1971

Oxygen Consumption and Heart Rate Recovery Curves of Subjects of Different Fitness Levels After Short and Long Duration Treadmill Runs.

George Edward Simpson
Louisiana State University and Agricultural & Mechanical College

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CURVES OF SUBJECTS OF DIFFERENT FITNESS LEVELS
AFTER SHORT AND LONG DURATION TREADMILL RUNS.

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OXYGEN CONSUMPTION
AND HEART RATE RECOVERY CURVES
OF SUBJECTS OF DIFFERENT FITNESS LEVELS
AFTER SHORT AND LONG DURATION TREADMILL RUNS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Education

in

The Department of Health, Physical, and
Recreation Education

by
George E. Simpson
B.S., Southwest Missouri State College, 1957
M.S., Louisiana State University, 1960
December, 1971
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ABSTRACT

The purpose of this study was to compare the oxygen uptake, heart rate and respiratory quotient recovery curves of high-average and low-average fitness subjects after high intensity-short duration and low intensity-long duration treadmill workbouts. A secondary purpose was to investigate the relationship between the heart rate, oxygen uptake and respiratory quotient recovery curves of the high-average and low-average fitness groups after the two workbouts.

The subjects were thirty male college students. Two groups of fifteen subjects each, one representing high-average cardiovascular fitness and one exhibiting low-average cardiovascular fitness, were selected on the basis of the Harvard Step Test (short form). Two treadmill workbouts were established for both groups: a high-intensity run of one-minute duration and a long-duration walk of fifteen minutes, with progressive increases in elevation. The criterion for the termination of each workbout was a heart rate level of approximately 180 beats per minute. Recovery heart rate and oxygen samples were taken during the 1st, 6th, 11th and 16th minutes of the recovery period.
The statistical matrix utilized in this study consisted of a three-factor analysis of variance with a nested factor. The three factors consisted of fitness categories, exercise time and recovery patterns. Comparisons were made of the three recovery patterns at the four levels outlined to determine whether or not significant differences existed between the high-average fitness and low-average fitness subjects after both workbouts.

The findings of this study were as follows:

1. The overall recovery heart rate mean for the high-average fitness group was significantly lower than that of the low-average fitness group. The overall recovery oxygen consumption for the low-average fitness group was significantly lower than that of the high-average fitness group.

2. The overall means for the three recovery variables were all significantly higher for the short workbout than for the long workbout.

3. The high-average fitness group experienced less heart rate stress on the slow workbout than the low-average fitness group.

4. All three variables demonstrated high linear recovery patterns with the greatest difference existing between the first and sixth minute.
intervals after the cessation of exercise.

5. The difference between the high-average group's and the low-average group's recovery heart rate was significantly greater during the first minute of recovery than at the other three intervals. The oxygen uptake difference was also significantly greater in the first minute of recovery.

6. The fast workbout respiratory quotient recovery pattern demonstrated a higher and more rapid decline than that of the slow workbout.

Within the limitations of this study, the following conclusions were justified:

1. The heart rate, oxygen uptake and respiratory quotient recovery patterns of high-average and low-average fitness subjects, following treadmill exercise terminated at a heart rate of 180 beats per minute, vary according to the intensity of the workbout used to achieve the 180 heart rate.

2. A workbout that produces a heart rate of 180 within one minute results in a higher heart rate, greater oxygen uptake and higher respiratory quotients during the recovery period after the cessation of exercise than a
workout in which the criterion heart rate
is reached after fifteen minutes of exercise.

3. There is a high relationship between the heart
rate, oxygen uptake and respiratory quotient
after the cessation of exercise as indicators
of cardiovascular condition.

4. The use of the 180 heart rate as a measure of
physiological incompetency, signifying the
point at which all individuals have reached
their maximum working capacity, is questioned
when the physiological responses of persons
of different fitness levels, engaging in
anaerobic and aerobic exercises, are compared.
CHAPTER I

INTRODUCTION

The importance of physical fitness, its achievement and maintenance, has been a topic of considerable interest and research in the United States as well as the world over. The term, "physical fitness," has been subject to numerous and varied interpretations. To many it is associated with sports and athletics, while to exercise physiologists, physical educators, and physicians the essence of physical fitness hinges largely upon cardiorespiratory efficiency.

The impetus behind the surge of interest in physical fitness stems from the negative influence that an automated and sedentary life has upon man's physical working capacity and organic health. Today's society has been labeled a hypokinetic environment. In similar fashion this influence upon man has been called hypokinetic disease. Paralleling this development, there has been an

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alarming increase in the statistics relating to mortality and morbidity associated with the cardiovascular and respiratory diseases. In consideration of all the components of physical fitness, there is a consensus of opinion among physical educators, physiologists and physicians alike that cardiorespiratory fitness constitutes the most vital area of concern. Cooper summarized this concern by stating:

In this paper physical fitness means only cardiovascular-pulmonary fitness, that is, a good heart, good blood vessels, and good lungs. This type of fitness is the most important, for a person's life depends upon these organs. Freedom from disease, or having large, bulging muscles is not enough. Without adequate reserves in the cardiovascular-pulmonary systems, a person is not prepared to meet the common or unusual stresses of daily living, that is, he is not physically fit.

In view of the foregoing situation, the various regimes of exercise for the development and maintenance of physical fitness have been the subject of extensive research. The question of intensity versus duration for

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the development of cardiorespiratory fitness has resulted in conflicting opinion. Brouha\(^6\) indicated that systematic studies should be undertaken to outline more clearly the best training methods for various kinds of exercise activities and to discern how the question of progressive increases in intensity and duration fit into the picture of daily exercise.

When discussing isometric exercise, Cooper summarized the intensity versus duration question by stating that no one has been able to show a measurable training effect from exercising just sixty seconds a day, regardless of the type. In reference to short intensive anaerobic exercise, Cooper stated that the exercises demand a lot of oxygen, produce an oxygen debt, and are over too quickly to produce a significant training effect. After four years of research, Cooper recommended two principles for exercise and training:

(1) If the exercise is vigorous enough to produce a sustained heart rate of 150 beats per minute or more, the training-effect benefits begin about five minutes after the exercise starts and continue as long as the exercise is performed. (2) If the exercise is not vigorous enough to produce or sustain a heart rate of 150 beats per minute, but is still demanding oxygen, the exercise must be continued

considerably longer than five minutes, the total period of time depending on the oxygen consumed.

