View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Eastern Illinois University

Eastern Illinois University
The Keep

Masters Theses

Student Theses & Publications

1976

Lactate Removal from the Blood of Trained Distance Runners Following Strenuous Intermittent Exercise

Benjamin F. Timson
Eastern Illinois University

This research is a product of the graduate program in Physical Education at Eastern Illinois University. Find out more about the program.

Recommended Citation
Timson, Benjamin F., "Lactate Removal from the Blood of Trained Distance Runners Following Strenuous Intermittent Exercise" (1976). *Masters Theses*. 3463.
https://thekeep.eiu.edu/theses/3463

This is brought to you for free and open access by the Student Theses & Publications at The Keep. It has been accepted for inclusion in Masters Theses by an authorized administrator of The Keep. For more information, please contact tabruns@eiu.edu.

LACTATE REMOVAL FROM THE BLOOD OF TRAINED DISTANCE RUNNERS FOLLOWING STRENUOUS INTERMITTENT EXERCISE

(TITLE)

BY

BENJAMIN F. TIMSON

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN PHYSICAL EDUCATION

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1976
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

7-27-76
DATE

ADVISER

7/26/76
DATE

PAPER CERTIFICATE #2

TO: Graduate Degree Candidates who have written formal theses.

SUBJECT: Permission to reproduce theses.

The University Library is receiving a number of requests from other institutions asking permission to reproduce dissertations for inclusion in their library holdings. Although no copyright laws are involved, we feel that professional courtesy demands that permission be obtained from the author before we allow theses to be copied.

Please sign one of the following statements:

Booth Library of Eastern Illinois University has my permission to lend my thesis to a reputable college or university for the purpose of copying it for inclusion in that institution's library or research holdings.

7-27-76
Date

Author

I respectfully request Booth Library of Eastern Illinois University not allow my thesis be reproduced because_____

_____

_____

_____
Date

_____
Author

pdm

ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Dr. M. Thomas Woodall for his guidance and direction in the completion of the study.

Appreciation is also extended to Dr. Walter S. Lowell and Dr. William F. Buckellew for their constructive criticism in the preparation of the paper.

The writer wishes to sincerely thank Dr. Sidney R. Steele, head of the Chemistry Department, for making available much of the equipment used in the study and Dr. C. Dan Foote and Dr. Karen Ferguson for their help in the chemical analyses required in the study. Thanks is also extended to the Eastern Illinois University Run for Your Life Program, for without their financial assistance the study could not have been undertaken.

The writer is grateful to the subjects who gave many hours of their time and put forth a great deal of effort to make the study possible, and to his wife, Kathy, for her patience and understanding which made the completion of the study a reality.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Many times upon completion of a race or hard work-out, a young athlete will throw himself to the ground in exhaustion, only to hear his coach shout, "get up and move around." For a number of years the practice of many coaches has been to have their athletes warm-down following strenuous activity. The intensity and duration of the warm-down period, however, is a topic upon which many coaches differ.

The purpose of the warm-down period is to prevent muscle stiffness and soreness which is a common aggravation witnessed by many individuals for a period of a few days following intense exercise. According to Shephard (17:193) immediate stiffness is due to an accumulation of fluid within the muscle which makes the fibers thicker, shorter, and more resistant to stretch. Soreness is caused by stimulation of pain receptors, which may be due to local accumulation of lactate and other metabolites. Shephard stated:

> Soreness and stiffness are important negative factors in reducing interest in and enthusiasm for an exercise program. It is thus vital that their incidence should be held to a minimum. The preventive value of a warm-up has been noted. A warm-down is also important, gentle activity following a contest promotes circulation through the previously

> active tissue, assisting in the removal of metabolites, and helping return fluid to the central circulation. Sudden cessation of activity while standing may lead to circulatory collapse.

The production of lactate occurs when one is not able to meet the energy demand of exercise by oxygen consumption. If the accumulation of lactate reaches high levels it will eventually lead to a reduced contractile power of the muscle which will cause cessation of work (2:33). The removal of the lactate produced during exercise is important to all athletes.

Energy for muscular contraction in an anaerobic state is derived from a series of chemical reactions called glycolysis. Anaerobic glycolysis is a series of ten reactions in which one mole of glucose is broken down into two moles of lactate. This reaction series forms two moles of adenosine triphosphate (ATP) which can then be used to supply energy for muscular contraction.

The final reaction of anaerobic glycolysis is the reduction of pyruvate to lactate in accordance with the following equation:

$$\underset{\text{pyruvate}}{CH_3\text{-}\overset{O}{\overset{\|}{C}}\text{-}COO^-} + NADH \overset{LDH}{\rightleftharpoons} \underset{\text{lactate}}{CH_3\text{-}\overset{OH}{\overset{|}{C}}H\text{-}COO^-} + NAD^+$$

Under anaerobic conditions the major portion of pyruvate is converted to lactate, which readily diffuses out of the muscle cell and into the extracellular fluid,

Therefore, lactate formation is an escape for glycolytic end products, thus allowing glycolysis to proceed much longer than if pyruvate was not removed from the reaction medium. (8:796).

When muscle cells of higher animals function anaerobically during short bursts of exceptionally vigorous activity, lactate escapes from the muscle cell into the blood in large quantities as waste. Fatigue in muscle fibers is due in part to their acidification, thus a large build up of lactate in the muscle fiber will cause fatigue (12:326). Lactate is removed from the muscle cell by diffusion into the blood where it is then carried to the liver and converted to glucose (12:326). Therefore, the rate of lactate removal from the blood is a good indication of the rate of lactate removal from the muscle.

PURPOSE OF THE STUDY

The purpose of the study was to investigate the rate of lactate removal from the blood of trained distance runners, during recovery from maximal intermittent exercise.

NEED FOR THE STUDY

In recent years several studies have been conducted to determine the rate of lactate removal following exercise, by using different warm-down procedures (4,10,19). These

studies have reported the activity of the warm-down procedure as a percentage of the maximum oxygen consumption ($\dot{V}O_{2\ max}$) of the subject. This type of warm-down procedure is difficult to interperet for a coach in a field situation. The coach very seldom has any idea of what the $\dot{V}O_{2\ max}$ of the athlete is, let alone the quantity of activity required to produce a certain percentage of that $\dot{V}O_{2\ max}$.

Since the determination of the intensity of the warm-down procedure from these previous studies is difficult to interperet the need for a study which used warm-down procedures of predetermined pace was evident.

NULL HYPOTHESIS

In order to determine if there was a statistically significant difference in the rate of lactate removal during recovery of different intensities from maximal intermittent exercise, the null hypothesis stating that there is no difference in the rate of lactate removal was investigated.

LIMITATIONS

The study was limited to five well trained college age distance runners.

DEFINITIONS

To promote a better understanding the investigator felt the following terms should be defined:

Centrifuge

A centrifuge is a rotary instrument used to separate substances of different densities.

Lactate Dehydrogenase (LDH)

Lactate dehydrogenase is the enzyme that catalyzes the reversible reaction of pyruvate to lactate.

