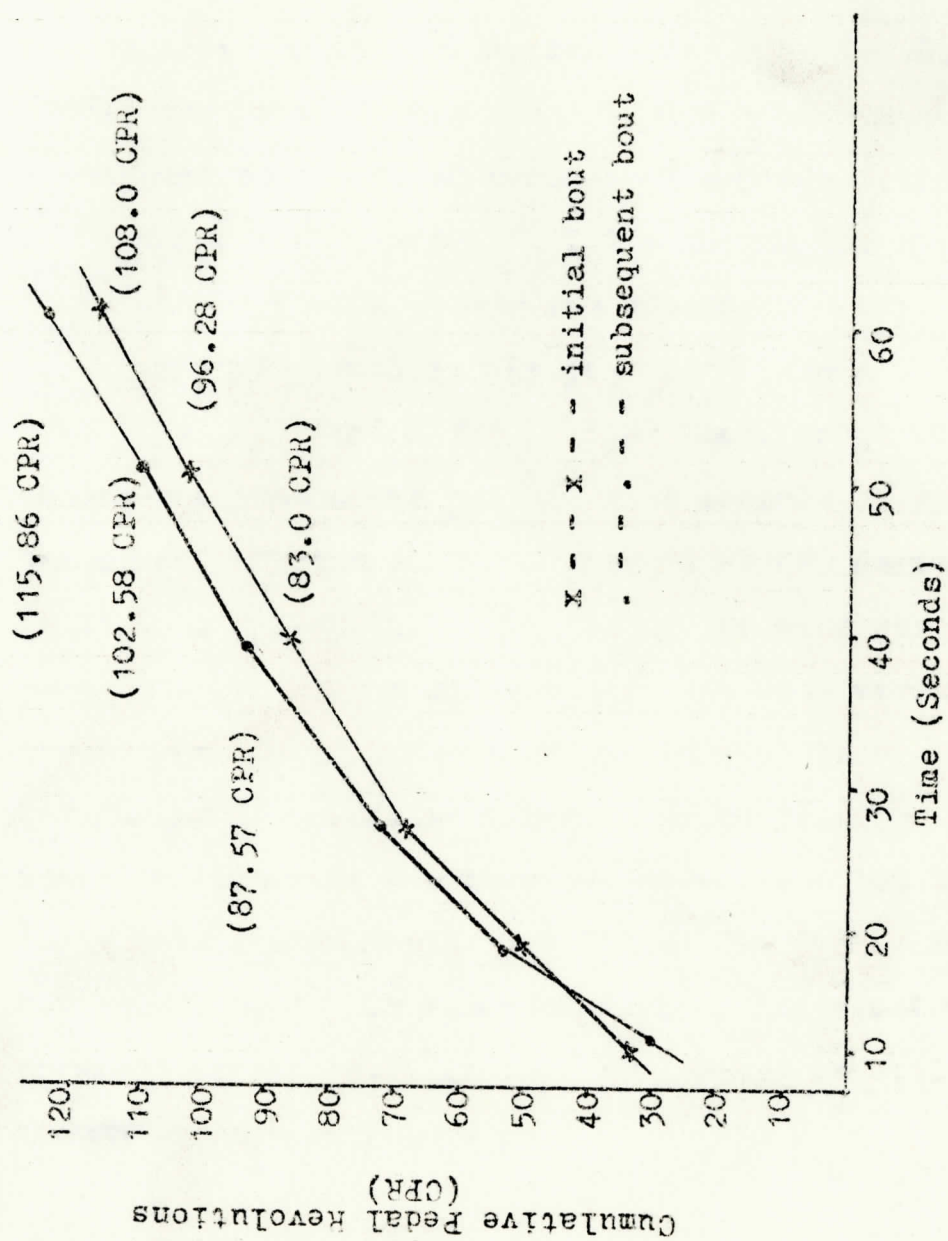Fig. 6.   The Mean Values for Cumulative Pedal
          Revolutions During Experimental Condition
          Two.

An Analysis of Initial and
Subsequent Performance
Scores During Experimental
Condition Three