Darling included both the aerobic and anaerobic aspects of fitness when he stated that physical fitness:

... consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous exertion and to restore promptly after exercise any equilibriums which have been disturbed.®

The foregoing statement, which is substantiated by the conclusions and opinions of other researchers,® points out the role that both intensive and duration-type fitness capabilities play in total physical fitness. Again, the point that physical fitness is highly task specific must be emphasized and training for one type of physical activity does not insure fitness for another. Cureton stated that physical fitness is the capacity that an individual possesses for doing prolonged heavy work.®

When discussing interval training, Steinhaus® said

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that one never performs at his maximum and this type of exercise over and over keeps supplying oxygen nearly as rapidly as it is needed. Thus, the individual is improving the enzyme systems involved in the control of this activity. Steinhaus asserted that the anaerobic phase of conditioning is not trainable.

Cooper in a study of the effects of short intensive exercise and prolonged intensive exercise upon cardiorespiratory fitness concluded that the quality and intensity of the exercises were more important than the quantity and duration.

Henry asserted that the use of the gross measure of oxygen debt as a means to indicate the efficiency of an individual's physiological adaptation to exercise stress is an oversimplification. Individual variation in oxygen transport efficiency, frictional energy loss, skill and other sources of inefficiency in the muscle system account for too much uncontrollable variation. In his conclusions he stated:

When a person has poor O₂ transport there is a large O₂ debt and a slow rate of pay-off, while with good transport there is small debt and a rapid pay-off, but the individual O₂ requirement, and O₂ income may be high, low, or intermediate in

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amount in either case. Nevertheless, O₂ requirement and O₂ debt are positively correlated.¹³

When discussing problems of training, Karvonen¹⁴ emphasized that the cardiovascular system can be thought of as trained only when a large cardiac output is possible as well as a high maximum oxygen uptake. The training to achieve these objectives is thought to bring about chemical, structural, and functional changes, some of which occur only when high pulse rate levels are reached.

The intensity of the exercise and the condition of the individual were cited by Karpovich¹⁵ as the determinant factors in the time it takes the heart rate to return to normal after exercise. Better physical condition tends to shorten the recovery period.

Herxheimer stated the following in reference to recovery from severe exercise:

Recovery from muscular exercise can be regarded as complete only when every function has returned to its pre-exercise level. In practice, the recovery period has often been regarded as over when oxygen consumption and respiration have returned to normal. After exhausting exercise, however, some factors of the circulation, for instance the pulse rate, does


not recover at the same rate as does respiration, $O_2$ intake and cardiac output.\(^{16}\)

Cardus and Spencer,\(^{17}\) when investigating the recovery time of heart frequency, found the time required to recover to be related to work intensity, total work, interaction of total work and work intensity, and to the age and physical condition of the individual. Thus, physically fit individuals exhibit a lower heart frequency response to physical exercise and a shorter recovery time than do untrained individuals. The authors suggested that heart frequency response to exercise might be used as a means of determining an individual's cardiovascular fitness for work.

Maxfield and Brouha\(^{18}\) found that the relationship between work done and both total and recovery cardiac cost was parabolic. Thus as the work level rose both the exercise and recovery heart rate rose. The recovery cost demonstrated an almost linear relationship to the total cost as evidenced by the cardiac strain. Thus recovery


\(^{18}\)Mary E. Maxfield and Lucien Brouha, "Validity of Heart Rate as an Indicator of Cardiac Strain," \textit{Journal of Applied Physiology}, Vol. 18 (November, 1963), 1099-1104.
pulse rates have been shown to be reliable indicators of cardiac strain.

Faulkner,\textsuperscript{19} in discussing new perspectives in methods for training to achieve maximal performance, illustrated the progress that coaches and exercise physiologists have made in this area. With regard to the optimal training procedure required to elicit maximal performance, he said: "A maximal training stimulus to the respiratory and circulatory systems probably requires a maximum demand on the oxygen transport system. Unfortunately, the best method to elicit the maximum demand has not yet been determined."\textsuperscript{20}

In light of the varied concepts and research findings in the area of the most efficient method of achieving conditioning, there appears to be ample room for research that relates to the development of physical fitness and methods for ascertaining this nebulous state. It is of signal importance to evaluate further the contributions and relationships that short intensive and long duration exercises have in the development of cardiovascular fitness.


\textsuperscript{20}\textit{Ibid.}, p. 744.
STATEMENT OF THE PROBLEM

The problem under investigation in this study was to determine whether or not high intensity-short duration exercise would produce different heart rate and oxygen consumption recovery curves than would low intensity-long duration exercise. In relation to the foregoing problem, the investigation was designed to determine if heart rate recovery and oxygen consumption recovery curves exhibited similar characteristics. A further topic of investigation was the differences, if any, that high-average fitness subjects and low-average fitness subjects exhibited during recovery from the two exercise bouts.

PURPOSE OF THE STUDY

The central purpose of this study was to compare the oxygen uptake, heart rate and respiratory quotient recovery patterns of high-average and low-average fitness subjects after high intensity-short duration and low intensity-long duration treadmill exercise bouts. A secondary purpose of the study was to investigate the relationship between the heart rate, oxygen uptake and respiratory quotient recovery data for the high-average and low-average fitness groups following the two workbouts.
IMPORTANCE OF THE STUDY

The relationship that oxygen consumption in recovery has to heart rate in recovery is important due to the fact that recovery heart rate is used so extensively as an indicator of the stress level of work and the condition of the individual. Research dealing with these two factors in recovery has not been as extensive as the research dealing with these factors during exercise. Therefore, research of this nature should be of value to individuals who are involved in the planning, execution and interpretation of exercise programs and athletics.