Nicotinamide Adenine Dinucleotide

Nicotinamide adenine dinucleotide is the coenzyme involved in the reversible reaction of pyruvate to lactate. In its oxidized form (NAD^+) it will oxidize lactate to pyruvate, in its reduced form (NADH) it will reduce pyruvate to lactate.

Spectrophotometer

A spectrophotometer is an instrument used to measure the light absorbance of a solution.

Supernatant

The supernatant is the liquid portion at the top of a test tube following centrifugation.

Warm-Down

Warm-down is the 30 minute period of activity immediately following maximal intermittent exercise.

SUMMARY

Lactate is produced in the muscle during intense exercise and if it is not removed from the muscle following

exercise it will very likely cause soreness. The purpose of the study was to investigate the rate of lactate removal from the blood of trained distance runners during recovery from maximal intermittent exercise.

Chapter 2

REVIEW OF RELATED LITERATURE

Very few statements are found in physiology textbooks, or in physical education and athletic journals concerning the effects of warm-down on the physiological responses of the human organism. Similarly, little research has been reported in this area. This chapter has been categorized into the following sections: lactate production during exercise, the effects of warm-down on muscle soreness, lactate removal following exercise, and the fate of lactate during recovery.

LACTATE PRODUCTION DURING EXERCISE

Lactate is produced in the muscle during strenuous work as a result of anaerobic glycolysis. Lactate is a small ion which easily diffuses across the muscle cell membrane into the blood.

Åstrand et al. (1) studied blood lactate concentration in 24 subjects after severe exercise of different duration. They found that in cross country skiing competition lasting for 35-36 minutes, the blood lactate was elevated from resting values of approximately 10 milligrams percent (mg%) to 139 mg%. In competition lasting from 110-116 minutes and 186-198 minutes the lactate values

increased to only 69 mg% and 39 mg% respectively. It was concluded that exercise which led to exhaustion in a shorter period of time caused the blood lactate concentration to increase to a greater value than exercise that led to exhaustion after a longer period of time.

Saltin and Essén (16) studied lactate production in three subjects during intermittent exercise lasting for 30 minutes. The subjects performed work for a predetermined amount of time followed by a rest period of twice that duration. Four different work time periods were used, 10, 20, 30, and 60 seconds. It was found that if exercise was performed for 10 second time periods the blood lactate concentration was elevated only from 1.1 millimolar (mM) (9 mg% = 1.0 mM) to 1.8 mM. Exercise of 20 and 30 seconds produced blood lactate values of 3.0 mM and 8.0 mM respectively. Intermittent exercise of 60 seconds produced blood lactate concentrations of 18.0 mM. According to these data it seemed that during intermittent exercise a work period of 60 seconds was necessary to produce a high blood lactate concentration. Work periods of a shorter duration did not produce values nearly as high.

Hermansen (9) examined blood lactate values on seven subjects during maximal intermittent exercise of one minute in duration with a four minute rest period between bouts. He found that blood lactate values increased after each of five work bouts to extremely high values. The highest were of a magnitude of 31.1 to 32.0 mM.

THE EFFECTS OF WARM-DOWN ON MUSCLE SORENESS

de Vries (5:138) described warm-down as being a common practice in athletic events that involve large circulatory adjustments. He suggested that this procedure is based on sound physiological principles and should be encouraged. He stated that if warm-down is not done, the venous blood return to the heart will drop too quickly, and blood pooling may occur in the extremities, which may result in shock, hyperventilation, and muscle soreness.

Shephard (17:193) stated that immediate muscle soreness is due to an accumulation of fluid within the muscle which makes the fibers more resistant to stretch. Soreness is also caused by stimulation of pain receptors, which may be due to a local accumulation of lactate and other metabolites. A short warm-down period following severe exercise should be performed by the athlete to help curb muscle soreness.

Cretzmeyer, Alley, and Tipton (3:33) stated that one of the problems confronting the athlete during the early season is muscle soreness. Sore muscles are perceived by sensory discharges from nerve fibers. This condition is associated with muscle ischemia, accumulation of metabolic by-products and the accumulation of fluids. The net effect is that the nerve endings are stimulated and discomfort is experienced. Removal of these products by the circulatory system, through a warm-down is associated with relief.

Wilt (20:256) described warm-down as exercise gradually diminishing in intensity following severe exertion, to return the body functions to a pre-exercise state. The purpose of a warm-down is to eliminate muscle soreness. He indicated that the athlete should jog, then shack (very slow bounding jog), and finally walk for a period of five to ten minutes.

LACTATE REMOVAL FOLLOWING EXERCISE

In 1937, Newman et al. (14) investigated the rate of lactate removal from the blood of three subjects. The subjects ran on a treadmill at 18.7 km/hr. and 12% grade until exhaustion. Recovery was on the treadmill at rates up to 12 times the basal oxygen consumption for 45 minutes. It was determined that the rate of lactate removal in recovery increased proportionately with the metabolic rate up to some critical level of activity, different for each subject.

In 1949, Rämmal and Ström (15) studied the rate of lactate removal following exercise on a bicycle ergometer. Two subjects performed continuous work for a period of 25 minutes at a level of 1260 kgm/min. Lactate removal was followed during recovery periods of 0, 540, 720, and 900 kgm/min. It was found that the optimal recovery level was 720 kgm/min.

In 1966, Gisolfi et al. (6) studied the effect of aerobic activity performed during recovery from exhausting

work. Four physically fit subjects performed a continuous exhausting run on a treadmill for three to five minutes. Lactate removal was monitored during a rest-recovery and an exercise-recovery period. It was found that lactate removal during the exercise-recovery was significantly higher than the rest-recovery in all subjects.

In 1969, Stensvold and Hermansen (19) studied the rate of lactate removal in five subjects following exhaustive intermittent exercise. Five different recovery intensities were used; rest, 30, 60, 70, and 80% of the subject's $\dot{V}O_{2\ max}$. It was found that lactate removal increased at recovery rates up to 60% of the subject's $\dot{V}O_{2\ max}$ and then decreased at 70 and 80%. It was concluded that recovery periods requiring the subject to perform aerobic work at 60-70% of his $\dot{V}O_{2\ max}$ was best for lactate removal.

In 1970, Davies et al. (4) investigated the rate of lactate removal during recovery of different intensities. The exhaustive work and recovery exercise was performed on a bicycle ergometer. The recovery intensities included aerobic work performed at 20, 30, 40, and 60% of the subject's $\dot{V}O_{2\ max}$. It was found that the maximal lactate removal rate occurred when aerobic exercise requiring 40% of the individual's $\dot{V}O_{2\ max}$ was performed.

This study was followed by another investigation by Hermansen and Stensvold (10), in 1972. They studied lactate removal from the blood of seven subjects during recovery from maximal intermittent exercise. The recovery

periods included aerobic work performed at 0, 30, 60, 70, and 80% of the individual's $\dot{V}O_{2\ max}$. The results of this study agreed with the results of their earlier study. The lactate removal rate was higher during exercise than during rest, and increased with increasing work load up to a critical level (60-70% of $\dot{V}O_{2\ max}$), beyond which a reduction was observed.

