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THE EFFECTS OF VARIOUS RECOVERY PATTERNS ON A SUBSEQUENT ANAEROBIC PERFORMANCE

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In Partial Fulfillment

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Master of Arts

in

The Department of Health and Physical Education

by

Vicki Coker Marsh

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by

Vicki Coker Marsh

APPROVED BY:

Vaughn K. Christian
Vaughn K. Christian
Associate Professor of Health, Physical Education and Recreation
Chairman, Thesis Committee

Roger Thomas
Roger Thomas
Professor of Health, Physical Education and Recreation
Committee Member

Carl Meeks
Carl Meeks
Professor of Health, Physical Education and Recreation
Committee Member

E. Ole Larson
E. Ole Larson
Chairman, Department of Health, Physical Education and Recreation

Joyce V. Lawrence
Joyce V. Lawrence
Dean of Graduate School

ABSTRACT

The purpose of the study was to discover the effects of selected recovery patterns on a subsequent anaerobic performance. A secondary purpose was to determine the effects of a recovery placebo during active and passive recovery on a subsequent anaerobic performance.

Each subject performed a one-minute maximal effort on an arm ergometer at a workload of 2.5 kilopounds, followed by an eight-minute recovery which was followed by a subsequent one-minute anaerobic performance using the same procedures as the initial performance. The four recovery patterns used were:

1. Passive recovery while breathing atmospheric air.

2. Active recovery while breathing atmospheric air.

3. Passive recovery while breathing atmospheric air as a placebo.

4. Active recovery while breathing atmospheric air as a placebo.

During the passive recovery, the subject sat with hands placed on a table. During active recovery, the subject pedalled the ergometer utilizing the arms at a speed of 50 revolutions per minute.

The findings of the study were as follows:

1. The subsequent anaerobic cumulative work output was not significantly altered from the corresponding initial anaerobic cumulative work output following any of the four recovery patterns.

2. The anaerobic breakpoint following passive recovery utilizing atmospheric air was 30 seconds.

3. The anaerobic breakpoint following active recovery utilizing atmospheric air was 40 seconds.

4. The anaerobic breakpoint following passive recovery utilizing atmospheric air as a placebo was 30 seconds.

5. The anaerobic breakpoint following active recovery utilizing atmospheric air as a placebo was 40 seconds.

The following conclusions from the study were:

1. The recovery patterns utilized in the study were not directly related to subsequent anaerobic cumulative work performances.

2. An active recovery pattern without a placebo lengthens the anaerobic breakpoint.

3. Breathing atmospheric air as an oxygen placebo during recovery does not appear to enhance the anaerobic breakpoint.

ACKNOWLEDGMENTS

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DEDICATION

The writer would like to dedicate this study to her husband and daughter, and other members of her family who have helped the writer by giving her a great deal of encouragement and understanding, and to the faculty and staff of the Department of Health and Physical Education at Appalachian State University.

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Chapter I

INTRODUCTION

Numerous studies have been conducted on the subject of aerobic exercise; however, the research available on anaerobic performance was limited. It has been demonstrated that the body derives energy from adenosine triphosphate. The high energy bonds, of adenosine triphosphate, are split to provide energy for the body's work. In order to restore adenosine triphosphate to its original high energy bond state, one of three situations must occur. Two of these processes involve anaerobic energy sources which are, therefore, the sources of anaerobic energy for short duration activities.

The adenosine triphosphate-phosphocreatine system provides quick energy for only a few seconds. In this system, phosphocreatine provides the necessary element to replenish the adenosine triphosphate's high energy bonds. This process was essential to provide energy. Energy was released and made available when the adenosine triphosphate's energy bond was split. Breaking the high energy bond converted adenosine triphosphate into adenosine diphosphate and a low energy phosphate. The addition of phosphocreatine provides the impetus needed to recombine the adenosine diphosphate with the low energy phosphate to form adenosine triphosphate which was then again ready to be a source of energy.

The lactic-acid system can also be a source of anaerobic energy. Adenosine triphosphate's high energy bonds are restored in this system also, but the process used to produce adenosine triphosphate differs from the adenosine triphosphate-phosphocreatine system. One of the end products of this system is lactic acid.

Both processes, the adenosine triphosphate-phosphocreatine system and the lactic-acid system are anaerobic. However, only a limited number of adenosine triphosphate molecules are produced by the anaerobic processes. The aerobic system provides adenosine triphosphate in greater amounts, but does require the presence of oxygen for the restoration of adenosine triphosphate. For extended periods of activity, the aerobic system is necessary because of its efficiency in producing energy from adenosine triphosphate.

Most of the modern day sports, however, are of the anaerobic variety. Anaerobic activity has been associated with intense movement, brief in duration. Although a sport activity may have lasted for several minutes, the actual performance time of continuous activity was of very short duration. An example would be the game of football. The movement and activities of the game were not designed for continuous performance. An actual "play" would have begun and ended in a few seconds. There was a pause in the activity between plays which offered some time for anaerobic stores to begin to be replenished. Softball, volleyball, and basketball would be additional examples of familiar sports which were primarily played in an anaerobic manner. The main workload of these sports would not place a continuous stress on the aerobic energy system, but rather on the anaerobic energy system. Other examples of individual sports which are anaerobic in nature would include the running of the 100-yard dash and weight lifting. Such activities which have been characterized by brief, but intense, energy requirements used anaerobic energy sources as the primary energy source for the work which was completed.

During exercise, the body's blood supply transports oxygen-rich blood to the portions of the body which are performing the work activity. Increased circulation provides better transportation of waste products and makes additional oxygen readily available for use in energy production. Circulation in the muscles aids the body in the dispersal of lactic acid which was produced as a waste product of an anaerobic energy production system. Later, during aerobic activity, the additional oxygen is used to replenish adenosine triphosphate by the aerobic method.

The shunting effect of the circulatory system has been studied in aerobic activity, and an active recovery has commonly been recommended to aid the body in the recovery process. For example, after a performer had run some extended distance, it was usually recommended that the runner continue to walk at the completion of the run to assist the recovery process. The slowed motion of the running activity encouraged circulation to the muscles which were most involved with the work.

