EFFECTS OF RECOVERY PATTERNS AND BLOOD LACTATE LEVELS ON ACHIEVEMENT OF PEAK POWER AND SUBSEQUENT ANAEROBIC PERFORMANCE OF MALES

A Thesis

by

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ABSTRACT

EFFECTS OF RECOVERY PATTERNS AND BLOOD LACTATE LEVELS
ON ACHIEVEMENT OF PEAK POWER AND SUBSEQUENT
ANAEROBIC PERFORMANCE OF MALES

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The primary purpose of the study was to analyze the differences among lactic acid levels of untrained males following two supramaximal performances that were separated by either active or passive recovery patterns. A secondary purpose was to analyze differences in time elapsed (seconds) before peak power was obtained between the two exercise performances that were separated by active and passive recovery patterns.

The supramaximal performances were 30 seconds in duration. Relative workloads were assigned according to body weight at .083 kiloponds per kilogram of body weight. Four blood samples were drawn during the testing procedure. The 26 subjects were randomly placed in an active or passive recovery group. One-Way Analysis of Variance with Repeated Measures was used to determine the effects of active and passive recovery patterns on blood lactate levels and the effects of active and passive recovery patterns on time to achieve peak power.

The findings of the study were as follows:

1. No significant difference at the .05 level of confidence existed between the groups when the four blood lactate samples for the active recovery and the passive recovery groups were compared.

2. No significant difference at the .05 level of confidence existed between time to achieve peak power when the active recovery and the passive recovery groups were compared.

The conclusions of the study were as follows:

1. Lactic acid levels were not affected by recovery patterns and were not a deterrent to a subsequent anaerobic performance.

2. Increased lactic acid levels did not directly influence the time required to achieve peak power in a subsequent anaerobic performance.

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CHAPTER 1

Introduction

Exercise that requires an intense effort utilizes the anaerobic energy system. In this system a steady state is not achieved. The circulatory system cannot provide an adequate supply of oxygen to the working muscles to maintain a maximal effort in a steady state. In the absence of oxygen the anaerobic energy system supplies the energy for the working muscles (De Bruyn-Prevost & Sturbois, 1980).

Many athletic events as well as routine endeavors depend upon the anaerobic energy system. With this realization, researchers have intensified efforts toward the study of all facets of anaerobic performance. The term anaerobic means without oxygen. Anaerobic metabolism is divided into two components, the ATP-PC system and the lactic acid system. At the onset of exercise, immediate energy is provided by the high energy phosphates, adenosine triphosphate and creatine phosphate, known as the ATP-PC system, and is stored in the muscle. These phosphates must be continually resynthesized in order for a maximal effort to continue to occur. A simple muscular contraction is sustained by

using ATP (Kraemer & Fleck, 1982). The total quantity of ATP in the body is approximately 3 ounces (McArdle, Katch & Katch, 1981). This energy system can supply enough energy to perform maximally for approximately 6 to 10 seconds. Therefore, ATP must be continually resynthesized. The most rapid supplier of resynthesis without oxygen comes from creatine phosphate. Creatine phosphate donates a phosphate (P) directly to adenosine diphosphate (ADP) to reform ATP. This transfer of bond energy is phosphorylation. Replenishment of the ATP-PC system occurs through the aerobic system, where available oxygen breaks down carbohydrates and fats to be used in the rebuilding of ADP and P back into ATP and PC. Within 3 minutes after intense exercise approximately all of the ATP-PC is restored (Kraemer & Fleck, 1982).

The second aspect of anaerobic metabolism involves energy derived from the lactic acid system. Production of this energy is termed anaerobic glycolysis. Carbohydrates are the fuel for glycolysis. Essentially glucose, a six carbon molecule, is transformed to two pyruvic acid molecules yielding ATP molecules to be used as an energy source. However, during glycolysis ATP is needed to phosphorylate a glucose molecule to glucose 6 phosphate. In this form the molecule can be polymerized with other glucose molecules to form glycogen, the storage form of glucose. The molecule is further phosphorylated to fructose 1,6 diphosphate. At this point in glycolysis there is no energy yield, however two molecules of ATP have been utilized in the phosphorylation of the glucose molecule. An end product of pyruvic acid is eventually achieved.

In the final steps of the anaerobic process, nicotinamide-adenine-dinucleotide (NAD) is reduced by hydrogen to form NADH2. If sufficient oxygen is not available, due to exercise intensity, NADH2 oxidizes by donating two hydrogens to pyruvic acid and thus forming lactic acid, the end product of anaerobic respiration. This oxidation allows the NAD to become a hydrogen acceptor again in glycolysis.

This process generates a total of four ATP molecules, with the loss of two ATP's in the initial phosphorylation of the glucose molecule. Therefore, the total gain of energy from anaerobic respiration is two ATP's. The continued accumulation of lactic acid will cause a reduction in exercise intensity due to pain and/or an interference with the muscular contraction process (Kraemer & Fleck, 1982). Removal of the lactic acid from the body has been found to be dependent on the type of recovery pattern followed (Gisolfi, Robinson & Turrell, 1966). It is currently thought that approximately 10 percent of accumulated lactic acid is converted to glucose while 75 percent is oxidized completely by the aerobic system to carbon dioxide and water. Therefore, 15 percent is still unaccounted for, while inactive and active skeletal muscle can use some lactic acid as fuel (Kraemer & Fleck, 1982).

With the onset of increased interest in this area as well as more sophisticated technology, research concerning anaerobic energy is needed. The effects of lactic acid accumulation on subsequent achievement of peak power output are of prime importance to athletic performance. The effect of lactic acid

on anaerobic performance merits continued investigation. This research was conducted to assist in clarifying questions related to the anaerobic energy system, achievement of peak power and recovery activities as factors in lactic acid accumulation.

Purpose of the Study

The primary purpose of the study was to analyze the differences among lactic acid levels of untrained males following two supramaximal performances that were separated by either active or passive recovery patterns. A secondary purpose was to analyze differences in time elapsed (seconds) before peak power was obtained between the two exercise performances that were separated by active and passive recovery patterns.

Definition of Terms

Peak Power. The highest recorded power output in watts.

Relative Workload. The workload determined in relation to body weight using .083 kiloponds of resistance per kilogram of body weight.

