THE EFFECTS OF CERTAIN PHYSIOLOGICAL AND PSYCHOLOGICAL TECHNIQUES ON RECOVERY FROM FATIGUE AND IMPAIRMENT IN ATHLETES

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This is to certify that the

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Title of Study: THE EFFECTS OF CERTAIN PHYSIOLOGICAL AND PSYCHOLOGICAL TECHNIQUES ON RECOVERY FROM FATIGUE AND IMPAIRMENT IN ATHLETES.

Statement of the Problem: The purpose of this study was to determine the effectiveness of three techniques on the recovery from fatigue and impairment in athletes. A fourth technique was used as a control to offer a basis of comparison for the three experimental techniques. The recovery techniques were: 1. Lying in a supine position (control), 2. Lying supine with arms and legs elevated, 3. Slow jogging or movement, 4. Watching sound movies. The criteria for recovery were repeat performance runs and rate of oxygen debt repayment.

Methodology: There were two parts to the study. Part One consisted of performance data collected on subjects at Oklahoma State University. Two subjects each made thirty-two repeat two-hundred yard swims during a fall semester and two subjects each made thirty-two repeat one-half mile runs during a spring semester. The recovery techniques were introduced during a ten minute rest period between the swims and runs. These data were treated by using the analysis of covariance technique to equalize the first run times and to test for differences between the techniques in terms of mean second run times.

Part Two consisted of data collected on two subjects in the laboratory at Michigan State University. Each of these two subjects made thirty-two experimental runs on the treadmill. Each run consisted of a standard five minute initial run, a ten minute recovery period and an all out performance run with the treadmill set at eight miles per hour and at a ten degree incline. Metabolic measures were taken so that rate of oxygen debt repayment during the recovery period could be computed. These data were treated by using the analysis of variance technique to test for differences between the techniques in terms of oxygen debt repayment and times of the all out runs.

Findings and Conclusions: 1. The technique of lying supine with arms and legs elevated proved to be the most effective of the recovery techniques studied in this experiment. 2. The slow jog or movement technique as used in this study was found to give no better performance results than the control, and it was signigicantly inferior to all other techniques in terms of oxygen debt repayment. 3. Watching sound movies as a recovery technique seems to offer some benefits although the results from this study were inconclusive. The results from this technique seemed to vary from one individual to another with the different types of movies shown. This technique needs further and more detailed study. 4. There was a high negative correlation between pulse rate immediately after exercise and the amount of oxygen debt repayment during the recovery period. This figure may be of value as a predictive factor and it would be practical to use. 5. This study could not effectively measure recovery from fatigue (as different from impairment) because there was not a sufficient measure available of the level of fatigue reached by each subject.

Advisor's Approval: ______________________________

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by

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A THESIS

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Appreciation is also expressed to Dr. Wayne Van Huss of the Physical Education Department at Michigan State University for his guidance and assistance during the data collection in the Summer of 1958. Although he was not a member of the committee for this study, without his help it would not have been possible to have collected the data at this time.

The author also wishes to thank Dr. Carl Marshall, head of the Statistical Laboratory at Oklahoma State University for his guidance and help on the statistical treatment of the data and for his helpful suggestions regarding the writing of this manuscript.

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CHAPTER I

STATEMENT OF THE PROBLEM

Man has struggled for many years with problems concerning fatigue. He has tried to find answers to such questions as; What is fatigue? What causes fatigue? What are the best ways to recover from fatigue? This study was concerned primarily with a particular aspect of the last question. However, before making a statement of the specific problem of this study, a brief discussion of the other questions is appropriate.

First of all, what is fatigue? If one searched all the physiological, psychological and medical literature he could doubtless find a hundred different definitions of fatigue. In addition, he would find reference to different kinds of fatigue, such as mental, physical, muscle, subjective, physiological, chronic, combat, etc. All of these various types of fatigue serve to show that there is not any one generally accepted definition of fatigue. Since this study is concerned with athletes, and uses a physiological approach, one might expect that a physiological viewpoint of fatigue would be used. This would be primarily that of a muscle being repeatedly stimulated until it failed to respond, or until it showed a drop-off in work performance. However, the writer has studied the work on fatigue by S.H. Bartley and has decided to adopt his viewpoint of fatigue as a basis for this study. This approach to fatigue is from the standpoint of the whole organism and of the layman. In this approach, fatigue is an experience that man has and can describe. It is a phenomenon of the nervous system and of the brain. It might well be described as a negative attitude toward action. As such, it is an experience which the common man on the street has had and can describe in his own words. For a detailed discussion of this viewpoint on fatigue the reader should consult Bartley and Chute's book, Fatigue and Impairment in Man.[1]

In using this approach it was necessary to use certain other terms to describe the things often times called fatigue or closely associated with fatigue. Two of these terms are impairment and work decrement, and they are now defined so as to distinguish them from fatigue.

Impairment refers to any change that takes place within the tissue. This includes such changes as oxygen deprivation, lactic acid accumulation, etc. Some of these changes were investigated in this study, hence the title "Recovery From Fatigue and Impairment ..." rather than just recovery from fatigue.

Work decrement refers to a lowered work output. This commonly happens when impairment takes place as well as when fatigue sets in, but it may happen in the absence of either or both of them.

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[1]S. Bartley and E. Chute. Fatigue and Impairment in Man (New York: McGraw-Hill Book Company, 1947). 429pp.

This study was concerned with recovery from fatigue and impairment in athletes. Athletic coaches and sports research specialists have long been interested in various techniques that might prove helpful in speeding recovery in athletes. This is especially important in such events as track and swimming where an individual may have to make two or more "all-out" efforts in one day with just a few minutes rest between events. It is also of importance to team members of such strenuous sports as basketball, football, soccer and hockey for use during half-time rest periods.

Many techniques have been tried and are currently being used by athletes and coaches throughout the world to facilitate recovery. Most of these are selected on the basis of some successful experience with it, without having any properly controlled research evidence as to it's worth. Other techniques are selected by men who are interested in experimenting to determine if some are more effective than others. Some of the most recent recovery techniques to be tried are breathing oxygen-rich mixtures, abdominal cold sprays and various types of feeding.

The effects of three specific techniques on recovery from fatigue, impairment or both were investigated in this study. These techniques were; elevation of the arms and legs while lying in a supine position, slow movement (jogging for runners, slow swimming for swimmers), and watching sound motion pictures (or in cases where it was not feasable to show movies, the act of reading). These three techniques were compared with a control technique which was simply lying in a supine position. The elevation of the arms and legs was to allow gravity to assist in promoting the return flow of venous blood to the heart which in turn would allow a greater heart output per minute and hence a faster recovery.

The slow movement was to allow the muscle action to aid in speeding venous return to the heart and eventually greater heart output and faster recovery. This technique has been shown by Newman and others to remove lactic acid from the blood at a much faster rate than under conditions of quiet rest.[2]

The watching of movies was designed to bring about a nervous reorganization within the individual by means of temporarily taking his mind off the task at hand. The task in this case required considerable physical effort, induced oxygen deprivation and thus impairment. Along with these feelings of discomfort due to the physical effort, there may also have been feelings of inadequacey to proceed with the task which would tend to produce fatigue. If the movies took the subject's mind off the uncomfortable and inadequate feelings of the immediate task, recovery from fatigue may have been facilitated.

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[2]E. V. Newman, D. B. Dill, H.T. Edwards and F.A. Webster, "The Rate of Lactic Acid Removal in Exercise," American Journal of Physiology, 118;457-62, March, 1937.

Statement of the Problem. The purpose of this study was to determine the effect of elevating the hands and arms, slow movement, and watching sound movies on the speed of recovery from fatigue and impairment in athletes. The effectiveness of recovery will be judged primarily on the basis of rate of recovery from oxygen debt and on a second performance test given after the recovery period.

In order to avoid repetition throughout the rest of the study in describing the various recovery techniques, they will be called by number. Number one is the control technique; number two, elevation of the arms and legs; number three slow jogging or swimming, depending on the activity and number four, watching sound motion pictures (or in one part of the study where movies could not be shown, the act of reading).

Limitations of the Study. The data for Part Two of this study were collected during a six-week summer term at Michigan State University. Due to the shortness of time, there were no trial runs made, using the complete experimental proceedure, by either the experimenter or the subjects prior to the actual start of data collection. This would increase the chances for various experimental errors during the first few runs.

As would be expected, the subjects of this study did show consistent improvement in their performance tests during the first three weeks. This was due to training or conditioning. However, this fact did not affect the results of the study as the various experimental techniques were alternated at random throughout the testing period and statistical allowances were made for improvements due to training.

Good control measures were not obtained for determining the oxygen debt figures for the slow jog recovery technique. However, some controls were taken at the close of the experiment and further corrections were made based on previous research evidence so that the oxygen debt repayment figures of the recovery jogs could be compared with those of the other experimental techniques.

Due to the amount of time required to make the trial runs and complete the gas analysis work in Part Two of this study it was only possible to handle two subjects. The results obtained from these two subjects can not be generalized as to apply to all people or even to all athletes. However, due to the large number of trials made with these two subjects, the results obtained can be considered as an accurate picture of the value of the recovery techniques for them. Insofar as these two subjects might be considered as typical young men competing in athletics, the results obtained for them might be considered as likely to appear in other similar young men.

Organization of the Study. This study was organized in the following manner; Chapter One, Statement of the Problem; Chapter Two, Review of the Literature; Chapter Three, Proceedure and Methodology; Chapter Four, Presentation of the Results; Chapter Five, Discussion of Results; and Chapter Six, Summary and Conclusions.

The methodology, results and discussion of results chapters were divided into two sections each. The first section of each of these chapters deals with performance data on two swimmers and two runners which were collected at Oklahoma State University during the school year of 1957-58. The second section of each of these chapters deals with data collected on two subjects who ran the treadmill thirty-two times during the summer term of 1958 at the research laboratory of Michigan State University.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature on the entire area of fatigue is abundant. Because so much of this literature does not deal directly with the present study, no attempt will be made to review all of it. Only a few of the outstanding studies in the general area of fatigue will be mentioned. Along with these is covered much of the work done in the area of recovery from fatigue.

General Studies on Fatigue. One of the early pioneers in fatigue work was Muscio, a psychologist. In a paper published in 1921,[1] he discussed the possibilities of devising a test of fatigue. He thought that it was not possible to devise a single test, but he was willing that the search for one continue. He felt that no test would be acceptable in theory or practice unless there was an agreed upon definition of fatigue, and unless some criteria of fatigue could be accepted outside of the characters indicated by the test itself, against which to assess the adequacy of the test indicator.

In 1925, Whiting and Bidwell reported a study [2] that did much to change the thinking about fatigue, particularly in psychological circles. They gave tests for speed,

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[1] B. Muscio, "Is a Fatigue Test Possible?" Brittish Journal of Psychology, 1:150-62, June, 1921.

[2] H. Whiting and Horace Bidwell, "Fatigue Tests and Incentives," Journal of Experimental Psychology, 8:33-49, 1925.

accuracy and difficulty of both physical and mental work to sixteen Wellesey College students. These tests were given early in the morning and repeated late in the evening with the idea that the fatigue that was built up from the days activity would show up on the test results. However, they found no significant differences between morning and evening tests. They followed by giving a forty-five minute battery of tests to sixty-four subjects, then repeating the same battery of tests in reverse order. Again, they found no loss of efficiency in speed of movement tests. Nevertheless, the subjects all reported marked feelings of fatigue. They advanced the hypothesis that fatigue is a negative emotional appetite. As such, it is to be differentiated from the physical phenomena of exhaustion, of which it is a concommitant. As an emotion, in the broader sense, fatigue is a conscious, negative, motive to action. Fatigue does not directly cause work decrement, but it raises the threshold at which work motives are effective.

In 1949, Charmichael,[3] and others, completed a study of young men who had been fatigued through lack of sleep. These men had been engaged in tracking and range-finding activities and on ten mile hikes. Their tests showed no work decrement although there were subjective feelings of fatigue. They concluded that there was no performance

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[3]Chonard Charmichael, John Kennedy and Leonard Mead, "Some Recent Approaches to the Experimental Study of Human Fatigue," Proceedings of the National Academy of Sciences, 35:691-96, December, 1949.

decrement for tasks which require discrete and short time periods for their execution. If the task is continuous and of long duration it is likely that the first signs of a physiological work decrement will be found in the subject's desire to make himself do the task.

In 1953, a classic in the field of fatigue was published in the form of a report on a Symposium on Fatigue held in England.[4] Several excellent papers on fatigue are presented within this one publication.

In the publication, Symposium on Fatigue, Davis[5] talks of fatigue in terms of responsiveness to "drives", for example, the drive for food or water or the drives for satisfaction and success. He says, "Frustration may be a cause of a decline in responsiveness. If the worker proves relatively unsuccessful in his work, the psychological danger may seem to become more imminent; anticipation then increases with consequent changes in his responses." Davis studied these changes in behavior experimentally, by placing subjects in situations which gained their interest but also aroused in them an anticipation of failure. At first, they tended to become overactive, then gradually they experienced

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[4]W.F. Floyd and A.T. Welford, editors, Symposium on Fatigue, (London: H.K. Lewis and Company Ltd.,1953) 193 pp.

[5]Russell Davis, "Satiation and Frustration as Determinants of Fatigue," Symposium on Fatigue, Chap.19 (H.K. Lewis and Company Ltd., 1953), pp.177-82

a decline in responsiveness. Within one to three hours they may become inactive or inert.

A.T. Welford, [6] the editor of Symposium on Fatigue points out that many experiments have shown that the onset of ordinary fatigue is not accompanied by a decrement of activity. Effectiveness of the activity may remain the same, or increase. He classifies fatigue into three catagories, one of which he calls "disorganization of performance". This is the kind of organization found in highly skilled work. Disorganization of performance occurs when the higher organization of a task breaks down leaving the details without coordination of "drive". This type of fatigue effect appears especially in complex highly organized skills.