Several studies have studied recovery patterns for aerobic activities, but there is limited information concerning the effects of recovery patterns on subsequent anaerobic performance.

An additional possibility existed in that subsequent performance was related to a psychological factor. Since only one study has investigated the breathing of atmospheric air as a placebo for oxygen, it was felt that this factor should also be considered as a component of the recovery patterns.

Statement of the Problem

The dearth of studies that have been conducted on recovery patterns and subsequent anaerobic performance warranted a study to determine the most appropriate type of recovery pattern for a subsequent anaerobic activity.

Purpose of the Study

The purpose of the study was to discover the effects of selected recovery patterns on a subsequent anaerobic performance. A secondary purpose was to determine the effects of a recovery placebo during active and passive recovery on a subsequent anaerobic performance.

Limitations

Due to influenza, eight of the 20 original subjects had to terminate the study prematurely. During this study, the microswitch which was attached to the revolution counter malfunctioned. A manual counter was utilized during four testing sessions as a result of the malfunctioning microswitch.

Delimitations

Twelve female subjects from Appalachian State University were the subjects of the study. The average age of the subjects was 19 years, 3 months. All subjects were considered to be non-athletes.

Definition of Terms

Active Recovery - That period in which the body parts imitated the test activity at a slower, prescribed work output.

Anaerobic Breakpoint - That time during the work performance when the correlation between work performed per inning and cumulative work performance did not appreciably change.

Anaerobic Test - A maximal effort of arm pedalling for one minute.

Cumulative Work Performance - The total number of revolutions obtained by the subject during an anaerobic performance of one minute as recorded by the cumulative print recorder.

Maximal Voluntary Effort - An "all out" effort in which the subject performed the anaerobic experimental test at an optimal level.

Non-athletes - Subjects who had not participated on a varsity athletic team on a collegiate level.

Passive Recovery - That period of time in which no activity was performed.

Placebo - The breathing of atmospheric air through a respirometer as an aid in the recovery process. The subjects were told that pure oxygen was being inhaled.

Chapter II

REVIEW OF LITERATURE

Several studies have investigated the effects of a particular recovery pattern on a subsequent performance. Most of these, however, have been studies involving aerobic activities, rather than anaerobic activities. Since most popular sports are anaerobic in nature, the writer has relied primarily on literature which dealt with anaerobic studies.

Studies Related to Anaerobic Testing

In 1980, a study was conducted by Angel (1) on the effects of recovery patterns on a supramaximal performance. In this study, the subjects performed a two-minute arm ergometer test which was followed by a twelve-minute recovery with a subsequent two-minute performance. Active versus passive recovery was tested. This test used a 24 hour interval between tests. The active recovery was performed at a speed of 50 metronome beats per minute. A visual-auditory metronome was used to indicate the cadence of the recovery performance. All subjects were tested at a maximal performance level. Findings in this study indicated that the passive recovery had little effect on the subsequent work performance while the active recovery pattern appeared to increase the anaerobic capacity of a subsequent anaerobic performance.

Christian (4) studied 26 subjects who performed a two-minute maximal intensity workout at two kpm of resistance. Analysis of data for each ten seconds of performance determined that, at the conclusion of 50 seconds, a correlation of .95 existed between cumulative work and the total work. There was no appreciable increase in correlation for any remaining inning. The results indicated that the anaerobic sources were primarily utilized for approximately 50 seconds of the work performance.

In a study by Weltman, Stamford, and Fulco (17), the effects of various recovery patterns were explored to determine the facilitory powers of each in lactate disappearance. The bicycle ergometer was used and findings indicated that the removal of lactate was enhanced by an active recovery. There was, however, no difference in the minute-by-minute or total work output. It was suggested that an important factor in lactate disappearance was the oxidation of lactate in the skeletal muscles.

A similar study by Katch, Weltman, Martin, and Gray (12), has also indicated that the anaerobic duration of operation seems to be approximately 40 seconds. A bicycle ergometer was used with pedals placed in a horizontal position when the signal was given to start. A microswitch counter was used to record the number of revolutions performed and verbal encouragement was used extensively. A visual-auditory metronome was used when speed had to be regulated.

Katch, Gilliam, and Weltman (11) conducted a study which utilized a sixty-second supramaximal workout followed by an active or passive recovery. Strong verbal encouragement was given to the subjects. The tests were separated by two days. The 14 subjects in this study were not athletes. The study revealed no significant differences in the cumulative work output.

From the literature studied, several conclusions were formed regarding testing procedures and equipment for this study. First, a visual-auditory metronome was an accepted method of controlling speed when using a bicycle or an arm ergometer. Most studies, such as the study by Angel (1) and the study by Katch, Gilliam, and Weltman (11), used a fifty-beats-per-minute cadence when an active recovery pattern was being tested. Also, a microswitch counter was used in almost every instance to ensure that an accurate count of revolutions was made. Additionally, verbal encouragement was necessary to aid the subject in the performance of a supramaximal workout. Since each subject was verbally motivated, verbal encouragement was not a variable in any of these studies.

Most of the studies cited, such as Weltman, Stamford, and Fulco (17), Davies, Knibbs, and Musgrove (5), Angel (1), McGrail, Bonen, and Belcastro (14), and Katch, Gilliam, and Weltman (11), tested an active versus a passive recovery. Studies by Angel (1), Katch, Gilliam, and Weltman (11), and Katch, Weltman, Martin, and Gray (12), which tested anaerobic performances consisted of one to two minute maximal intensity workouts with a recovery period of eight to 20 minutes followed by a subsequent anaerobic performance. Those studies which used the arm ergometer instead of a bicycle ergometer, used between two and two and one-half kilopounds of resistance which was applied after the subject began pedalling.

Studies Related to Utilization of the Arm Ergometer to Measure Work Performance

Several studies have been cited in the preceeding portion of this chapter which utilized the arm ergometer for testing anaerobic work performance. In addition, some studies have studied the usefulness and validity of the arm ergometer for other purposes.