Supramaximal Performance. A 30 second maximal effort of pedalling the cycle ergometer at a relative workload of .083 kiloponds per kilogram of body weight (Inbar, 1983).

Active Recovery. A 5 minute period following each supramaximal performance in which the subject continued to pedal at a chosen resistance at 50 revolutions per minute.

Passive Recovery. A 5 minute period following each supramaximal performance in which the subject was seated motionless in a chair adjacent to the cycle ergometer.

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

Latent period. Period of no activity prior to drawing blood samples.

Basic Assumptions

1. All subjects were tested under identical conditions.

2. All subjects performed on the cycle ergometer at a maximal effort.

3. All subjects pedalled at a resistance relative to their body weight (.083 kiloponds per kilogram of body weight) (Inbar, 1983).

Delimitations

Each subject was oriented to the testing procedure prior to testing. Subjects were asked not to eat at least two hours prior to testing. Subjects were screened according to blood pressure. Individuals with a systolic pressure exceeding 140 mm/Hg or a diastolic pressure exceeding 90 mm/Hg were excluded from the study. Venous blood samples were drawn from the antecubital vein in the forearm prior to exercise, 5 minutes following each exercise performance, and immediately following the initial recovery pattern. All subjects performed two supramaximal exercise bouts for 30 seconds each with a 5 minute rest interval followed by either an active or passive recovery pattern of 5 minutes duration. The 26 subjects selected for testing were untrained males currently enrolled at Appalachian State University.

Limitations

Several subjects experienced nausea and dizziness during the 5 minute latent period between the two supramaximal performances. However, these subjects were able to continue the remainder of the test. One subject was eliminated from the study due to nausea and was unable to complete the second supramaximal performance within the allotted time limit.

CHAPTER 2

Related Literature

Overview

Within the broad area of anaerobic performance, researchers have begun to narrow research endeavors to study specific aspects of anaerobic exercise. Current trends in the literature reveal several specific categories that include: (1) the relationship of muscle fiber type to anaerobic performance; (2) the accumulation and removal of lactic acid during exercise; (3) trends in the development of a specific test to assess anaerobic capacity; and (4) defining and determining peak power during anaerobic performance. The following review of literature attempts to focus on these four aspects of anaerobic research.

The Relationship of Fiber Type to Anaerobic Performance

The depletion of various anaerobic substrates and increases in muscle and blood lactic acid during maximal exercise have been proposed by De Bruyn-Prevost and Sturbois (1980) as limiting factors in maximal exercise of short duration. This was studied by performing muscle biopsies in man after exhaustive exercise and evaluating the relationship between fatigue, fiber type, and concentration of lactate.

Karlsson and Saltin (1970) obtained biopsy specimens from the quadriceps femoris after three subjects performed maximally for 2,

6, and 16 minutes. The biopsy specimens revealed that the breakdown of ATP and CP was maximal after 2 minutes of work in each experiment, averaging 2.7 millimoles (mmoles) kg^{-1} and 3.6 mmoles kg^{-1} muscles, respectively. Lactate accumulation in the muscle during the 6 minute and 2 minute performance (medium and high loads, respectively) averaged 16.1 mmoles kg^{-1} wet muscle and 12.0 mmoles kg^{-1} during the 16 minute ride (lowest load). Karlsson and Saltin concluded that low ATP and PC stores were not the reason for fatigue. Furthermore, if muscle lactate concentration caused fatigue of the two heaviest loads, another component must be present to explain exhaustion during the work bout with the lightest load.

Tesch (1978) concluded that subjects with the highest anaerobic power and capacity possessed predominantly fast twitch fibers. Seven aerobically trained males performed a supramaximal exercise at 120 percent of each subject's maximal aerobic capacity. A positive relationship was found between maximal aerobic capacity and percent of slow twitch fibers. The average fast twitch to slow twitch lactate ratio was one to four. Lactate concentration in the fast twitch muscles averaged 25.8 mmoles kg^{-1} wet muscle and the slow twitch muscles averaged 18.7 mmoles kg^{-1} wet muscle ($p < 0.05$). Tesch further concluded that fast twitch fibers form more lactate than slow twitch fibers.

Studying the differences in fast and slow twitch muscle fiber efficiency in man during cycle work, Suzuki (1979) concluded that subjects with predominately slow twitch fibers had reduced pedalling efficiency. By obtaining muscle biopsies, subjects

were classified as slow twitch (78 percent slow twitch fibers) and fast twitch (76 percent fast twitch fibers). Subjects were tested at 60 and 100 revolutions per minute at workloads below 80 percent maximum $\dot{V}O_2$. Reduced pedalling efficiency occurred at the 100 rpm workload in the slow twitch fiber subjects. It was further concluded that the use of slow twitch fibers at rapid pedal rates may require a substantial increase in energy expenditure.

Tesch (1981) tested ten subjects for the point of onset of blood lactic acid accumulation during a cycle ergometer exercise which increased every 4 minutes by 25 watts. Blood samples were collected during the last minute of each of four workloads. Subjects were tested a second time with a muscle biopsy taken from the vastus lateralis when the onset of blood lactate accumulation was maintained for 4 minutes. Results indicated that muscle lactate concentration varied from 2.1 to 12.6 mmoles kg^{-1} at the onset of blood lactate accumulation. There was no relationship between blood and muscle lactate accumulation.

Sjodin (1981) determined the effects of training on the onset of blood lactate accumulation and muscle lactate accumulation. Eight well trained middle and long distance runners exercised once a week for 14 weeks on a treadmill for 20 minutes at the velocity where the initial onset of blood lactate accumulation occurred. A muscle biopsy was taken at each training session. Results indicated after 14 weeks that the onset of blood lactic acid increased significantly. The phosphofructokinase (PFK) decreased significantly from 7.7 ± 2.0 to 5.4 ± .05 moles x 10^{-6} ($p < 0.05$). The activity of lactate dehydrogenase (LDH) and citrate synthetase

(CS) was unchanged. Sjodin concluded that a more balanced activity existed between the glycolytic enzymes PFK and LDH to the oxidation enzyme CS following training.