In the same publication,[7] R.C. Brown says in regard to fatigue, "It is a fact that prolonged application to a task produces symptoms in the subject and signs in the performance. It is also clearly a fact that performance is related to environment and that it shows a natural diurnal and nocturnal rhythm. But it is a fiction that there is a single entity called fatigue and that the search has only to be long enough to find a single test for it."

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[6]A.T. Welford, "The Psychologists Problem in Measuring Fatigue," Ibid., Chap. 20, p.183

[7]R.C. Browne, "Fatigue, Fact or Fiction?" Ibid., Chap. 13, p.141

Recovery Studies Using Techniques Not Used in This Study. In 1942, Folz, Ivy and Barborka[8] reported a study on the influence of caffeine on recovery from fatigue. Four subjects had caffeine injections after exercise and before a ten minute rest period. They found a higher work performance in two subjects and no change in the other two. One important aspect of this study is the use of the double work period. They gave the subjects an initial work period on the finger ergograph, then a recovery period and a repeat exercise bout on the finger ergograph. The subjects worked as long as they could each time rather than having any specific number of exercises to complete or rate of exercise to follow. A per cent of recovery was computed by comparing the amount of work done during the post-recovery bout with that done during the pre-recovery bout. The authors concluded that this double work period method of collecting data and making use of the per cent of recovery figures gave them data with smaller variability than that collected from a single work period. It was from this study that the present writer took the proceedure of using a double work period. (performance runs in swimming and running.)

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[8] E. Folz, A.C. Ivy and C.J. Barborka, "The Use of Double Work Periods in the Study of Fatigue and the Influence of Caffeine on Recovery." American Journal of Physiology, 136:79-86, March, 1942.

In 1947, Cuthbertson and Knox[9] studied the effects of analeptics on fatigued subjects. They found that the oral administration of fifteen mgs. of benzidrine or ten mgs. of methedine increased the subject's capacity to sustain a given level of work on a bicycle or arm ergometer. Fifteen mgs. of methedine diminished fatigue and discomfort on an eighteen mile march after no sleep for twenty-four hours. Some unfavorable signs and symptoms did occur among these subjects. They concluded that these drugs should not be given indiscriminately to large numbers of people because of the wide range of individual responses.

In 1947, Newman[10] reported on the effect of amphetamine sulfate on the performance of normal and fatigued subjects. He found that a dose of ten mgs. of amphetamine sulfate given orally was incapable of improving performance of a monotonous, skilled task for a short period of time unless performance had been reduced by previously existing fatigue. In fatigued subjects, who had gone sleepless for thirty-six hours, he found significant restoration of performance although not to the pre-fatigue level.

In 1948, Berg[11] reported recovery rates from moderate

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[9]D.R. Cuthbertson, and J.A.C. Knox,"The Effects of Analeptics on Fatigued Subjects," Journal of Physiology, 106:42-58, March, 1947.

[10]Henry Newman, "The Effect of Amphetamine Sulfate on Performance of Normal and Fatigued Subjects," Journal of Pharmacology and Experimental Therapeutics, 89:106, February, 1947.

[11]W.E. Berg, "Metabolic Recovery Rates From Exercise After Alteration of Alkaline Reserves," American Journal of Physiology, 152:465-95, February, 1948.

exercise after alteration of the alkaline reserves. In one subject the administration of twenty grams of $NaHCO_3$ brought about a twenty-three per cent increase in the rate of recovery from moderate exercise as measured by the amount of carbon dioxide eliminated. On other subjects, Berg did not get these results however, and he did not offer any statistical analysis of any of his data.

Hellebrandt[12] studied the influence of mecholyl and histamine ion transfers in recovery from fatigue in 1949. She used 310 ergographic experiments designed to test recovery from local muscular fatigue. Double periods of exhausting, repetitive work were performed on the finger, radio-ulnar and wrist ergographs. Experimental or control measures were presented during a half-hour rest period between exercise bouts. She concluded that the administration of mecholyl chloride by ion transfer has a significantly greater effect on recovery that histamine alone, sodium chloride alone or plain rest. The magnitude of the recuperative effects of mecholyl approaches but does not reach that of statistical significance.

In 1949, Yost[13] studied the effects of 100 per cent oxygen inhalation on performance and recovery in swimming.

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[12]F.A. Hellebrandt, and others. "The Influence of Mecholyl and Histamine Ion Transfer on Recovery From Fatigue," Archives of Physical Medicine, 30:578-603, September, 1949.

[13]Mary Yost, "The Effect of 100 Per Cent Oxygen Inhalation on Performance and Recovery in Swimming," Unpublished Ph.D. Thesis, Ohio State University, 1949

A total of 283 tests were made on sixteen subjects for performance and 397 tests made on twenty-two subjects for recovery. The evidence showed no improvement in performance or speed of recovery from fatigue when 100 per cent oxygen was inhaled.

Miller, Perdue, Teague and Ferebee[14] studied the effects of administration of oxygen and oxygen rich mixtures upon both performance and recovery. They found no faster recovery by administration of pure oxygen or oxygen rich air before exercise or during recovery. Their criteria for recovery was in terms of heart rate, blood pressure, blood lactate, endurance and subjective impressions.

Abdominal Cold Application Studies. The use of cold applications to the abdominal region to promote recovery from fatigue was first studied at the University of Iowa in 1949 by Tuttle, Wilson and Happ.[15] They made use of ice packs which were applied to the abdomen during recovery between exercises on the bicycle ergometer. They took several physiological measures on the subjects and concluded that recovery was facilitated by the cold applications. They found a lowered oxygen requirement, an increase in the resting systolic and diastolic blood pressure, and a lower

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[14] A.T. Miller and others, "Influence of Oxygen Administration on Cardiovascular Function During Exercise and Recovery," Journal of Applied Physiology, 5:165-68, 1952

[15] W.W. Tuttle, Marjorie Wilson and William Happ, "Physiological Effects of Abdominal Cold Packs," Research Quarterly, 20:2:153-69, May, ~~1944.~~ 1949

resting pulse rate. The pulse rate during recovery was found to be significantly lower up to six minutes after exercise.

Another cold application study was made at Iowa in 1952 by Rosen.[16] His subjects were sixteen members of the University of Iowa track team. He had them run repeat 440 yard dashes at maximum speed on two different days. On one day the subjects moved around during the recovery period of twenty minutes. On the other day they jogged for five minutes, had ten minutes of abdominal cold spray starting at seventy-five degrees and lowering to forty-five degrees, and then had five minutes to warm up for the second run. Rosen found a significant difference at the five per cent level in speeds of the second run time and in the fall off in time of the second run. The differences were in favor of the days on which the cold sprays were used. He concluded that although the abdominal cold sprays were advantageous to some, they were of no advantage to others.

In 1956, another cold spray study was conducted at the University of Iowa by Sills and O'Riley.[17] They used eighteen students as subjects. The subjects warmed up and then performed five ten-second bouts of running in place, during which the steps were counted electrically. The sub-

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[16] Melvin Rosen, "Effects of Cold Abdominal Sprays on A Repeat Performance in the 440 Yard Run," Research Quarterly, ~~20:2:153-69,~~ May, ~~1944.~~
23 " 1952

[17] Franklin Sills and Vernon O'Riley, "Comparative Effects of Rest, Exercise and Cold Spray Upon Repeat Performances in Spot Running," Research Quarterly, 27;2:217, May, 1956

jects then rested for eight minutes, during which time they lay supine, exercised or had an abdominal cold spray. After the rest period they repeated the five, ten-second bouts of running in place. They concluded that the repeat performances were improved more by the cold sprays than either by rest or by moving about during the rest period. These differences were statistically significant at the five per cent level.

Studies on fatigue directly related to the present Study. In 1926, Lamb[18] investigated the influence of radiant heat, massage and galvanic current in stimulating recovery. His subjects were tested on an ergograph for the flexor muscles of the elbow joint. He theorized that the inability of the muscle to contract was due to an accumulation of lactic acid and that the ability of the muscle to do additional work after fatigue depended upon the freeing of the acid substances from the muscle by oxidation, restoration to its precursor or removal to other parts of the body by circulation. He found that with a five minute massage the muscle was able to perform eighteen per cent more work than when the muscle was simply rested for the same length of time. After a ten minute rest the muscle performed eighty-two and two tenths per cent of its initial effort. Radiant heat enabled the muscle to do 101.3 per cent or twenty-eight and one-tenth per cent more than with plain rest.

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[18]A.S. Lamb, "Localized Fatigue and Recovery," American Physical Education Review, 31:9:1044-53, November, 1926.

Galvanism enabled the muscle to do 110.3 per cent or twenty-eight and one-tenth per cent more than with plain rest. He concluded that the removal of lactic acid from the muscle was apparently hastened by all of these measures which in turn enabled the muscle to do more post recovery work than during the initial exercise. He theorized that the massage stimulated a more rapid removal of the waste products of fatigue.

Jaraslov,[19] in 1929, studied the effects of massage on a single athlete after a strenuous run. He found that with massage the blood pH returned to normal sooner, the output of CO_2 was greater and consumption of oxygen was more during the first few minutes of recovery. The alkali reserve, the blood pressure and the pulse rate return to normal much faster with massage. He concluded that massage is an important regulatory activity after strenuous exercise.

In 1930, Turner, Newton and Haynes[20] reported a study on circulatory reaction to gravity. They performed thirty-five experiments on twenty young women by having them stand quietly in a can of water. They found that there was a progressive increase in the volume of the legs to a point

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[19]Melka Jaraslav, "Vyznam Masaz pri Sportavnich Vyonech," Bratislavske Lekavske Listy, 9(4):933-39, 1929

[20]Abby H. Turner, Isabel Newton and Florence Haynes, "The Circulatory Reaction to Gravity in Healthy Women, American Journal of Physiology, 94:3:507-20, September, 1930.

above the knees for a time period of about fifteen minutes. This increase was due to the stagnation of the circulatory fluid in the legs. The same experimenters also found evidence of stagnation of blood in the abdominal region on quiet standing of their subjects. They were able to lessen this stagnation by bandaging for support.

In 1930, McCurdy[21] studied recovery processes of swimmers while in and out of the water. He wanted to find out if swimmers recovered faster in terms of heart rate, blood pressure, body temperature and gaseous metabolic exchange if they simply remained at rest in the water. He had ten subjects that were tested numerous times after a 250 yard swim. He concluded that swimmers do recover quicker in the water than when out of the water lying on a bench. He suggests that this is because of a lessened resistance in the capillaries which results in more rapid circulation of the blood. He noted an increase in the oxygen consumption and the carbon dioxide production, lower blood pressures, faster heart rate and higher venous pressures when the subjects stayed in the water. He theorized that since more oxygen was absorbed while in the water the oxygen debt was being repaid more rapidly. There was a possibility that these results were due to an increased

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[21]Hugh McCurdy, "Comparison of Recovery Processes of Swimmers While In and Out of the Water," Unpublished Masters Thesis, Wesleyan University, 1930, 92pp.

oxygen cost due to the cold water temperature rather than to a greater repayment of oxygen debt. The water temperature in this case was about ten degrees colder than the temperature in the pool room.

In 1933, Grill[22] investigated the volume changes in the extremities during and after exercise. He studied these volume changes by means of a plethysmograph. He found that during exercise the volume of the extremities at first decreases. During continuous exercise the initial decrease is followed by a gradual increase. In long intensive work this may lead to an overcompensation of the initial decrease. Immediately after exercise the volume of the extremities increases. This indicates a pooling of the venous blood in the extremities.

Marschak,[23] in 1933 conducted an experiment in which he compared active and passive recuperation from exercise. He had two subjects perform repeated bouts of ergographic work separated by pauses of twenty to thirty seconds. During passive recuperation, both extremities were at rest. During active recuperation, either epsilateral or contra-

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[22]Claes Grill, "Plethysmoproprophische Unterchungen Uber des Arm Und Bien Volumen Warend Und Nach der Arbeit der Extremitaten Beluchten," Skandanavian Archives of Physiology, 67:1-35, 1933

[23]M.E. Marschak, "Experietelle Unterchungen Uber der Einfluss der Aktiven Erholung aus die Arbeits Fahigkeit des Menshen," Arbeitsphysiologie, 6:645, 1933

lateral extremities performed light, ryhthmic exercise. When the rest period was utilized for severe exercise there was a diminution of subsequent performance. With the light, rhythmical exercises he found that more total work was accomplished. He concluded that so-called active recuperation was more beneficial than passive recuperation.

In 1934, Progen and Dexter[24] measured the venous flow of blood during and after exercise by inserting a needle into the veins. They found that the velocity of the blood flowing in the superficial and the deep veins behaves antagonistically with exercise. The flow in the deep veins becomes more rapid while the flow in the superficial veins becomes slower than while at rest. They also found that in the veins of the arms the velocity of the blood flow is slower with the arms elevated and more rapid with the arms hanging down than when they are held horizontally. They explain this by suggesting that the distension of the elastic vessels caused by the weight of the column of blood gives more peripheral resistance while the arm is hanging down and thus the faster flow and greater volume.

Newman and others[25] studied the rate of lactic acid removal after exercise under various conditions of rest and exercise in 1937. It is commonly accepted that the accumu-

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[24] S.H. Progen and L. Dexter, "Continuous Measurement of Venous Blood Flow," American Journal of Physiology, 109 (4):688-92, May, 1934

[25] E.V. Newman, and others, "The Rate of Lactic Acid Removal in Exercise," American Journal of Physiology, 118: 457-62, March, 1937

lation of lactic acid during severe exercise is an indicator of fatigue, so the rate of removal of lactic acid during recovery should be a good indicator of the speed of the recovery. These investigators had three subjects who engaged in a near exhaustive run on the treadmill, then went through a forty-five minute recovery period. During the recovery periods one subject rested, one walked at three and five-tenths miles per hour on the treadmill and the other ran at seven miles per hour on the treadmill. Blood samples were taken periodically so that recovery rates could be traced for each subject in terms of lactic acid content of the blood. They found that the blood lactate level in the subject that ran at seven miles per hour returned to normal in fifteen minutes. In the subject that walked on the treadmill, the blood lactate returned to normal in thirty-five minutes and in the subject that rested it was still above normal at the end of forty-five minutes. The authors interpret this increased rate of removal of lactic acid to be due to two factors. One is an increase in the blood flow proportional to the metabolic rate with more rapid transfer of the lactic acid to the reactive centers. The other is that some of the lactic acid may be used up as fuel for additional work. They suggest that by exercising during recovery an economy might be effected in paying the oxygen debt since conversion of lactic acid to glycogen is moderately expensive. They state, "This expense is a part of the oxygen debt of anerobic work if payment is made during complete rest. On the other hand if the debt is paid during moderate work the expense of the resynthesis may be reduced or eliminated."[26] The authors feel that their preliminary investigations have supported this theory but so far no quantitative measures have been made. It is hoped that some evidence to support or disprove this theory might result from the present study.