Bonen, Wilson, Yarkony, and Belcastro (3) conducted a study to determine whether an arm ergometer provided comparable results to those obtained on swimmers in free, tethered, and flume swimming on measurements of maximal oxygen uptake. Although the study determined that the arm ergometer gave lower oxygen uptake predictions, the study did affirm that maximal oxygen consumption was much lower for arm exercise than for leg exercise.

Studies cited in a paper by Pendergast, Ceretelli, and Rennie (15), have shown that arm exercise produced relatively higher blood lactate levels than those produced by leg exercise. Lower anaerobic thresholds were also found for arm work as compared to leg work.

Studies Related to the Effect of Recovery Patterns on a Subsequent Performance

In a study by Falls and Richardson (6), three types of recovery were tested: complete rest, light exercise, and a cold shower. The speed of performance was improved significantly in all three situations. Findings indicated that the cold shower provided the best aid to recovery and there was no significant difference between the rest or passive recovery and the light exercise or active recovery pattern.

In several studies of aerobic workouts, the effects of recovery have been studied. Many of these studies indicated that the removal of lactate was quicker when an active recovery was used. In the study by Gisolfi, Robinson, and Turrell (7), it was determined that oxygen debt and the rate of lactate removal were improved substantially by an active recovery.

According to Davies, Knibbs, and Musgrove (5), exercise had a dilatory effect on the blood vessels of the muscles. By increasing the inner area of these vessels, more blood was circulated through the muscles, and thus, provided a more efficient transport system for the removal of lactate. An active recovery of 40 percent of the main activity provided the most efficient lactate removal.

Angel's study (1) found that an active recovery did increase anaerobic metabolism in a subsequent maximal effort. No significant effect was found when a passive recovery was used.

Weltman, Stamford, and Fulco (17) determined that lactate disappearance was aided by an active recovery. It was also suggested that the oxidation of lactate in the skeletal muscles was an important factor in lactate disappearance.

McGrail, Bonen, and Belcastro (14) found that the amount of lactate increased linearly with muscle metabolism. The rate of lactate removal was checked at rest, during exercise, and during active recovery. The slowest rate of lactate removal was found during rest.

The splitting of adenosine triphosphate and creatine phosphate stores and the resulting lactate formation were the sources which provided anaerobic energy for skeletal muscles (10). It was also apparent, as mentioned by Hermansen (9), that anaerobic performances have caused the production of lactate, which was diffused from the muscle cell to the blood.

Katch, Gilliam, and Weltman (11) conducted a test using 14 male subjects who recovered passively or actively from a one-minute supramaximal effort on the bicycle ergometer. The active recovery was performed at 50 revolutions per minute with no resistance. This speed was chosen in accordance with the findings of Whipp, Seard, and Wasserman (18) who suggested that it would result in a better recovery because of preferable oxygen uptake with an active 50 beats per minute cadence over that obtained in a complete resting condition. According to the study by Katch, Gilliam, and Weltman (11), those in favor of active recovery believed that the venous blood flow return was enhanced by the muscles which help to pump the excess blood back to the heart. This action prevented the pooling of the blood in those areas which had previously performed the supramaximal work. Another consideration was that the increased heart rate and oxygen uptake were helpful in circulating the blood to its optimal location after the exercise. The active recovery provided the sources of the increased heart rate and oxygen uptake. However, proponents of passive recovery argue that a passive recovery increases the rate of return to a baseline level of net oxygen uptake, as well as offering a faster net heart rate (11).

Studies Related to the Use of Atmospheric Air as a Placebo to Recovery

According to the study done by Katch, Gilliam, and Weltman (11), the additional oxygen made available during an active recovery period increased the oxidation of lactate. The appropriate level of activity in the active recovery would depend on the individual's state of fitness.

The effects of breathing 100 percent pure oxygen during recovery and exercise were studied by Hagerman, Bowers, Fox, and Ersing (8). This study utilized an anaerobic test. The administration of 100 percent pure oxygen during exercise and rest was shown to have no beneficial physiological effects on the performance of the subjects.

Psychological effects of breathing pure oxygen have not been thoroughly explored, but nearly all of the subjects in the study by Weltman, Katch, and Sady (13), stated that a better performance was achieved while breathing pure oxygen.

Although several studies have attempted to demonstrate the effects of breathing pure oxygen, both during exercise and as an aid to recovery, most studies have been conducted with aerobic test performances, rather than with anaerobic tests. Only one study was found in which oxygen was replaced with a placebo of atmospheric air. The study used an anaerobic test. Bjorgum and Sharkey (12), used three recovery aids: oxygen, a placebo tank of atmospheric air, and ordinary atmospheric air. Both runners and non-runners were used in the study. The oxygen was of more benefit to the non-runners than to the runners because the non-runners were performing closer to a maximal oxygen uptake level than the runners. There was, however, no noticeable difference in the recovery of any of the subjects. It would be assumed that neither of the recovery patterns had a significant effect.

Summary of Literature

The findings of most of the literature perused, indicated that the anaerobic energy sources seemed to falter between 40 and 50 seconds.

Studies have also shown that the arm ergometer was an acceptable piece of equipment for the measurement of an anaerobic work performance which was executed with the arms.

Although some studies have explored the effectiveness of an active recovery as compared to that of a passive recovery, most studies have focused on aerobic activity and recovery rather than anaerobic activity.

Only one study was found which utilized atmospheric air as a placebo for oxygen. While it seemed to indicate that subjects believed that performance was enhanced by the inspiration of pure oxygen, no significant difference among groups appeared.

Chapter III

PROCEDURES

The purpose of this study was to analyze the effects of various recovery patterns on a subsequent anaerobic performance. A secondary purpose was to determine the effects of a recovery placebo during active and passive recovery on a subsequent anaerobic performance.