The Accumulation and Removal of Lactic Acid

Astrand, Hallback, Hedman, and Saltin (1963) determined blood lactate levels in three groups of cross country skiers following performances in distances of 10 km, 30 km, and 50 km. Lactate accumulation levels decreased as the distance of the event increased with an average of 139 mg/100 ml of blood for the 10 km event; 68 mg/100 ml of blood for the 30 km event; and 39 mg/100 ml for the 50 km event.

Gisolfi et al. (1966) compared active exhaustive exercise with the rate of lactic acid removal. Four physically fit men participated in a study which concluded that active recovery increased the rate of lactate removal when compared to values observed from passive recovery.

Davies, Knibbs, and Musgrove (1970) using four subjects, tested the maximum aerobic capacity before initiating a series of four experimental tests. In each test the subject exercised at 80 percent aerobic capacity for 6 minutes on a cycle ergometer. With each exercise bout a different recovery pattern was prescribed at 30, 45, and 60 percent of $\dot{V}O_2$ maximum. Three subjects participated in a fifth recovery pattern which was passive and no exercise was performed. Six to eight blood samples were drawn from the fingertip at exponentially spaced intervals during the entire 40 minute recovery. Davies et al. (1970) concluded that the recovery period which was closest to 40 percent of the

subjects $\dot{V}O_2$ maximum was most desirable for optimum blood lactate removal during recovery.

Hermansen and Stensvold (1972) studied lactate as an inhibiting factor in exercise. Four females and three males participated in a pre-test session where oxygen uptake was measured during at least three submaximal and two maximal work bouts on a treadmill at 5.25 percent grade. On consecutive days following the pre-test subjects performed 30 minutes of continuous walking or running at 30, 60, 70, and 80 percent of maximal oxygen consumption. On five following consecutive days the subjects performed a maximal intermittent exercise consisting of three maximal workloads lasting approximately 60 seconds. The maximal exercise was followed by 30 minutes of continuous treadmill exercise at 30, 60, 70, and 80 percent of the subject's oxygen uptake. On the final day subjects rested in a chair 30 minutes following the maximal intermittent exercise program on the ninth experimental day. Blood samples were drawn from the fingertip before and during the exercise and rest periods. Findings indicate that during continuous running blood lactate increased minimally up to 60-80 percent of the maximal aerobic capacity. Above 60-80 percent of the maximal aerobic capacity a pronounced decrease in the removal rate was observed. During maximal intermittent exercise blood lactate was elevated to 130-220 mg/100 ml of blood. The following recovery period decreased these levels to resting values. Hermansen and Stensvold concluded that the rate of lactate removal was affected by the workload intensity

and a workload of 60 to 80 percent of maximum aerobic capacity appeared to be a significant level for lactate accumulation.

Belcastro and Bonen (1975) studied lactate removal during controlled and uncontrolled recovery patterns after a standardized 6 minute cycle exercise (89 percent $\dot{V}O_2$ maximum). Lactic acid removal rates were compared during the recovery at rest, and exercise at 29.7, 45.3, 61.8, and 80.8 percent $\dot{V}O_2$ maximum while the subjects regulated individual recovery patterns. Blood samples from the finger were taken after the standardized work bout and every 5 minutes during the recovery periods. Belcastro and Bonen concluded that during controlled recovery, lactic acid removal was dependent upon the intensity of the recovery. Optimal recovery was cited at approximately 32 percent maximum $\dot{V}O_2$. Self selected recovery removal rates did not vary from the value ($p < 0.05$), but were faster than during recovery at rest and exercise at 61.8 and 80.8 percent $\dot{V}O_2$ maximum. There was no difference during self selected recovery and recovery at 29.7 and 45.3 percent maximum $\dot{V}O_2$. Conclusions indicate that the subjects were able to remove lactic acid effectively during self selected recovery patterns.

Weltman, Stamford, Moffatt, and Katch (1977) investigated the relationship between different recovery patterns, (active vs. passive, with and without O_2 inhalation) after high intensity, short duration exercise and subsequent performance. Eleven males completed one maximal cycle test with frictional resistance of 33.0 kgm x rev^{-1}. The subjects then recovered actively or passively, breathing room air or 100 percent oxygen for a 10 or 20

minute period. A subsequent exercise performance followed. Blood samples from the antecubital vein were collected at minutes 3-4, 9-10, and 19-20 during the 20 minute period. Active and 20 minute recovery patterns resulted in the higher pedal revolutions in the subsequent performance. No significant difference was observed between room air and 100 percent oxygen inhalation. However, Weltman noted that blood lactate levels at the end of recovery and pedal revolutions in the subsequent performance, gave a non-significant correlation of -.19. The researchers indicated that factors other than lactate removal may influence subsequent performances.

Bonen, Campbell, Kirby and Belcastro (1978) exercised ten women at 90 percent maximum $\dot{V}O_2$ for 6 minutes. Blood samples were drawn from the forearm every 5 minutes for the duration of the 20 minute recovery period, which was prescribed at 40 percent $\dot{V}O_2$ maximum. Muscle biopsies from the vastus lateralis were obtained several weeks prior to the experiment and after the lactic acid removal experiment. The mean rate of lactic acid removal was 4.77 ± 0.44 mg per 100 ml per minute. A moderate ($r = 0.544$), but significant ($p = 0.05$) relationship was found between percent of slow twitch fibers and lactate removal rates.

De Bruyn-Prevost and Sturbois (1980) studied ten males performing a short endurance anaerobic test on a cycle ergometer. Lactic acid levels were evaluated at precise points during the test by dividing the total test into four shorter experiments. Results indicated that lactic acid production proceeded at a constant rate during the exercise. Lactic acid was lower at the

beginning of work and for work durations up to 12 seconds for some subjects. De Bruyn-Prevost and Sturbois confirmed the existence of some alactacid emergency processes yielding energy. However, it cannot be assumed that these processes are always sufficient to cover the energy demand during the first 5 or 10 seconds of work.