Another factor of importance in this study evolves around the elements that motivate the average individual to choose and maintain a fitness program on his own. There is no question concerning the physiological benefits that accrue from a duration-type fitness program.  

Even the studies comparing duration-type cardiovascular tests to the more intensive type tests usually recommend the duration tests. However, these programs do present a considerable investment in time on the part


of the individual; also, there are the added factors of "pain" and boredom which, in themselves, are not to be criticized but which do deter some individuals. The short duration-high intensity type programs may well offer an exercise regimen which is palatable both with regard to time requirements and in the quality of effort category.

The short duration-high intensity type programs which require that a greater anaerobic role be invoked more closely simulate the kind of requirements that the average person is exposed to in his selected physical activity regimen and in emergency situations. In many instances it is just this kind of sudden exertion that, in the abnormal and untrained individual, produces the cardiovascular demand that is associated with heart failure. A progressive conditioning program combining both long-duration and high-intensity exercise may serve to play a role in helping to alleviate the chance of heart failure by providing a level of cardiovascular fitness wherein anaerobic and aerobic demands can be handled.

Hermansen, in his discussion of the physiology of anaerobic energy release, emphasized the importance of research in this area in his summary:

In conclusion, it might be pointed out that impairment of energy metabolism in the tissue, in one way or another, is the ultimate cause of death in
all fatal injuries or lethal diseases. A better understanding of the vital energy yielding processes and the physiological mechanisms that sustain the necessary supply of energy to the cells will continue to be a major objective of biology and medicine.  

DEFINITION OF TERMS

Short duration-high intensity exercise. This exercise consisted of a treadmill run of sufficient speed and elevation to produce an exercise heart rate of approximately 180 beats per minute in one minute of exercise.

Long duration-low intensity exercise. This workbout consisted of a treadmill walk of 3.5 miles per hour with sufficient progressive increases in elevation to produce an exercise heart rate of approximately 180 beats per minute during the fifteenth minute of exercise.

High-average fitness subject. This term referred to subjects who exhibited a physical efficiency index fitness score of seventy-five or above on the Harvard Step Test (Short Form).

Low-average fitness subject. This category included subjects who demonstrated a physical efficiency index fitness score of sixty-five or below on the Harvard Step Test.


Resting Heart Rate. This factor was defined as the pulse rate taken for one minute after five minutes of rest in a sitting position prior to the start of the short and long exercise bouts.

Resting Oxygen Consumption. This term referred to a one-minute gas sample taken after five minutes of rest in a sitting position prior to the start of the short and long exercise bouts.

Recovery Heart Rate. This measure consisted of one-minute pulse counts taken at four intervals, five minutes apart after exercise with the subject resting in a sitting position.

Recovery Oxygen Consumption. This term referred to one-minute gas samples taken at four intervals, five minutes apart, after exercise with the subject resting in a sitting position.

Metabolic Respiratory Quotient (MRQ). This measure referred to the relationship of carbon dioxide produced to the oxygen consumed and was considered to be the physiological indicator of the contemporary oxidation of food stuffs being utilized for energy supply. This interpretation was applied only to the times when the subject was resting or in a steady state of exercise. The following

\[25\] Ibid.
formula for MRQ computation was used:

\[ MRQ = \frac{\text{volume } \text{CO}_2 \text{ produced}}{\text{volume } \text{O}_2 \text{ consumed}} \]

Recovery Respiratory Quotient (RQ). This term was used to describe a ventilatory RQ, the expiratory exchange ratio or excess carbon dioxide, and was not considered to reflect truly the contemporary oxidation of foodstuffs occurring to supply energy. In this sense, the recovery RQ (or excess RQ) was employed to denote the percentage of participation of the anaerobic energy sources in the exercise bouts.27

DELIMITATIONS OF THE STUDY

The subjects for the study were composed of thirty male undergraduate students at Southwest Missouri State College, Springfield, Missouri. The research was conducted throughout the first and second semesters of the school years 1969-70 and 1970-71. The study was limited to two types of exercise bouts—long duration walking and short duration running on a treadmill. The long duration bout was of fifteen minutes duration and the short duration bout was of sixty-second duration. Both exercise bouts were terminated when a heart rate of 180 beats per minute

26Herbert A. deVries, Physiology of Exercise (Dubuque: Wm. C. Brown Company, 1966), p. 158.

Heart rate, oxygen consumption and respiratory quotient in recovery were the three physiological factors selected to represent the degree of exercise stress.

Rather than using extreme high and low fitness scores it was decided to use high-average and low-average fitness categories based upon the Harvard Step Test (Short Form).

**LIMITATIONS OF THE STUDY**

All subjects used in the study were selected on a voluntary basis which may have introduced a quality which might have been eliminated if a purely randomized approach had been used. It was felt that the procedure used in recruiting introduced a form of randomization which was acceptable in light of the design of the study.

Each subject was selected or rejected for the fitness categories on the basis of a single administration of the Short Form of the Harvard Step Test. The tests were given at varied times during the day which resulted in a difference of background interference as the testing area was used for varying purposes throughout each day. Since the Harvard Step Test is dependent to some degree on subject motivation, it is possible that some variance

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might have occurred even though specific attention was
devoted to motivation and proper testing techniques at
each testing session.

Due to student class schedules and availability
of laboratory facilities it was impossible to test all
subjects at the same time period during the day. This
situation may have introduced error factors related to
time of day, temperature, meals and varying levels of
fatigue. The testing conditions were controlled as much
as possible and with the close control of each indi-
vidual's testing situation, it was felt that the error
factors were acceptable within the study design.
CHAPTER II

REVIEW OF RELATED LITERATURE

The volume of literature that relates directly and indirectly to heart rate and oxygen consumption as measures of and predictors of physical fitness and exercise stress is enormous in its scope and depth. This review of literature presented studies selected for their particular relevance to the central theme of the study and for their ability to illustrate the status of conflicting evidence surrounding the subject. The literature centered upon the following topical areas:

1. Studies that were devoted to the comparison of intensity versus duration training for the attainment of cardiovascular fitness.