Twelve of the original 20 volunteer subjects completed the study. All subjects were female undergraduate students at Appalachian State University who were non-athletes. Each subject participated in four anaerobic testing sessions with a different recovery pattern utilized at each session. Each session consisted of a one-minute maximal effort on a Monark arm ergometer followed by an eight-minute recovery period and a subsequent maximal anaerobic performance on the ergometer. Subjects were verbally motivated at all times.

Work performance was monitored and the number of revolutions which were completed was recorded by a microswitch which was attached to the cumulative print recorder. During two of the recovery patterns, atmospheric air was used as a placebo for pure oxygen. Active recovery was regulated to 50 beats per minute.

The four recovery patterns were:

1. Passive recovery with the inspiration of atmospheric air.

2. Active recovery with the inspiration of atmospheric air.

3. Passive recovery with the inspiration of atmospheric air as a placebo.

4. Active recovery with the inspiration of atmospheric air as a placebo.

Selection of Subjects

Twenty female volunteers were chosen as subjects for the study. The subjects were undergraduate students at Appalachian State University who were enrolled in physical education classes during the 1981 Spring Term. None of the subjects were involved in any sports on the varsity level and all were classified as non-athletes. The subjects had an age range of 18 years, 4 months to 20 years, 4 months with an average age of 19 years, 3 months. The average height was 161.2 centimeters and the average weight was 53.22 kilograms. (See Appendix A). Illness prevented eight of the original subjects from completing the study. All testing was performed in the Human Performance Laboratory at Appalachian State University.

Equipment

Adjustable Bench - Each subject was seated on an adjustable height bench during the testing period. Before each anaerobic test, the bench was adjusted to accomodate the subject's seated height which was necessary for standardization of the test procedures.

Arm Ergometer - A Monark arm ergometer was used for measuring the anaerobic work performance. The ergometer was purchased from Quinton Instruments, located at 2121 Terry Avenue, in Seattle, Washington.

Burdick Electrocardiograph - During this study, the electrocardiogram was monitored as a safety precaution. The CS/25 monitor and an electrocardiograph were attached to the subject by means of three leads which were connected to three electrodes on the subject's sternum and ribs.

Cumulative Print Recorder - To ensure accuracy in the counting of pedal revolutions, a cumulative recorder was used. The cumulative recorder with a microswitch was attached to the ergometer which was activated by each pedal revolution. The revolutions per second were recorded on graph paper for the entire test period. This piece of equipment may be obtained by requesting the Heath Servo Recorder, model no. EUW-20A, from the Heath Manufacturing Company which is located in Denton Harbour, Michigan.

Metronome - The active recovery periods required the use of an electric metronome which was made by the Franz Manufacturing Company, Inc., located on Printer's Lane, South Boulevard Business Park, in New Haven, Connecticut. The metronome was a visual-auditory model which was used to set the pace for the subject who was pedalling during recovery at a specific cadence of 50 beats per minute.

Nine-Liter Respirometer - A Collins nine-liter respirometer was used as the equipment utilized for breathing atmospheric air as an oxygen placebo. It was purchased from the Warren Collins Company, Inc., located at 220 Wood Road, Braintree, Maine.

Stopwatch - A stopwatch was used to initiate the timing of the anaerobic exercise trials as well as the recovery periods.

Familiarity Procedures

All testing was completed in the Human Performance Laboratory at Appalachian State University between the hours of 12 a.m. and 8 p.m.

The procedures that were adhered to during the familiarization period were as follows:

1. Each subject was asked to read and sign a consent form. (See Appendix B).

2. A number was then assigned to each subject.

3. A brief explanation of the testing procedures and reasons for the testing followed.

4. The subject was clinically prepared for electrode placement.

5. The bench height was adjusted to accomodate the stem height of the subject.

6. The pedals of the arm ergometer were placed in horizontal alignment.

7. The height of the breathing valve of the respirometer was adjusted for the subject's comfort. The proper technique for insertion of the mouthpiece of the respirometer was explained if the placebo was to be used in the recovery pattern.

8. The recovery pattern which was to be used at that particular session was explained.

If the recovery pattern was to be passive, the subject was instructed to sit quietly in place with hands flat on the table on which the ergometer was placed. For an active recovery, the subject was asked to pedal the ergometer in cadence with the metronome and was advised that a ten-second warning would be given before the subsequent performance, which provided time to stop and place the pedals in a horizontal plane in readiness for the subsequent minute of anaerobic activity. If the recovery pattern utilized the inspiration of atmospheric air as an oxygen placebo, the subject was instructed to insert the mouthpiece of the respirometer during recovery. Subjects were asked to breathe as normally as possible while breathing the placebo oxygen. The inspiration of atmospheric air required no equipment.

Preparation for Electrode Placement

Subjects were asked to wear halter or tank tops to the testing sessions to facilitate the preparation for electrode placement. Redux Paste was applied in a circular motion for approximately 30 seconds to the surface of the skin at the predetermined electrode sites. The surface area was then wiped with a clean cotton ball to remove any traces of residue. A lead electrode with a disposable adhesive patch was then attached to the selected surface area.

After the electrode placement was completed, the electrode wires were attached to the electrodes. A three-inch wide elastic bandage was then wrapped around the subject to further secure the two electrodes which were located on the ribs. The sternum electrode was secured with adhesive tape.

Procedures for Locating the Electrode Placement

Three electrode sites were used. The first electrode was placed on the sternum, the second electrode was placed on the fifth rib below the left nipple, and the third electrode was placed on the fifth rib below the right nipple.

Anaerobic Testing Procedures

The following procedures were used:

1. The electrodes were placed on the selected sites of the subject.

2. The subject was instructed to sit on an adjustable bench with one arm extended and one arm flexed when placed on the pedals of the ergometer.

3. The subject was asked to sit erect with feet slightly apart to stabilize the subject during the activity.

4. The subject was advised to pedal only in one direction.

5. The subject was told to pedal as fast as possible while the writer adjusted the resistance knob, which took

no longer than two seconds. When two kilopounds of resistance had been reached, the performance formally was commenced by the initiating of the timing device.