In analyzing cumulative pedal revolutions for experimental condition three, a ten-minute passive recovery pattern, it was observed that at 10 seconds of exercise the mean performance scores were 30.71 CPR during the initial bout, and 31.14 CPR during the subsequent bout. At 20 seconds of exercise, the mean performance scores were 54.71 CPR during the initial bout, and 56.0 CPR during the subsequent bout. At 30 seconds of exercise, the mean performance scores were 75.57 CPR during the initial bout, and 76.43 CPR during the subsequent bout. At 40 seconds of exercise, the mean performance scores were 94.0 CPR during the initial bout, and 95.15 CPR during the subsequent bout. At 50 seconds of exercise, the mean performance scores were 110.29 CPR during the initial bout, and 112.29 CPR during the subsequent bout. At 60 seconds of exercise, the mean performance scores were 124.43 CPR during the initial bout, and 127.42 CPR during the subsequent bout. A small interaction occurred at 60 seconds of exercise during experimental condition three, as can be seen in Figure 7.
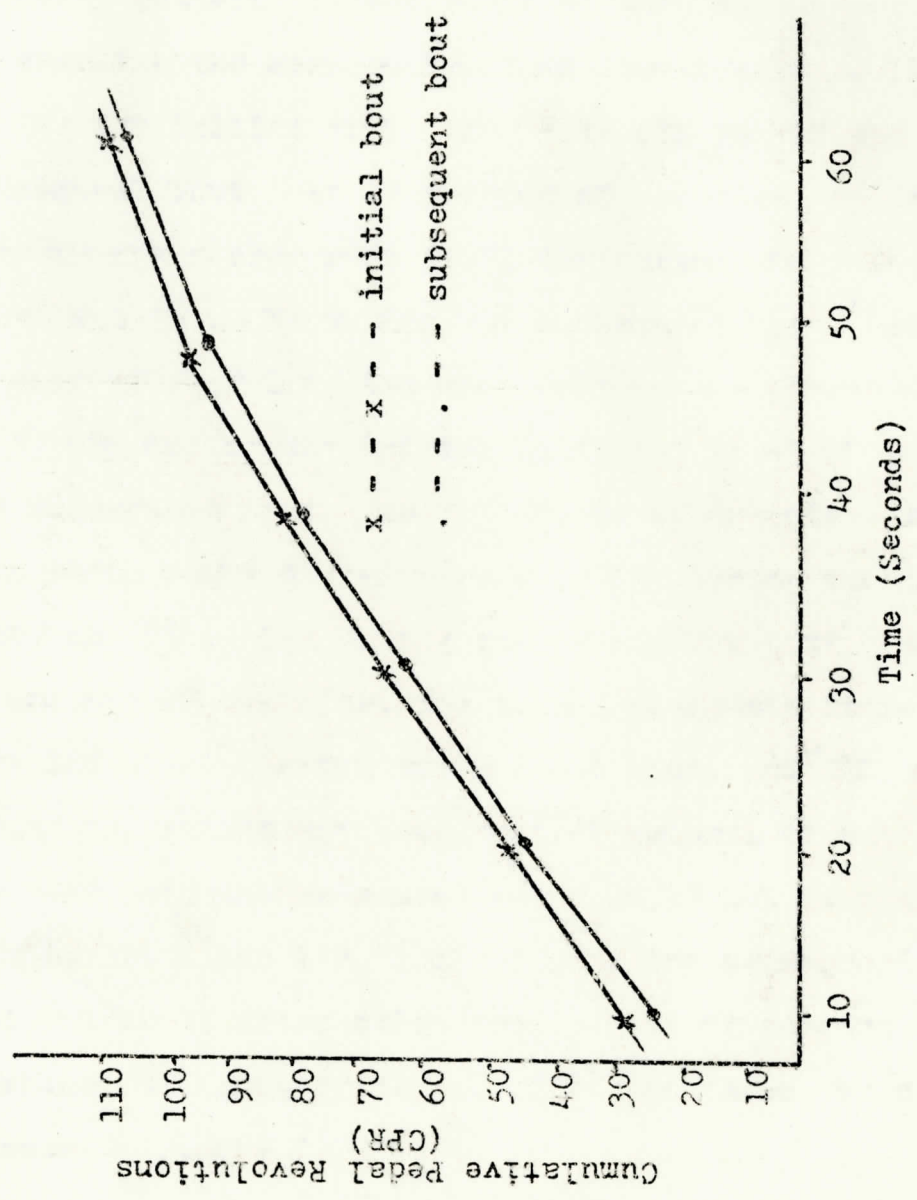
Fig. 7.   The Mean Values for Cumulative Pedal
Revolutions During Experimental Condition
Three
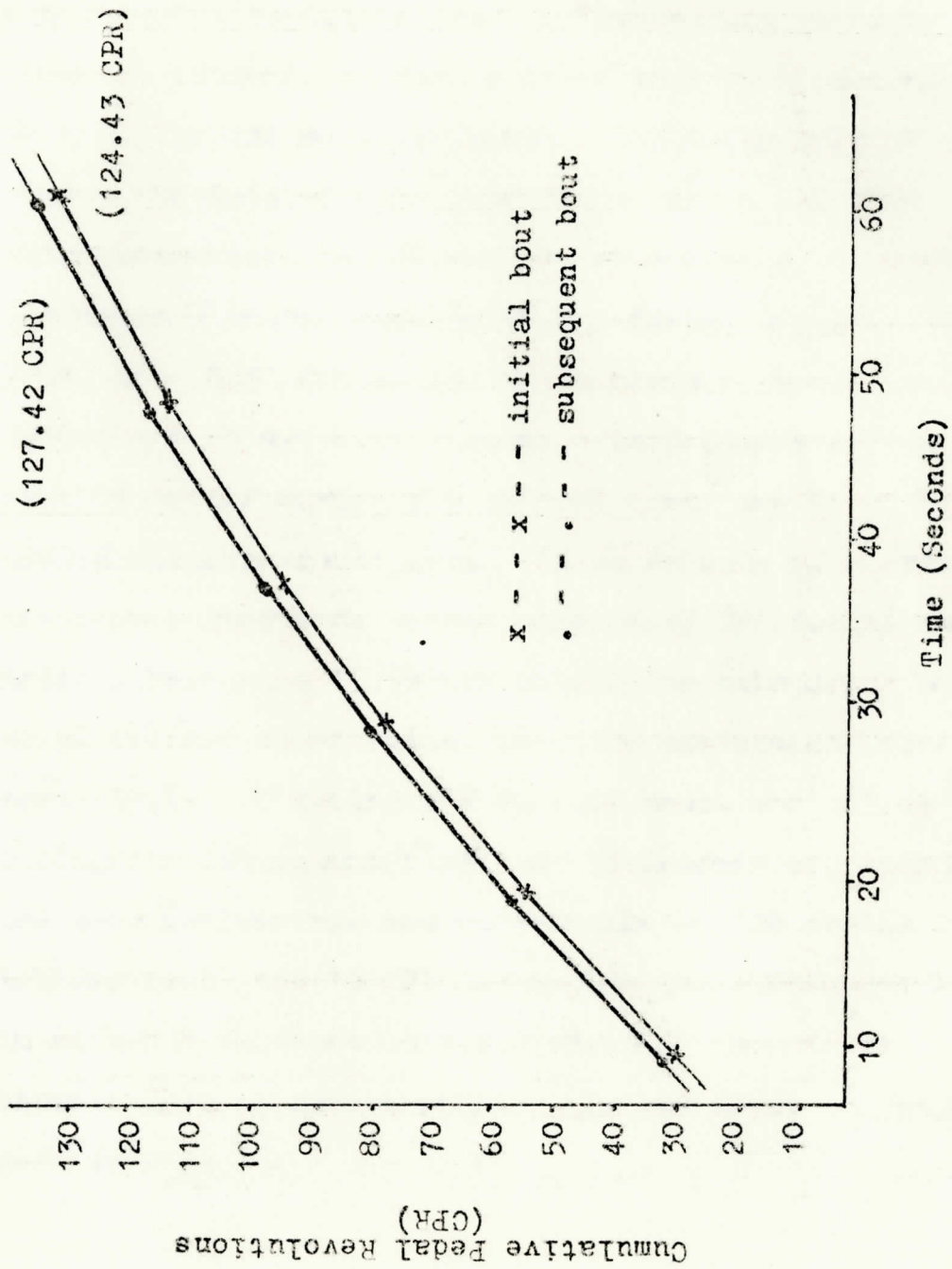
An Analysis of Initial and
Subsequent Performance
Scores During Experimental
Condition Four