2. Literature that dealt with the use of heart rate, oxygen consumption and respiratory quotient before, during and after exercise as measures of, or indicators of, exercise stress and as means for the comparison of trained and untrained subjects.

3. Research related to the use of the motor driven treadmill as a research instrument.
STUDIES CONCERNING INTENSITY
VERSUS DURATION OF TRAINING

The question of intensity versus duration has been investigated extensively in the area of muscle strength development. The work of Hettinger and Muller\(^1\) stimulated interest in the realm of optimal response to efforts of short duration and high intensity. There appears to be a similar two-fold approach to cardiovascular-pulmonary fitness training, one being a duration-aerobic type approach and the other being an intensity-anaerobic type of exercise.

Sharkey and Holleman\(^2\) touched upon the two approaches when they investigated the hypothesis that intense activity is necessary to bring about the changes associated with cardiorespiratory endurance. Sixteen normally active college men were assigned to three training groups (TR) plus a control group. The training sessions consisted of ten-minute treadmill walks at 3.5 miles per hour three days a week for a total of sixteen sessions. The treadmill grades were varied to elicit heart rates of


120, 150 or 180 beats per minute. The desired heart rates were reached after two minutes of exercise and held there til the exercise was terminated. The control subjects were enrolled in a fencing class. The Balke treadmill test plus the Astrand-Ryhming nomogram prediction of aerobic capacity were administered prior to and after training.

Analysis of group differences revealed that the TR 180 group's improvement was significantly greater than the other groups' in all tests and the TR 150 group was significantly different from the TR 120 group and the control group. No changes were noted in resting heart rates among the four groups. The results also demonstrated almost similar pre- and post-training oxygen pulse values for the three training groups indicating that the subjects were able to do more work without an increase in energy.

The authors suggested that in order to elicit a training stimulus, more intense rather than light or moderate activity is needed. In conclusion the authors stated:

Thus the results of this study indicate the need for exertion prompting heart rates above 150 beats/min. Further study using exercise intensities between TR 150 and maximum exertion would be useful to help answer the question of a possible threshold training stimulus. The results of this investigation do not preclude the possibility that a submaximal stimulus might elicit optimal adjustments to endurance training.  

\[^{3}\text{Ibid.}, \text{ p. 703.}\]
Jackson et al. also delved into the question of cardiorespiratory training at specified frequencies. Twenty college-age subjects were divided into five training groups who trained by running on a treadmill at seven miles per hour for ten minutes. The groups trained for one, two, three and five days a week for five weeks. A control group played volleyball for five weeks.

Each group was given pre- and post-training tests of cardiovascular fitness which consisted of the Balke treadmill test, the Astrand-Rhyming test of physical fitness, and the Taylor, Buskirk and Henschel test of maximal oxygen uptake.

The results of the study showed that the Balke test indicated significantly greater improvement for the five day group. The other measurement methods showed the two or three day groups exhibited greater improvement. Thus the results in general indicated that the two or three days a week of training were about as beneficial as the five day training. In summary, the authors concluded:

The optimal frequency of exercise participation required to elicit changes in physical fitness is difficult to establish since it is dependent upon the particular aspect of fitness desired, the age and fitness level of the subjects involved, as

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well as the intensity and duration of the training regimen.\(^5\)

McArdle \textit{et al.}\(^6\) used telemetry systems to compare the cardiac response of varsity trackmen prior to, during and in recovery from races of varying distances. Eighteen varsity trackmen and four untrained subjects warmed up, then ran races of 60 yards, 220 yards, 440 yards, 880 yards, one-mile and two miles. Resting heart rates were taken after reclining for ten minutes and the recovery rates were taken for fifteen minutes in the reclining position.

The recovery heart rates for the non-conditioned subjects were higher for all events. In reference to the heart rate patterns the authors observed that the all-out run recovery patterns for both the trained and untrained were not significantly different even though the trained runners completed the races in less time.

In recovery from the 440 run the unfit subjects showed heart rates of 164, 115, 109 and 105 beats/min. at one, six, ten and fifteen minutes respectively; while the trained runners evidenced heart rates of 148, 110, 110, and 110 for the same time periods. During recovery from

\(^5\)Ibid., p. 295.

the mile run, the unfit subjects demonstrated heart rates of 155, 117, 115 and 112 beats/min.

Cooper, who stresses the importance of aerobic training, refutes the concept that anaerobic training programs have value in an ordinary physical fitness program. He cites two types of anaerobics:

An example of the first is any exercise that can make you "huff and puff," but is usually over too quickly for the "steady state" to be established, like running for a short distance, cycling a few blocks, swimming a few laps, or walking to the corner drugstore.

An example of the second is any exercise that demands so much oxygen in so short a time that the heart and lungs can't possibly supply it, thus creating an "oxygen debt" that must be paid quickly. And the only way to pay it is to stop and recover. Wind sprints, interval training, the 100-yard dash, swimming and bicycle sprints all qualify.

Costill looked at the contribution of low intensity training to the maximal oxygen uptake, maximal heart rate and post-exercise lactic acid capacities among champion marathon runners. Six national champion marathon runners performed a treadmill run at 240 m/min which began on the level. The treadmill was raised to 4 percent after four minutes and thereafter, raised 2 percent each minute.

The mean maximal rates for oxygen consumption,

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heart rate and post-exercise lactic acid were 71.4 ml/kg.min, 185 beats/min. and 97.7 mg percent respectively. It was concluded that the low work intensities of marathon training were sufficient to stress the oxygen delivery system sufficiently to produce a high level of development and efficiency.

Falls et al. looked at the estimation of maximum oxygen uptake in adults from items on the AAHPER Youth Fitness Test. Eighty-seven adult subjects were used in the study. Multiple correlations were used to determine the relationship that the fitness test items had with gross oxygen uptake, oxygen uptake per kilogram of body weight, and oxygen uptake per kilogram of lean body weight. In regard to this approach the authors said:

... the trend in contemporary studies of aerobic capacity is to correct the gross maximum oxygen uptake for body weight or lean body weight since the level of oxygen uptake depends upon the amount of body tissue that must be supplied with oxygen as well as the intensity of exercise. Very little use is made of gross oxygen uptake.