FATE OF LACTATE DURING RECOVERY

The fate of lactate produced during exercise has been studied extensively for many years, but the problem remains far from solved. Two excellent reviews (7,11), which cited research by several authors on this topic, have been written by leaders in this field and it is the purpose of this section to bring out the main points of those reviews.

The locations of removal and fate of lactate and the various removal sites are only partially understood. Removal has been observed in the heart, liver, and in resting limbs with resting skeletal muscle tissue presumably playing a dominant role in the latter. The kidneys might remove a significant quantity through gluconeogenesis. Negligible amounts are also found in urine or excreted in sweat.

Lactate appears to be used as a substrate in the heart and skeletal muscle. It is generally believed that it is impossible for gluconeogenesis to occur in human skeletal muscle because the enzymes necessary to convert pyruvate to phosphoenolpyruvate are not present. In the

liver, it is generally believed that lactate undergoes gluconeogenesis.

It has been estimated that approximately 50% of the total amount of lactate eliminated is removed by the liver, indicating that the liver is the main site for lactate removal during recovery exercise. However during these studies the blood lactate and the total amount of lactate removed amounted to approximately 150 mg/min which was only about 3-4% of the total amount of lactate removed in a different study.

The importance of the working skeletal muscles in the removal of lactate has been neglected. The skeletal muscles constitute the largest organ in the body representing approximately 40% of the body weight. Furthermore, it is known that the splanchnic blood flow is reduced markedly during exercise. A similar reduction in blood flow also occurs in other organs as well. On the other hand, the blood flow through the working skeletal muscle is increased with increasing work load, and thus the turnover of metabolic substrates is high.

It was thus concluded that the skeletal muscle, rather than the liver may be the main site for the removal of lactate during recovery exercise. This conclusion was based on the assumption that the oxidation of lactate in the working muscles is the preferred pathway, rather than oxidation or gluconeogenesis in other tissues.

SUMMARY

It has been known for a long time that if light exercise is performed during a period of time immediately following strenuous activity the rate of lactate removal from the blood will be increased. There seems, however, to be a different optimum level at which this exercise should be performed, which is dependent upon the type of exercise performed. If the subject is running on a treadmill, it appears that the optimum level is in the range of 60-70% of his $\dot{V}O_{2\ max}$. If the exercise is performed on a bicycle ergometer, the optimum level appears to be approximately 40% of the $\dot{V}O_{2\ max}$ of the subject.

Chapter 3

METHODOLOGY

The purpose of the study was to investigate lactate removal from the blood of trained subjects during three separate recovery periods of different work intensities. The description of the subjects, testing procedures, and the instruments used in the testing are included in this chapter.

SUBJECTS

Five well trained male subjects were selected for the study. The physical characteristics of the subjects have been presented in Table 1.

Table 1

Physical Characteristics of the Subjects

Subject	Height (cm)	Weight (kg)	$\dot{V}O_{2\ max}$ (ml/kg/min)
JK	168	59.77	72.28
GM	183	72.95	67.03
BC	175	66.48	71.15
KB	177	62.20	68.32
RJ	168	63.40	70.18
Mean	174	64.96	69.79

Four of the subjects were members of the Intercollegiate Cross Country team and one was a member of the Intercollegiate Soccer team at Eastern Illinois University during the fall of 1975. The subjects had continued their training during the winter and were all in good physical condition.

PRELIMINARY INFORMATION

Prior to the actual testing procedure preliminary data were collected on each subject. These data included maximum oxygen consumption ($\dot{V}O_{2\ max}$), resting blood lactate level, and oxygen consumption ($\dot{V}O_2$) during running and walking at different submaximal work loads.

$\dot{V}O_{2\ max}$ was determined by having the subject run uphill on the treadmill until he experienced a feeling of exhaustion. The subject started running at eight miles per hour (mph) with no treadmill elevation. After two minutes the speed was increased to ten mph. Following two minutes at this speed, the grade was raised to six percent. Every two minutes from this point the grade was raised another two percent while the speed remained constant. Once the grade became ten percent it was no longer raised. Two expired air samples were taken during the run. The first was a 30 second sample taken during the time period from 5:30 to 6:00 from the beginning of the run. The last sample was taken during the final 30 seconds of the run. The timing of the final sample was left to the discretion

of the subject who was instructed to place the mouthpiece in his mouth when he felt that he could only run for another 45 seconds. The exact test procedure has been placed in Appendix A. The oxygen consumed in the last sample was determined to be the $\dot{V}O_{2\ max}$ of the subject.

The resting blood lactate level for each subject was determined by drawing a three cubic centimeter (cc) sample of blood from an arm vein of the subject with a sterile syringe, while the subject was at rest. The subject was instructed not to perform any intense exercise during the day on which the sample was to be taken. The blood was analyzed by the process discussed later in this chapter.

The $\dot{V}O_2$ for each subject was measured at four sub-maximal work loads, six, seven, eight, and nine mph with no grade. This was done to determine at what percentage of the individual's $\dot{V}O_{2\ max}$ he was working at these loads. The subject ran at each speed for five minutes. During the final 30 seconds of each period, an expired air sample was taken. The $\dot{V}O_2$ of each sample was compared to the $\dot{V}O_{2\ max}$ of the subject to determine the percentage required to perform the work.

TESTING PROCEDURES

Each subject was tested on three different occasions using a different method of recovery from standardized treadmill running, on each occasion. All of the testing

took place in the Human Performance Laboratory at Eastern Illinois University.

Pre-Exercise Procedures

The subject reported to the laboratory at an appointed time dressed in running shorts and shoes. The subject's body weight (wearing shorts only) was taken. Surface electrodes were then placed on his chest at three positions, on the sternum approximately two inches above the level of the nipples, and one approximately two inches below each nipple. The subject was then taken to the treadmill and the electrode wires were connected to the Sanborn 500 Viso-Cardiette. A ten minute warm up procedure which consisted of five minutes of jogging followed by five minutes of stretching was initiated as shown below.

	Time (min)	Speed (mph)	Grade (%)
A. Five minute jog	0-1	6	0
	1-2	8	0
	2-3	8	6
	3-4	6	6
	4-5	6	0
B. Five minutes of stretching			

Exercise Procedures

The exercise consisted of two minute bouts of treadmill running at ten mph up an 8.6% grade. Between exercise bouts the subject stood at rest on the treadmill for two minutes. Each subject performed three bouts. If

following the third bout the subject felt that he could continue, he started a fourth bout at the same speed and grade. This bout was continued until the subject felt that he could not continue. Expired air samples were taken during the final 30 seconds of each exercise bout. Heart rates were recorded during the final 30 seconds of each exercise bout and during the rest period between each bout.