Stamford, Weltman, Moffatt, and Sady (1981) tested six male subjects on a maximal exercise test with one of three types of recovery patterns: (1) passive recovery; (2) 40 percent $\dot{V}O_2$ maximum recovery; or (3) 70 percent $\dot{V}O_2$ maximum recovery. The recovery periods lasted 40 minutes. Conclusions indicated that lactate disappearance is greatest early in recovery and slower late in recovery. This suggests the possibility that a single optimal recovery intensity does not exist. Rather, a progressively decreasing intensity commensurate with the decreasing blood lactate concentration may be most effective. Stamford et al. (1981) suggest that low intensity exercise may be more effective late in recovery than higher intensity exercise and that there is a possibility that the higher intensity exercise may have a greater impact early in recovery.

Regan (1981) studied the effects of recovery patterns following a workload of 110 percent maximum $\dot{V}O_2$. Two maximal exertions were performed, separated by a 20 minute active recovery at 40 percent $\dot{V}O_2$ maximum and a passive recovery. No significant differences were found between the two treatments. Elevated levels of blood lactate were found to exert no demonstrable effect on the subsequent maximal exertion.

Miller (1983) analyzed the differences among lactic acid levels of females following two supramaximal performances that were separated by either an active or passive recovery pattern. Conclusions indicated that lactic acid levels were not affected by recovery patterns and were not detrimental to anaerobic performance. The recovery patterns produced a significant change in percent decrement of the total cumulative revolutions favoring the active recovery pattern.

Babij, Matthews, and Rennie (1983) investigated changes in blood ammonia and lactate during bicycle ergometer exercise in man. Eight males performed three tests at 25, 50 and 75 percent $\dot{V}O_2$ maximum. Blood was sampled using an indwelling cannula at rest in the final minute of each exercise period and at intervals up to 30 minutes post exercise. Results indicated a linear relationship between blood ammonia and lactate production during exercise suggesting that the two processes may be linked to a common process of short term energy provision. Babij et al. (1983) cited some evidence that ammonia may act as an activator of phosphofructokinase.

Trends in the Development of Cycle Ergometer Tests to Assess Anaerobic Power

The absence of information regarding anaerobic performance stems from the lack of experimental methods to assess anaerobic capacity. Tests such as the Margaria Step Test, or 30 to 60 second sprint tasks reflect some indication of anaerobic capacity. However, these procedures are often considered non-specific,

exhaustive, or requiring a high level of motivation (McArdle, Katch & Katch, 1981).

Inbar and Bar-Or (1976) completed a study involving aerobic and anaerobic components of a 30 second supramaximal cycle test. Sixteen male and female athletes performed a 30 second all out performance at a workload relative to body weight. The subjects also performed an all out aerobic capacity treadmill test and an all out aerobic capacity cycle test. Oxygen debt was calculated for the anaerobic test as being 76 percent of the oxygen debt measured after the treadmill exercise and 112 percent of the oxygen debt measured after the aerobic cycle test. This latter measure indicates that using the same muscle groups, the 30 second test requires greater anaerobic components than does the commonly used all out aerobic tests. Inbar and Bar-Or concluded that the 30 second task was anaerobic in nature. This test became known as the WaNT test (Wingate Anaerobic Test).

Inbar, Kaiser, Dotan, Bar-Or, Schele and Karlsson (1979) correlated fiber type distribution and running performance with the WaNT. Long and middle distance runners, physical education students and sedentary men were evaluated in three running events measured in meters (m). The vastus lateralis of each subject was biopsied. Peak mechanical power output, total power output and a fatigue index was calculated from the WaNT. Inbar et al. concluded that running performance in the 40 m ($R = 0.79$), 300 m ($R = 0.72$) and 2000 m ($R = 0.71$) was fairly well related to the indices derived from the WaNT and to muscle fiber type distribution.

Welshinger (1983) studied the determination of a specific resistance workload for evaluating anaerobic performance in women. Welshinger concluded that a frictional resistance of four kiloponds for at least a 40 second time period was necessary for evaluating anaerobic performance in females. The study indicated that anaerobic performance was time dependent rather than work dependent.

Dotan and Bar-Or (1983) defined the optimal loads for eliciting maximal power output in the leg and arm mode of the WaNT. The WaNT was performed at different intervals 5 times each for the arms and legs. Loads were assigned according to body weight. The maximization of the body-weight-relative mean power (MPkg-1) was calculated from the end product of the assigned relative load and total number of revolutions multiplied by the distance covered by the fly wheel in relation to the friction belt crank per revolution. A parabolic regression calculation was applied to each set of MPkg-1 means and the maximum was defined as the respective optimum load setting. Optimal loads and cranking rate values were derived. Dotan and Bar-Or further concluded that perfect load optimization depends on maximal power and the WaNT is insensitive to moderate variation in load. Deviations from derived optimum load settings of ±.5 joule rev-1 kg BW reduce power output by less than 1.4 percent and 2.2 percent in the legs and arms, respectively. Consequently, loads may be modified by taking into account anaerobic fitness in the relevant muscle groups as well as deviations from normal body build or composition.

Defining and Determining Peak Power During Anaerobic Performance

The ability to determine peak power during an all out anaerobic performance has been somewhat limited by the method in which anaerobic capacity is measured. Many researchers have made use of the cycle ergometer as the most direct method of assessing ones ability to generate peak power.

Inbar (1983) in the Wingate anaerobic test, defined peak power as the highest power at any 5 second period in the exercise bout. This presumably represents the alactic phosphagen component of anaerobic power production.

Christian (1984) reported peak power as the point of maximal power output per supramaximal performance. By interfacing a computer via a microswitch attached to the cycle ergometer, detection of revolutions performed was calculated every 8 milliseconds. Power output was therefore determined per revolution.

CHAPTER 3

Procedures

Overview

The primary purpose of the study was to analyze the differences among lactic acid levels of untrained males following two supramaximal performances that were separated by either an active or passive recovery pattern. A secondary purpose was to analyze differences in time elapsed (seconds) before peak power was obtained between the two exercise performances that were separated by active and passive recovery patterns. Relative workloads were pre-assigned according to body weight at .083 kiloponds per kilogram of body weight (Inbar, 1983). Venous blood samples were drawn from the antecubital vein in the forearm, before exercise, following both supramaximal performances and the initial 5 minute recovery pattern (McGrail, Bonen & Belcastro, 1978). The exercise performance and recovery pattern were separated by a 5 minute latent period. The subjects were 26 male volunteers from Appalachian State University. The subjects were randomly placed in either an active or passive recovery group. A pre-test orientation period was held to allow the subject to become familiar with the testing procedures, to sign a consent form, and to obtain blood pressure and body weight.