In 1948, Herxheimer[27] found that the pulse rates of four subjects returned to normal faster when the extremities were compressed with bandages. His experiments with the leg plethysmograph showed that leg volumes increase after severe exercise. His explanation for this was the diminished venous return caused by peripheral vasodilation. The heart adapts itself to the decreasing amount of blood by a decrease in the size and the stroke volume falls. In regards to his findings he states, "It can be regarded as certain that such a vasodilation occurs from severe exercise. The increased amount of lactic acid in the blood probably is responsible for the vasodilation."[28]

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[26] Ibid., p.460

[27] H. Herxheimer, "Hearth Rate in Recovery From Severe Exercise," Journal of Applied Physiology, 1(4):279, 1949

[28] Ibid., p.283

In 1953, Hemingway made an interesting comment to the Symposium on Fatigue in London regarding blood flow after exercise.

> Since the supply of materials to the active tissues must necessarily be carried through the blood, it is natural to expect that limitations of blood supply may set a limit to effort. Generally it is supposed that muscular activity itself tends to ensure an adequate blood supply, partly by ensuring a better return of blood to the heart and therefore an increase in heart output and partly by a local dilation of the blood vessels. But, in some cases, side effects may arise from muscular activity which may limit the blood flow through the tissue.[29]

He is referring primarily to muscular contraction stopping the flow of circulating fluids.

In 1955, Zankel, Clark and Shipley[30] investigated the effect of posture and local pressure on venous circulation time of the leg. They found that leg elevation will usually reduce circulation time and increase the velocity of the deep venous flow. They also found that circulation time could be reduced by sinusoidal stimulation of the calf muscle, mechanical vibration and application of a cuff around the calf.

Following this line of research further, the same

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[29]A. Hemingway, "The Physiological Background of Fatigue," Symposium on Fatigue, (London, H.K. Lewis and Company Ltd., 1953) p.73

[30]H.T. Zankel, R.A. Chipley and R.E. Clark, "Effect of Posture and Local Pressure on Venous Circulation Time of the Leg," Archives of Physical Medicine, 36:226, April, 1955

investigators compared the effectiveness of several techniques in speeding up venous circulation time in the legs.[31] These investigators made use of radio iodine as a tracer substance in determining venous circulation time from the foot to the groin. The techniques used in this study were, application of an elastic bandage from the foot to the knee, ultrasonic diathermy, and histamine ion tophoresis. They concluded that none of these techniques can be expected to consistently increase the venous flow in the legs. These authors are of the opinion that out of some ten different techniques that they have investigated in an effort to promote venous flow in the legs, simple elevation of the legs gives the best and most consistent results.

Summary. One can see from the studies that have been mentioned here that much study and many comments and theories have been forthcoming on the various problems of fatigue and recovery. The various studies on techniques of recovery seem to offer but little encouragement in the search for a sure and consistent method. The slow jogging technique employed by Newman and associates seems to offer real evidence of faster removal of blood lactate. However, they were not able to show the effects of this jogging on oxygen debt which is one of the most important criteria of recovery.

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[31] H.T. Zankel, R.A. Chipley and R.E. Clark, "Effect of Elastic Bandage, Ultrasonic Diathermy and Histamine Ion Tophoresis on Venous Circulation Time of the Lower Extremities," Archives of Physical Medicine, 37:11:706, September, 1957

The abdominal cold sprays and packs do seem to offer good possibilities of promoting recovery and certainly these methods deserve further study and use. It was not possible to include the use of this technique in this study.

The only other consistently encouraging technique seems to be in the promoting of venous return to the heart by massage or elevation of the extremities. As shown by Zankel and assiciates[32] in their recent studies, elevation of the legs offers the best method of achieving this. This method was further investigated in the present study.

Further study along two of these lines was carried out in the current investigation: namely the slow jogging and elevation of the extremities to promote venous return. This offers a chance to corroborate or repudiate the effectiveness of these techniques in terms of metabolic measures as well as a post recovery run.

In addition, a technique for promoting recovery which has not previously been investigated was introduced. This is a psychological technique, based on the assumption of a reorganization of the nervous system and the reaction of the whole individual, rather than on recovery from lactic acid accumulation, oxygen debt or other forms of impairment.

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[32] Loc. cit.

CHAPTER III

PROCEDURE AND METHODOLOGY

Part One

Part One of this study was conducted at Oklahoma State University during the school year of 1957-58. Three subjects participated in four experiments for this part of the study. One subject participated in two experiments. Data were collected during the entire school year. Subjects were readily available from the undergraduate physical education classes, however laboratory facilities were not available for this part of the study. The criteria for recovery in Part One was in terms of a repeat performance test.

The experiment started in the fall with two swimmers. One of the subjects, L.M. was a former olympic swimmer for the Union of South Africa and a former varsity swimmer for the University of Oklahoma. His competitive event was the backstroke but in this study he used the front crawl stroke. The second subject, B.H. was a student who liked to swim and was a good swimmer but not of varsity or competitive level. Neither subject had been swimming regularly for some time prior to the start of this study. The two subjects spent several days of swimming at the beginning of the experiment to get into condition. After the data collection started, each subject swam either two or three times a week depending upon scheduling feasability and the health of the subject. Each subject made thirty-two experimental swims using each recovery technique eight times. The subjects swam two-hundred yards at maximum speed, had a ten minute recovery period and then a repeat two-hundred yard swim at maximum speed. The various recovery techniques were introduced during the recovery periods in random order and in blocks of four. The four experimental recovery techniques were as follows; 1. lying in a supine position at the side of the pool, 2, legs and arms elevated while lying supine at the side of the pool, 3, slow swimming of any stroke the subject desired, 4, watching sound movies while lying in a supine position.

Following is a typical trial run for one subject. The subject reported to the pool, undressed and showered. He warmed up for five minutes by slow swimming and calesthenics. His estimate of how he felt was recorded according to a four point scale of poor, fair, good, or excellent. He was then instructed to swim ten lengths of the pool or two-hundred yards at maximum speed using the front crawl stroke. Lap times were given at the end of each forty yards and the subjects were encouraged to step up the pace of the early laps as the experiment progressed. At the end of the two-hundred yard swim one of the recovery techniques was used during the ten minute recovery period. If technique number one was being used the subject climbed out of the pool and lay in a supine position on some towels at the edge of the pool. If technique number two was being used the subject lay supine on some towels and placed his feet up on the diving board which is about three feet high, and his hands rested on a chair which was placed near his head. If technique number three was being used he stayed in the water and swam slowly up and down the pool using any stroke that he wished. This was usually the elementary back or the breast stroke. For technique number four, the subject climbed from the pool and walked quickly to an adjoining room where a sound movie projector was all set up and ready to run. He laid in a supine position on some blankets on the floor as soon as he reached the room and the movie was started. The picture was projected high on the wall so that it could be easily seen by the subject while lying down. The movies were chosen to be of special interest to the subjects. For example, one was on deep sea fishing, one on basketball, one a musical short, one on travel in the Caribean Islands, etc. At exactly ten minutes after the finish of the first swim, the subject was again asked to express his estimate of how he felt accoring to the four point scale and he was again instructed to swim the ten lengths at maximum speed. The lap times were given as during the first swim.

The times for the first and second swims were recorded to the nearest one-tenth of a second. Percentages of recovery were computed by dividing the second swim time into the first swim time and these recovery per cents were compared. However, it was decided to discard this comparison technique in favor of a statistical analysis using covariance to equalize all the first swim times for each subject. It was then possible to analyze and compare the second swim times, knowing that the work done during the first swim had been equalized for all trials. Using the analysis of covariance technique, the F values were obtained for testing the difference between the means of the second swim times for each recovery technique.

It was impossible to make any statistical analysis of the reported feelings of the subjects since practically all reports were good before the first swim and either good or fair after the recovery period.

Section two of this part of the experiment was carried out in the Spring semester with two runners. One was B.H. the second swimming subject who volunteered to carry on through the running experiment. The other subject,G.N. was a physical education undergraduate student who had been a distance runner in high school but was not active or competing in track in college.

The procedure for this section of the experiment was very similar to that for the swimming., The subjects reported to the track two or three times per week according to a prearranged schedule. They warmed up for five minutes by jogging and calesthenics, reported how they felt according to the four point scale and made a half mile run at maximum speed. At the end of the run there was a ten minute recovery period during which the four recovery techniques were introduced in random order in blocks of four. The only difference in the recovery techniques used in this section was in technique number four. The inaccesability of a place to show movies made it impossible to use that particular method, so the reading of an interesting book while lying in a supine position was substituted to accomplish the same purpose. The subjects chose books to read that they thought would be particularly interesting to them.

After the ten minute recovery period the subjects again reported their feelings and ran one half mile at maximum speed. Both run times were recorded to the nearest second. The mean second run times for each recovery technique were compared by using the analysis of covariance to equalize the first run times and to test the difference between the means. The randomized block technique was used in computing this covariance. A basic assumption of this technique is that the four experimental techniques are presented at random in blocks of four. This would mean that no technique would be repeated a second time until all four had been given once, etc. Although all of these data do not exactly fit this particular assumption, it does seem to be close enough to justify the use of this technique for analysis.

Part Two

Part Two of this study was conducted during the summer term of 1958 at Michigan State University. The same four recovery techniques were tested, but in this part of the study, physiological data were collected as well as performance data. Two physical education graduate students were the subjects for this part of the study. A third subject started the experiment but was forced to drop out about mid-way through due to personal reasons and his data were not used.

Because of the similarity of the initials of the two subjects that participated in Part Two, they will be referred to by number. Subject 1 was a former varsity cross-country runner. He had not been running regularly for several years and he had been a graduate student at Michigan State University for two years prior to the start of this experiment.

Subject 2 had been a varsity athlete in high school but not in college. He had been coaching in a high school for the year prior to the start of this experiment and his physical condition was only fair at the beginning of the runs.

The subjects reported to the laboratory five to six times per week for the runs during this experiment. As nearly as possible the runs were made at the same time each day but in some instances it was not possible to accomplish this.

Following is a description of one day's run for one subject. Upon reporting to the laboratory the subject laid down and rested on a cot from five to ten minutes. During this time oral temperature, room termperature, relative humidity, barometric pressure and the subjects estimate of how he felt were all taken and recorded. A five minute resting collection of expired air was then taken in a Douglas Bag by having the subject breath into a one way valve which allowed him to inhale room air and forced his expired air into the bag. This resting gas collection was made with the subject lying on a cot. During this time the resting pulse rate was also taken.

The subject then made a five minute run on the treadmill. This was a standard work run which started at a slow pace with no incline and ended at a faster pace and at an incline of ten degrees. The treadmill speeds and incline during this run were as follows; two minutes at six miles per hour and no incline, one minute at six miles per hour and five degrees incline, one minute at eight miles per hour and five degrees incline and one minute at eight miles per hour and ten degrees incline. During this run, loud march music was played over an amplifying system. The purpose of changing the speed and incline of the treadmill and of the loud music was to aid in inducing fatigue by introducing some uncertain and distracting elements to the situation. The subjects were told that the speed and incline of the treadmill would be changed periodically and that they were to be ready to adjust to the changes. It was felt that these elements might serve to make this experimental situation more like that encountered by an athlete during an actual contest. Since it was necessary to follow the same routine in the changes of the treadmill to keep the amount of work constant, the subjects undoubtedly did get accustomed to this routine about midway through the experiment.

During the five minute standard run the subject's expired air was collected in a Douglas bag which was attached to a framework over the treadmill. At the close of the standard run the subject switched immediately to another mouthpiece and another Douglas bag to start gas collection for the recovery period.

The four recovery techniques were administered as in Part One of this study. A matress was placed beside the treadmill upon which the subject laid for techniques one, two, and four. In technique two, the legs and arms were elevated by placing a chair under the legs and also a chair near the head for the arms to rest upon. In technique number four, the movies were shown high on the wall so that they could be seen while lying down. When technique number three was being used the subject stayed on the treadmill and jogged slowly at five miles per hour and no incline.

Pulse rates were taken at the close of the five minute standard run, after five minutes of recovery, and again after ten minutes of recovery. These pulse rates were all taken for fifteen seconds and multiplied by four to get the rate per minute. At the close of the ten minute recovery period the subject reported how he felt and got back on the treadmill to make an all out performance run at ten degrees incline and eight miles per hour. The subject was instructed to stay on and run as long as he possibly could. There was no gas collection during this all out run. The time of the all out run was taken with a stop watch from the time of the first step on the treadmill until the time that the subject stepped, jumped or was helped off at the end of the run. The experimenter was stationed at the rear of the treadmill to give assistance in getting off if needed, but the subjects were usually able to grasp the framework over the treadmill and step off without being helped. They were encouraged to stay on as long as possible and both subjects seemed highly motivated throughout the whole experiment to try to better their previous best time each day. The time that they had been on the treadmill during this all out run was called out to them every thirty seconds.

Each subject made a total of thirty-two runs on the treadmill with each of the experimental recovery techniques being used eight times. The recovery techniques were used in a random order and as nearly as possible in blocks of four, although this could not always be accomplished. This method of introducing the techniques helps to eliminate the effects of training when comparing the four techniques for their relative effectiveness, and also makes the data acceptable for the randomized block statistical treatment.