6. The cumulative printer recorder was turned on simultaneously with the initiation of the stopwatch so that revolution readings were taken during the entire activity.

7. Verbal encouragement was given throughout the anaerobic performance.

8. At the end of one minute, the subject was instructed to stop.

9. The subject was instructed to begin the predetermined recovery pattern.

10. The recovery pattern was timed for eight minutes. The subject was periodically advised of the time which remained.

11. When only ten seconds remained in the recovery period, the subject was asked to stop and to prepare for the subsequent anaerobic activity.

12. The same procedures were followed for the subsequent minute of anaerobic activity that were utilized for the first minute of activity.

13. At the end of the subsequent minute of activity, the subject was asked to pedal slowly without resistance until the subject's heart rate, as monitored by the electrocardiogram, had returned to normal limits.

14. The electrode wires were detached and the electrodes were removed. The subject was advised to apply lotion to the electrode sites to prevent irritation.

15. The graph drawn by the cumulative recorder was analyzed to determine the number of revolutions performed during each ten second interval of activity.

16. The order in which a subject experienced each recovery pattern was counterbalanced to avoid any training effect in the study.

Administrative Procedures for the Recovery Patterns Following Each Initial Anaerobic Test

Recovery Pattern Number One. (Passive activity for eight minutes). Recovery pattern one combined the components of passive activity for eight minutes with the inspiration of atmospheric air. The subject was asked to sit quietly with hands on the table while breathing normally. The subject continued to breathe atmospheric air while seated passively at the table until a ten-second warning was given to prepare for the subsequent anaerobic exercise.

Recovery Pattern Number Two. (Active recovery for eight minutes). Recovery pattern two consisted of an active recovery while the subject was breathing atmospheric air. The subject was instructed to pedal the arm ergometer for the eight-minute recovery period without resistance to the beat of the metronome which was provided while breathing normally. The subject continued the recovery protocol until a ten-second warning was given to prepare for the subsequent anaerobic activity.

Recovery Pattern Number Three. (Passive recovery for eight minutes with atmospheric air as an oxygen placebo). Recovery pattern three required the subject to be seated passively with hands on the table, as in recovery pattern one, for eight minutes while breathing atmospheric air as a placebo for oxygen through the respirometer. The subject was instructed to breathe normally while using the nine-liter respirometer. Although the respirometer was a placebo instrument, procedures emulated the breathing of pure oxygen. This recovery pattern continued until a ten-second warning was given.

Recovery Pattern Number Four. (Active recovery for eight minutes with atmospheric air as an oxygen placebo). Recovery pattern four required the subject to have an active recovery for eight minutes while breathing atmospheric air as a placebo for oxygen. Again, the nine-liter respirometer was used and all procedures were executed as if pure oxygen was being used instead of the atmospheric air placebo. The recovery protocol was continued until a ten-second warning was given.

Statistical Analysis

The data used in the statistical analysis in this study were derived from cumulative revolutions scores which were obtained during an anaerobic work performance on an arm ergometer. An analysis of variance with repeated measures was used to determine if any significant differences existed among subsequent anaerobic work performances, following each of four recovery patterns.

Correlations were computed among work performances by innings in order to estimate potential changes in the anaerobic breakpoint for the four recovery patterns.

Chapter IV

PRESENTATION AND ANALYSIS OF DATA

The purpose of this study was to analyze the effects of various recovery patterns on a subsequent anaerobic performance. The first recovery pattern was a passive recovery while breathing atmospheric air. The second recovery pattern involved an active recovery while breathing atmospheric air. In the third recovery pattern, a passive recovery was adhered to while the subject breathed atmospheric air as an oxygen placebo. The last recovery pattern utilized an active recovery while the subject breathed atmospheric air as an oxygen placebo. A second aspect of this study involved a correlation of each cumulative inning with the total cumulative work output. These correlations were used to identify the anaerobic breakpoint which indicated that the aerobic energy system had become the primary source of energy. The anaerobic breakpoint was assumed when correlations between inning work output and cumulative work output showed no appreciable increase from one inning to the next inning. A secondary purpose was to determine the effects of a recovery placebo during an active or passive recovery on a subsequent anaerobic performance.

Analysis of the Cumulative Work Output Among the Four Pretest Trials

Analysis of the data on cumulative work output among the four pretest anaerobic trials showed no significant difference in the work output for each subject on any of the subject's four testing days. There was a significant difference among the revolutions turned within individual innings for each test, but the total work output did not change significantly. Table I illustrates these findings.

Table I

ANALYSIS OF CUMULATIVE WORK OUTPUT
AMONG FOUR PRETEST TRIALS

Source	SS	df	MS	F	P
Mean	93961.125	1	93961.125		
Error	276.70833	11	25.153		
Treatment	22.01389	3	7.33796	.29	N.S.
Error	822.81944	33	24.93392		
A (among	4346.0	5	869.2	144.79	.01
innings)	330.16667	55	6.00303		
TA	23.02778	15	1.53519	.54	N.S.
Error	468.13889	165	2.83721		

Analysis of the Cumulative Work Output
Among the Four Post Test Trials

An analysis of the data on the cumulative work output following four post-recovery patterns showed no significant difference in work output for any of the recovery patterns. There was a significant difference among the revolutions turned within the individual innings for each test but the total work output did not change significantly. These findings are shown in Table II.

Table II

ANALYSIS OF CUMULATIVE WORK OUTPUT
AMONG FOUR POST TEST TRIALS

Source	SS	df	MS	F	P
Mean	87222.72222	1	87222.72222		
Error	285.86111	11	25.98737		
T (Trials)	46.750	3	15.58333	.82	N.S.
Error	629.0	33	19.06061		
B (among innings)	2665.19444	5	533.03889	117.63	.01
Error	249.22222	55	4.53131		
TB	57.83333	15	3.85556	1.06	N.S.
Error	599.41667	165	3.63283		

Analysis of the Relationship Between the Cumulative Work Output Per Inning and the Total Cumulative Work Output for the Passive Recovery Utilizing Atmospheric Air

The relationship of each cumulative inning's work output with the total cumulative work output showed an anaerobic breakpoint after 40 seconds in the pretest condition and after 30 seconds in the post test. (See Table III). The means and standard deviations for the work output may be found in Appendix C.