Each subject performed supramaximally on a Monark cycle ergometer for 30 seconds at a workload of .083 kiloponds per kilogram of body weight (Inbar, 1983). A 5 minute period of no activity (latent period) followed the bout of supramaximal work. The latent period was followed by performance of either an active or passive recovery pattern lasting 5 minutes. Blood lactate levels were measured at rest, 5 minutes following each work period and immediately following the initial 5 minute recovery pattern.

Equipment

Monark Cycle Ergometer* A cycle ergometer pedalled at a frictional resistance of .083 kiloponds per kilogram of body weight to produce a supramaximal performance (Inbar, 1983).

Commodore PET Computer+ A computer interfaced via a microswitch to record the number of pedal revolutions and time of each revolution for the purpose of determining peak power.

Microswitch** A mechanical switch that was used with the PET computer to transmit electric current to the computer.

Stopwatch++ The timing device used to measure the duration of the testing session.

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* Manufactured by: Quinton Instruments, 2121 Terry Avenue, Seattle, Washington.

+ Manufactured by: Commodore Business Machines, 487 Devon Park Drive, Wayne, Pennsylvania.

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

Manufactured by: Yellow Springs Instruments, Inc., Yellow Springs, Ohio.

YSI Stat Lactate Analyzer[#] A semi-automated system for measuring lactate in whole blood plasma.

Analog to Digital Converter[##] A converter which converts information (impulses) into quantitative data for computer storage and manipulation.

Procedure for Administering the Supramaximal Test

The subject was positioned on the seat of the cycle ergometer with the one leg slightly flexed and the other leg flexed at 90 degrees. The subject's arms were extended to grip the handle bars of the cycle ergometer (Miller, 1983). Toe clips were used on the pedals to prevent the feet from slipping off the pedal (Inbar, 1983). Upon the command of "GO", the subject began pedalling, triggering the microswitch that was interfaced with the Commodore PET computer. Full resistance was set as the subject began pedalling thereby triggering the microswitch that was interfaced with the Commodore PET computer. The Commodore PET computer was used to determine the number of revolutions in 30 seconds and power output in relation to the 30 second workout. The computer recorded the number of revolutions at a resolution of every 8 milliseconds. Verbal encouragement was given to each subject throughout the activity as well as information pertaining to work time remaining in each bout of exercise. The command of "STOP"

Manufactured by: Yellow Springs Instruments, Inc., Yellow Springs, Ohio.

Designed and constructed by: Christian, V. K., and Nicklin, R. C., Appalachian State University, Boone, North Carolina.

was given at the conclusion of the activity. The subject was then seated in a chair beside the cycle ergometer for a 5 minute latent period before blood was drawn (Miller, 1983).

Procedure for Collecting Blood Lactate Samples

Five milliliters of blood were obtained from the antecubital vein in the forearm using a vacutainer syringe containing potassium oxalate and sodium fluoride. Samples were obtained prior to exercise, 5 minutes following each 30 second supramaximal performance and immediately following the initial 5 minute recovery period. The supramaximal performance and recovery period were separated by a 5 minute latent period. Each subject performed two supramaximal performances separated by an active or passive recovery period. The blood was centrifuged and placed in an ice bath. Samples were analyzed within 2 hours by injecting the plasma directly into the YSI lactate analyzer.

Procedure for Administering Active Recovery

Immediately following the initial 30 second work interval the subject was given a 5 minute latent period which consisted of the subject remaining in a seated position in a chair adjacent to the cycle. At the end of the latent interval the subject began to pedal the cycle ergometer at the subject's desired resistance. Initially, the researcher set the resistance at zero kiloponds and added resistance if the subject so desired. A metronome set at a cadence of 50 revolutions per minute aided the subjects in maintaining a steady pace (Belcastro & Bonen, 1975). A command of "STOP" was given at the end of the 5 minute recovery interval.

Procedure for Administering Passive Recovery

Following the initial 30 second work interval the subject was given a 5 minute latent period which consisted of the subject remaining in a seated position in a chair adjacent to the cycle. At the end of the latent period the subject remained seated in the chair to complete passive recovery.

Analysis of Data

The four blood samples from each subject were analyzed by the YSI Stat lactate analyzer to determine if any differences existed among the levels of blood lactate for each subject as related to the active or passive recovery patterns. The results of the four samples from each subject were analyzed utilizing the One-Way Analysis of Variance with Repeated Measures. One-Way Analysis of Variance with Repeated Measures was used to analyze achievement of peak power in relation to active and passive recovery patterns.

CHAPTER 4

Presentation and Analysis of Data

Overview

The primary purpose of the study was to analyze differences among lactic acid levels of untrained males following two supramaximal performances that were separated by either active or passive recovery patterns. A secondary purpose was to analyze differences in time elapsed (seconds) before peak power was obtained between the two supramaximal performances that were separated by active and passive recovery patterns. One-Way Analysis of Variance with Repeated Measures was the statistical analysis used to determine the differences existing among the four levels of blood lactate for each subject as related to the recovery pattern. One-Way Analysis of Variance with Repeated Measures was also used to determine significant peak power differences existing between the two supramaximal performances. The descriptive characteristics of the 26 untrained subjects that were grouped in either the active and passive recovery groups were reported in mean values. These variables were resting blood pressure, body weight and workload.

Descriptive Characteristics of the Active and Passive Recovery Groups

The physical characteristics of the subjects were obtained for screening purposes as well as determination of workload

relative to body weight. The mean systolic pressure of the active and passive group was 114.76 with a range of 8.06 mm/Hg and 120.15 with a range of 9.36 mm/Hg, respectively. The mean value for the diastolic pressure was 71.23 with a range of 5.38 mm/Hg for the active group and 73.07 with a range of 8.62 mm/Hg for the passive group. The mean weight of the active and passive group was 160.65 with a variance of 18.6 pounds and 161.69 with a variance of 12.7 pounds, respectively. The mean workload for the active group was 6.03 with a range of .70 kiloponds and 6.06 with a range of .46 kiloponds for the passive group (See Appendix C).