After the subject had finished the all out run, the gas that had been collected in Douglas bags during the pre-exercise resting period, the standard run, and the first and second five minute recovery periods was analyzed for oxygen and carbon dioxide content and metered for volume. The oxygen percentages were determined by passing a sample of the gas directly from the Douglas bag through a Beckman E-2 Oxygen Analyzer. The readings of this oxygen analyzer were considered very accurate as the instrument was checked before the data collection began against several gas samples that had been analyzed by an experienced operator on the Haldane apparatus. Two out of three of these checks were within .05% of each other and the other was only slightly larger. The Beckman Oxygen Analyzer was calibrated for zero point and span each day during the experiment with commercial nitrogen and outside air. The manufacturers claim an accuracey of 0.025% oxygen for this analyzer when properly calibrated.

Three gas samples from each Douglas bag were collected over mercury in sample bottles to be analyzed for carbon dioxide content. These analyses were made on the Haldane Apparatus following the procedure suggested in Metabolic Methods.[1] Two of the samples were analyzed in all cases. If they came within a range of one-tenth of one per cent carbon-dioxide of each other the third sample was not checked. If the difference was greater than this a third sample was analyzed.

After the gas samples had been removed from the

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[1]Frank Consalazzio, Robert Johnson and Evelyn Marek, Metabolic Methods, (St. Louis, C.V. Mosby Company, 1951), p.316

Douglas bags the gas was metered out through a Precission Wet Test Meter. This meter was manufactured by the Precission Scientific Company of Chicago, Illinois and it had been previously calibrated in the laboratory. The gas was drawn through the meter with a vacuum pump at a very slow rate of speed so as not to affect the accuracy of the readings. Corrections were made in the gas volumes for the amounts taken out for oxygen and carbon dioxide analyses. The volume of expired air for each of the periods; resting, five minute standard work, and two five minute recovery periods were entered on a metabolic calculation sheet as pulmonary ventilation. The respiratory quotient and the true oxygen were found using the line charts in the book, Metabolic Methods.[2,3]

The rate of oxygen debt repayment was found by subtracting the total amount of oxygen used during the ten minute recovery period from an amount that would be used in the equivalent time in a resting position. This was recorded in liters per minute. This technique of finding the amount of oxygen debt repayment could not be used with recovery technique number three or slow jogging since there was no similar control measure to compare it with. In order to compare oxygen debt repayments for this technique a ten minute control run to give the normal oxygen intake in ten

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[2]Ibid. p.334

[3]Ibid. Inside back cover

Minutes of slow jogging was needed. These control runs were made during the last two days of data collection and the figures obtained used to compute oxygen debt repayments for the eight runs involving the slow jogging recovery technique. Each subject made two control runs at times apart from the regular experimental runs on two consecutive days. The figures obtained for each subject on these control runs were very consistent. The average figures from the two control runs were used in each case.

A further correction was necessary in order to make these control oxygen debt figures comparable to the experimental ones. This was the addition of a factor to correct for the fact that the control runs were made from a resting state while the recovery jogs were made after a five minute run which had served as a warm up and as such resulted in the accumulation of a certain amount of oxygen debt. The figure of two and eight-hundredths liters was chosen as this correction factor. It was obtained from Noltie's study[4] which was reported in Symposium on Fatigue. Noltie collected oxygen consumption figures on two subjects while they warmed up by jogging. The average oxygen debt accumulations for the warm ups were two liters for one subject and two and seventeen hundredths for the other. A mid-point between these

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[4]H.R. Noltie, "A Factor on Postponing the Onset of Fatigue," Symposium on Fatigue. Chap.9, (London, H.K. Lewis and Company Ltd., 1953) p87.

figures or two and eight-hundredths was chosen to be used with the data in this study to try to make the oxygen debt figures for the slow jog recoveries comparable to those of the other recovery techniques.

The data for Part Two of this study were treated statistically by making use of the analysis of variance and the randomized block technique. As previously mentioned, it was not possible to alternate the techniques according to strict randomized block specifications, but it was reasonably close and should be amenable to this type of treatment. Making use of the randomized block design and the analysis of variance technique, it was possible to eliminate statistically, the effects of training upon the subjects.

The mean oxygen debt repayment and the mean all out run time for the eight runs of each technique were compared using the analysis of variance. If significant F values were found in the analysis of variance, a Duncan Multiple Range Test[5] was utilized to test these differences and determine which techniques were significantly different from the others.

In order to determine if there were any significant relationships between any of the recorded factors such as temperature, humidity, hours sleep, pulse rate, respiratory quotient, etc. and oxygen debt or all out run time; correlation coefficients were computed. These coefficients serve

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[5]David Duncan, "Multiple Range and Multiple F Tests," Biometrics, Vol.119:10, March, 1955.

to show if any of these factors might be of value in predicting the all out run time or the oxygen debt repayment.

The results of the various statistical analyses on the data of this study are presented in the following chapter.

CHAPTER IV

RESULTS

Part One

The analysis of covariance results for the two swimming subjects are shown in Tables I and III. A comparison of the means of the second swim times is shown in tables II and IV.

Subject B.H., who was an average swimmer had relatively slow second swim times throughout the experiment, with not a great deal of variation between his best and his poorest times. His second swim times generally showed an increase of from twenty to thirty seconds over his first swim time, and the subject was obviously very tierd at the end of the second swim. The analysis of covariance for the swim times of B.H. is shown in Table I. The F value of 2.02 indicates no significant difference between the four techniques in this subject. Table II shows that technique IV produced the best mean second run time.

Subject L.M. a former varsity and olympic swimmer had much better times on both first and second swims. His second swim times generally were from ten to fifteen seconds slower than his first swim times. However on a few occasions on the second swim he was able to equal or better the first swim time. These results indicate both more natural swimming skill and speed, and better condition than subject B.H. The analysis of covariance for L.M. shown in Table III, resulted in an F value of 1.37, which indicates no significant difference between the four recovery techniques. Table IV shows that technique II resulted in the best mean second swim time for subject L.M.

TABLE I

FIRST (X) AND SECOND (Y) 200 YARD SWIM TIMES OF B.H. ON 4 RECOVERY TECHNIQUES. COVARIANCE IN RANDOMIZED BLOCKS.

					Deviations from Regression		
Source	df	ΣX^2	ΣXY	ΣY^2	df	S.S.	M.S.
Total	31	2330.57	712.80	2013.05			
Repl.	7	747.06	626.10	840.03			
Treat.	3	269.92	64.61	289.43			
Error	21	1313.59	22.09	883.59	20	883.22	44.16
T.+ E.	24	1583.51	86.70	1173.02	23	1169.27	
Treatment adjusted					3	268.05	89.35

F=2.02

TABLE II

UNADJUSTED MEANS OF SECOND 200 YARD SWIM TIMES FOR B.H. FOR EACH RECOVERY TECHNIQUE

Treatment	IV	II	III	I
Time (sec.)	3:41:6	3:45:4	3:47:2	3:49:85

Times connected by an underscored line are not significantly different from each other.

TABLE III

FIRST (X) AND SECOND (Y) 200 YARD SWIM TIMES OF L.M. ON 4 RECOVERY TECHNIQUES. COVARIANCE IN RANDOMIZED BLOCKS.

					Deviation from Regression		
Source	df	ΣX^2	ΣXY	ΣY^2	df	S.S.	M.S.
Total	31	493.70	71.89	543.50			
Repl.	7	277.93	113.21	105.07			
Treat.	3	1.69	-11.22	77.40			
Error	21	214.08	-31.10	361.03	20	356.80	17.84
T.+ E.	24	215.77	-41.32	438.43	23	430.52	
Treatment adjusted					3	73.72	24.57

F=1.377

TABLE IV

UNADJUSTED MEANS OF SECOND 200 YARD SWIM TIMES FOR L.M. FOR EACH RECOVERY TECHNIQUE

Treatment	II	III	I	IV
Time (sec.)	2:26:1	2:28:6	2:29:6	2:31:2

Times connected by an underscored line are not significantly different from each other.

The analyses of covariance for the repeat one half mile runs are shown in tables V and VII. The comparison of the means of the second runs for each subject are shown in Tables VI and VIII.

Subject B.H. who participated in the swimming experiment in the fall went into the running experiment in the spring. He was only a fair runner with no varsity or competitive experience in either high school or college track. He was primarily interested in some form of regular exercise to keep in good physical condition. The analysis of covariance for his run times is shown in Table V. His second run time was generally as least fifteen seconds slower than his first run time. In this case the F value is 12.72, which indicates a significant difference at the one per cent level. This difference lies primarily in technique III, after which the second run times were significantly slower or greater. Table VI shows this difference between the adjusted means according to the Duncan Multiple Range Test.[1] It also shows

[1] Duncan, loc. cit.

that technique IV gave the best mean second run time for this subject although they were not significantly better than II or I.

Subject G.N. had been a varsity middle distance runner in high school but was not out for track in college. His first run times were generally fifteen to twenty seconds faster than his second runs. Table VII shows the analysis of covariance for his run times. The F value of 1.21 indicates no significant difference between recovery techniques for this subject. Table VIII shows that technique II gave the best mean second run time for this subject.

TABLE V

FIRST (X) AND SECOND (Y) $\frac{1}{2}$ MILE RUN TIMES OF B.H. ON FOUR RECOVERY TECHNIQUES. COVARIANCE IN RANDOMIZED BLOCKS.

					Deviation from Regression		
Source	df	ΣX^2	ΣXY	ΣY^2	df	S.S.	M.S.
Total	31	2172.5	935.2	1972.0			
Repl.	7	748.0	114.7	347.8			
Treat.	3	756.3	822.2	1288.5			
Error	21	688.2	-1.7	395.7	20	395.7	19.78
T.+E.	24	1429.5	820.5	1624.2	23	1151.6	
Treatment adjusted					3	755.9	251.70

F=12.72 Sig. at 5% level

TABLE VI

ADJUSTED MEANS OF SECOND $\frac{1}{2}$ MILE RUN TIMES FOR B.H. FOR EACH RECOVERY TECHNIQUE.

Treatment	IV	II	I	III
Time (sec.)	3:17:53	3:19:49	3:23:78	3:33:29

Times connected by an underscored line are not significantly different from each other.

TABLE VII

FIRST (X) AND SECOND (Y) ½ MILE RUN TIMES OF G.N. ON 4 RECOVERY TECHNIQUES. COVARIANCE IN RANDOMIZED BLOCKS.

Source	df	ΣX^2	ΣXY	ΣY^2	Deviation from Regression df	S.S.	M.S.
Total	31	1168.72	267.90	1731.00			
Repl.	7	481.97	52.40	337.25			
Treat.	3	270.35	-11.22	47.87			
Error	21	416.75	226.72	1345.88	20	1122.44	56.12
T.+E.	24	686.75	215.50	1393.75	23	1326.44	
Treatment Adjusted					3	204.00	68.00

$F = 1.21$ Not significant

TABLE VIII

ADJUSTED MEANS OF SECOND ½ MILE RUN TIMES FOR G.N. FOR EACH OF 4 RECOVERY TECHNIQUES

Treatment	II	III	IV	I
Time (sec.)	2:52:26	2:54:77	2:56:37	2:57:93

Times connected by an underscored line are not significantly different from each other.

All subjects in Part One indicated that they felt more like starting out on a second swim or run if they had been moving around during the recovery period rather than lying down. However, the results show no improvement in performance after technique III, slow movement, had been used. On the contrary, in one case, B.H. running, there was significantly poorer performance after the use of the slow jog recovery technique.

Part Two

The criteria for recovery used in this part of the study were time of an all out treadmill run after the recovery period and the amount of oxygen debt repaid during the recovery period.

The results of the analysis of variance on the all out run times for subject 1 are shown in Table IX. The F value of 9.615 indicates a significant variation in the run times due to training. This would be an expected variance due to the strenuous character of the treadmill runs which were made on a daily basis. However these training effects were held constant in computing the F between recovery techniques. The F value for the variance between recovery techniques was 3.179 which is significant at the five per cent level.

TABLE IX

ANALYSIS OF VARIANCE BETWEEN MEAN ALL OUT RUN TIMES AFTER 4 RECOVERY TECHNIQUES. SUBJECT 1

Source	df	S.S.	M.S.	F
Total	31	139245		
Training	7	95758	13679	9.613**
Treatment	3	13581	4527	3.179*
Error	21	29906	1424	

** Sig. at 1% level * Sig. at 5% level

Table X shows the mean all out run times for each recovery technique. They are arranged in order from the least or poorest on the left to the greatest or best on the right. According to the Duncan Multiple Range Test,[2]

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[2] Duncan, Loc.Cit.

lines are used to underscore and connect those means which are not significantly different from one another. In this case the mean of technique II is significantly poorer than the means of III and IV.

TABLE X

DIFFERENCE OF MEANS OF ALL OUT RUN TIMES AFTER 4 RECOVERY TECHNIQUES. SUBJECT 1. 5% LEVEL

Treatment	II	I	III	IV
Time (sec.)	218	235	263	269

Means connected by an underscored line are not significantly different from each other.

The results of the analysis of variance of all out run times for subject 2 are shown in Table XI. It shows a significant variation in run times due to training but no significant difference between recovery techniques.

TABLE XI

ANALYSIS OF VARIANCE BETWEEN MEAN ALL OUT RUN TIMES AFTER 4 RECOVERY TECHNIQUES. SUBJECT 2.

Source	df	S.S	M.S.	F
Total	31	18065		
Training	7	15297	2185	21.08**
Treatment	3	581	191	1.84
Error	21	2185	104	

**Sig. at 1% level

Table XII shows the means of all out run times of subject 2 in order of their ranking. Technique III has the greatest and therefore the best mean all out run time for this subject.

TABLE XII
DIFFERENCE OF MEANS OF ALL OUT RUN TIMES
AFTER 4 RECOVERY TECHNIQUES. SUBJECT 2.

Treatment	I	IV	II	III
Time 9sec.)	93	99.57	104	104.22

Times connected by an underscored line are not significantly different from each other.

Table XIII shows the analysis of variance between the oxygen debt repayments during the four recovery techniques for subject 1. In this case there is no significant variance due to training but a highly significant (F=32.98) variance between recovery techniques. Table XIV shows that this variance lies between technique III and the others. This indicates that significantly less oxygen debt was repaid during the use of technique III than when the other techniques were used.