The criterion measure was established as a bicycle ergometer ride at 150 kpm/min for two minutes with an increase of 150 kilopondmeters each succeeding minute. Heart rate was counted the last fifteen seconds of each minute. The

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10 Ibid., p. 196.
subjects rode to exhaustion or until two consecutive heart rate counts were achieved. A gas sample taken during the last minute of the ride was analyzed for oxygen and carbon dioxide content.

The primary finding of the study that had implications for the development of cardiorespiratory fitness was a correlation of .64 between the 600 yard run-walk and maximum oxygen intake.

In a follow-up study, Doolittle and Bigbee\footnote{11} questioned the accuracy of the 600-yard run-walk as an indicator of cardiorespiratory fitness. They compared the twelve-minute run with the 600-yard run-walk using 153 ninth grade boys as subjects. The subjects were given a test-retest trial at the twelve-minute run which yielded a correlation coefficient of .94.

Nine subjects, selected at random, performed a maximum oxygen uptake test on a bicycle ergometer. Three one-minute samples of expired air were collected when the heart rate reached or neared 180 beats per minute. The maximum oxygen intake in milliters per kilogram of body weight per minute were utilized for the determination of the validity of the twelve-minute run-walk and the 600-yard.

run-walk tests.

For the nine subjects, a Spearman rank difference correlation coefficient of .90 was found between the maximum oxygen uptake and the twelve-minute run. The correlation between the maximal oxygen uptake and the 600-yard run-walk was found to be .62. Thus the authors concluded that the twelve-minute run was preferable as an indicator of cardiorespiratory fitness.

Durnin et al. studied programs of varying severity on selected measurements of physical fitness. Twenty-four untrained Air Force men, average age 22 years, were divided into three exercise groups and a control. The exercise routines were daily walks of 10 kilometers, 20 kilometers and 30 kilometers five days a week for two consecutive periods of five days.

All subjects were tested on a fifteen minute treadmill walk at ten percent grade before, during and after the exercise periods. Pulmonary ventilation, oxygen consumption and heart rate were monitored continuously. Recovery heart rate was followed for a period of ten minutes.

The results of the study indicated that significant

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physical fitness improvement occurred in all three groups and that the 20 kilometer group showed the most improvement in cardiorespiratory fitness. All three groups lowered significantly their resting heart rates. The 20 kilometer group was the only group that exhibited a lowered recovery heart rate and that only occurred during the 2-2.5 minute interval after exercise.

Corbin et al. tested twenty low fitness college men in a study on the length of training sessions. The Balke-Ware treadmill test was utilized to ascertain the fitness levels of the subjects with the maximal oxygen uptake being scored in $O_2/KgBW/min$. Baselines were established through the use of a medical examination, lean body weight calculations, the AAHPER Youth Fitness Test and the treadmill test. The tests were administered before and after the ten week, five days a week, training period.

Three equal exercise groups and one control group were selected on a random basis. Groups I, II and III rode a bicycle ergometer at a heart rate of 180 beats per minute for twenty, forty and sixth minutes per day respectively. The control group engaged in normal activities

during the training period.

The sixty minute group made significant changes at the .05 percent level of confidence on 23 of the 52 variables. The 20 minute group had significant changes in 19 variables, the 40 minute group improved on 17 variables and the control group improved on 4 variables. This study indicated that duration-type exercise performed at near maximum heart levels was more efficient for the achievement of physical fitness. Duration was the major factor as the intensity was uniform in all groups.

Graded intensities of exercise were utilized by Campbell\(^\text{14}\) to determine the post exercise heart rate curves on two groups of different fitness levels. Two groups of seven pubescent age boys were selected from those scoring in the top quarter and bottom quarter on a 600-yard run.

All subjects performed five series of bench stepping at cadances of 16, 23, 34, 40 and 48 steps per minute with two minute rest intervals between exercise bouts. Telemetry equipment was used to record the first and second minute of recovery during the rest periods.

Analysis of variance of trends disclosed that the

deceleration heart rate patterns were the same for the two groups. The group in the bottom quarter displayed significantly higher over-all heart rate recovery values than the high group. The results implied that the subjects' heart rate responses were directly proportional to the severity of the exercise. The relationship was found to be rectilinear. Pre-exercise heart rate had little or no effect on the recovery rate.

Elbel\(^\text{15}\) compared the pre-exercise and post-exercise pulse rate after three different intensities of step-up exercise. Fifty male college subjects in good condition performed step-up exercise for thirty seconds at eighteen steps per minute, for sixty seconds at eighteen steps per minute and for sixty seconds at thirty-six steps per minute. The pre-exercise heart rate data were compared with the post-exercise heart rate data. The correlation between the pre-exercise pulse rate and the increase in heart rate due to step-up exercise for thirty and sixty seconds at eighteen steps per minute was positive but non-significant. A negative correlation was discovered between the pre-exercise pulse rate and the increase that resulted from the four step-up exercise bouts performed at thirty-six steps per minute. For the

post-exercise, taken fifteen seconds following exercise, a significant difference was found between the mean increase for the low pulse rate group and the group with a rapid post-exercise rate, with the low pulse rate group exhibiting the smallest increase.

Henry used bicycle ergometer exercises to study the individual differences in oxygen metabolism at two intensities of work. Thirty-five male college students who were classified as non-athletes participated in the study. Two intensities of work were utilized: one was a near maximal ride at sixty-nine RPM with a load of 620 KG-M/min; the other was a high intensity ride at 116 RPM with a load of 95 KG-M/min. Both exercise bouts were the same in metabolic cost. Thirty-five subjects performed two tests with the slow movement work and twenty-five of these subjects also performed the fast movement work. The re-test was performed one week after the initial test.