Descriptive Characteristics of the Active Recovery Group's Self-Selected Workload

Each subject assigned to the active recovery pattern was allowed to choose the recovery workload. Each minute the subject was asked if the workload was suitable and was altered by the subject if so desired. The workloads ranged from 0.0 kiloponds to 1.0 kiloponds. Subjects pedalled at the desired workload at 50 revolutions per minute (See Appendix D).

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

No significant difference at the .05 level of confidence existed between the groups for each of the corresponding four blood lactate samples measured in the active recovery group and the passive recovery group (See Table 1). The mean value for the pre-test lactic acid sample was 1.15 mmole for the active group and 1.28 mmole for the passive group. The mean value for the second lactate sample was 14.33 mmole for the active group and 14.36

Table 1

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

Source	SS	DF	MS	F	P
Group	24.42459	1	24.42459	1.32	0.2619
Error	444.10953	24	18.50456		
Treatment	4068.44214	3	1356.14738	502.24	0.000
TxG	20.57151	3	6.85717	2.54	0.0632
Error	194.41438	72	2.70020		

mmole for the passive group. The third lactate measurement was 12.40 mmole for the active recovery group and 14.29 mmole for the passive recovery subjects. The final lactate sample had a mean value of 16.86 mmole for the active recovery group and 18.68 mmole for the passive recovery group (See Figure 1 and Appendix E).

Analysis of the Effects of Active and Passive Recovery Patterns on Achievement of Peak Power

No significant difference at the .05 level of confidence existed between time to achieve peak power when the active recovery group and passive recovery group were compared (See Table 2).

The mean value for the time interval to achieve peak power was 2.90 seconds for the active group and 2.61 seconds for the passive group. The mean value for the time interval to achieve peak power for the second supramaximal performance was 3.50 seconds for the active recovery group and 3.80 seconds for the passive recovery group (See Appendix F and Figure 2).

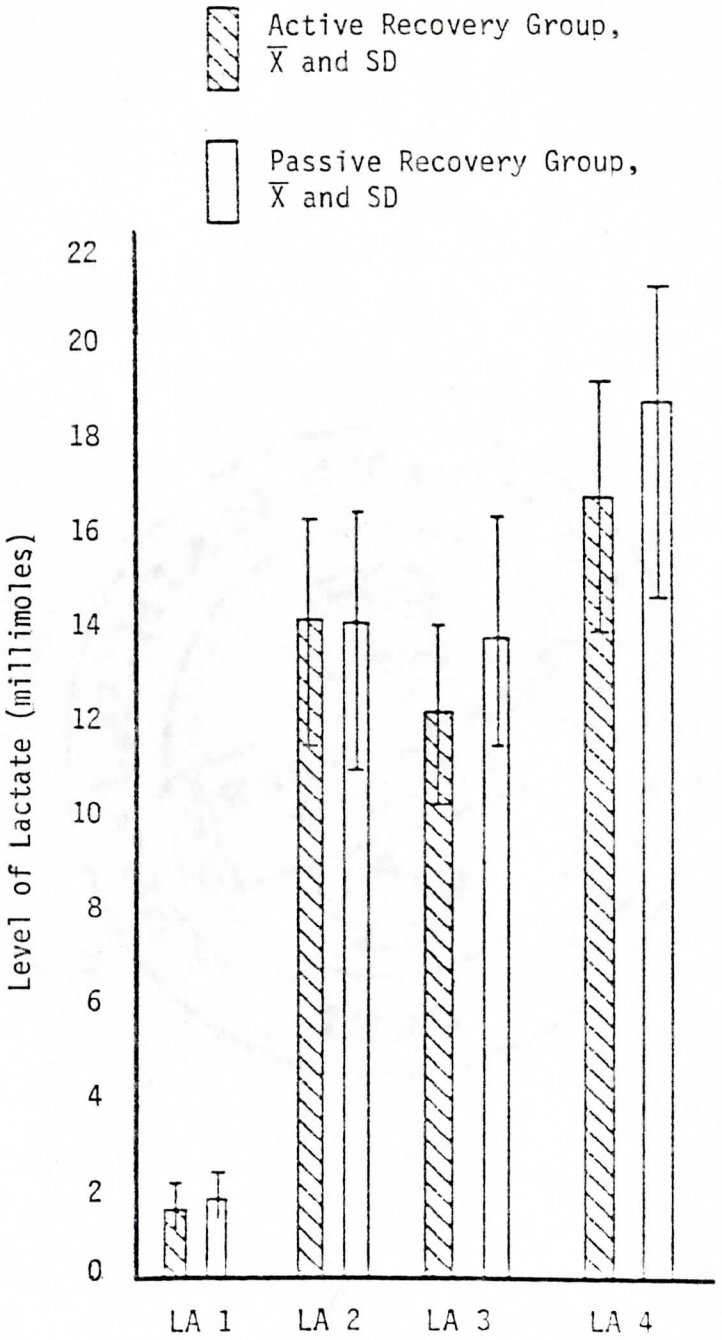

Figure 1. A comparison of means and standard deviations of the four blood lactate samples of the active and passive recovery groups.

Table 2

Statistical Analysis of the Effects of Recovery Patterns on Peak Power

Source	SS	DF	MS	F	P
Group	.00062	1	.00062	0.00	0.9876
Error	60.57320	24	2.52388		
Treatment	10.42228	1	10.42228	6.58	0.0170
TxG	1.17000	1	1.17000	0.74	0.3985
Error	38.00512	24	1.58355		