TABLE XIII

ANALYSIS OF VARIANCE BETWEEN MEAN OXYGEN DEBT REPAYMENT FOR SUBJECT 1 DURING EACH OF 4 RECOVERY TECHNIQUES.

Source	df	S.S.	M.S.	F
Total	31	97.76		
Training	7	7.02	1.00	1.29
Treatment	3	76.51	25.50	32.98**
Error	21	16.23	.773	

**Significant at 1% level

TABLE XIV

DIFFERENCE OF MEANS OF OXYGEN DEBT REPAYMENT AFTER EACH OF 4 RECOVERY TECHNIQUES. SUBJECT 1

Treatment	III	IV	I	II	*
Mean (liters)	.016	2.12	3.69	3.88	

* IV, I, and II are significantly different from III at the 1% level.

The results of the analysis of variance for subject 2 on oxygen debt repayment during the various recovery techniques are shown in Table XV. The variance due to training (F=11.49) is significant at the 1% level. Table XVI shows that the variance lies in the difference between technique III and the other three techniques. In this case, instead of having repaid the oxygen debt during the recovery period, there was a slight increase in oxygen debt during the use of technique III. This is indicated by the mean value of -1.61 liters of oxygen.

TABLE XV

ANALYSIS OF VARIANCE BETWEEN MEAN OXYGEN DEBT REPAYMENTS FOR SUBJECT 2 DURING EACH OF 4 RECOVERY TECHNIQUES.

Source	df	S.S.	M.S.	F
Total	31	306.38		
Training	7	39.00	5.56	11.49**
Treatment	3	191.73	63.911	17.75*
Error	21	75.64	3.60	

**Sig. at 1% level * Sig. at 5% level

TABLE XVI

DIFFERENCE OF MEANS OF OXYGEN DEBT REPAYMENTS AFTER EACH OF 4 RECOVERY TECHNIQUES. Subject 2. 5% LEVEL

Treatment	III	II	IV	I	
Mean (liters)	-1.61	3.65	3.80	4.49	*

*II, IV and I are significantly different from III

TABLE XVII

SUMMARY OF RANKINGS OF 4 RECOVERY TECHNIQUES ON ALL SUBJECTS

RANK regardless of significance	Treatment Number			
	I	II	III	IV
1	1	3	1	3
2	1	3	3	1
3	3	1	1	3
4	3	1	3	1

Table XVII shows the number of times that each recovery technique ranked first, second, third or fourth in terms of relative effectiveness when the data for all subjects in Parts One and Two were combined. This table indicates that technique II, which ranked first three times and second three times was the most effective of the recovery techniques used in this study. The statistical significance, if any,of the various rankings was not considered in Table XVII.

Table XVIII shows a summary of the correlations of the various data that were noted and recorded during Part Two of the study with the oxygen debt repayments and the all out run times.

TABLE XVIII

SUMMARY OF CORRELATIONS BETWEEN SEVERAL VARIABLES AND ALL OUT RUN TIME AND OXYGEN DEBT REPAYMENT.

variable	r			
	Subject 1		Subject 2	
	All out run time	O_2 debt repaid	All out run time	O_2 debt repaid
Air temperature	-.005	-.12	+.226	+.01
Relative humidity	-.09	-.154	+.179	+.11
Barometric pressure	-.03	+.03	-.162	-.58**
Body temperature	-.24	+.62**	-.10	-.089
Hours sleep	+.27	+.23	+.38*	+.017
Resting R.Q.	+.177	-.169	+.265	+.14
Second Recovery R.Q.	+.38	+.17	+.349*	+.42*
Resting Pulse	-.043	-.016	-.14	+.148
Pulse after exercise	+.21	-.457**	-.175	-.555**
Pulse 10" after ex.	-.198	-.588**	+.068	-.76**
Oxygen debt repayment	-.183	------	-.207	------

* Sig. at 5% level.   ** Sig. at 1% level

Table XVIX shows the correlations of second recovery R.Q. and pulse rate after exercise with all out run time and oxygen debt repayment with training effects removed. The training effects were removed by a blocking technique which reduced the number of degrees of freedom to seven and therefore none of these correlations can be called statistically significant. However,the correlations between pulse rate after exercise and oxygen debt repayment approaches statistical significance at the 5% level in both subjects.

TABLE XVIX

CORRELATIONS OF CERTAIN VARIABLES WITH TRAINING EFFECTS REMOVED.

Variable	r			
	Subject 1		Subject 2	
	all out run time	O_2 debt repaid	all out run time	O_2 debt repaid
Second Recovery R.Q.	-.074	+.396	-.28	+.35
Pulse after exercise	+.30	-.625	-.056	-.641

.66 is sig. at 5% level

CHAPTER V

DISCUSSION OF RESULTS

Part One

There was only one instance of a significant difference found between the various recovery techniques in Part One. This was found in the analysis of the data for the one-half mile run times of B.H. which showed the second run times after technique III to be significantly slower than the times after the other three techniques. This is likely to be a chance significance since the same subject participated in the swimming experiment, in which case the same technique, number III, gave the second best results of all the techniques. There is also a possibility that there may be a difference in the effectiveness of the same technique on the same individual in different activities. For example, here the subject was recovering one time by swimming slowly and at another time by slow jogging. It is possible that there are effects from being in the water apart from the effects of the slow swimming. On the other hand it may be that some techniques are somewhat consistent within the individual from one activity to another, but vary from one person to another. For example, in these data, B.H. had the best performances in both swimming and running after the administration of technique IV. However there is no other evidence in this study to warrant this conclusion.

There seems to be no trend established in this performance data of Part One whereby one could say that any of these recovery techniques is superior or inferior to the others.

Part Two

Analysis of the performance data in Part Two shows significant differences between recovery techniques in one subject and no difference in the other. As shown in Table X, subject 1 had a significantly poorer time in the all out run after technique number II had been used. This difference was significant only in comparison with techniques III and IV. However, this does seem to indicate a real difference with this subject and indicates that there was something taking place during the use of this recovery technique which was having an adverse effect on the subsequent performance runs.

Both subjects showed statistically significant variance during the thirty-two runs due to training. This would be expected due to the strenuous nature of the daily runs and the fact that neither subject was in top condition at the start of the runs.

The oxygen debt figures show one consistent significant difference. This is in technique III, which in both subjects resulted in a smaller repayment of oxygen debt. On the face of the matter, this would seem logical. That is, one would not expect a rapid repayment of oxygen debt while continuing to work. However, Newman and his associates[1] found that the lactic acid was removed from the blood about

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[1]Newman, Loc. cit.

three times faster when his subjects jogged at seven miles per hour than when they rested. Theoretically, there should be some relationship between the amount of oxygen debt and the amount of lactic acid accumulation.

There are several factors which may serve in part to explain this apparent discrepancy. The length and amount of initial work done is one factor. Newman's subjects ran to near exhaustion at 18.8 Km/hr and at a twelve per cent grade. The subjects in this study made a five minute standard run starting on the level at six miles per hour and gradually speeding up to eight miles per hour and changing to an incline of ten degrees. The intensity of the exercise in Newman's subjects then, was greater, but the length of the exercise was shorter. The intensity of the exercise plays an important part in determining the amount of lactic acid accumulation. According to Margaria and his co-workers[2] no increase in lactic acid appears in the blood until a work output of about two-thirds maximum is reached. From two to four liters of oxygen debt can be accumulated with no concurrent lactic acid build up in the blood. They call this the "alactacide oxygen debt". After this point is reached the lactic acid is being released faster than it can be resynthesized in the muscles and it diffuses into the blood stream This allows for the accumulation of additional oxygen

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[2]R. Margaria, H.T. Edwards and D.B. Dill, "Oxygen Debt and Lactic Acid in Muscular Contraction," American Journal of Physiology, 106:713, 1933

debt which they refer to as the "lactacide" oxygen debt. Only people exercising very strenuously reach this anerobic state of work which produces the lactacide oxygen debt.

It is known that both subjects in this study accumulated oxygen debts of from three to five liters because these were the average amounts paid off during the ten minute recovery periods. The alactacide oxygen debt of from two to three liters is generally paid off rapidly in the first two or three minutes of recovery according to Margaria and his coworkers.[3] This would indicate that the subjects in this study did accumulate some lactacide oxygen debt and had lactic acid accumulation in the blood. However, the level of lactic acid accumulation in these subjects is unknown. It was undoubtedly greater in subject 2 who was in poorer condition and who generally showed a greater oxygen debt repayment during recovery. It is quite possible that there was not a great deal of lactic acid accumulation in the blood of subject 2, particularly after the first eight to ten runs, as he adjusted to the work very quickly and was in better condition at the start.

So it is possible that Newman's subjects reached a higher lactic acid accumulation with their higher intensity of work. Thus, they had to pay off more lactacide oxygen which involves a different mechanism than that of paying off the alactacide debt.

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[3]*Ibid*. p. 707

Another factor which makes it difficult to compare the results between the lactic acid figures and the oxygen debt figures of this study is that it takes from two to eight minutes to reach the point of maximum lactic acid accumulation in the blood.[4] The subjects in Newman's study rested for five minutes after their exercise, then had a blood sample drawn before they started their slow jog. The subjects in this study started the slow jog within thirty seconds after the end of the standard five minute run. Actually then, the recovery periods of the two studies are almost entirely different. Thus, it is possible that if the oxygen debt repayment of the subjects in this study could have been followed during the slow jog recovery technique for a period of from thirty to forty minutes as in Newman's study the results might have been more closely parallel.

Regardless of all these various factors which make it difficult to compare the results of the two studies, the fact remains that in this study one subject contracted additional oxygen debt and the other failed to repay any substantial amount during the ten minute recovery jogs. It is difficult to reconcile these figures with those of Newman which show an increased removal of lactic acid from the blood during a recovery jog of approximately the same speed. While the results of these two studies may not be

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[4]Loc. Cit.

in direct conflict, it is certain that further study needs to be made along these lines to clear up some of the questions that have arisen.

Subject 2 showed a significant variance in his oxygen debt repayments due to training which the other subject did not show. A probable explanation of this difference lies in the relative condition of the two subjects at the start of the runs. Subject 1 was in much better condition as indicated by the all out run times, and he was also an experienced runner.

There was no relationship whatever, in the subjects of this study between repayment of oxygen debt during recovery and the time of the all out runs after recovery. This points out again the difficulty of trying to predict human performance on the basis of physiological measures alone.

In Table XVIII, it can be seen that there are very few factors which were significantly related to all out run time or oxygen debt repayment. The -.58 correlation for subject 2 between oxygen debt repayment and barometric pressure and the +.62 correlation for subject 1 between oxygen debt repayment and body temperature were probably chance relationships.

One relationship which showed a tendency to be consistent is that between second recovery R.Q. and both oxygen debt repayment and all out run time in both subjects. However, when training effects are eliminated from this relationship, as can be seen in Table XVIX, the correlations change.

Although there are still fair positive correlations between second recovery R.Q. and oxygen debt repayment, they are no longer statistically significant due to the reduced number of degrees of freedom. The relationships between second recovery R.Q. and all out run time both change to negative when training effects are removed. This is what would be expected since a lower R.Q. should be an indication of better or faster recovery. These relationships however, are too small to be considered of any significance.

The pulse rate after exercise also follows a pattern of consistent relationship with oxygen debt repayment and all out run time in both subjects. This relationship can be seen in Table XVIII. These oxygen debt correlations are negative and are consistent with the theory that the lower the pulse rate at the end of an exercise, the more efficiently the heart is working and therefore the greater will be the amount of recovery. These relationships continue to hold after the training effects are removed as can be seen in Table XVIX. Both of these correlations (-.62, -.64) approach the 5% level of statistical significance. This would indicate that the pulse rate after exercise should be a good indicator of the amount of oxygen debt that will be repaid during a ten minute recovery period. The correlations between pulse rate after exercise and all out run time become inconsistent and of no significance when training effects are removed. The pulse rate after exercise then, can not be considered of any value in predicting post recovery performance.

The pulse rates ten minutes after exercise are more highly related in both subjects to the amount of oxygen debt repayment than the pulse rate immediately after exercise. However, this is only natural that a higher pulse rate be found during the use of the slow jog technique than in the other techniques where the subject is merely lying and resting. Since the slow jog technique also had the least amount of oxygen debt repayment this would tend to throw doubt on the significance of this relationship. From these figures, the pulse rate ten minutes after exercise could not be considered as a good predictor of performance after recovery.

The pulse rate immediately after exercise does seem to offer some possibility as a predictor of recovery from oxygen debt however, and this figure is not affected by the jogging during recovery. It also proved to be stable when the training effects were removed from the relationship.

Analysis of the effect of each technique. Technique 1, which was lying quietly in a supine position was included in this study as a control technique. It was felt that the other techniques should prove to be significantly superior to this technique if they were to be of any practical value to coaches and athletes. This technique did not prove to be significantly superior or inferior to any of the other techniques except in the repayment of oxygen debt where it was significantly superior to the slow jogging technique.

In terms of over-all effectiveness it was the poorest of the four techniques, ranking third three times and fourth three times as shown in Table XVII.

Technique II, elevation of the extremities, was designed to allow gravity to assist the venous return. It turned out to be the most effective of the four techniques in over-all effectiveness. It ranked first three times and second three times. It was not significantly superior except over technique III in terms of oxygen debt repayment. If any one of the techniques used in this study were to be recommended for use by coaches and athletes or for further study as to its effectiveness, it would have to be this technique. It is easy to administer, would be practical to use with groups such as athletic teams, and it is based on sound physiological theory backed up by previous research evidence.[5]

Technique III was included in this study to further investigate the favorable results obtained by Newman and others.[6] Although the subjects in this study generally reported that they felt more like running or swimming again after recovery when they had continued to move during the recovery period, there were no performance nor oxygen debt figures to show any benefits from the use of this technique. On the contrary, the oxygen debt repayment was found to be

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[5]Zankel and others. Op.Cit. p.227

[6]Newman and others, Loc.Cit.

significantly less in both subjects, and in one subject, B.H., the second one-half mile run time was significantly slower. On the basis of the results of this study this recovery technique can not be recommended as being effective.