Recovery Procedures

Three recovery periods of different work intensities were used in the study. Each recovery period was 30 minutes in duration. One recovery period consisted of the subject sitting in a chair that was placed on the treadmill. Another consisted of the subject walking on the treadmill at four mph with no grade. The third consisted of the subject jogging on the treadmill at eight mph with no grade. The order in which the recovery periods were performed was varied with each subject, so that the same sequence of recovery periods was not performed by any two subjects, thus eliminating any training effect.

Expired air samples were obtained during the recovery period at 30 second intervals between 2:30-3:00, 14:30-15:00, and 29:30-30:00 following exercise. Heart rates were taken at random during the recovery periods. Blood samples were drawn from an arm vein of the subject with a three cc sterile syringe during the recovery period at five, 15, and 30 minutes following exercise.

Gas Analysis

Expired air samples were collected by having the subject inspire air through a rubber mouthpiece which was attached to a triple-J valve. A rubber nose clip prevented the subject from respiring through his nose. Room air was taken in by the subject through a Parkinson-Cowan CD-4 meter which measured the volume of air moved by the subject. The expired air was blown through the triple-J valve into a plexyglass chamber which mixed the air. A vacumn pump with a rubber hose attached to the chamber, pulled out a sample of the expired air and forced it into a small aluminum bag. The temperature of the expired air was measured with a Yellow Springs Telethermometer. By using the temperature of the gas and the barometeric pressure, the standard temperature and pressure of the dry gas was determined by a nomogram. The subject's pulmonary ventilation, true O_2, and $\dot{V}O_2$ were determined via nomograms and a metabolic work sheet. This work sheet has been presented in Appendix B.

Blood Analysis

The blood samples were analyzed for lactate concentration employing the procedure described in Appendix C.

SUMMARY

Five well trained college age males were used as subjects in the study. Each subject was tested on three

different occasions using a different method of recovery from standardized treadmill running on each occasion. Lactate removal from the blood was followed during each 30 minute recovery period. The data on the lactate level collected on each subject has been placed in Appendix D. The procedures used to obtain the data have been discussed in this chapter. All testing and analyses were conducted in the Human Performance Laboratory and the Biochemistry Laboratory at Eastern Illinois University.

Chapter 4

ANALYSIS OF THE DATA

The study was conducted to investigate the effect of three warm-down intensities on the rate of lactate removal from the blood of trained subjects. Blood lactate concentrations were determined during three separate warm-down procedures following maximal intermittent exercise bouts. Oxygen consumption ($\dot{V}O_2$) and heart rate were also determined during the exercise bouts and warm-down procedure so as to evaluate the intensity of the work and recovery periods.

DATA CONVERSION

The heart rates were recorded by the Sanborn 500 Viso-Cardiette and converted to beats per minute (bpm). The $\dot{V}O_2$ data were corrected to Standard Temperature and Pressure Dry (STPD) and $\dot{V}O_2$ was expressed in milliliters per kilogram of body weight per minute (ml/kg/min). The blood lactate data were expressed in milligrams of lactate per 100 milliliters of blood (mg%).

STATISTICAL TREATMENT

The Friedman two-way analysis of variance by ranks (18:166) was applied to the raw data to determine

whether there were any statistically significant differences between the mean blood lactate values of the three warm-down procedures. This method was chosen because of the small number of subjects, and because it could be applied to the same group of subjects under each of the three conditions.

The .05 level of confidence was established for the study to demonstrate statistical significance. To determine the integer for statistical significance tables listed in Siegel (18:280) were consulted.

FINDINGS

Exercise Heart Rates and $\dot{V}O_2$

Heart rates and $\dot{V}O_2$ measurements were determined during the final 30 seconds of each two minute exercise bout.

The mean values of these measurements have been placed in Figure 1. The mean heart rate and $\dot{V}O_2$ for the first two minute bout were 171 bpm and 60.88 ml/kg/min respectively. At the completion of the third bout of exercise the mean values had risen to 180 bpm and 64.57 ml/kg/min respectively.

Recovery Heart Rates

Heart rates during recovery periods were randomly recorded, therefore, an intersubject comparison was not possible. However, the mean values for several