Intercorrelations between the varied exercise metabolism data were treated with a simplified factor analysis. The results indicated the debt velocity constant to be a measure of differences exhibited by the individuals in oxygen transport efficiency and that the peak oxygen uptake in recovery was a result of individual

differences in oxygen requirement. Oxygen debt was considered to be a composite of the two preceding dissociated factors and as such it was warned that oxygen debt could be misconstrued to be an indicator of differences in physiological work adjustment. Oxygen transport was found to be less efficient in the fast-moving exercise. Henry concluded that inter-individual differences were present for all measures in the slow-movement exercise but with the fast-movement work, stable inter-individual differences were almost non-existent in the oxygen transport measures.

Cogswell, Henderson and Berryman studied intense and duration-type exercise using the Harvard Step Test, the bicycle ergometer and treadmill runs. Seven subjects, aged twenty-three to twenty-eight, trained on the step test and bicycle ergometer three times a week for four weeks and then to avoid boredom, exercised one time per week for the remaining eleven months. The treadmill exercise was employed once a week for the twelve month period.

The step test was a submaximal exercise wherein a

steady state was achieved. Pulse rates were taken prior
to, during and after each exercise bout. For all subjects
the treadmill exercise consisted of a speed of six miles
per hour at ten percent grade. Each subject performed two
four-minute periods with a rest of ten minutes in between
bouts. The treadmill work was as close to maximal as
possible. Pulse rates were recorded prior to and for three
minutes after the bouts. Two sixty-second bicycle ergo-
meter rides with a ten minute intervening rest represented
an exhausting exercise work load for all subjects. Ride
length was recorded along with pulse rates taken at
fifteen seconds, two minutes and six minutes after exercise.

The results of the study demonstrated that the
pulse rates after submaximal exercise decrease with
training, and that the pulse rates after maximal exercise
did not demonstrate a decrease after training. Subjects
with resting pulse rates that were higher than average
also demonstrated higher than average post-exercise pulse
rates.

Harper, Billings and Matthews\(^{18}\) compared two
physical conditioning programs on cardiovascular fitness
parmiters. Twenty-five college men were placed in three

\(^{18}\)Donald D. Harper, Charles E. Billings and Donald
K. Matthews, "Comparative Effects of Two Physical Condi-
tioning Programs on Cardiovascular Fitness in Man," Research
matched groups on the basis of their oxygen consumption derived during a series of five-minute bicycle ergometer rides and from their index scores on the Harvard Step Test. Group one, the army program, was assigned to a physical conditioning program which consisted of combative drills, calisthenics and forced marches performed at 120 and 180 steps/min. The weekly duration of exercise increased progressively from 1 hour in the first week to $1\frac{1}{2}, 1\frac{3}{4}, 2, 2\frac{1}{4}, 3$ and $3\frac{1}{4}$ in the second, third, fourth, fifth, sixth and seventh weeks, respectively.

The second group was involved in an interval-training program that included intervals of 220, 440 and 880 yards. Warm-up activities were employed prior to each training session. Each subject performed a set of runs, then after five minutes of rest, ran another set. Repetitions were increased, run times were shortened and rest intervals were shortened in order to increase the intensity of the exercise. In both experimental groups, recovery heart rates were utilized to determine intensity increases.

The third group served as a control and took part in archery, golf, scuba diving and recreational swimming. All groups participated in their programs five days a week for seven weeks.

The subjects were re-tested on their oxygen
consumption and on the Harvard Step test at the end of
the training period. The t test for paired samples was
used to determine differences in training programs. The
interval training group showed a significant improvement
in oxygen consumption while the other two groups failed
to exhibit a significant change. Both experimental
groups demonstrated significant changes in their index
scores on the Harvard Step Test. The control group did
not exhibit a significant improvement in the Harvard Step
Test.

In view of the results and the higher post-
exercise heart rates of the interval training group
recorded during training, the authors noted that while
the army group spent more hours in conditioning, the in-
terval group achieved more improvement. As a result the
authors cited intensity of training as being the critical
factor for the improvement of cardiovascular fitness.

Four college athletes and four non-athletes were
compared by Andrew, Guzman and Becklake¹⁹ as to their
ventilation, oxygen consumption, cardiac output and heart
rate before and after a period of athletic training. Three
submaximal workloads on the bicycle ergometer were used to

¹⁹G. M. Andrew, C. A. Guzman, and M. R. Becklake,
"Effect of Athletic Training on Exercise Cardiac Output,"
Journal of Applied Physiology, Vol. 21 (March, 1966),
603-608.
collect the data. The athletes rode the bicycle at work loads of 550, 750 and 900 kilograms per minute, with a rest period of fifteen minutes between rides. The non-athletes rode at work loads of 350, 550 and 750 Kg/min, with the same rest interval.

The athletes trained from six to eight hours per week and participated in one type of athletic game per week. The non-athletes took part in one hour training sessions, five days per week. The exercises included bench jumping, rope climbing and running. Both groups trained for a period of four months.

The results indicated that the training resulted in a significant lowering of heart rate for the athletes on the 500 and 900 Kg/min. workloads and on the 350 and 550 Kg/min. workloads for the non-athletes.

Sinisala and Juurtola investigated the problem of intensity versus duration in a study of ski-training regimens. Two different training methods were studied; one consisted of skiing at a constant speed and the other called for an interval training approach. The training sessions were of one hour duration three times a week for eight weeks.

Both skiing programs produced a significant

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decrease in pulse rate during skiing and also during the recovery periods. The vital capacity measures did not show significant changes. The study revealed no statistically significant differences between the two ski-training methods.

In reference to heart action in duration and intensity Brouha and Radford, as cited by Johnson, summarized:

After light work the cardiovascular functions soon return to the pre-exercise resting level. The heavier the load, the higher will be the maximum heart rate and the longer it will take to return to the resting level. The duration of the exercise also influences the recovery process. If the load is light, duration has little influence unless it extends over several hours. For heavy work that can nevertheless be maintained in a steady state, the longer the duration of the exercise, the longer the recovery to the resting level (e.g. marathon-runners, mountain climbers). On the other hand, for comparatively short efforts pushed to exhaustion or nearly so, the duration of the performance does not influence appreciably the recovery processes. No matter how long it takes to reach exhaustion, the return to the resting heart rate always follows the same pattern and takes about the same time.  