Technique IV was designed to bring about a nervous reorganization which would take the subject's mind off the unpleasantness of the task at hand and thus facilitate recovery from fatigue. The results show that this did not consistently occur in this study even though the technique does rank second best in terms of over-all effectiveness with three first, one second and three thirds. There are several possible explanations as to why this technique did not produce better and more consistent results. It was difficult to find a standard initial work that would bring about a similar level of fatigue in all subjects. For example, L.M. a former Olympic swimmer was evidently not very fatigued from his two hundred yard swim, while B.H. with no competitive swimming experience was obviously very tired. Another example of this problem was found in the treadmill subjects. Subject 1 was a former cross country and varsity distance runner. After the first few runs, the initial five minute work period did not seem much of a task for him. The other treadmill subject, number 2, who had no varsity track experience was obviously very tired after each five minute run throughout the whole experiement. So, it was impossible to reach a uniform level of impairment or fatigue in all of the subjects. Thus, while it is probable that there was some degree of fatigue induced in all subjects, it is also probable that some subjects were considerably more fatigued than others. In order to have reached a uniform level of fatigue in the various subjects, the measurement would have to be in personalistic terms in which the subject determines his own level of fatigue rather than in terms of some standard work load. This might be such as having a subject reach a certain level of fatigue on a scale according to his own report, or it could involve a long work period in which the subject was asked to continue until he felt that he could not go on. This level of fatigue would be different for each individual and it would vary within the individual from day to day. It would be directly related to the level of impairment but probably would be somewhat associated with it.

It can thus be seen that it is difficult, if not impossible, to get good measures of recovery from both fatigue and impairment in the same investigation. A study investigating recovery from fatigue should be oriented to the specific problem of fatigue rather than impairment, and it should be designed in terms of personalistic measures.

Another factor which might have affected the effectiveness of this technique was the type of movies that were shown. The assumption was that in order to accomplish the purpose, the movie had to be something interesting enough to get and hold the attention of the subject. The choice of movies for this study was limited. There were some musicals, some on travel and several on sports. While these were probably of some interest to all of the subjects, the degree of interest probably varied considerably from subject to subject. Better results might have been obtained with this technique if a full length, highly dramatic movie could have been shown in serial fashion, or a movie appealing to the subject's sexual nature could have been used. It is quite possible that one individual would react favorably to one type of movie, a musical for example, while another subject would react more favorably to a detective thriller. Having to use several different types of movies may have tended to mask the possible effectiveness of this technique. The use of this technique seems to deserve further study.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary. This study was concerned with testing the relative effectiveness of four different techniques in facilitating the recovery from fatigue and impairment in athletes. From the practical standpoint, it was desired to know if an athletic coach could expect to get consistently better performance from his athletes if he used one or another of these specific recovery techniques during rest periods. In order to have some standard with which to compare the other techniques, lying quietly in a supine position was used as a control technique. This is a practice commonly followed at present by many athletes during recovery periods. The experimental techniques which were compared with the control were, elevation of the extremities to allow gravity to promote venous return, slow movement (jogging or swimming) to promote venous return through the muscular squeezing action, and watching sound movies to bring about a nervous reorganization and thereby reduce fatigue. The criteria used to measure the amount of recovery from fatigue and impairment were performance runs (or swims) after recovery and oxygen debt repayment during recovery.

The study was conducted in two parts. Part One utilized data from two subjects who completed thirty-two repeat two-hundred yard swims and two subjects who completed thirty-two repeat one-half mile runs. Each of the recovery techniques was used on eight of the days in random block

fashion. The data were treated by analysis of covariance to equalize the first run times on each of the trials and to test for differences between means for the second run times.

Part Two of the study utilized data from two subjects that each completed thirty-two runs on the treadmill in the research laboratory at Michigan State University. These subjects made a standard initial run of five minutes during which loud music was played and the speed and incline of the treadmill were periodically changed. There followed a ten minute recovery period during which the four recovery techniques were introduced in randomized block order. After the recovery period the subjects made an all out performance run on the treadmill at eight miles per hour and at a ten degree incline. Metabolic measures were taken before and during the standard run and during the recovery period so that recovery oxygen debt figures could be computed. Analysis of variance was used to determine the differences between the means of the all out run times and the mean oxygen debt repayments of the various recovery techniques.

<u>Summary of Results</u>. 1. Oxygen debt repayment was significantly different when the slow jog technique was used between treadmill runs. This difference shows less oxygen debt being repaid with this technique than with the other three.

2. Out of a possible eight chances to rank first in effectiveness throughout this study, elevation of the arms and legs ranked first three times and second three times

for the best record in this respect. However none of these high rankings showed any statistical significance. Elevation of the arms and legs was found to be significantly inferior at the 5% level to the slow jog and watching movies techniques in one subject in Part One of the Study.

3. Slow movement during recovery (slow jogging or swimming) was found to be significantly inferior to resting in a supine position, elevation of the arms and legs and watching movies at the 1% level in one subject on the repeat one-half mile runs of Part One. This was the only significant difference found in the four recovery techniques in Part One.

4. Slow movement (jogging or swimming) was ranked first in effectiveness among the four techniques only one time out of a possible eight and this was not significant.

5. Slow movement (jogging) was found to be significantly inferior to the other three recovery techniques in terms of amount of oxygen debt repayment during recovery in both subjects of Part Two.

6. Watching movies was ranked first in effectiveness three times, second once and third three times. Only one of these represented a significant superiority and that was over only one technique, elevation of arms and legs.

7. The evidence, although not real strong indicates that elevation of the arms and legs was the most effective of the four recovery techniques used in this study and that the slow movement technique was the least effective.

8. The technique of watching movies to bring about a nervous reorganization, and thus recovery from fatigue as different from impairment, showed inconsistent results. This may have been due to a failure to produce much true fatigue in some of the subjects or a failure of some of the subjects to respond to the types of movies shown.

9. In one subject, B.H., that participated in both the swimming and running experiments of Part One, the recovery techniques ranked four, two, three, one for swimming, and four, two, one, three for running in relative effectiveness. These figures parallel each other very closely and indicate that a recovery technique effective for a swimmer would probably be equally as effective for a runner.

10. There is no relationship between oxygen debt repayment during recovery and time of an all out run on the treadmill after recovery in these subjects.

11. There was a high negative correlation between pulse rate after exercise and amount of oxygen debt repaid during the ten minute recovery period in both subjects. This figure offers good possibilities as a predictive factor.

Conclusions. 1. The technique of lying supine with arms and legs elevated proved to be the most effective of the recovery techniques studied in this experiment.

2. The slow jog recovery technique as used in this study was found to give no better performance results than the control, and it was significantly inferior to the control in terms of oxygen debt repayment. Jogging at six

miles per hour brought no recovery from oxygen debt in one subject and induced additional debt in the other.

3. This study could not effectively measure recovery from fatigue because there was not a sufficient measure available of the level of fatigue reached by the various subjects.

4. Pulse rate immediately after exercise seems to be of value in predicting the amount of oxygen debt that will be repaid during a ten minute recovery period. The slower the pulse rate after the exercise, the greater will be the amount of oxygen debt repaid.

Recommendations for further study. Further studies on the effects of various techniques on recovery from fatigue should be made which are oriented toward the experience of fatigue. Subjects should reach a uniform level of fatigue rather than to have any standard work load to perform.

As a result of this study it seems that further investigation should be made comparing recovery while moving at various speeds in terms of both blood lactate and oxygen debt repayments. These measures can be taken simultaneously.

It is also recommended that further study be made with various recovery techniques using more subjects and fewer runs to determine whether there is any specificity of techniques within individuals. In other words, is it possible that one technique will be more effective for one person and another technique more effective for another?

Although there is no statistical proof of this to be found in the results of this study, the author suspects that this may be the situation. If this should prove to be the case, we could stop our search for a technique which will prove to be universally effective for all athletes.

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APPENDIX

APPENDIX A.

Order of Runs and Times of Subjects in Part I.

L.M. Swimming 200 Yards

Swim no.	Date 1957	Recovery Technique	1st Time	2nd. Time
1.	Oct. 15	I	2:30:8	2:40
2.	Oct. 29	IV	2:29	2:28
3.	Oct. 31	I	2:26:5	2:27:6
4.	Nov. 4	II	2:25:8	2:28:6
5.	Nov. 5	IV	2:32:5	2:36:5
6.	Nov. 7	III	2:25:5	2:27:4
7.	Nov. 9	I	2:24:4	2:28:1
8.	Nov. 12	II	2:22:7	2:31:7
9.	Nov. 14	III	2:24:7	2:28:4
10.	Nov. 19	IV	2:22:8	2:35
11.	Nov. 21	I	2:23:4	2:28
12.	Nov. 23	II	2:25:9	2:30
13.	Nov. 26	IV	2:27:7	2:30:5
14.	Dec. 3	IV	2:32:5	2:30:5
15.	Dec. 7	I	2:24:2	2:33:8
16.	Dec. 8	II	2:28	2:30:2
17.	Dec. 10	III	2:21:5	2:25:5
18.	Dec. 12	I	2:26:7	2:27:8
19.	Dec. 14	II	2:26:7	2:23:3
20.	Dec. 17	IV	2:24:5	2:28:2
21.	Dec. 19	III	2:27:3	2:26:5
22.	Dec. 20	I	2:20:6	2:24:5
23.	Jan. 9 '58	III	2:26:4	2:38:6
24.	Jan. 10	III	2:25	2:28
25.	Jan. 11	II	2:20:9	2:23
26.	Jan. 14	IV	2:13:1	2:34
27.	Jan. 15	I	2:15:9	2:26:8
28.	Jan. 23	II	2:25:9	2:23:4
29.	Jan. 29	III	2:21:5	2:20
30.	Feb. 2	II	2:20	2:26:8
31.	Feb. 4	IV	2:19:3	2:29:6
32.	Feb. 6	III	2:21:7	2:29:6

B.H. Swimming 200 Yards

Swim no.	Date	Recovery Technique	Ist Time	2nd. Time
1.	Oct. 1 '57	I	3:35	3:55:6
2.	Oct. 3	I	3:29	4:03
3.	Oct. 5	II	3:23:6	3:53
4.	Oct. 8	III	3:22	3:59
5.	Oct. 15	I	3:29	3:58
6.	Oct. 17	II	3:23	3:42
7.	Oct. 19	III	3:43:2	3:53
8.	Oct. 22	IV	3:24:1	3:45:2
9.	Oct. 29	IV	3:27:7	3:44
10.	Oct. 31	I	3:32:9	3:51:2
11.	Nov. 2	II	3:23:8	3:44
12.	Nov. 5	IV	3:21:9	3:44:5
13.	Nov. 19	IV	3:20:4	3:42:2
14.	Nov. 21	I	3:21	3:40:2
15.	Nov. 26	IV	3:29	3:33
16.	Dec. 3	IV	3:23:2	3:35:8
17.	Dec. 5	III	3:31	3:48
18.	Dec. 8	II	3:28	3:55
19.	Dec. 12	III	3:39	3:46:4
20.	Dec. 13	I	3:33:4	3:41:7
21.	Dec. 17	IV	3:17:4	3:37:3
22.	Dec. 18	II	3:15:6	3:44:5
23.	Dec. 19	III	3:13:2	3:40:9
24.	Jan. 7 '58	I	3:13:5	3:40:3
25.	Jan. 8	II	3:16:8	3:39:4
26.	Jan. 9	III	3:14:9	3:47:9
27.	Jan. 10	III	3:11	3:49:1
28.	Jan. 12	II	3:12	3:32:5
29.	Jan. 31	I	3:21:4	3:51:2
30.	Feb. 4	IV	3:28:5	3:30:8
31.	Feb. 6	II	3:09:1	3:52:7
32.	Feb. 9	III	3:12:5	3:34

G.N. Running ½ Mile

Run No.	Date 1958	Recovery Technique	1st Time	2nd. Time
1.	Feb. 10	I	2:36	2:45
2.	Feb. 13	I	2:42	2:55
3.	Feb. 17	II	2:47	2:57
4.	Feb. 19	II	2:44	2:56
5.	Feb. 21	I	2:39	3:10
6.	Mar. 3	II	2:46	2:58
7.	Mar. 5	III	2:49	3:02
8.	Mar. 7	IV	2:43	2:59
9.	Mar. 11	IV	2:42	3:00
10.	Mar. 12	III	2:40	3:00
11.	Mar. 14	I	2:35	2:50
12.	Apr. 2	III	2:31	3:06
13.	Apr. 7	III	2:36	2:54
14.	Apr. 9	III	2:44	2:54
15.	Apr. 11	III	2:32	2:59
16.	Apr. 12	I	2:35	3:11
17.	Apr. 14	II	2:38	2:48
18.	Apr. 16	I	2:33	2:56
19.	Apr. 22	II	2:42	3:02
20.	Apr. 27	IV	2:33	2:50
21.	Apr. 30	IV	2:34	2:57
22.	May 2	II	2:36	2:55
23.	May 6	I	2:47	2:57
24.	May 8	IV	2:28	2:40
25.	May 12	II	2:56	2:55
26.	May 16	III	2:39	2:41
27.	May 18	IV	2:33	2:52
28.	May 20	IV	2:38	3:01
29.	May 21	I	2:36	2:55
30.	May 22	II	2:37	2:47
31.	May 23	III	2:39	2:41
32.	May 24	IV	2:33	2:56