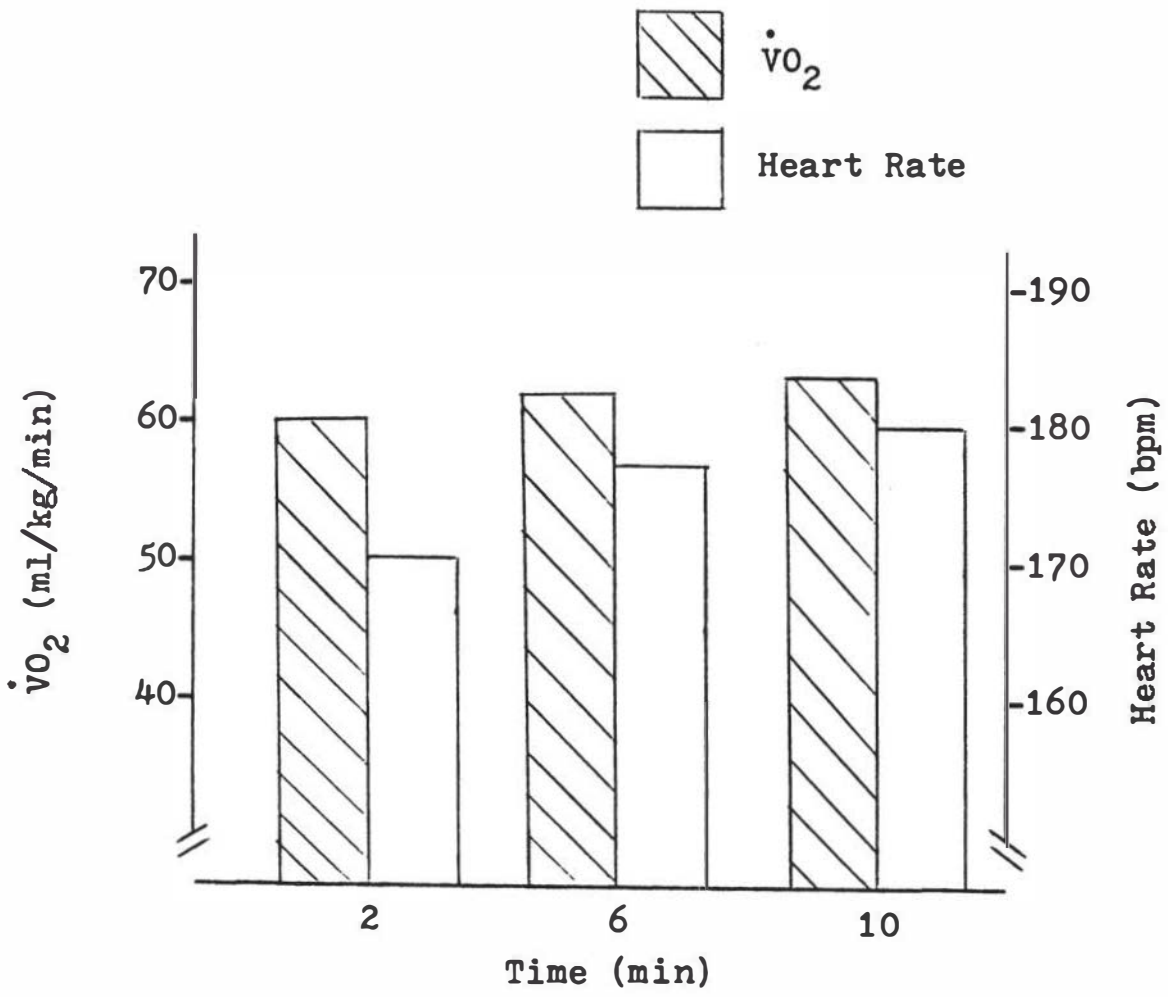

Figure 1

Exercise Heart Rates and $\dot{V}O_2$

subjects taken at the same time at various points during each recovery period have been placed in Figure 2. The mean heart rate immediately following the third exercise bout was 180 bpm. This mean rate dropped to 155 bpm five minutes following exercise during the jog recovery period and 153 bpm 30 minutes following exercise. The mean heart rate dropped to 122 bpm and 101 bpm five minutes following exercise during the walk and sit recovery periods respectively. Thirty minutes following exercise the heart rate had dropped to 109 bpm and 88 bpm during the walk and sit recovery periods respectively. During all three recovery periods there was a large initial drop in the heart rate during the first five minutes of recovery which tended to level off during the last 25 minutes of the recovery period.

Lactate and $\dot{V}O_2$ During Recovery

Blood samples were drawn from an arm vein of the subject five, 15, and 30 minutes following the final two minute work bout. $\dot{V}O_2$ was determined just prior to each blood sample. The mean values of these data have been placed in Figure 3.

The mean blood lactate values during the sit recovery period decreased from 135.97 mg%, five minutes following exercise, to 71.24 mg% 30 minutes following exercise. During the walk recovery period the mean value five minutes following exercise was 129.54 mg%, this value dropped to 41.14 mg% 30 minutes following exercise. The