In analyzing cumulative pedal revolutions for
experimental condition four, a five-minute passive
recovery pattern, it was observed that at 10 seconds
of exercise the mean performance scores were 26.57 CPR
during the initial bout, and 29.28 CPR during the
subsequent bout. At 20 seconds of exercise, the mean
performance scores were 50.57 CPR during the initial
bout, and 53.57 CPR during the subsequent bout. At
30 seconds of exercise, the mean performance scores
were 71.43 CPR during the initial bout, and 74.43 CPR
during the subsequent bout. At 40 seconds of exercise,
the mean performance scores were 78.57 CPR during the
initial bout, and 92.43 CPR during the subsequent bout.
At 50 seconds of exercise, the mean performance scores
were 106.14 CPR during the initial bout, and 108.29 CPR
during the subsequent bout. At 60 seconds of exercise,
the mean performance scores were 120.86 CPR during the
initial bout, and 122.71 CPR during the subsequent bout.
An observed interaction occurred at 40 seconds of
exercise during experimental condition four, as can be
seen in Figure 8.

Fig. 8.   The Mean Values for Cumulative Pedal
Revolutions During Experimental Condition
Four
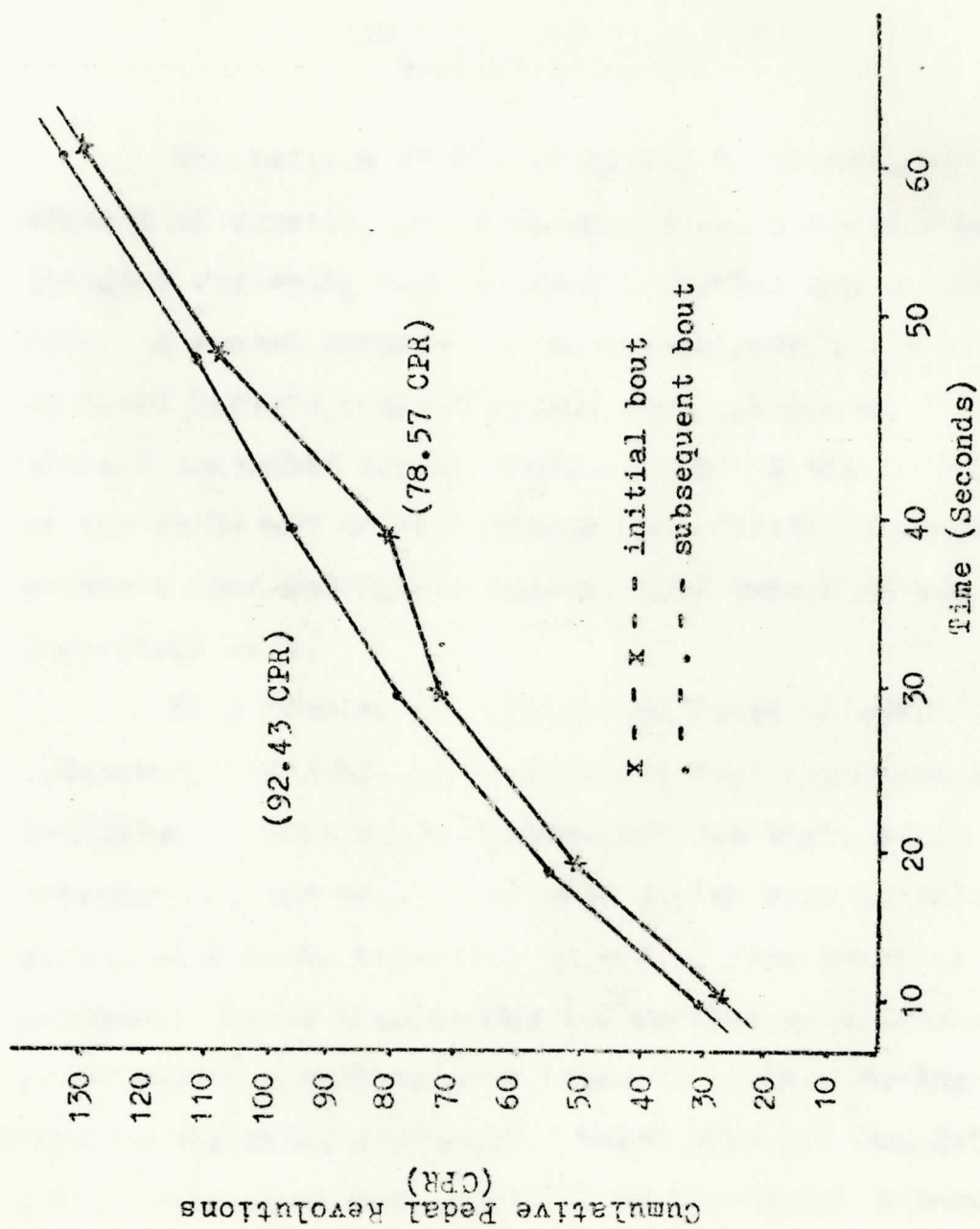
CHAPTER V

FINDINGS, DISCUSSION, AND
RECOMMENDATIONS

The purpose of the study was to investigate the
effects of recovery patterns upon blood lactate concen-
trations following supramaximal anaerobic arm ergometric
work. A second purpose was to investigate the effects
of blood lactate concentrations upon subsequent supra-
maximal anaerobic arm ergometric work. A third purpose
of the study was to investigate the effects of recovery
patterns upon subsequent supramaximal anaerobic arm
ergometric work.