B.H. Running ½ Mile

Run No.	Date 1958	Recovery Technique	1st Time	2nd. Time
1.	Feb.13	I	2:54	3:27
2.	Feb.15	I	3:14	3:34
3.	Feb.25	II	2:51	3:26
4.	Feb.26	III	3:01	3:38
5.	Feb.27	I	3:06	3:32
6.	Feb.28	III	3:25	3:37
7.	Mar.1	II	3:11	3:15
8.	Mar.3	III	3:13	4:04
9.	Mar.4	II	3:01	3:05
10.	Mar.5	I	2:57	3:28
11.	Mar.6	III	3:05	3:25
12.	Mar.10	IV	2:52	3:21
13.	Mar.11	II	3:01	3:18
14.	Mar.12	IV	3:10	3:02
15.	Mar.14	I	3:11	3:28
16.	Mar.15	II	3:09	3:27
17.	Mar.16	III	3:15	3:29
18.	Mar.17	IV	3:09	3:21
19.	Mar.19	III	3:21	3:35
20.	Mar.21	II	3:12	3:25
21.	Mar.22	I	3:10	3:19
22.	Mar.25	II	3:13	3:20
23.	Mar.31	III	3:09	3:20
24.	Apr.1	IV	3:01	3:12
25.	Apr.22	IV	2:54	3:20
26.	Apr.23	I	2:55	3:23
27.	Apr.29	III	3:00	3:25
28.	Apr.30	I	3:03	3:09
29.	May 1	IV	3:03	3:18
30.	May 7	II	3:03	3:20
31.	May 8	III	2:59	3:21
32.	May 19	III	2:44	3:20

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH

APPENDIX B.
TABULATION SHEET

Subject 1

TOPIC J. A. [illegible] Part II

DATE OF TABULATION Summer 1958

TABULATED BY A. Harrison

#	Date	Technique	Time	Air Temp. °Cent.	Rel. Humidity	Barometric Pressure mm-Hg	Body Temp. (oral)	Hours Sleep	Feeling Pre-Exercise	Feeling Post Recovery	Pulse Rate Pre-Exercise	Pulse Rate after Exercise	Pulse Rate 5 min. after Exercise	Pulse Rate 10 min. after Exercise	All Out Run Time Seconds	O_2 % Resting	CO_2 % Resting	O_2 % Exercise	CO_2 % Exercise	O_2 % Recovery #1 Bag	CO % Recovery #1 Bag	#
1	July 8	1	9AM	23.0	61%	744.1	97.9	7	Good	Poor	66	128	112	108	110	15.61	4.45	15.35	5.31	17.51	5.74	1
2	July 9	2	9A.M.	25.0	62%	746.4	98.3	8	Good	Fair	58	132	108	96	130	16.78	3.21	15.95	4.26	17.27	4.79	2
3	July 10	3	9A.M.	26.5	75%	742.3	97.8	7	Good	Fair	66	168	132	156	153	16.52	3.31	15.82	4.49	16.74	4.33	3
4	July 11	4	1P.M.	28.8	50%	741.8	98.3	7	Good	Good	68	174	108	96	182	16.26	3.05	15.30	3.82	16.53	3.89	4
5	July 12	1	9A.M.	25.0	60%	741.0	98.3	7.5	Fair	Fair	66	168	108	102	154	16.93	3.62	15.75	3.43	16.92	4.10	5
6	July 14	2	2P.M.	28.6	69%	739.9	97.6	9	Fair	Fair	60	168	102	108	168	16.76	2.81	16.22	3.76	17.17	3.66	6
7	July 15	3	9A.M.	26.0	79%	739.0	98.4	7	Fair	Fair	70	158	126	120	200	16.78	3.11	16.07	3.27	17.17	3.87	7
8	July 16	1	1P.M.	22.3	59%	743.8	98.8	6	Good	Fair	69	162	108	102	182	17.69	2.52	16.56	4.40	17.75	4.31	8
9	July 17	4	9A.M.	22.7	61%	746.9	98.0	7	Good	Fair	66	162	96	90	209	17.82	3.40	16.58	4.12	17.90	4.29	9
10	July 18	3	1P.M.	25.9	60%	740.7	97.0	8	Fair	Fair	58	162	152	114	243	16.76	2.42	16.45	3.10	17.85	3.61	10
11	July 19	1	9A.M.	23.0	57%	739.0	98.6	8	Good	Fair	60	156	96	88	257	16.65	3.52	16.15	3.76	17.55	4.13	11
12	July 21	2	9A.M.	23.8	54%	743.5	98.4	8.5	Fair	Fair	66	156	96	84	243	16.59	2.77	15.70	4.13	17.37	4.21	12
13	July 22	3	9A.M.	23.1	65%	741.0	98.6	7	Poor	Fair	57	174	120	120	261	16.57	2.89	17.08	3.52	18.06	4.23	13
14	July 23	4	9A.M.	24.0	59%	741.8	97.6	7	Fair	Fair	54	162	90	90	288	17.45	3.00	16.26	4.36	17.71	4.44	14
15	July 24	4	6P.M.	30.0	50%	739.0	98.2	7	Fair	Fair	58	156	100	100	261	17.63	2.91	16.88	3.55	17.28	4.58	15
16	July 25	2	9A.M.	23.8	78%	731.3	98.0	8	Good	Fair	54	150	92	88	188	16.91	3.52	15.83	4.30	17.05	4.61	16
17	July 26	1	9A.M.	26.0	57%	741.4	97.6	8.5	Good	Fair	54	148	92	88	303	17.18	2.92	16.54	4.01	17.54	4.56	17
18	July 28	4	9A.M.	26.0	75%	738.7	98.4	8	Good	Fair	54	156	80	84	319	16.98	3.49	16.49	4.34	17.88	4.23	18
19	July 29	2	9A.M.	23.5	62%	740.0	97.6	8	Good	Fair	50	156	88	80	303	17.26	3.25	16.67	4.13	17.59	4.34	19
20	July 30	3	1P.M.	24.8	70%	739.7	98.6	7	Fair	Fair	48	156	124	136	274	16.96	3.21	16.45	4.23	17.34	4.47	20
21	July 31	4	9A.M.	22.0	64%	741.8	98.6	8.5	Fair	Fair	54	160	96	88	345	17.45	3.01	16.74	4.02	17.70	4.44	21
22	Aug. 1	2	1P.M.	27.0	50%	745.0	97.4	8.5	Good	Fair	50	152	92	92	319	17.15	3.36	17.10	3.95	17.79	4.74	22
23	Aug. 2	4	9A.M.	24.2	60%	742.7	97.2	7.5	Fair	Fair	54	148	92	88	243	17.56	3.04	16.45	4.34	17.72	4.52	23
24	Aug. 4	3	9A.M.	24.1	60%	745.5	97.0	7.5	Good	Fair	54	168	132	124	363	17.58	2.87	17.03	4.12	17.93	4.40	24
25	Aug. 5	1	11A.M.	27.2	57%	742.5	97.6	8	Good	Good	54	148	80	80	241	17.39	3.15	16.93	3.93	17.84	4.61	25
26	Aug. 7	3	9A.M.	24.2	74%	740.5	97.8	8	Good	Fair	56	164	112	116	303	17.26	3.28	17.10	3.86	17.18	4.28	26
27	Aug. 8	4	6P.M.	28.8	45%	742.4	97.3	8	Fair	Fair	56	140	92	92	304	17.21	3.28	16.73	4.37	18.03	4.41	27
28	Aug. 9	2	9A.M.	26.2	55%	743.6	97.2	8	Poor	Poor	60	140	92	92	190	17.15	3.33	16.54	4.16	17.86	4.65	28
29	Aug. 11	1	11A.M.	29.0	60%	742.5	97.8	8	Good	Good	58	152	92	84	331	17.02	3.66	16.46	4.38	17.75	4.65	29
30	Aug. 12	2	6P.M.	29.2	56%	738.8	97.9	7.5	Fair	Fair	52	140	92	84	204	16.92	3.34	16.41	4.45	17.63	4.44	30
31	Aug. 13	3	9A.M.	23.0	58%	741.7	96.8	7.5	Good	Fair	58	172	132	116	304	17.43	3.62	16.45	4.31	17.39	4.11	31
32	Aug. 15	1	9A.M.	23.2	73%	741.4	97.8	8	Fair	Fair	60	152	92	80	303	17.31	3.59	16.29	4.76	17.42	4.92	32
33																						33
34																						34
35																						35

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

TOPIC J.A. Raw Scores Part II

DATE OF TABULATION Summer 1958

TABULATED BY A.B. Harrison

	O_2 % Recovery #2 Bag	CO_2 % Recovery #2 Bag	Volume 5 Min. Resting liters	Volume 5 Min. Exercise liters	Volume Recovery #1 liters	Volume Recovery #2 liters	Gross O_2 debt 10 min. liters	Net O_2 debt Repayment 10 min. liters	R.Q. Resting	R.Q. Exercise	R.Q. Recovery #1	R.Q. Recovery #2	True O_2 Resting liters	True O_2 Exercise liters	True O_2 Recovery #1 liters	True O_2 Recovery #1 liters	Gross O_2 Intake l/min.	Net O_2 Intake l/min.			
1 July 8	17.26	3.87	.900	9.400	6.700	1.800	6.24	3.77	.80	.94	2.09	1.05	2.83	5.63	2.80	3.62	2.619	2.372			1
2 July 9	16.90	3.76	1.320	9.220	6.250	1.498	6.82	4.01	.72	.82	1.41	.88	4.39	5.18	3.37	4.12	2.320	2.039			2
3 July 10	16.03	4.28	1.489	8.893	6.611	4.668	12.25	.93	.69	.85	1.03	.84	4.71	5.24	4.15	5.05	2.224	1.887			3
4 July 11	15.53	3.20	1.750	7.380	3.750	1.719	6.20	1.92	.59	.62	.81	.67	5.11	6.10	4.58	4.70	2.200	1.770			4
5 July 12	16.99	2.98	1.183	8.079	5.293	2.652	7.79	5.29	.59	.60	1.02	.70	4.38	5.65	3.98	4.21	2.208	1.958			5
6 July 14	17.30	2.91	1.468	7.218	5.522	2.520	7.37	4.18	.61	.75	.96	.75	4.53	4.92	3.79	3.83	1.870	1.551			6
7 July 15	16.55	3.61	1.571	8.436	6.723	5.222	4.94	.62	.69	.60	1.02	.78	4.43	5.38	3.73	4.58	2.210	1.884			7
8 July 16	17.60	3.26	1.595	8.788	6.755	2.072	6.60	3.89	.71	1.01	1.48	.95	3.45	4.30	2.92	3.38	1.860	1.590			8
9 July 17	17.31	3.43	1.591	6.244	5.915	1.444	3.46	1.57	1.10	.94	1.53	.93	3.08	4.32	2.71	3.66	1.340	1.096			9
10 July 18	16.65	3.58	1.107	7.167	9.341	4.078	11.08	-.24	.52	.63	1.21	.79	4.61	4.85	2.95	4.46	1.680	1.434			10
11 July 19	17.26	3.30	1.623	8.279	6.952	2.119	7.50	3.89	.78	.74	1.29	.85	4.48	5.08	3.20	3.79	2.080	1.719			11
12 July 21	16.04	3.43	1.571	1.977	5.636	1.893	7.09	3.41	.57	.74	1.23	.64	4.78	5.50	3.40	5.30	2.150	1.782			12
13 July 22	17.08	3.65	1.057	1.106	10.220	4.322	11.54	.22	.60	.88	1.65	.92	4.77	3.94	2.52	3.90	1.500	1.276			13
14 July 23	17.60	3.42	1.569	1.954	5.943	2.187	6.04	3.25	.82	.91	1.50	1.02	3.60	4.78	2.91	3.30	1.890	1.611			14
15 July 24	17.50	3.88	1.597	9.049	5.763	2.530	6.75	4.12	.85	.83	1.33	1.16	3.40	4.18	3.40	3.31	1.827	1.564			15
16 July 25	16.97	3.46	1.716	8.502	5.854	2.098	7.33	3.84	.84	.80	1.24	.84	4.16	5.32	3.69	4.10	2.200	1.851			16
17 July 26	17.33	3.70	1.352	9.077	5.863	2.357	6.45	3.84	.72	.88	1.45	1.12	3.98	4.50	3.10	3.56	1.987	1.725			17
18 July 28	17.68	3.31	1.503	8.533	6.604	2.101	6.01	3.05	.84	.96	1.53	1.00	4.08	4.48	2.74	2.23	1.801	1.505			18
19 July 29	17.24	3.50	1.405	9.161	6.189	1.665	7.15	5.34	.85	.95	.98	.92	3.28	4.30	4.35	3.76	1.935	1.674			19
20 July 30	16.32	4.18	1.497	8.477	9.567	3.561	12.19	.87	.76	.92	1.32	.87	4.17	4.56	3.36	4.72	1.933	1.597			20
21 July 31	17.60	3.40	1.103	8.593	6.151	2.165	6.26	3.20	.82	.94	1.51	1.00	3.60	4.21	2.92	3.32	1.809	1.503			21
22 Aug. 1	17.26	3.74	1.460	7.546	6.023	1.827	5.13	2.97	.85	1.02	1.59	1.01	3.89	3.81	2.80	3.65	1.804	1.528			22
23 Aug. 2	17.44	3.58	1.410	8.241	6.150	1.808	5.71	3.41	.86	.95	1.53	1.02	3.47	4.51	2.90	3.48	1.843	1.573			23
24 Aug. 4	16.75	4.00	1.513	8.136	7.624	5.354	11.85	.93	.81	1.16	1.56	.93	3.50	3.83	2.63	4.25	1.649	1.412			24
25 Aug. 5	17.55	3.16	1.417	9.081	5.981	3.244	5.41	2.88	.85	.96	1.70	1.13	3.66	4.02	2.70	3.30	1.749	1.490			25
26 Aug. 7	16.24	4.28	1.596	7.146	6.446	4.044	10.31	-1.01	.95	1.00	1.12	.88	3.78	3.83	3.60	4.81	1.690	1.399			26
27 Aug. 8	17.31	3.80	1.485	7.775	6.101	1.114	5.12	2.11	.84	1.04	1.75	1.07	3.82	4.14	2.50	3.50	1.593	1.292			27
28 Aug. 9	17.46	3.57	1.311	7.145	6.435	1.753	5.84	3.21	.84	.92	1.74	1.02	3.90	4.44	2.66	3.45	1.987	1.724			28
29 Aug. 11	17.10	4.16	1.613	8.497	6.116	1.660	5.62	2.52	.91	.96	1.65	1.10	3.99	4.50	2.80	3.75	1.841	1.531			29
30 Aug. 12	16.90	4.17	1.483	7.430	6.149	2.549	6.87	3.90	.78	.97	1.46	1.02	4.20	4.53	3.01	4.00	2.032	1.735			30
31 Aug. 13	16.18	3.80	1.140	7.845	7.173	3.022	9.12	-2.20	1.02	.95	1.20	.88	3.48	4.50	3.40	4.25	2.178	1.880			31
32 Aug. 15	17.52	3.71	1.578	7.926	5.858	2.141	6.22	3.45	.97	1.02	1.55	1.10	3.62	4.62	3.16	3.34	2.219	1.942			32
33																					33
34																					34
35																					35