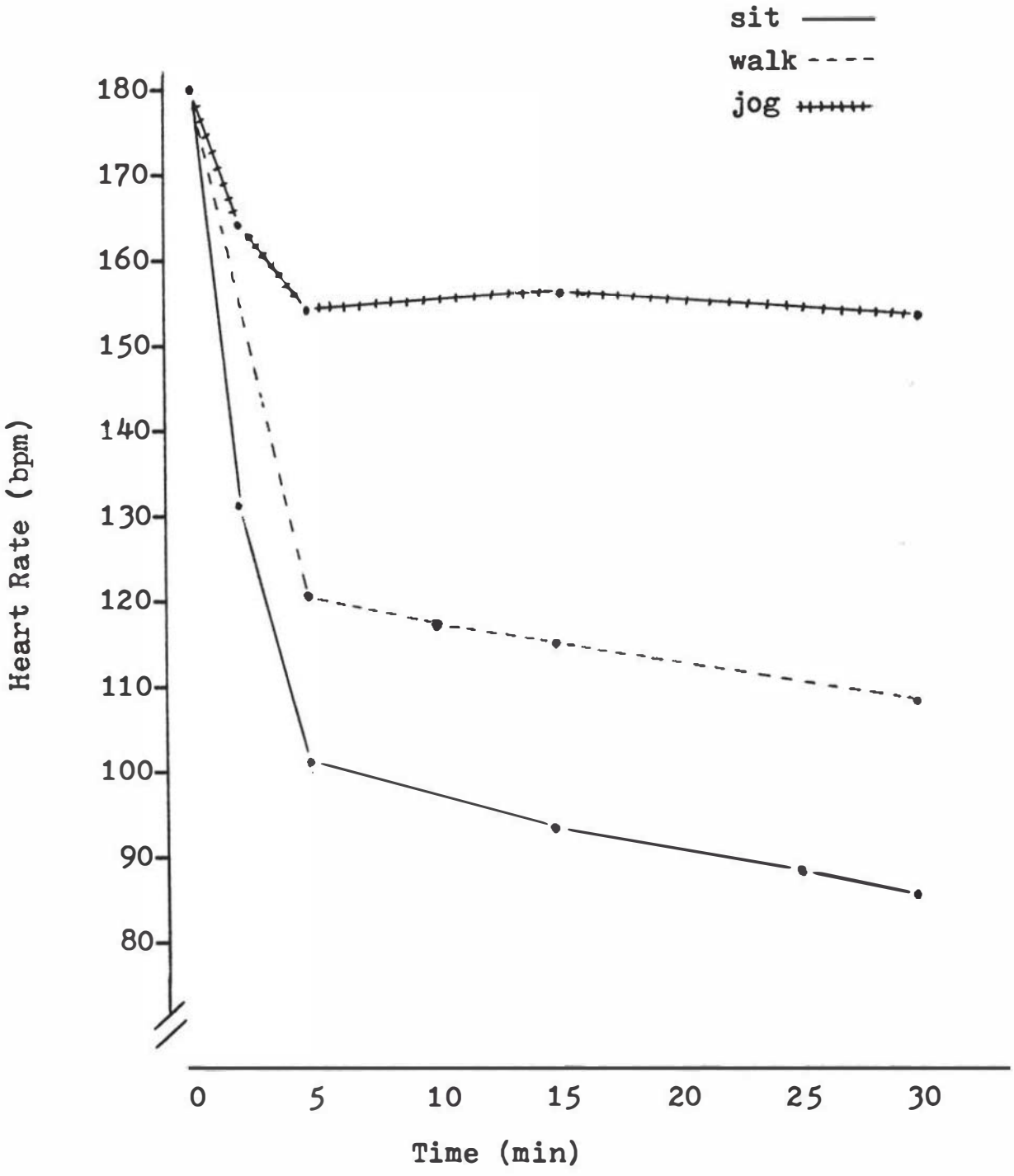

Figure 2

Recovery Heart Rates

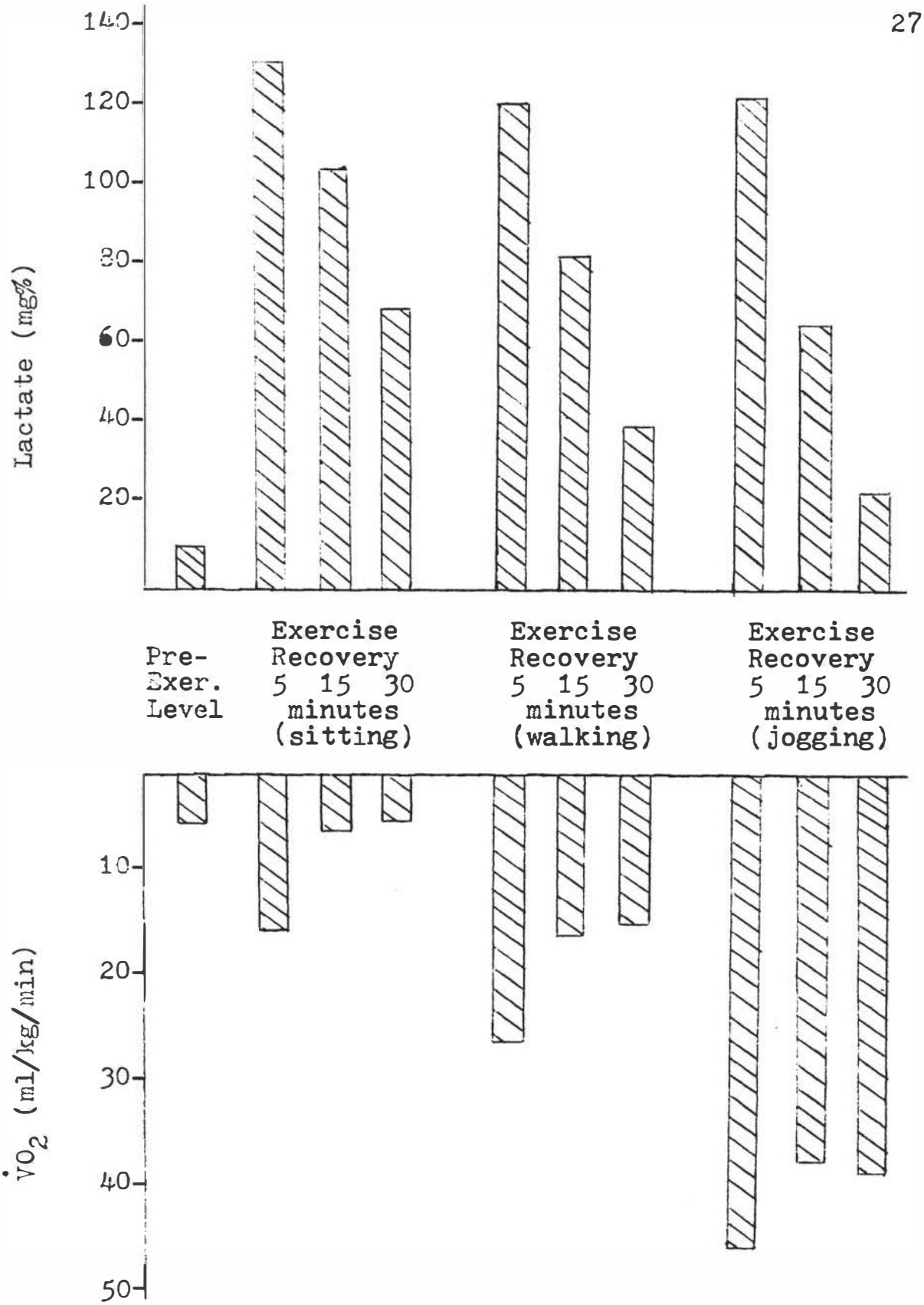

Figure 3

Recovery Lactate and $\dot{V}O_2$

jog recovery period caused a decrease from 130.74 mg% to 28.05 mg% during the same time period.

There was no significant difference between the mean lactate concentrations of the three recovery procedures, five minutes following exercise. Fifteen minutes following exercise, the mean lactate value was significantly lower in the walk recovery than in the sit recovery, and significantly lower in the jog than in the walk recovery. Thirty minutes following exercise the mean lactate value was also significantly lower in the jog recovery than in the walk, and significantly lower in the walk recovery than in the sit recovery.

The mean $\dot{V}O_2$ values during the sit recovery decreased from 15.77 ml/kg/min, five minutes following exercise, to 4.98 ml/kg/min 30 minutes following exercise. During the walk recovery the mean values dropped from 24.99 ml/kg/min, five minutes following exercise, to 15.51 ml/kg/min 30 minutes following exercise. The $\dot{V}O_2$ during the jog recovery remained fairly constant, it decreased only from 44.84 ml/kg/min, five minutes following exercise, to 39.17 ml/kg/min 30 minutes following exercise.

DISCUSSION

Lactate is produced in large quantities in the working muscle during strenuous muscular activity. It then diffuses out of the muscle into the blood where it is transported to various other organs and removed from

the system. The quantity of lactate that appears in the blood following maximal intermittent exercise is dependent upon the duration of the exercise bout (16). Exercise bouts of short duration (10-20 seconds) do not produce high blood lactate values, however, if the exercise bouts are of 60 seconds in duration the blood lactate values obtained are very high.

Average lactate values obtained with maximal intermittent exercise bouts of 60 seconds have been reported by Hermansen and Stensvold (10) at 165 mg%. The average maximal lactate value obtained in the present study was 132 mg%. There are several factors which could explain these lower maximal lactate values.

The subjects used in the present study were all highly trained distance runners. The great majority of their training was aerobic in nature, thus their systems had been trained against a large lactate build up. This is because the trained person oxidizes more fat and less carbohydrate than does the untrained person (13:273), thus the lactate accumulation would be less. Subject KB, who won a major marathon race two months following this investigation, had a maximal lactate value of only 106 mg% following one of his test runs. Several other maximal lactate values obtained were in the range of 110-120 mg%.

The duration of the exercise bouts could have been another factor causing the lower maximal lactate values. The

exercise bouts used in the present study were two minutes in duration while the exercise bouts in the study by Hermansen and Stensvold (10) were one minute in duration. It is not clear as to the exact time period of the intermittent exercise bout which will produce the highest blood lactate concentration, however by comparison of the results of the present study with those of Saltin and Essén (16) and Hermansen and Stensvold (10) it would appear that this time period is closer to one minute than to two.

It is evident that the exercise bouts in this study were near maximal by investigation of the heart rates and $\dot{V}O_2$ of the subjects during exercise. At first glance an average heart rate of 180 bpm might not seem to be near maximal, however all five of the subjects were highly trained distance runners and a reduction in maximal heart rate is particularly evident in athletes engaged in endurance training over a period of many years (13:289).

The average $\dot{V}O_2$ during the third exercise bout was 64.57 ml/kg/min which is 93% of the average $\dot{V}O_{2\ max}$. It was therefore assumed that the exercise bouts were very near maximal and the blood lactate concentration five minutes following the third exercise bout was very near the upper limit attainable by the subjects using this test format.

The results of this study indicate that there is a direct relationship between the rate of lactate removal and $\dot{V}O_2$ consumption. That is, the greater the $\dot{V}O_2$ consumed

in recovery, the greater the rate of lactate removal. In trying to find an explanation for this relationship the results of two previous studies must be brought into the discussion.

As has been reported earlier, approximately 50% of the lactate eliminated is removed by gluconeogenesis in the liver (7). If this were the case there would be no apparent dependence upon the $\dot{V}O_2$ for lactate removal. The greater $\dot{V}O_2$ would then be explained solely on the fact that it is required for the oxidation of glucose and free fatty acids needed to supply the energy to perform the walk and jog recoveries.