Table III

CORRELATION OF PRE AND POST TEST CUMULATIVE WORK OUTPUT PER INNING WITH TOTAL CUMULATIVE WORK OUTPUT FOR PASSIVE RECOVERY UTILIZING ATMOSPHERIC AIR

Seconds	Pretest
10	.85811
20	.85244
30	.92891
40	.96835
50	.98867

Seconds	Post Test
10	.81006
20	.88125
30	.93102
40	.94115
50	.98094

Analysis of the Relationship Between the Cumulative Work Output Per Inning and the Total Cumulative Work Output for the Active Recovery Utilizing Atmospheric Air

The analysis of the relationship of each cumulative inning's work output with the total cumulative work output, showed an anaerobic breakpoint after 40 seconds in the pretest condition and after 40 seconds in the post test condition. (See Table IV). The means and standard deviations for the work output may be found in Appendix D.

Table IV

CORRELATION OF PRE AND POST TEST CUMULATIVE WORK OUTPUT PER INNING WITH TOTAL CUMULATIVE WORK OUTPUT FOR ACTIVE RECOVERY WITH ATMOSPHERIC AIR

Seconds	Pretest
10	.88247
20	.87703
30	.88454
40	.91804
50	.98554

Seconds	Post Test
10	.88359
20	.87855
30	.89965
40	.94012
50	.98048

Analysis of the Relationship Between the Cumulative Work Output Per Inning and the Total Cumulative Work Output for the Passive Recovery Utilizing a Placebo

The analysis of each cumulative inning's work output with the total cumulative work output revealed an anaerobic breakpoint after 30 seconds in the pretest condition and after 30 seconds in the post test condition. (See Table V). The means and standard deviations for the work output may be found in Appendix E.

Table V

CORRELATION OF PRE AND POST TEST CUMULATIVE WORK OUTPUT PER INNING WITH TOTAL CUMULATIVE WORK OUTPUT FOR PASSIVE RECOVERY UTILIZING A PLACEBO

Seconds	Pretest
10	.92588
20	.94212
30	.95007
40	.97733
50	.99241

Seconds	Post Test
10	.89616
20	.94426
30	.97049
40	.96731
50	.98693

Analysis of the Relationship Between the Cumulative Work Output and the Total Cumulative Work Output for the Active Recovery Utilizing a Placebo

The analysis of the relationship of each cumulative inning's work output with the total cumulative work output demonstrated an anaerobic breakpoint after 40 seconds in the pretest condition and after 40 seconds in the post test condition. (See Table VI). The means and standard deviations for the work output may be found in Appendix F.

Table VI

CORRELATION OF PRE AND POST TEST CUMULATIVE WORK OUTPUT PER INNING WITH TOTAL CUMULATIVE WORK OUTPUT FOR ACTIVE RECOVERY UTILIZING A PLACEBO

Seconds	Pretest
10	.74120
20	.83834
30	.90175
40	.95325
50	.98661

Seconds	Post Test
10	.57657
20	.70596
30	.80617
40	.87675
50	.94333

Chapter V

SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS, AND FURTHER RECOMMENDATIONS

Summary

The purpose of this study was to discover the effects of selected recovery patterns on a subsequent anaerobic performance. A secondary purpose was to determine the effects of a recovery placebo during an active or passive recovery on a subsequent anaerobic performance.

Twelve female volunteer subjects from Appalachian State University were used in this study. None of the subjects were athletes and all were between the ages of 18 and 20. Subjects were all enrolled in physical education activity courses at the time of the study.

A one-minute anaerobic work performance, followed by an eight-minute recovery period, and a subsequent one-minute anaerobic work performance was used for this study. The anaerobic work consisted of a one-minute maximal pedalling effort on the arm ergometer. An eight-minute recovery period was administered, following the work performance using one of the prescribed recovery patterns. Following the specified recovery pattern, another anaerobic trial was administered.

During the entire testing period, the subject's electrocardiogram was monitored. During the work periods, a microswitch cumulative counter was used to determine the number of pedal revolutions which were performed per ten-second time interval.

An analysis of variance with repeated measures was used to determine if any significant differences existed among subsequent anaerobic work performances following each of four recovery patterns. Correlations were computed among work performances by innings in order to estimate potential changes in the anaerobic breakpoint.

Findings

The findings of the study were as follows:

1. The subsequent anaerobic cumulative work output was not significantly altered from the corresponding initial anaerobic cumulative work output following any of the four recovery patterns.

2. The anaerobic breakpoint following passive recovery utilizing atmospheric air was 30 seconds.

3. The anaerobic breakpoint following active recovery utilizing atmospheric air was 40 seconds.

4. The anaerobic breakpoint following passive recovery utilizing atmospheric air as a placebo was 30 seconds.

5. The anaerobic breakpoint following active recovery utilizing atmospheric air as a placebo was 40 seconds.

Discussion

In an effort to discover the effects of various recovery patterns on a subsequent anaerobic performance, the writer compared the work output of each trial. Each recovery pattern was studied separately to detect the effect of each recovery pattern. The results of the study showed that there was no significant difference in the total work output recorded from each subsequent performance, regardless of recovery pattern. There was no more than an eight revolution difference between the average for the pre-recovery and post-recovery tests. This indicated that there was virtually no effect on the subsequent anaerobic performance as a result of the recovery pattern that was utilized.

Some studies have studied anaerobic exercise, but few studies have dealt with the effectiveness of various recovery patterns on a subsequent anaerobic activity. Investigators have reported that any work performed for more than a few seconds would involve some aerobic energy sources. Aerobic recovery studies have favored an active recovery as compared to passive recovery to quickly return heart rate to normal limits. Proponents of the active recovery suggested that an active recovery has helped the body to effectively shunt the blood back to its usual location in the body after activity in which certain body parts have had need of increased circulation to perform the activity.