Nine females at Appalachian State University
volunteered as subjects to complete four experimental
conditions. Each subject completed two tests of
supramaximal arm ergometric work during each experi-
mental condition, separated by one of four recovery
patterns. Blood samples for the purpose of determining
lactate concentrations were taken four times during
each experimental condition. Heart rate and cumulative
pedal revolutions were recorded by ten-second intervals
during all anaerobic performances.

Analysis of mean values for blood lactate
concentrations and cumulative pedal revolutions were

illustrated through the use of scatter plot graphs.

Findings

The findings in the study were as follows:

1. In comparing blood lactate levels during experimental
    condition one (a ten-minute active recovery pattern)
    and experimental condition three (a ten-minute
    passive recovery pattern), it was observed that
    prior to exercise, lactate levels were 11.49
    milligram percent and 14.08 milligram percent
    respectively. After the initial exercise bout,
    blood lactate levels rose to 92.09 milligram percent
    for subjects performing experimental condition one,
    and 77.33 milligram percent for subjects performing
    experimental condition three. Following the recovery
    period, blood lactate levels dropped to 65.04
    milligram percent for subjects performing experi-
    mental condition one, and 55.86 milligram percent
    for subjects performing experimental condition three.
    After the subsequent exercise bout, blood lactate
    levels rose to 97.12 milligram percent for subjects
    performing experimental condition one, and 127.48
    milligram percent for subjects performing experi-
    mental condition three.

2. In comparing blood lactate levels during experimental
    condition two (a five-minute active recovery pattern)

and experimental condition four (a five-minute
passive recovery pattern), it was observed that
prior to exercise, lactate levels were 8.91 milligram
percent and 9.66 milligram percent respectively.
After the initial exercise bout, blood lactate
levels rose to 98.49 milligram percent for subjects
performing experimental condition two, and 101.04
milligram percent for subjects performing experi-
mental condition four. Following the recovery
period, blood lactate levels rose to 99.21 milligram
percent for subjects performing experimental
condition two, and dropped to 90.40 milligram
percent for subjects performing experimental condi-
tion four. After the subsequent exercise bout,
blood lactate levels rose to 110.79 milligram
percent for subjects performing experimental
condition two, and 138.08 milligram percent for
subjects performing experimental condition four.

3. In comparing blood lactate levels during experimental
condition one (a ten-minute active recovery pattern)
and experimental condition two (a five-minute active
recovery pattern), it was observed that prior to
exercise, lactate levels were 11.49 milligram per-
cent and 8.91 milligram percent respectively. After
the initial exercise bout, blood lactate levels rose
to 92.09 milligram percent for subjects performing
experimental condition one, and 98.49 milligram

percent for subjects performing experimental condition two. Following the recovery period, blood lactate levels dropped to 65.04 milligram percent for subjects performing experimental condition one and rose to 99.21 milligram percent for subjects performing experimental condition two. After the subsequent bout, blood lactate levels rose to 97.12 milligram percent for subjects performing experimental condition one, and 110.79 milligram percent for subjects performing experimental condition two.

4. In comparing blood lactate levels during experimental condition three (a ten-minute passive recovery pattern) and experimental condition four (a five-minute passive recovery pattern), it was observed that prior to exercise, lactate levels were 14.08 milligram percent and 9.66 milligram percent respectively. After the initial exercise bout, blood lactate levels rose to 77.33 milligram percent for subjects performing experimental condition three, and 101.04 milligram percent for subjects performing experimental condition four. Following the recovery period, blood lactate levels dropped to 55.86 milligram percent for subjects performing experimental condition three, and 90.40 milligram percent for subjects performing experimental condition four. After the subsequent

exercise bout, blood lactate levels rose to 127.48 milligram percent for subjects performing experimental condition three, and 138.08 milligram percent for subjects performing experimental condition four.

5. In analyzing cumulative pedal revolutions (CPR) for experimental condition one during a ten-minute active recovery pattern, it was observed that at 10 seconds of exercise, the mean performance scores were 27.33 CPR during the initial exercise bout, and 27.0 CPR during the subsequent bout. At 20 seconds of exercise, the mean performance scores were 49.43 CPR during the initial bout and 50.57 CPR during the subsequent bout. At 30 seconds of exercise, the mean performance scores were 67.86 CPR during the initial bout, and 70.43 during the subsequent bout. At 40 seconds of exercise, the mean performance scores were 83.0 CPR during the initial bout and 87.57 CPR during the subsequent bout. At 50 seconds of exercise, the mean performance scores were 96.28 CPR during the initial bout, and 102.58 CPR during the subsequent bout. At 60 seconds of exercise, the mean performance scores were 108.0 CPR during the initial bout, and 115.86 CPR during the subsequent bout.

6. In analyzing cumulative pedal revolutions for experimental condition two, a five-minute active

recovery pattern, it was observed that at ten seconds of exercise, the mean performance scores were 28.85 CPR during the initial bout, and 24.71 CPR during the subsequent bout. At 20 seconds of exercise, the mean performance scores were 47.71 CPR during the initial bout, and 46.63 CPR during the subsequent bout. At 30 seconds of exercise, the mean performance scores were 65.71 CPR during the initial bout, and 65.0 CPR during the subsequent bout. At 40 seconds of exercise, the mean performance scores were 81.41 CPR during the initial bout, and 80.86 CPR during the subsequent bout. At 50 seconds of exercise, the mean performance scores were 95.43 CPR during the initial bout, and 95.0 CPR during the subsequent bout. At 60 seconds of exercise, the mean performance scores were 108.14 CPR during the initial bout, and 107.86 during the subsequent bout.