If, on the other hand, it is assumed that lactate is removed largely by its oxidation in the skeletal muscle (10), the faster removal rate can be explained by a greater $\dot{V}O_2$. When there is a greater amount of oxygen present in the skeletal muscle the lactate can return to the muscle from the blood and be oxidized to carbon dioxide and water. This process could supply the energy needed to perform the recovery exercise by using lactate as a substrate without drawing extensively from the glycogen stores of the muscle. This process could also remove lactate from the blood without a great portion of the lactate being sent to the liver.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The study was conducted to observe the effects of three different warm-down intensities on the rate of lactate removal from the blood of trained subjects following bouts of strenuous intermittent treadmill runs. Each of the warm-down procedures lasted for 30 minutes.

Five well trained distance runners from Eastern Illinois University were chosen for the study. All the subjects were given an orientation to treadmill running prior to the test procedure and had maximum oxygen consumptions in the range of 67.03 to 72.28 ml/kg/min.

The test procedure consisted of three, two minute bouts of treadmill running at ten miles per hour up an 8.6% grade, with two minute rest periods between bouts. Three warm-down procedures, which began immediately following the third exercise bout, were used in the study. The 30 minute warm-down recoveries were sitting, walking at four miles per hour, and jogging at eight miles per hour. Blood samples were drawn from an arm vein of the subject five, 15, and 30 minutes following exercise. The blood samples were then analyzed for lactate concentration.

A Friedman two-way analysis of variance by ranks was used to test whether there were any significant differences between the blood lactate concentrations of the different warm-down procedures.

CONCLUSIONS

Based on the results of this study, the null hypothesis is rejected. It is concluded that the thirty minute, eight mile per hour jog (57% of $\dot{V}O_{2\ max}$) is a better warm-down procedure than the thirty minute, four mile per hour walk (23% of $\dot{V}O_{2\ max}$) for removal of lactate from the blood of trained distance runners. Sitting for thirty minutes following exhaustive anaerobic work bouts is the least effective method of lactate removal.

RECOMMENDATIONS

Based on the study the following recommendations for further study appear justified.

A study on lactate removal during recovery from maximal exercise, at the cellular level could be conducted by using the muscle biopsy technique. If facilities are not available for using the muscle biopsy, a study using blood lactate could be conducted using a greater number of warm-down intensities in an attempt to determine an optimal intensity.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Åstrand, P.O., I. Hallbäck, R. Hedman, and B. Saltin. "Blood lactates after prolonged severe exercise." Journal of Applied Physiology. 18: 619-622, 1963.

2. Costill, D.L. What Research Tells the Coach About Distance Running. Washington D.C.: AAHPER, 1968.

3. Cretzmeyer, F.X., L.E. Alley, and C.M. Tipton. Track and Field Athletics. St. Louis: C.V. Mosby Co., 1974.

4. Davies, C.T.M., A.V. Knibbs, and J. Musgrove. "The rate of lactic acid removal in relation to different baselines of recovery exercise." Internationale Zietschrift fur Angewandte Physiologie. 28: 155-161, 1970.

5. de Vries, H.A. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: Wm. C. Brown Co., 1971.

6. Gisolfi, C., S. Robinson, and E.S. Turrell. "Effects of aerobic work performed during recovery from exhausting exercise." Journal of Applied Physiology. 21: 1767-1772, 1966.

7. Gollnick, P.D. and L. Hermansen. "Biochemical adaptations to exercise: Anaerobic metabolism." In Exercise and Sport Sciences Reviews. J. Wilmore, ed. New York: Academic Press, 1-43, 1973.

8. Guyton, A.C. Textbook of Medical Physiology. Philadelphia: W.B. Saunders Co., 1971.

9. Hermansen, L. "Lactate production during exercise." In Muscle Metabolism During Exercise. B. Pernow and B. Saltin, ed. New York: Plenum Press, 401-407, 1971.

10. Hermansen, L. and I. Stensvold. "Production and removal of lactate during exercise in man." Acta Physiologica Scandinavica. 86: 191-201, 1972.

11. Knuttgen, H.G. "Lactate and oxygen debt: An introduction." In Muscle Metabolism During Exercise. B. Pernow and B. Saltin, ed. New York: Plenum Press, 361-369, 1971.

12. Lenninger, A.L. Biochemistry. New York: Worth Publishers, Inc., 1972.

13. Mathews, D.K. and E.L. Fox. The Physiological Basis of Physical Education and Athletics. Philadelphia: W.B. Saunders Co., 1976.

14. Newman, E.V., D.B. Dill, H.T. Edwards, and F.A. Webster. "The rate of lactic acid removal in exercise." American Journal of Physiology. 118: 457-461, 1937.

15. Rämmal, K. and G. Ström. "The rate of lactate utilization in man during work and rest." Acta Physiologica Scandinavica. 17: 452-456, 1949.

16. Saltin, B. and B. Essén. "muscle glycogen, lactate, ATP, and CP in intermittent exercise." In Muscle Metabolism During Exercise. B. Pernow and B. Saltin, ed. New York: Plenum Press, 419-424, 1971.

17. Shephard, R.J. Alive Man! The Physiology of Physical Activity. Springfield, Illinois: Charles C. Thomas, 1972.

18. Siegel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Co., 1956.

19. Stensvold, I. and L. Hermansen. "The rate of lactic acid removal during recovery while working and resting." (Abstract) Acta Physiologica Scandinavica. 77: Supplementum 330, 85, 1969.

20. Wilt, F. Run Run Run. Los Altos, California: Track and Field News, Inc., 1964.

APPENDIXES

APPENDIX A

$\dot{V}O_{2\ max}$ TEST PROCEDURE

Min.	Speed (mph)	% Grade
0 - 1	8	0
1 - 2	8	0
2 - 3	10	0
3 - 4	10	0
4 - 5	10	6
5 - 6	10	6
6 - 7	10	8
7 - 8	10	8
8 - 9	10	10
9 -10	10	10

APPENDIX B

CALCULATION OF VENTILATION, CO_2 PRODUCTION AND O_2 CONSUMPTION

UBJECT _____ DATE _____ ACTIVITY _____

GE _____ yrs. HT _____ cm. WT _____ Kg. BODY SURFACE _____ M^2

ODE (Identification)					
ULMONARY VENTILATION					
a. Meter Temp. ^oC					
b. P_{Bar} mmHg.					
c. STPD Factor (Nomo)					
d. Meter Factor					
e. Vol. 2 at Time 2					
f. Vol. 1 at Time 1					
g. Δ Vol. / Δ Time(min.)					
h. $\dot{V}_E$ = c x d x g					
CARBDON DIOXIDE PRODUCTION					
a. CO_2 Reading (LB-1) %					
b. L / min = 2h x 3a /100					
c. gm./min.= 3b x 1.9769					
d. CO_2 (ml/Kg/min) = $\frac{3b \times 1000}{Bdy.\ Wt\ in\ Kg.}$					
OXYGEN CONSUMPTION					
a. O_2 Beckman (E2) Fraction					
b. % O_2 from Formula					
c. "True O_2" (Nomogram)					
d. L / min = 2h x 4c / 100					
e. gm./min. = 4d x 1.4290					
f. O_2 (ml/Kg/min) = $\frac{4d \times 1000}{Bdy.\ Wt.\ in\ Kg.}$					
RESPIRATORY QUOTIENT(R.Q.) from Nomogram					

ote: 1 liter of O_2 Consumed equals approximately 5 calories burned

APPENDIX C

BLOOD ANALYSIS

Reagents*

1. 8% perchloric acid ($HClO_4$)
2. Glycine buffer, with hydrazine pH = 9.4
3. Lactate dehydrogenase (LDH)
4. Nicotinamide adenine dinucleotide, oxidized form (NAD^+)
5. Deionized water

Procedure

1. Immediately after the blood samples were drawn, one milliliter (ml) of blood was pipetted into a culture tube containing two ml of cold 8% $HClO_4$.