Because of the lactate production which was a normal part of anaerobic energy production, fatigue could be an important factor in anaerobic activity. Increased levels of lactic acid in the muscles have been associated with increased fatigue. The more rapid removal of this substance by the use of an active recovery would appear to prevent fatigue from being such an important factor in anaerobic exercise since increased levels of lactic acid would not have increased.

Only one study was found (2) related to the utilization of atmospheric air as an oxygen placebo during a recovery pattern which was inconclusive. The psychological effects of the use of oxygen as a placebo, could not be determined in the study.

Angel's study (1) found that the passive recovery did not enhance or inhibit the duration of the anaerobic energy source. In the study, the 40, 50, and 60 second innings were carefully studied to determine if the results were similar to those in Angel's study. The anaerobic capacity was relatively unchanged by the use of the passive recovery protocol. That study did, however, indicate that the active recovery protocol was effective in increasing the anaerobic capacity when following an active recovery period. However, the study did not use the variable of atmospheric air versus atmospheric air as an oxygen placebo. Also, a longer performance and recovery time were utilized in Angel's study. The active recovery was used to assist the circulation of blood after exercise. This circulation aid helped to provide the shunting effect which active recovery proponents have stated is necessary to enhance recovery. The writer's study supports the findings of Angel (1) since it was found that the anaerobic breakpoint was increased following active recovery utilizing atmospheric air when compared to the anaerobic breakpoint of the passive recovery pattern.

There was no significant difference in the cumulative work output, although there was a difference among the work outputs for each inning as computed within the ten-second intervals. In an anaerobic workout utilizing a maximal effort, the time of anaerobic energy source would necessarily be of short duration. It was anticipated that the subject reached the point at which aerobic sources had completely replaced anaerobic sources as the energy supplier for the workload when the number of revolutions began decreasing during each ten-second interval. The writer found that this situation did occur. The number of revolutions per interval remained the same or decreased as each progressive inning occurred. The buildup of lactic acid during the initial exercise would be a contributing factor to the subject's fatigue which would have affected the subject's performance. The increasing levels of fatigue would prohibit the subject from performing the same or more revolutions as the time of the trial continued.

The changeover of anaerobic sources for energy to aerobic sources was also expected to signal the changeover of fast-twitch fibers in the muscles to slow-twitch fibers which would then have assumed the main portion of the workload. Fast-twitch fibers tend to work more efficiently, for biochemical reasons, under anaerobic conditions while slow-twitch fibers work best under aerobic conditions (13).

The assumption was made that aerobic energy pathways would supplant the anaerobic pathways when anaerobic energy sources had been depleted. When the correlations showed no appreciable increases, the anaerobic breakpoint was assumed to be an alteration in energy systems being used.

An analysis of the anaerobic breakpoints found in this study did reveal some differences. With one exception, all of the pre-recovery trials reached the anaerobic breakpoint after 40 seconds. The one exception was the recovery pattern which used passive sitting while breathing atmospheric air as a placebo for oxygen which had an anaerobic breakpoint of 30 seconds.

The recovery pattern which included a passive recovery while breathing atmospheric air seemed to be the pattern which was the least beneficial to subsequent anaerobic performance. The pre-recovery anaerobic breakpoint was found at the end of 40 seconds. This finding indicated that the recovery pattern had an inhibitory effect on the subsequent performance of the subject.

The pre-recovery anaerobic breakpoint for the passive recovery utilizing a placebo was reached after 30 seconds and the post-recovery trial anaerobic breakpoint was reached after 30 seconds. Although the initial breakpoint was shorter than that found with the other treatments, there was no difference in the locations of the breakpoint of the pre-recovery and post-recovery trials. The passive recovery with atmospheric air as an oxygen placebo had no effect on the anaerobic breakpoint in the subsequent trial because there was no difference in the breakpoint location.

The fourth recovery pattern studied the active recovery with the atmospheric air as a placebo. The writer had hypothesized that a comparison of these two patterns would have shown that the active recovery would increase the anaerobic breakpoint of the subsequent anaerobic trial because of the psychological effects of the placebo. In this treatment, the pre-recovery trial breakpoint occurred at the end of 40 seconds and the post-recovery trial breakpoint was estimated to be 30 seconds. The similar findings of the placebo could be attributed to awkwardness of the placebo equipment utilized for these conditions.

While there was no significant difference in the cumulative workloads of the four treatments, the assumed anaerobic breakpoint of the energy systems seems to have shown that some of the recovery patterns which were tested would appear preferable to others. The least beneficial recovery pattern was the passive recovery with the inspiration of atmospheric air, although the only difference in this pattern and the treatment which used a passive recovery utilizing atmospheric air as a placebo may have been attributed to psychological factors not measured. There was no difference in the anaerobic breakpoint following placebo recovery patterns when compared to initial anaerobic breakpoints.

Conclusions

The following conclusions from the study were:

1. The recovery patterns utilized in the study were not directly related to subsequent anaerobic cumulative work performances.

2. An active recovery pattern without a placebo lengthens the anaerobic breakpoint.

3. Breathing atmospheric air as an oxygen placebo during recovery does not appear to enhance the anaerobic breakpoint.

Recommendations

It is recommended that study be conducted to determine the effects of oxygen as an aid in the recovery process.

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APPENDICES

APPENDIX A

HEIGHT, WEIGHT, AND AGES OF ALL SUBJECTS

	Height (cm)	Weight (kg)	Age (months)
S1	66.5	124	242
S2	61.1	103.5	228
S3	66	121	220
S4	61.5	125	231
S5	63.5	105.5	232
S6	61	101	233
S7	62.25	106	223
S8	66	152	231
S9	62.5	117	244
S10	63.5	128	226
S11	65	124	222
S12	66	118	230

APPENDIX B

INFORMED CONSENT FOR ANAEROBIC EXERCISE TEST

1. Explanation of the Anaerobic Test
   You will perform an exercise test on an arm ergometer. The work level will be two kilopounds of resistance at an all out effort for one minute, followed by an eight-minute recovery period, followed by a subsequent minute of all-out effort. We may stop the test at any time because of abnormal signs. We do not wish you to exercise at a level which is abnormally uncomfortable for you.