7. In analyzing cumulative pedal revolutions for experimental condition three, a ten-minute passive recovery pattern, it was observed that at ten seconds of exercise, the mean performance scores were 30.71 during the initial bout, and 31.14 CPR during the subsequent bout. At 20 seconds of exercise, the mean performance scores were 54.71 CPR during the initial bout, and 56.0 CPR during

the subsequent bout. At 30 seconds of exercise, the mean performance scores were 75.57 CPR during the initial bout, and 76.43 CPR during the subsequent bout. At 40 seconds of exercise, the mean performance scores were 94.0 CPR during the initial bout, and 95.15 CPR during the subsequent bout. At 50 seconds of exercise, the mean performance scores were 110.29 CPR during the initial bout, and 112.29 CPR during the subsequent bout. At 60 seconds of exercise, the mean performance scores were 124.43 CPR during the initial bout, and 127.42 CPR during the subsequent bout.

8. In analyzing cumulative pedal revolution for experimental condition four, a five-minute passive recovery pattern, it was observed that at ten seconds of exercise, the mean performance scores were 26.57 CPR during the initial bout, and 29.28 CPR during the subsequent bout. At 20 seconds of exercise, the mean performance scores were 50.57 CPR during the initial bout, and 53.57 CPR during the subsequent bout. At 30 seconds of exercise, the mean performance scores were 71.43 CPR during the initial bout, and 74.43 CPR during the subsequent bout. At 40 seconds of exercise, the mean performance scores were 78.57 CPR during the initial bout, and 92.43 CPR during the subsequent bout. At 50 seconds of exercise, the mean performance scores were 106.14 CPR during

the initial bout, and 108.29 CPR during the subsequent bout. At 60 seconds of exercise, the mean performance scores were 120.86 CPR during the initial bout, and 122.71 CPR during the subsequent bout.

Discussion

It had been accepted that lactic acid in the blood was increased as a result of muscular exercise (3, 19, 23). However, the significance of lactate production during muscular exercise, especially during anaerobic exercise has not been widely studied. Therefore, it was the initial purpose of the study to determine whether an active or passive recovery pattern was better for dissipating blood lactate.

Several studies showed that lactate removal was significantly greater when moderate exercise was performed during recovery (3, 9, 10, 23, 32, 40). Support for a passive recovery was based on a study by Katch et al (1978), which showed that a passive recovery resulted in a faster net heart rate recovery, as well as an increase in the rate of return to the baseline level of net oxygen uptake (28: 153-61). In the present study, a trend appeared which favored passive recovery of a shorter duration for dissipating lactic acid. However, another trend emerged favoring active recovery patterns of longer durations as being equal or slightly better for the purpose of dissipating lactic acid.

Ahlborg et al (1975), indicated that during a
passive recovery, the resting muscles exhibited consider-
able metabolic activity. Significant glycogen loss
and electromyographic activity were also reported. There-
fore, the "resting" muscle could be mimicking an active
recovery (1: 718-23). If this were the case, then
factors which had previously been contributed to enhanc-
ing lactate removal during an active recovery, would be
as significant in a passive recovery, but perhaps at a
lower intensity than the actual active recovery.

Bonen and Belcastro (1976) suggested that the
uptake of blood lactate was greater in high oxidative
slow-twitch fibers, since supramaximal anaerobic
exercise recruits predominently low oxidative fast-twitch
fibers. Since lactate will continue to diffuse from
the muscle for a considerable period of time after
exercise has been terminated, it was possible that the
lactate may not only have been taken up from the
circulating blood by the high oxidative slow-twitch
fibers, but also diffused directly from the low oxidative
fast-twitch fibers. In this way recruitment of the
slow-twitch fibers would have enhanced lactate removal
(6: 176-78).

If lactate removal were critical for the resump-
tion of exercise, then recovery patterns in which lactate
removal was enhanced, subsequent performance should have
been significantly increased (40: 786-95). The

present study found that there was not a noticeable
trend favoring any one recovery pattern for the purpose
of increasing work performance on a subsequent anaerobic
test. However, by increasing experimental recovery
times from five to ten minutes more lactate had
dissipated. A ten-minute recovery pattern would allow
for enhanced tissue and glycogen regulation, and faster
energy phosphate resynthesis.

Furthermore, all recovery patterns, apart from
the five-minute active recovery, resulted in a trend
toward an improvement between initial and subsequent
anaerobic performance scores, even though blood lactate
levels were elevated much higher for the subsequent
performance as compared to the initial performance. The
data therefore did not tend to support the theory that
high lactate levels were detrimental to subsequent
anaerobic performance. Lamb (1978) suggested that as
training had often been reported to increase an athlete's
capacity to produce lactic acid during maximal work, this
greater production of lactic acid had been associated with
increased maximal work capacity and a delayed onset of
fatigue. It could therefore be deduced that lactic acid
may not be the single cause of fatigue (31: 184-87).

Although one hour or more for recovery has
previously been required before resting lactate levels
were reached (2: 312-13), considerably less time
appeared to be necessary to obtain pre-recovery exercise

performance scores for high intensity short duration
anaerobic exercise in this study. Subjects performing
any of the four experimental conditions were capable
of reaching or improving upon pre-recovery performance
scores, even with the increased levels of lactic acid
remaining within the body. This suggested that lactate
removal was not critical for subsequent anaerobic
performance, and increased lactate levels found in the
study did not affect subsequent anaerobic performance.
Therefore, fatigue during supramaximal anaerobic perform-
ance may be caused by other factors within the active
muscle.

Recommendations for Further Study

The following recommendations were made for
further study:

1. The same study could be utilized using a
   larger sample of subjects so that results
   could be analyzed statistically.

2. The study would be further strengthened if
   muscle biopsies were taken in order to
   observe what was occuring in the muscle at
   different stages during each condition.