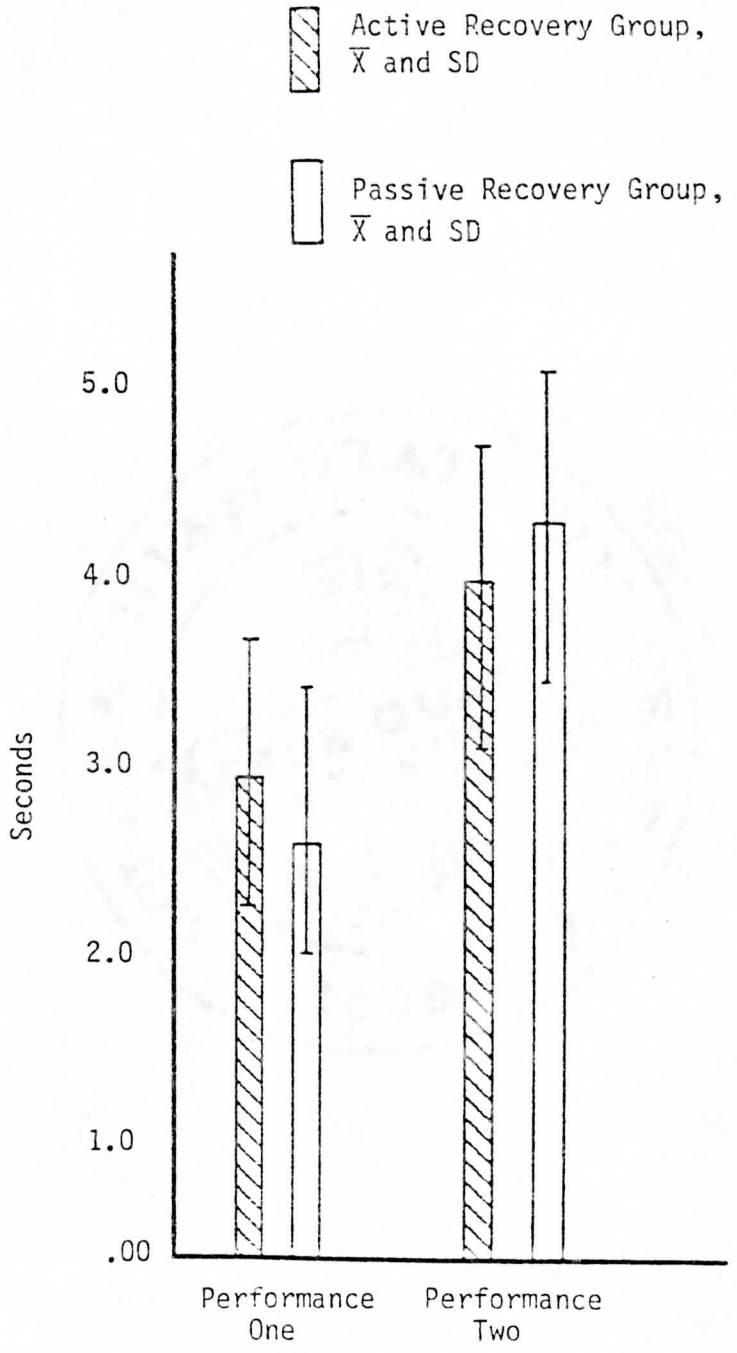

Figure 2. A comparison of the means and standard deviations of the time to achieve peak power for the initial and subsequent performance of the active recovery and passive recovery groups.

CHAPTER 5

Summary, Findings, Discussion of the Findings, Conclusions and Recommendations

Overview

The primary purpose of the study was to analyze the differences among lactic acid levels of untrained males following two supramaximal performances that were separated by either active or passive recovery patterns. A secondary purpose was to analyze differences in time elapsed (seconds) before peak power was obtained between the two exercise performances that were separated by active and passive recovery patterns. Relative workloads were pre-assigned according to body weight (Inbar, 1983). Venous blood samples were drawn from the antecubital vein in the forearm before exercise, following both supramaximal performances and the initial 5 minute recovery pattern. The exercise performances and recovery patterns were separated by a 5 minute latent period. The subjects were 26 untrained males from Appalachian State University. The subjects were randomly placed in either an active or passive recovery group. A pre-test orientation period was held to allow the subject to become familiar with the testing procedures, to sign a consent form, and to obtain blood pressure and body weight.

Each subject performed supramaximally on a Monark cycle ergometer for 30 seconds at a workload of .083 kiloponds per

kilogram of body weight. Blood lactate levels were measured at rest, 5 minutes following each work period and immediately following the assigned recovery pattern. The 5 minute latent period was required to allow the lactate to diffuse from the muscle into the blood stream (Inbar, 1983). One-Way Analysis of Variance with Repeated Measures was used to determine the effects of active and passive recovery patterns on blood lactate levels and the effects of active and passive recovery patterns on peak power output.

Findings

The findings of the study were as follows:

1. No significant difference at the .05 level of confidence existed between the groups when the four blood lactate samples for the active recovery group and the passive recovery group were compared.

2. No significant difference at the .05 level of confidence existed between time to achieve peak power when the active recovery group and the passive recovery group were compared.

Discussion of the Findings

Previous research has dealt primarily with blood lactate accumulation and aerobic performance or muscle fiber type. Tesch (1981) when studying fiber types suggested that fast twitch muscle produced higher levels of lactate during exercise. Tesch further indicated that the high lactate levels and pH levels were factors of fatigue, however, decreases in performances were not indicated (Miller, 1983).

Research further indicates that a specific recovery pattern may increase the rate of lactate removal. Gisolfi et al. (1966) concluded that active recovery increased the rate of lactate removal when compared to values observed from passive recovery. Davies (1970) concluded that an active recovery rate at 40 percent of maximum aerobic capacity increased lactate removal during recovery.

Recently, researchers have concentrated on lactic acid accumulation during anaerobic performance. Regan (1981) concluded that lactic acid accumulation did not hinder a subsequent anaerobic performance. An active or passive recovery pattern did not alter the subsequent performance significantly.

Miller (1983) concluded that significant differences did not exist between levels of lactic acid in active and passive recovery groups following recovery patterns and subsequent performance. However, significant differences were found between the recovery groups when analyzing the percent decrement in the total cumulative revolutions between the initial and subsequent supramaximal performances in favor of the active recovery group.