STUDIES RELATING TO THE USE OF HEART RATE AND OXYGEN CONSUMPTION BEFORE, DURING AND AFTER EXERCISE

The properties of maximal and submaximal exercise, the resulting physiological variation and the measurement

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of exercise tolerance were investigated by Taylor. 22

Thirty-one subjects ranging in age from nineteen to twenty-six years were divided into four groups representing different fitness levels. The fitness levels were low, low average, high average and high. A four-minute submaximal treadmill run of 108 meters per minute at five percent grade was used to study the relationship of oxygen uptake to body weight. After a four-minute rest, the subjects ran a ten-minute maximal treadmill run of 162 meters per minute which began at five percent grade and was increased one percent per minute. The recovery period lasted for sixteen minutes. Heart rate and oxygen consumption were taken before, during and after exercise, and lactate samples were collected during recovery. Determination of resting physiological data were not collected because earlier unpublished work done by the author demonstrated very low correlations between resting data and the measures of exercise tolerance. Three days later the same procedure was repeated.

The results of the study revealed that heart rate and blood lactate were the most reliable measures for the submaximal walk but were approached by oxygen consumption

in the maximal run. Oxygen consumption in the submaximal walk was found to be chiefly a function of body weight and only slightly related to fitness; however, in the maximal run the correlation with weight dropped markedly and the length of running time, correlated more highly with oxygen consumption levels. Respiratory quotient was found to be too strongly influenced by blood gas displacement to exhibit true levels of catabolism.

Higher heart rates, respiratory rates, blood lactates, ventilations and oxygen consumptions were exhibited by the less fit subjects. After four minutes of walking, the average exercise heart rates ranged from approximately 118 beats/min. for the highest fitness group to 148 for the lowest fitness group. In recovery the high group recovered to 85 beats/min. after four minutes while the low fitness group recovered to about 92 beats/min.

During the maximal run, the low fitness group ran approximately four minutes and the high fitness group ran for ten minutes. The low fitness group attained maximum heart rates of approximately 200 beats/min. and the high fitness group's mean maximum heart rate was approximately 192 beats/min. For all groups combined, maximum run resulted in a mean exercise heart rate of 198.1 beats/min. and a mean oxygen consumption of 3.48 liters/min.; while
the submaximal run produced a mean heart rate of 130 beats/min. and a mean oxygen consumption of 1.65 liters/min.

During recovery from the maximal run, the low fitness group demonstrated heart rates of approximately 164, 120, 117 and 116 beats/min. at one, six, eleven and sixteen minutes respectively. The high fitness group exhibited recovery rates of approximately 150, 117, 115 and 115 beats/min. during the same time intervals.

In conclusion the author stated: "It seems clear that one must look to the responses during exercise, particularly the later phases of adaptation, for critical measures of fitness for hard work, not to the resting or recovery states." 23

Astrand and Saltin 24 studied maximal oxygen uptake and heart rate in various types of exercise. Seven well-trained male and female subjects whose ages ranged from twenty-two to forty-eight performed the following exercises: 1) Cycling a bicycle ergometer sitting upright, and 2) in a supine position, 3) treadmill running, 4) simultaneous arm and leg work on bicycle ergometer,


5) skiing, 6) swimming and 7) arm cranking. All the experiments were conducted over a period of three to five months.

Heart rate and oxygen consumption, pulmonary ventilation and blood lactate data were collected. In the treadmill run the subjects ran at seven miles per hour at an elevation predicted from their scores on a Harvard fitness test that would cause them to reach their maximum in less than two minutes and forty-five seconds.

The results indicated that the maximum $V_{O_2}$ was a few percent higher in the treadmill running than in cycling, cranking and cycling and skiing. Heart rate values followed the same pattern. The average maximum $V_{O_2}$ attained in treadmill running was 4.69 liters while the mean maximum heart rates was 189 beats/min.

Capen$^{25}$ used a 300 yard run to measure the development of cardiovascular fitness after participation in weight training and conditioning programs. Forty-two college male subjects formed one training group and exercised with systematic isotonic weight training forty minutes a day two days a week for eleven weeks. The second group of twenty-nine subjects trained for the same time and duration by taking part in conditioning, tumbling, tumbling,

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relays, gymnastics and running.

Tests of athletic power, muscular strength, and circulo-respiratory endurance as measured by a 300 yard run were administered prior to and after training. The use of t-tests demonstrated that the weight training was as effective as the program of endurance activities for the development of cardiorespiratory fitness. The weight training group made a greater gain in the strength measures.

Ekblom et al. used submaximal and maximal bicycle ergometer rides to determine the effect of training upon the circulatory response to exercise. Eight male subjects aged nineteen to twenty-seven were tested on submaximal and maximal bicycle ergometer rides before and after sixteen weeks of physical training that included cross country running, interval training, distance running and repetitions of thirty to sixty-second uphill dashes.

The submaximal ride was preceded by a warm-up at fifty percent of maximum oxygen consumption and consisted of seven to eight minute rides at twenty, fifty and seventy-five percent of maximum oxygen uptake. The maximal work was set individually to achieve complete exhaustion.

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in three to five minutes.

The study results showed that the maximum heart rates did not change so it was deduced that increases in stroke volume accounted for the increase in maximum oxygen consumption from 3.15 to 3.68 liters/min. Maximum efficiency for the submaximal workloads was increased. After the maximum workbout the mean blood pressure and peak lactate were higher. For a given submaximal oxygen uptake blood lactate, heart rate and cardiac output were lower. It was concluded that the return to normal oxygen saturations in all divisions of the circulatory system is a major component of oxygen debt.

Magel et al. recorded telemetry heart rates prior to, during and in recovery from selected competitive swimming events. The purpose of the study was to research the cardiac response to swimming events of varied intensity and duration which was an area that had not been investigated adequately.

Seven male members of a college swimming team were studied while swimming 50, 100, 200, 500 and 1,000 yards. A treadmill run was used to determine each subject's aerobic capacity. Each subject also ran on an indoor track

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for time periods that equalled the time periods for each swim. This procedure was followed to control the effects of the duration of work when the authors compared heart rates in swimming with those in running.