BIBLIOGRAPHY

1. Ahlborg, G; Hagenfeldt, I; Lahren, J. "Substrate Utilization In The Inactive Leg During One Leg or Arm Exercise". _Journal of Applied Physiology_, Vol. 39, 1975.

2. Astrand, P.; Rodahl, K. _Textbook of Work Physiology: Physiological Bases of Exercise_, McGraw-Hill Publishing Company, New York, N.Y., 1977.

3. Bang, O.; "The Lactate Content of the Blood During and After Muscular Exercise in Man". _Scandinavian Archives of Physiology_, Vol. 74, Supplement 10, 1936.

4. Belcastro, A.N.; Bonen, A. "Lactic Acid Removal Rates During Controlled and Uncontrolled Recovery Exercise". _Journal of Applied Physiology_, Vol. 36 (6), 1975.

5. Bergstrom, J.; Harris, R.C.; Hultman, E.; Nordensjo, L.O. "Energy Rich Phosphagens in Dynamic and Static Work", In Pernow, B; Saltin, B. (eds). _Advances in Experimental Medicine and Biology Vol. II: Muscle Metabolism During Exercise_, Plenum Press, Plenum Publishing Corporation, New York, N.Y., 1971.

6. Bonen, A.; Belcastro, A.N. "Comparison of Self-Selected Recovery Methods on Lactic Acid Removal Rates". _Medicine and Science in Sports_, Vol. 8 (3), 1976.

7. Bonen, A.; Campbell, C.; Kirby, R.; Belcastro, A.N. "Relationship Between Slow-Twitch Muscle Fibers and Lactic Acid Removal". _Canadian Journal of Applied Sport Sciences_, Vol. 3, 1978.

8. Brooks, G.A.; Brauner, K.E.; Cassens, R.C. "Glycogen Synthesis and Metabolism with Various Combinations of Arm and Leg Work". _American Journal of Physiology_, Vol. 224, 1973.

9. Davies, C.T.M.; Knibbs, A.V.; Musgrove, J. "The Rate of Lactic Acid Removal in Relation to Different Baselines of Recovery Exercise". Reprint from _International Zeitschrift Fur Angewante Physiologie_.

10. Gisolfi, C.; Robinson, S.; Turrell, E.S. "Effects of Aerobic Work Performed During Recovery From Exhaustive Work". Journal of Applied Physiology, 1966.

11. Gollnick, P.D.; Hermansen, L. "Biochemical Adaptations To Exercise: Anaerobic Metabolism". In Wilmore, J.H. (ed). Exercise & Sport Science Reviews, Vol. I, Academic Press, Inc., New York, N.Y., 1973.

12. Hagberg, J.M. "The Kinetics of Oxygen Consumption and Blood Lactate Levels in Exercise and Recovery". Unpublished Thesis for Ph.D. in Physical Education, University of Wisconsin at Madison, 1976.

13. Hagberg, J.M.; Hickson, R.C.; Ehsani, A.A.; Hollosky, J.O. "Faster Adjustments to and Recovery from Submaximal Exercise in the Trained State". Journal of Applied Physiology, Vol. 48 (2), 1980.

14. Hagberg, J.M.; Mullins, J.P.; Nagle, F.J.; "Oxygen Consumption During Constant-Load Exercise". Journal of Applied Physiology, Vol. 45 (3), 1978.

15. Hermansen, L.; "Lactate Production During Exercise". In Perno , B.; Saltin, B. (eds). Advances in Experimental Medicine and Biology Vol. II: Muscle Metabolism During Exercise, Plenum Press, Plenum Publishing Corporation, New York, N.Y., 1972.

16. Hermansen, L.; Stensvold, I. "Production and Removal Lactate During Exercise in Man". Acta Physiologica Scandinavia, Vol. 86, 1972.

17. Hermansen, L.; Vaage, O. "Lactate Disappearance and Glycogen Synthesis in Human Muscle After Maximal Exercise". American Journal of Physiology, Vol. 233, 1977.

18. Hickson, R.C.; Bomze, H.A.; Hollosky, J.O. "Faster Adjustment of Oxygen Uptake to the Energy Requirement of Exercise in the Trained State". Journal of Applied Physiology, Vol. 44 (6), 1978.

19. Hill, A.V.; Lupton, H. "Muscular Exercise, Lactic Acid, and the Supply and Utilization of Oxygen". Quarterly Journal of Medicine, Vol. 16, 1923.

20. Hultman, E.; Bergstrom, J. "Local Energy-Supplying Substrates as Limiting Factors in Different Types of Leg Muscle Work in Normal Man". In Keul, J. (ed). Limiting Factors of Physical Performance. George Thieme Publishing Co., Stuttgart, Germany, 1973.

21. Issekutz, B.; Shaw, W.A.A.; Issekutz, A.C. "Lactate Metabolism in Resting and Exercising Dogs". Journal of Applied Physiology, Vol. 40 (3), 1976.

22. Ivy, J.L.; Lithers, R.T.; Van Handel, P.J.; Elger, D.M.; Costill, D.L. "Muscular Respiratory Capacity and Fiber Type as Determinants of the Lactate Threshold". Journal of Applied Physiology, Vol. 48 (3), 1980.

23. Jervell, O. "Investigation of the Concentration of Lactic Acid in Blood and Urine". Acta Physiologica Scandinavia, Supplement No. 338, 1928.

24. Jorfeldt, L. "Metabolism of L (-) - Lactate in Human Skeletal Muscle During Exercise". Acta Physiologica Scandinavia, Supplement No. 338, 1970.

25. Jorfeldt, L.; Juhlin-Dannfeldt, A.; Karlsson, J. "Lactate Release in Relation to Tissue Lactate in Human Skeletal Muscle During Exercise". Journal of Applied Physiology, Vol. 44 (3), 1978.

26. Karlsson, J. "Lactate and Phoshagen Concentrations in Working Muscles of Man". Acta Physiologica Scandinavia, Supplement No. 358, 1970-71.