The present study which concentrated primarily on the effects of lactate on two anaerobic performances separated by either an active or passive recovery pattern agrees with the results reported by Regan (1981). Significant differences did not exist between levels of lactic acid in the active and passive recovery groups. The present study also examined the effects of lactic acid accumulation on time to achieve peak power in a subsequent performance. No significant difference existed in the time that

elapsed before peak power was reached in the active recovery group and the passive recovery group. The present study suggested that lactic acid levels regardless of recovery method did not directly influence subsequent supramaximal performance and subsequent time to achieve peak power. These findings further suggested that lactic acid accumulation may have little relation to fatigue in supramaximal anaerobic exercise. This is contrary to the widely held belief that lactic acid accumulation inhibits muscular performance. This theory states that the effect of decreased pH (increased acid) affects muscle contraction. There is evidence that the formation of actin-myosin cross bridges may be inhibited by low pH. Also several enzymes of energy metabolism may be inhibited by excess acid (phosphorylase or phosphofructokinase, regulated enzymes of glycolosis) (Lamb, 1978). However, Lamb has suggested that although the rate of lactic acid accumulation correlates with the development of fatigue, the total amount of acid accumulated is not necessarily greatest at the time of fatigue. Lamb further suggested that the rate of change of pH may be more detrimental than a total accumulation of lactic acid thus causing a pH imbalance further causing fatigue.

The present study suggested that the increased lactic acid levels did not directly influence subsequent time to achieve peak power in the active and passive recovery groups. The findings of this study may support Lamb's theory that the rate of change of pH in the body is more critical to fatigue rather than increased lactic acid accumulation. Therefore, the body was able to

recover and duplicate the initial effort regardless of recovery pattern or increased lactate level.

Conclusions

1. Lactic acid levels were not affected by recovery patterns and were not a deterrent to a subsequent anaerobic performance.

2. Lactic acid levels were not detrimental in time elapsed before obtaining peak power in a subsequent anaerobic performance.

Recommendations

Further research is needed in the area of anaerobic exercise as related to the rate of change of pH in the muscle fiber during anaerobic exercise. Future studies are also needed to investigate fiber types and specific training techniques in relation to ability to generate peak power output.

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APPENDIX A

Subject Consent to Procedure

SUBJECT CONSENT TO PROCEDURE

I, _____, (print name of subject), hereby authorize members of the Appalachian State University Health, Physical Education and Recreation Department, and their designated assistants, nurse and/or lab technician, to administer to me the physical performance tests and medical analysis as described in the following procedure:

1) A six to eight minute relaxation period where resting blood pressure and resting heart rate will be measured.
2) A thirty second supramaximal performance on the cycle ergometer.
3) A five minute rest period.
4) A five minute recovery period (active or passive) for five minutes.
5) A subsequent supramaximal performance on the cycle ergometer for thirty seconds.
6) A post test evaluation of blood pressure and heart rate.

Blood samples of three milliliters will be taken by a qualified nurse or lab technician. Samples will be drawn before exercise, after each supramaximal performance, and after the initial recovery pattern. The nurse or lab technician will be present during the entire test. Heart rate will be monitored throughout the test.

I am aware that certain discomforts and consequences are associated with the procedures described such as, pain associated with insertion of the needle for the purpose of drawing blood, and related soreness. I have also been informed that maximal exercise may constitute a risk to persons with medical or health problems. I certify that I am in good health and have no known medical or health problems which limit my physical exercise.

I have understood the above explanation of procedures and voluntarily agree to participate in this study.

Signed:

_____

Date:

_____

I am scheduled to report to the Human Performance Laboratory on:

_____

APPENDIX B

Subject Data Sheet

SUBJECT DATA SHEET

Name _____

Date _____

Recovery _____

Weight _____

Workload _____

Resting BP _____ Finish BP _____

Supramaximal Performance I

Number of Revolutions _____

Peak Power _____

Work (joules) _____

Active Recovery	Workload
minute	load
1	
2	
3	
4	
5	

Supramaximal Performance II

Number of Revolutions _____

Peak Power _____

Work _____

Level of Lactic Acid

1.

2.

3.

4.

Remarks:

APPENDIX C

Descriptive Characteristics of the Active and Passive Recovery Groups

DESCRIPTIVE CHARACTERISTICS OF THE
ACTIVE AND PASSIVE RECOVERY GROUPS

VARIABLE	N	X	SD
RESTING B.P. (SYSTOLIC)			
active	13	114.76	± 8.06
passive	13	120.15	± 9.36
RESTING B.P. (DIASTOLIC)			
active	13	71.23	± 5.38
passive	13	73.07	± 8.62
BODY WEIGHT			
active	13	160.65	± 18.6
passive	13	161.69	± 12.7

APPENDIX D

Descriptive Characteristics of the Active Recovery Subjects Self Selected Workload

DESCRIPTIVE CHARACTERISTICS OF THE ACTIVE RECOVERY SUBJECTS SELF SELECTED WORKLOAD

MINUTE	N	$\overline{X}$	SD
1	13	.67	±.31
2	13	.65	±.24
3	13	.59	±.24
4	13	.59	±.24
5	13	.59	±.24

APPENDIX E

Lactate Levels of the Active and Passive Recovery Groups

LACTATE LEVELS OF THE ACTIVE
AND PASSIVE RECOVERY GROUPS

VARIABLE	N	$\overline{X}$	SD
PRE TEST LA			
active	13	1.15	±.52
passive	13	1.28	±.45
LA II			
active	13	14.33	±2.61
passive	13	14.36	±3.06
LA III			
active	13	12.40	±2.18
passive	13	14.29	±3.14
POST TEST LA			
active	13	16.86	±3.37
passive	13	18.68	±3.23

APPENDIX F

Time Required to Achieve Peak Power of the Active and Passive Recovery Groups

TIME (SECONDS) REQUIRED TO ACHIEVE PEAK POWER
OF THE ACTIVE AND PASSIVE RECOVERY GROUPS

VARIABLE	N	$\overline{X}$	SD
PERFORMANCE I			
active	13	2.90	±1.05
passive	13	2.61	±1.22
PERFORMANCE II			
active	13	3.50	±1.06
passive	13	3.80	±2.11

VITA

Edna Kathleen Foster was born in Winston-Salem, North Carolina, on June 1, 1958. Her family later moved to Greenville, South Carolina, where she completed her schooling, graduating from Wade Hampton High School in 1976. Miss Foster attended Appalachian State University where she received a Bachelor of Science degree in Physical Education with a minor in athletic training. In 1980, she accepted a teaching position at Bryson Middle School in Fountain Inn, South Carolina, where she was Intramural Coordinator and Department Chairperson. In 1982, Miss Foster returned to Appalachian State University to pursue a master's degree in Physical Education with a concentration in Exercise Science. She is employed by Champion International in Asheville, North Carolina as an Exercise Specialist.