G-1979

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH Subject 2

APPENDIX B.
TABULATION SHEET

TOPIC J. C. Raw Scores Part II

DATE OF TABULATION Summer 1958

TABULATED BY A. B. Harrison

Date	Technique	Time	Air Temp. °Cent.	Rel Humidity	Barometric Pressure mm-Hg	Body Temp. (Oral)	Hours Sleep	Feeling Pre-exercise	Feeling Post Recovery	Pulse Rate Pre-exercise	Pulse Rate after Exercise	Pulse Rate 5 Min. after Exercise	Pulse Rate 10 Min. after Exercise	All out Run Time Seconds	O_2 % Resting	CO_2 % Resting	O_2 % Exercise	CO_2 % Exercise	O_2 % Recovery #1 Bag	CO_2 % Recovery #1 Bag
1 July 8	1	3P.M.	26.0	49%	744.5	97.7	5	Fair	Poor	66	170	112	116	39	17.26	3.30	16.20	3.68	18.03	4.41
2 July 9	3	3P.M.	29.0	53%	746.5	98.4	6	Fair	Poor	74	162	138	150	55	17.55	3.20	16.54	4.11	17.88	4.18
3 July 11	4	3P.M.	26.9	54%	744.0	98.5	3	Fair	Poor	64	156	132	120	47	17.25	3.09	16.54	2.97	18.59	2.28
4 July 14	2	3P.M.	29.2	63%	739.6	98.8	5.5	Fair	Good	76	156	132	120	92	17.06	2.93	16.61	3.10	18.39	1.90
5 July 15	1	3P.M.	28.0	72%	739.0	98.5	6.5	Fair	Fair	76	162	114	96	63	17.32	3.15	16.89	3.46	18.28	3.30
6 July 16	4	3P.M.	24.0	51%	743.5	96.9	6.5	Fair	Good	74	156	120	108	77	17.51	3.05	17.32	3.47	18.39	3.46
7 July 17	3	3P.M.	26.0	52%	746.5	98.0	6	Fair	Good	70	168	144	150	82	17.02	3.36	17.05	3.63	18.31	3.56
8 July 18	1	3P.M.	26.2	67%	740.0	98.4	5	Fair	Fair	80	156	108	114	83	17.77	3.15	16.79	3.29	17.68	4.01
9 July 19	2	11A.M.	25.0	59%	740.5	97.3	8	Good	Fair	66	156	114	108	86	17.54	3.15	17.97	3.83	18.41	3.40
10 July 20	3	1P.M.	26.0	55%	744.0	98.0	9.5	Good	Good	66	174	138	150	89	17.70	3.16	17.17	3.51	17.61	4.03
11 July 21	2	3P.M.	28.8	41%	742.6	98.2	5	Fair	Poor	74	156	120	114	90	17.45	3.29	16.89	3.58	18.00	3.78
12 July 22	4	3P.M.	27.9	55%	741.0	98.2	5.5	Good	Good	88	168	108	120	100	17.63	3.12	17.23	3.59	18.36	3.70
13 July 23	2	3P.M.	30.0	55%	741.6	97.7	6	Good	Good	66	156	120	102	106	17.19	3.33	17.80	3.66	18.52	3.86
14 July 24	4	3P.M.	31.0	42%	740.0	98.6	6	Fair	Fair	78	156	108	102	109	17.50	3.35	17.24	3.86	18.42	3.73
15 July 28	1	3P.M.	26.0	75%	738.5	97.6	8	Good	Fair	74	160	112	120	100	17.43	3.55	16.54	4.40	18.42	4.10
16 July 29	3	3P.M.	26.2	70%	739.3	98.8	6	Good	Fair	72	172	160	152	111	16.86	3.90	16.68	4.28	18.05	3.86
17 July 30	1	3P.M.	25.0	66%	740.5	98.6	6	Fair	Poor	72	156	108	100	105	17.55	3.59	16.98	4.16	18.60	4.01
18 July 31	2	3P.M.	24.0	61%	742.0	97.3	7	Good	Fair	58	156	116	116	107	17.44	3.56	17.53	3.71	18.78	3.89
19 Aug. 1	4	3P.M.	29.0	48%	744.0	97.2	4.5	Fair	Fair	64	156	112	112	111	17.22	3.50	17.15	3.86	18.61	4.09
20 Aug. 2	3	11A.M.	26.7	50%	742.7	97.4	8	Good	Good	70	164	148	156	119	17.57	3.22	17.63	4.06	18.02	3.92
21 Aug. 3	4	12 Noon	32.0	51%	739.0	98.0	7	Good	Good	62	152	112	124	119	17.29	3.32	17.20	3.72	18.46	3.95
22 Aug. 4	2	11A.M.	26.0	47%	742.5	98.0	8	Good	Good	68	160	108	108	115	17.87	3.59	17.48	3.89	18.92	4.10
23 Aug. 5	4	3P.M.	31.5	54%	742.3	97.7	7	Good	Good	66	156	108	108	123	17.75	3.42	17.87	3.64	18.75	4.21
24 Aug. 6	1	3P.M.	26.0	78%	740.5	97.2	7.5	Good	Fair	72	152	104	106	111	17.75	3.76	17.40	3.85	18.37	3.84
25 Aug. 7	4	3P.M.	29.5	60%	739.4	97.4	6.5	Fair	Good	74	152	108	108	112	17.85	3.80	17.26	3.84	18.95	3.26
26 Aug. 8	3	11A.M.	24.6	70%	742.4	97.0	7	Good	Good	58	160	152	144	124	17.70	3.60	17.60	3.70	17.95	3.31
27 Aug. 10	1	11A.M.	29.0	62%	741.0	97.6	8	Good	Good	66	156	112	108	119	17.76	3.53	17.39	3.71	19.23	2.98
28 Aug. 11	2	11A.M.	27.5	68%	742.5	97.5	6	Fair	Fair	58	160	116	112	110	17.36	3.66	17.19	3.96	18.66	4.00
29 Aug. 12	3	3P.M.	31.9	51%	739.1	97.9	5	Fair	Fair	58	160	144	148	127	17.57	3.35	17.39	3.77	17.92	4.17
30 Aug. 13	1	11AM.	25.8	58%	741.7	96.5	8	Good	Good	74	160	104	108	127	17.21	3.90	17.52	3.47	18.72	3.85
31 Aug. 14	2	11AM.	27.2	61%	740.5	96.7	6.5	Fair	Fair	72	160	112	112	130	16.94	3.63	17.19	3.66	18.38	4.05
32 Aug. 15	3	11AM.	27.5	77%	744.5	98.2	6	Fair	Fair	76	168	148	156	131	17.59	3.61	17.33	3.99	18.15	3.49
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MICHIGAN STATE UNIVERSITY
DEPARTMENT OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

TOPIC J. C. Raw Scores Part II

DATE OF TABULATION Summer 1958

TABULATED BY A. B. Harrison

Date	O_2 % Recovery #2 Bag	CO_2 % Recovery #2 Bag	Volume 5 min. Resting liters	Volume 5 min. Exercise liters	Volume Recovery #1 liters	Volume Recovery #2 liters	Gross O_2 debt 10 min. liters	Net O_2 debt Repayment 10 min. liters	R.Q. Resting	R.Q. Exercise	R.Q. Recovery #1	R.Q. Recovery #2	True O_2 Resting liters	True O_2 Exercise liters	True O_2 Recovery #1 liters	True O_2 Recovery #2 liters	Gross O_2 Intake L/min.	Net O_2 Intake L/min.
1 July 8	18.26	2.67	1.488	10.023	4.484	3.214	4.84	2.09	.86	.73	1.76	.98	3.77	5.00	2.49	2.67	2.460	2.185
2 July 9	17.79	3.12	1.522	9.463	9.940	3.795	12.66	-5.56	.92	.92	1.50	.97	3.43	4.46	2.76	3.18	2.050	1.795
3 July 11	18.53	2.15	1.273	8.744	7.598	1.564	4.84	2.97	.78	.57	1.30	.88	3.09	5.15	2.11	2.42	2.200	2.013
4 July 14	18.21	2.23	1.370	9.701	6.513	4.027	7.12	4.40	.70	.66	.72	.77	4.12	4.64	2.74	2.89	2.175	1.903
5 July 15	18.31	2.52	2.265	9.579	9.691	3.836	8.32	4.09	.80	.82	1.34	.94	3.88	4.20	2.47	2.65	1.930	1.507
6 July 16	18.30	2.84	2.009	9.100	7.359	3.706	6.50	3.00	.85	.93	1.48	1.09	3.55	3.67	2.30	2.59	1.640	1.290
7 July 17	17.38	3.15	1.811	9.037	11.082	7.278	11.54	-6.68	.78	.91	1.48	.85	4.10	3.93	2.48	3.64	1.740	1.357
8 July 18	17.97	2.83	2.514	9.558	8.578	4.127	9.46	6.11	.98	.74	1.30	.93	3.18	4.38	3.06	3.01	2.450	2.115
9 July 19	18.23	2.48	2.488	10.582	9.220	5.621	8.98	4.76	.90	1.39	1.47	.91	3.48	3.72	2.30	2.77	1.410	.988
10 July 20	17.40	3.14	2.608	9.850	11.451	8.238	16.14	-2.08	.95	.90	1.28	.85	3.28	3.82	3.12	3.66	1.790	1.377
11 July 21	18.36	2.51	2.819	10.333	11.650	4.538	10.44	5.63	.91	.85	1.38	.95	3.55	4.18	2.71	2.60	2.080	1.599
12 July 22	18.59	2.59	1.786	9.346	11.599	4.964	9.09	5.89	.92	.95	1.64	1.14	3.35	3.75	2.28	2.28	1.687	1.310
13 July 23	18.51	2.75	2.016	9.684	11.942	6.103	9.28	4.87	.85	1.20	1.85	1.15	3.86	3.00	2.05	2.32	1.395	.954
14 July 24	18.30	3.01	2.122	10.638	9.554	3.956	7.37	3.87	.95	1.04	1.69	1.18	3.47	3.65	2.20	2.52	1.847	1.417
15 July 28	18.53	2.14	2.305	9.126	12.222	6.670	9.86	5.97	1.00	1.00	1.90	1.30	3.48	4.38	2.10	2.25	1.938	1.549
16 July 29	17.08	3.52	1.465	9.550	12.115	11.468	18.55	.33	.94	1.00	1.46	.88	4.10	4.25	2.61	3.93	1.964	1.594
17 July 30	18.56	2.42	2.343	9.338	11.657	3.887	7.46	3.76	1.05	1.06	2.09	1.30	3.32	3.89	1.89	2.21	1.775	1.396
18 July 31	18.78	2.78	1.715	9.238	9.349	4.738	6.27	2.99	1.01	1.01	2.24	1.40	3.47	3.32	1.70	2.00	1.471	1.143
19 Aug. 1	18.47	3.02	2.110	10.031	11.384	3.215	6.88	3.05	.92	1.02	2.18	1.30	3.77	3.77	1.86	2.30	1.821	1.438
20 Aug. 2	17.38	3.34	2.216	9.163	11.842	12.667	18.71	.49	.94	1.17	1.48	.97	3.40	3.43	2.63	3.57	1.540	1.171
21 Aug. 3	18.00	2.41	1.850	9.817	11.665	3.917	8.25	5.01	.87	.98	1.86	.97	3.74	3.75	2.10	2.95	1.725	1.401
22 Aug. 4	19.13	2.52	1.888	9.944	14.272	5.026	7.41	4.72	1.20	1.14	2.50	1.35	2.93	3.34	1.50	1.80	1.618	1.349
23 Aug. 5	18.63	2.77	2.473	9.761	12.589	3.338	6.61	2.64	1.00	1.24	2.50	1.38	3.39	2.90	1.66	2.10	1.374	.977
24 Aug. 6	18.34	2.12	2.538	9.633	10.323	4.134	7.66	3.49	1.23	1.10	1.71	1.15	3.02	3.45	2.21	2.10	1.615	1.243
25 Aug. 7	18.50	2.72	2.678	9.918	11.818	3.952	7.77	4.02	1.30	1.05	2.00	1.28	2.90	3.63	1.62	2.30	1.725	1.550
26 Aug. 8	17.80	3.38	2.316	10.122	16.713	11.660	20.63	2.41	1.14	1.13	2.90	1.09	3.12	3.24	2.90	3.80	1.730	1.377
27 Aug. 10	18.70	3.04	1.827	9.908	11.974	5.392	6.96	4.25	1.03	1.04	1.80	1.70	3.08	3.51	1.62	1.78	1.670	1.399
28 Aug. 11	17.94	2.73	2.091	9.484	14.411	6.292	8.54	4.97	1.02	1.06	2.20	2.40	3.55	3.70	1.80	1.52	1.689	1.332
29 Aug. 12	17.45	3.30	2.611	10.376	13.577	10.399	17.41	-.81	.98	1.08	1.54	.92	3.36	3.49	2.70	3.53	1.717	1.300
30 Aug. 13	17.74	2.66	1.951	10.233	12.296	5.226	9.73	6.21	1.04	1.00	2.15	1.44	3.69	3.41	1.78	1.82	1.702	1.350
31 Aug. 14	[illegible]	2.92	2.013	10.125	12.046	4.538	9.04	5.08	.87	.95	1.90	1.15	4.10	3.78	2.15	2.80	1.836	1.440
32 Aug. 15	17.34	3.42	1.810	9.638	11.038	12.342	17.07	-1.05	1.09	1.12	1.34	.92	3.29	3.50	2.58	3.65	1.658	1.352
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