27. Karlsson, J.; Saltin, B.; "Lactate ATP and CP in Working Muscles During Exhaustive Exercises in Man". Journal of Applied Physiology, Vol. 19, 1970.

28. Katch, V.L.; Gilliam, T.; Weltman, A. "Active vs. Passive Recovery From Short-Term Supramaximal Exercise". Research Quarterly, Vol. 49 (2), 1978.

29. Klausen, K.; Knuttgen, H.G.; Forster, H.V. "Effects of Pre-Existing High Blood Lactate Concentration on Maximal Exercise Performance". Scandinavian Journal of Clinical and Laboratory Investigation, Vol. 30, 1972.

30. Knuttgen, H.G. "Lactate and Oxygen Debt: An Introduction in Pernow, B.; Saltin, B. (eds),

Advances in Experimental Medicine and Biology
Vol. II: Muscle Metabolism During Exercise,
Plenum Press. Plenum Publishing Corporation, New
York, N.Y., 1971.

31. Lamb, David R. "Physiology of Exercise: Responses
and Adaptations," McMillan Publishing Company,
Inc., New York, N.Y., 1978.

32. McGrail, J.C.; Bonen, A.; Belcastro, A.N.
"Dependence of Lactate Removal on Muscle
Metabolism in Man". European Journal of Applied
Physiology and Occupational Physiology, Vol. 39,
1978.

33. Newman, E.V.; Dill, D.B.; Edwards, H.T.; Webster,
F.A. "The Rate of Lactic Acid Removal in
Exercise". American Journal of Physiology,
Vol. 118, 1937.

34. Sharkey, Brian J. Physiology and Physical Activity.
Harper and Rowe Publishing Company, New York,
N.Y., 1975.

35. Simonsen, E. "Ischemic Fatigue in Dynamic Work".
In Simonsen, E. (ed). Physiology of Work Capacity
and Fatigue, Charles C. Thomas Publishing Company,
Springfield, Illinois, 1971.

36. Sjodin, B. "Lactate Dehydrogenase in Human
Skeletal Muscle". Acta Physiologica Scandinavia,
Supplement No. 436, 1976.

37. Tesch, P. "Local Lactate and Exhaustion". Acta
Physiologica Scandinavia, Vol. 104, 1978.

38. Tesch, P.; Sjodin, B.; Thorstenssen, A.; Karlsson,
J. "Muscle Fatigue and its Relation to Lactate
Accumulation and LDH Activity in Man". Acta
Physiologica Scandinavia, Vol. 103, 1978.

39. Tibes, U.; Hemmer, B.; Bonning, P. "Heart Rate
and Ventilation in Relation to Venous Osmobility,
PH, PCO_2, PO_2 (Orthophosphate), and (Lactate),
In Athletes and Non-Athletes". European Journal
of Applied Physiology and Occupational Physiology
Vol. 36, 1977.

40. Weltman, A.; Stamford, B.A.; Moffat, R.J.; Katch,
V.L. "Exercise Recovery, Lactate Removal, and
Subsequent High Intensity Exercise Performance".
Research Quarterly, Vol. 48 (4), 1977.

41. Williams, C.; Lyndham, C.; Kok, R.; Von Rahden,
    M.   "Effect of Training on Maximum Oxygen Intake
    and on Anaerobic Metabolism in Man".
    International Zeitschrift Fur Angewande
    Physiologie, Vol. 24, 1967.

APPENDICES

APPENDIX A

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 four (4) test
sessions, each consisting of:

1) A one-minute maximum, all-out test pedalling
an arm ergometer;
2) One of four exercise recovery patterns;
3) A subsequent all-out test on the arm
ergometer.

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 testing, subjects
will be wired to an electrocardiogram via three
electrodes.

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 the pain of application and
removal of electrodes for the electrocardiogram,
and soreness associated with these procedures and
exercises.

3. I have also been informed that all-out 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 four
sessions over a period of three weeks during

February and March. Subjects will be needed
for a maximum of half an hour per session,
Monday-Friday, 3:30-5:30 p.m.

_____
Signature of Subject

_____
Date of Consent

APPENDIX B

List of Pre-Exercise Requirements

1. Please arrive at Human Performance Laboratory (in Varsity Gym), ready to commence testing.

2. Wear loose fitting clothing e.g. track suit, or shorts and T-shirt, etc.

3. Do <u>not</u> wear nylon clothing.

4. Please do not eat three (3) hours prior to testing.

5. Do <u>not</u> exercise one (1) day prior to start of your testing sessions, nor during testing.

6. Do <u>not</u> wear any jewelry to testing session.

APPENDIX C

Table 1. Characteristics of Subjects

Subject	Age (yrs)	Height (ins.)	Weight (lbs.)	$\dot{V}O_2$ max (ml/kg/min)
1	46	62	126	39
2	25	64	119	35
3	24	62	97	32
4	20	62	123	73
5	22	65	132	40
6	21	63	104	49
7	23	67	194	43
8	24	61	98	31
9	27	66	130	34

Master Data Sheet Identifying Subject Cumulative
Revolutions Utilizing Four Recovery Patterns

Time (Seconds)	Exercise Bout	Subject 1	2	3	4	5	6	7	8	9
10	1	20	25	--	28	31	32	33	23	--
	2	20	29	--	29	24	32	33	22	--
20	1	36	46	--	51	56	56	59	42	--
	2	39	52	--	54	51	58	58	42	--
30	1	51	61	--	70	77	77	82	57	--
	2	56	70	--	76	76	79	81	55	--
40	1	64	74	--	84	95	95	100	69	--
	2	71	85	--	95	97	98	100	67	--
50	1	75	86	--	100	111	109	116	77	--
	2	84	98	--	113	115	114	116	77	--
60	1	85	97	--	113	125	123	129	84	--
	2	94	112	--	129	131	129	130	86	--

Recovery Pattern   Active   10 mins.