2. Risks and Discomforts
   There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure and increased heart rate. Every effort will be made to minimize them by observations during testing. Emergency equipment and trained personnel are available to deal with unusual situations which may arise.

3. Inquiries
   Any questions about the procedures are welcome. If you have any doubts or questions, please ask us for further explanations.

4. Freedom of Consent
   Permission for you to perform this exercise test is voluntary. You are free to deny consent if you so desire.

I have read this form and I understand the test procedures that I will perform and I consent to participate in this test.

____
Signature of Subject

________________ ____________________________
Date Witness

Subject # ________________

APPENDIX C

MEANS AND STANDARD DEVIATIONS FOR PRE AND POST RECOVERY PATTERN ONE

Innings/ 10 seconds	Pretest $\bar{X}$	SD
I1	23.9167	4.1222
I2	20.75	2.9886
I3	18.8333	2.6572
I4	16.6667	2.3484
I5	15.1667	3.2146
I6	12.75	2.7675
Total	108.0833	14.3429

Innings/ 10 seconds	Post Test $\bar{X}$	SD
I7	22.0	3.3303
I8	19.4167	2.4664
I9	18.50	2.3549
I10	16.0	2.1320
I11	14.75	2.0505
I12	12.9167	2.7784
Total	103.5833	12.1988

N=12

APPENDIX D

MEANS AND STANDARD DEVIATIONS FOR PRE AND POST RECOVERY PATTERN TWO

	Pretest	
Innings/ 10 seconds	$\overline{X}$	SD
I1	24.9167	3.8009
I2	21.9167	2.8110
I3	18.50	1.2432
I4	17.1667	1.5859
I5	14.9167	2.2344
I6	13.4167	2.3916
Total	110.8333	10.5385

	Post Test	
Innings/ 10 seconds	$\overline{X}$	SD
I7	22.6667	4.2498
I8	19.250	2.5271
I9	18.50	2.2764
I10	16.1667	1.6967
I11	15.50	2.3549
I12	14.3333	2.0597
Total	107.0833	10.4225

N=12

APPENDIX E

MEANS AND STANDARD DEVIATIONS FOR PRE AND POST RECOVERY PATTERN THREE

	Pretest	
Innings/ 10 seconds	$\overline{X}$	SD
I1	24.3333	4.1633
I2	21.3333	3.1140
I3	18.5	2.1106
I4	16.8333	1.9924
I5	14.5	1.9306
I6	12.9167	2.1515
Total	108.4167	13.2147

	Post Test	
Innings/ 10 seconds	$\overline{X}$	SD
I7	23.5833	4.6799
I8	20.9167	3.5280
I9	18.0	1.95
I10	16.25	1.2154
I11	14.1667	1.8007
I12	13.9167	2.4293
Total	106.8334	12.5975

N=12

APPENDIX F

MEANS AND STANDARD DEVIATIONS FOR PRE AND POST RECOVERY PATTERN FOUR

Innings/ 10 seconds	Pretest $\overline{X}$	SD
I1	24.3333	3.8455
I2	20.5	2.7798
I3	18.8333	1.4035
I4	16.25	1.6026
I5	14.1667	1.7495
I6	12.0833	2.2344
Total	106.1667	10.4083

Innings/ 10 seconds	Post Test $\overline{X}$	SD
I7	21.5	1.8829
I8	18.8333	1.6967
I9	17.5833	2.0652
I10	15.9167	1.8809
I11	14.5	2.3160
I12	12.5	3.3233
Total	100.8333	9.0437

N=12

APPENDIX G

MODEL DATA SHEET

<u>1st exercise period</u>

<u>Seconds</u>
0
10
20
30
40
50
60

<u>Recovery Period</u>

<u>Seconds</u>
10
20
30
40
50
60
70
80
90
100
110
120
130

<u>Recovery period</u>

<u>Seconds</u>
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360
370

<u>Recovery Period</u>

<u>Seconds</u>
380
390
400
410
420
430
440
450
460
470
480

<u>2nd Exercise Period</u>

<u>Seconds</u>
10
20
30
40
50
60

Recovery Patterns:
1. passive with atmospheric air
2. active with atmospheric air
3. passive with atmospheric air as a placebo
4. active with atmoshperic air as a placebo

Name:____________________

Number:__________________

Date:____________________

Type of recovery:________

VITA

Vicki Coker Marsh was born in Gastonia, North Carolina, on February 4, 1951. Mrs. Marsh's permanent address is P. O. Box 95, Gastonia, North Carolina. The author's secondary education was obtained from Hunter Huss High School, Gastonia, North Carolina.

The author attended Erskine College for two years and continued undergraduate education at Western Carolina University. Mrs. Marsh obtained a Bachelor of Science degree in Health and Physical Education from Western Carolina University on June 4, 1973.

At Erskine College, she was a member of the Athenian Literary Society, Physical Education Majors Club, and Epsilon Sigma Tau. She participated in intramurals at Western Carolina University where she was also a member of the Physical Education Majors Club and the student organization of the North Carolina Association of Educators.

Upon college graduation, Mrs. Marsh became a teacher of physical education at Hunter Huss High School where she remained for six years. While at Hunter Huss, Mrs. Marsh was the Director of Intramurals, Cheerleader sponsor, and Advisor to the Girls' H Club. The writer has served as school Association of Classroom Teachers representative, and as a member of the Gaston County Physical Education Curriculum Committee where she served as the chairperson for the Senior High Physical Education Curriculum Committee.

In January, 1980, Mrs. Marsh took an educational leave of absence from Gaston County Schools and began work as a graduate student at Appalachian State University in the department of health and physical education. Mrs. Marsh has returned to Gaston County and is now employed as a physical education specialist on the elementary school level.

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