2. The cap was then placed on the culture tube and the solution was shaken vigorously and placed in the refrigerator until ready for further analysis.

3. When the tubes were ready for further analysis they were removed from the refrigerator and placed in the centrifuge and allowed to spin for at least five minutes.

4. The supernatant was then removed with a transfer pipet and placed in a clean culture tube.

5. A cocktail was then prepared by mixing eight ml of deionized water with four ml of glycine buffer, 0.2 ml of LDH and ten milligrams (mg) of NAD^+. This quantity of cocktail was sufficient to analyze four samples.

6. The reaction was set up in a clean culture tube by adding 0.1 ml of the supernatant and 0.1 ml of deionized water to 2.8 ml of the cocktail.

7. A reagent blank was prepared by adding 0.1 ml of 8% $HClO_4$ and 0.1 ml deionized water to 2.8 ml of cocktail.

*Purchased from Sigma Chemical Company, P.O. Box 14508, St. Louis, Missouri 63178

8. A reaction tube was also set up using a standard lactate solution of 19.0 milligrams per 100 ml (mg%) following the same procedure as the blood sample reaction test tubes.

9. After all of the reaction tubes had been set up they were taken to the Biochemistry Laboratory at Eastern Illinois University.

10. They were allowed to stand at room temperature for a period of one hour to allow the reaction to be carried out to completion.

11. The Bausch & Lomb Spectrophotometer 70 was set to read infinity on the absorbance scale before it was turned on. It was then turned on and allowed to stand for at least 30 minutes to warm up.

12. The reagent blank was then placed in the spectrophotometer and the absorbance through the solution was set to read zero, at a wavelength of 340 nanometers.

13. The standard lactate solution was then placed in the spectrophotometer. The purpose of the standard solution was to make sure that the enzyme (LDH) was active. If the absorbance read .145 the enzyme was active.

14. The light absorbance of the sample solutions were then measured.

15. The absorbance reading was then multiplied by 131 to obtain the lactate concentration in mg%.

APPENDIX D

DATA ON BLOOD LACTATE LEVELS FOR EACH TIME PERIOD AND WARM-DOWN PROCEDURE

Subject JK

Recovery	Time (min)	Absorbance (340 nm)	Lactate (mg%)
sit	5	1.240	162.44
	15	.998	130.74
	30	.780	102.18
walk	5	1.150	150.65
	15	.710	93.01
	30	.368	48.21
jog	5	.950	124.45
	15	.368	48.21
	30	.178	23.32

Subject GM

Recovery	Time (min)	Absorbance (340 nm)	Lactate (mg%)
sit	5	.840	110.04
	15	.640	83.84
	30	.469	61.44
walk	5	.998	130.74
	15	.718	94.06
	30	.360	47.16
jog	5	1.080	141.48
	15	.560	73.36
	30	.160	20.96

(nm) refers to nanometers

(mg%) refers to milligrams percent

Subject BC

Recovery	Time (min)	Absorbance (340 nm)	Lactate (mg%)
sit	5	.970	127.07
	15	.793	103.88
	30	.460	60.26
walk	5	.875	114.73
	15	.555	72.71
	30	.285	37.34
jog	5	.950	124.45
	15	.521	68.25
	30	.258	33.79

Subject RJ

Recovery	Time (min)	Absorbance (340 nm)	Lactate (mg%)
sit	5	1.050	137.55
	15	.725	94.98
	30	.420	55.03
walk	5	.970	127.07
	15	.708	92.75
	30	.242	31.70
jog	5	1.200	157.09
	15	.700	91.70
	30	.275	36.03

Subject KB

Recovery	Time (min)	Absorbance (340 nm)	Lactate (mg%)
sit	5	1.090	142.79
	15	.900	117.90
	30	.590	77.29
walk	5	.950	124.45
	15	.431	56.46
	30	.315	41.27
jog	5	.810	106.11
	15	.328	42.97
	30	.200	26.20

VITA

BENJAMIN F. TIMSON

The writer was born in Passaic, New Jersey, on January 1, 1952. At the age of five he moved with his family to Rosewood Heights, Illinois. He attended Roxana High School in Roxana, Illinois where he earned eight varsity letters in cross country, basketball, and track. During his senior year he served as president of the Varsity Letterman's Club and was elected "Athlete of the Year" by the members of that club. He graduated in 1970 and entered Eastern Illinois University in the fall of that year.

While at Eastern he competed on the varsity cross country and track teams for four years. He was a member of the 1973 cross country team that finished third in the nation. As an undergraduate he was a physical education major, a member of the physical education majors club, Phi Epsilon Kappa, and the Varsity Club.

He graduated from Eastern in 1974 with a B.S. in education, and accepted a graduate assistantship there for the 1974-75 school year. He married Kathleen Ann Dugopolski of Bellwood, Illinois on August 17, 1974.

ABSTRACT

The purpose of the study was to investigate the rate of lactate removal from the blood of trained distance runners, during recovery from maximal intermittent exercise.

Five well trained male subjects (mean $\dot{V}O_{2\ max}$ of 69.79 ml/kg/min) were selected for the study. Four of the subjects were members of the 1975 Intercollegiate Cross Country team and one was a member of the 1975 Intercollegiate Soccer team at Eastern Illinois University. Each subject received an orientation to the treadmill and a maximum oxygen consumption test prior to the actual test procedure. The test procedure consisted of three separate warm-down periods following maximal intermittent exercise. The three warm-down periods were 30 minutes in duration and consisted of sitting, walking at four miles per hour, and jogging at eight miles per hour. Blood samples were drawn from an arm vein of the subject five, 15, and 30 minutes following exercise and were analyzed for lactate.

A Friedman two-way analysis of variance by ranks was used to test whether there were any significant differences between the blood lactate concentrations of the different warm-down procedures. It was concluded that the 30 minute, eight mile per hour jog was a better warm-down procedure than the 30 minute, four mile per hour walk for removal of lactate from the blood of trained distance runners. Sitting for 30 minutes was the least effective method.