Subject

Time (Seconds)	Exercise Bout	1	2	3	4	5	6	7	8	9
10	1	24	25	—	31	24	23	33	21	—
10	2	25	20	—	33	25	21	31	18	—
20	1	43	45	—	55	50	45	59	37	—
20	2	47	38	—	60	50	42	55	33	—
30	1	59	61	—	75	70	65	81	49	—
30	2	65	55	—	82	72	61	76	44	—
40	1	72	75	—	92	91	83	100	57	—
40	2	80	70	—	102	90	76	95	53	—
50	1	84	87	—	108	109	97	118	65	—
50	2	93	83	—	120	107	90	111	61	—
60	1	95	97	—	124	126	109	134	72	—
60	2	104	93	—	137	123	102	128	68	—

5 mins. Active Recovery Pattern

63

| Time (Seconds) | Exercise Bout | Subject | | | | | | | | |

63

Subject

Time (Seconds)	Exercise Bout	1	2	3	4	5	6	7	8	9
10	1	22	23	21	30	30	29	32	-	28
10	2	21	22	21	28	32	29	33	-	32
20	1	39	43	36	52	54	51	50	-	48
20	2	41	41	35	52	59	50	62	-	53
30	1	55	59	48	72	77	70	84	-	64
30	2	56	56	46	72	80	68	86	-	71
40	1	68	72	58	89	97	86	106	-	82
40	2	70	69	56	91	100	85	107	-	88
50	1	80	83	66	105	115	99	128	-	96
50	2	83	80	64	109	119	101	127	-	103
60	1	90	92	73	119	130	112	147	-	108
60	2	94	90	71	125	137	114	145	-	116

10 mins. Passive Recovery Pattern

Recovery Pattern   **5 mins. Passive**

Time (Seconds)	Exercise Bout	Subject 1	2	3	4	5	6	7	8	9
10	1	21	21	-	21	26	23	31	20	23
	2	21	23	-	26	26	27	34	19	29
20	1	39	39	-	42	49	44	57	39	45
	2	39	42	-	46	49	50	60	36	53
30	1	54	55	-	61	69	64	80	54	63
	2	56	56	-	65	69	71	82	51	71
40	1	67	69	-	77	88	82	101	67	79
	2	69	69	-	80	87	89	101	63	89
50	1	78	80	-	92	105	97	119	77	95
	2	82	80	-	94	103	105	118	73	103
60	1	87	90	-	106	120	111	138	87	107
	2	93	91	-	108	118	119	134	82	114

APPENDIX E

Preparation of Testing Solution*

1. <u>Eight percent perchloric acid solution</u>:

   8.2 mls of 60% perchloric acid was added to 100 mls
   of the final volume.

2. <u>Enzyme solution</u>:

   2 mls glycine buffer solution (Sigma stock no. 826-3).

   3.1 mls H_2O.

   0.1 ml enzyme (LDH-Sigma stock no. 826-6), was added
   to an NAD vial (Sigma stock no. 260-110) containing
   10 mg NAD.

3. <u>Lactic acid standard stock</u>:

   1.0 ml of lactic solution (Sigma stock no. 826-10).

   3.5 mls of 7% perchloric acid.

   Standards were prepared by diluting the lactic acid
   stock with a dilutant.

4. <u>Dilutant</u>:

   2 mls H_2O.

   1 ml of NaF.

   6 mls of 7% perchloric acid

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*Sigma chemicals may be purchased from Sigma Chemicals,
Inc., P.O. Box 14508, St. Louis, Missouri 63178.

Master Data Sheet Identifying Subject Blood Lactate Levels Utilizing Four Recovery Patterns

Recovery Patterns	Blood Sample	Subject								
		1	2	3	4	5	6	7	8	9
Active 10 mins.	1	10.1	10.9	—	3.3	8.0	13.0	6.5	28.6	—
	2	62.8	82.9	—	76.7	113.7	133.4	98.8	76.3	—
	3	58.1	45.0	—	43.4	81.5	81.5	63.6	74.5	—
	4	87.1	96.5	—	96.6	65.1	129.9	111.9	87.7	—
Active 5 mins.	1	5.6	7.8	—	9.5	7.5	14.5	8.5	8.8	—
	2	61.8	128.9	—	152.0	81.5	108.7	110.1	46.4	—
	3	56.8	94.9	—	151.3	95.1	112.0	93.2	91.1	—
	4	97.8	112.1	—	187.9	119.1	93.6	92.0	72.8	—
Passive 10 mins.	1	7.1	12.5	12.3	9.6	12.7	13.1	15.6	—	—
	2	65.1	63.3	70.3	71.5	65.8	54.4	130.9	—	—
	3	45.6	66.9	77.7	41.2	—	58.3	101.3	—	—
	4	84.1	175.2	150.1	79.2	40.1	102.6	161.0	—	—
Passive 5 mins.	1	7.2	8.2	8.7	8.7	5.5	12.3	9.1	7.1	9.3
	2	51.0	78.9	82.7	87.7	86.7	111.0	53.9	164.1	78.8
	3	36.4	65.9	—	—	85.9	102.3	88.9	168.4	84.8
	4	67.8	95.8	131.9	131.9	115.2	122.0	105.0	183.6	145.1

VITA

Fern Allison Cowen

Candidate For The Degree Of
Master of Arts

In Health & Physical Education

BORN: September 1, 1957
        Calcutta, India

EDUCATION:

        Northumberland College of Higher Education
        Ponteland
        Newcastle-Upon-Tyne
        England
        1976-1979

        St. Catherines R.C. School
        Watling Street
        Bexleyheath
        Kent, England
        1972-1976

        Bexleyheath Comprehensive School
        Bexleyheath
        Kent, England
        1968-1972

DEGREE:

        Certificate of Education
        Majors: Physical Education
                 Education

        Minors: Environmental Science
                 Art & Design

CERTIFICATION:

        Secondary 11-18 years