The results of the study indicated that the heart rates increased rapidly in the early stages of each distance, then continued upward toward maximums as the races continued. Heart rate plateaus were reached several times in the 500 and 1,000 yard swims. The longer swimming events elicited higher heart rates than did the shorter events. Recovery from the 70 yard swim was more rapid than recovery from the other distances.

When running heart rate response was compared with the same swimming event, there were no appreciable differences. The magnitude of the heart rate response and the maximum heart rates attained were greater in the running events.

During the fifteen-minute recovery period, the mean heart rates for the fifty-seven second 100-yard swim were: 140, 95, 95 and 92 beats/min. at one, six, ten and fifteen minutes respectively. For the thirteen-minute 1,000-yard swim, the recovery heart rates were: 128, 100, 92, and 94 beats at the same time intervals.
Hartley et al., used trained and untrained subjects in a study of the influence of heavy exercise prior to submaximal work. Five trained and four untrained subjects performed upright bicycle ergometer work at 40 percent, at 70 percent and 40 percent of their maximal oxygen uptake. The first load was performed for fifteen minutes, then after ten minutes rest, they rode the heavy load for fifteen minutes and lastly after another ten minutes of rest, they rode the light ride again.

The study revealed the following data for the two groups. The low fitness group had a resting heart rate of 68.5 beats/min. and a resting oxygen consumption of .34 liters/min. while the trained group had a resting oxygen uptake of .33 liters/min. and a resting heart rate of 60.5 beats/min. After ten minutes of recovery the untrained group exhibited an oxygen uptake of .41 liters/min. and a heart rate of 99 beats/min., while the trained group showed an oxygen uptake of .33 liters/min. and a heart rate of 77 beats/min.

Faulkner used athletes and non-athletes to study

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the influence of previous training for a maximum bicycle ride on the adjustment to a minimal effort. Twenty non-athletes and forty athletes were randomly assigned to two groups. Group A performed one one-minute trial followed by three training trials. On the second day they performed another one-minute trial. Group B performed five maximal output trials of ten seconds each before duplicating the work of group A. Electrocardiogram recordings were used to measure heart rate during seated rest prior to exercise, during exercise and for sixty seconds in recovery.

The results prompted the author to conclude the anticipatory heart rate to be a composite of genetic factors and long-term conditioning patterns that were a result of training. The rapid mobilization of bodily resources was considered a desirable response pattern to be attained immediately before short duration intense muscular activity. The mechanism was considered to be ineffective in long-duration activities. The anticipatory adjustments were found to be conditioned by repeated trials at the same task and to evidence high task specificity.

Taylor made a series of studies that centered

around the effects of exercise upon oxygen consumption. In one study, where two subjects performed twenty-four different bicycle ergometer workloads, the heart rates were found to rise in linear fashion with the work loads particularly in the low and intermediate ranges of work. In relation to maximal work Taylor concluded: "Rates at or in excess of 190 are incompatible with effective heart output since in all cases when this level has been reached, the subject is very near to exhaustion." \(^{31}\) A correlation of .969 was found between the heart rate and work load.

When discussing the operation of the respiratory quotient (R.Q.) in exercise and rest, Taylor stated:

The respiratory quotient obtained in step-up experiments is the result of two effects: a, the proportion of fat, protein and carbohydrate catabolized, and b, changes in carbon dioxide content of the blood. A true R.Q., e.g., indicative of the concurrent metabolism, is obtained only when the body is in the basal state or the steady state of exercise. This trend is evident in the present experiments but the erratic nature of the curves and quotients in exercise of unity are ascribed to washing out of blood carbon dioxide reserves in the periodic transition to higher work levels as well as dyspnea occurring at exhaustion. \(^{32}\)

The series of studies indicated that all the variables—heart rate, oxygen consumption, total ventilation and respiratory quotient increased in approximately linear fashion with the work load. The regression line slope and

\(^{31}\) Ibid., p. 34.

\(^{32}\) Ibid., p. 38.
the final level attained were individual variables.

Astrand et al.,\textsuperscript{33} used bicycle ergometer work to
investigate cardiac output during submaximal and maximal
work. Eleven women and twelve men twenty to thirty-one
years of age had oxygen uptake, cardiac output, stroke
volume and oxygen content of arterial blood determined
before and during three or four submaximal rides and one
maximal work load. Arterial blood was sampled after work
for concentration of hemoglobin and lactates.

The findings of the study demonstrated that maxi­
mum stroke volume was reached when the subjects worked
at a load that elicited an oxygen uptake about forty
percent of maximum and a heart rate of 110 beats/min.
In maximal work there was no tendency for a decrease in
stroke volume to occur even when heart rates reached 200
beats/min. in work that lasted for six minutes. Hence
at high heart rates, the diastolic phase allowed maximal
filling. The maximum cardiac output for women was 18.5
liters/min. and for men it was 24.1 liters/min. For the
submaximal as well as maximal workloads, the women
demonstrated a higher cardiac output per liter of oxygen
than the men due to their lower concentration of hemo­
globin.

\textsuperscript{33} Per-Olof Astrand, T. Edward Cuddy, Bengt Saltin,
and Jesper Stenberg, "Cardiac Output During Submaximal and
(March, 1961), 268-274.
In a physiological discussion of the determinants of cardiorespiratory fitness, Shephard\textsuperscript{34} agreed with the conclusions of others that heart rate increases progressively with oxygen consumption increases. However the author questioned the use of heart rate as a determiner of oxygen consumption unless several other variables are controlled.

With regard to maximum heart rates, Shephard reported that rates as high as 260-300 have been recorded in short bursts of exhaustive work but in steady state work the heart rates for men plateau at 170-180 and rarely exceed 200 beats/min. It was pointed out that it was not clear as to whether the variance between steady state pulse plateau and the higher rates demonstrated in brief bursts of exercise is due to intracardiac or extra-cardiac influences. Shephard concluded saying that there was still a need for more measurement of the role of the oxygen transfer process and its relationship to cardiovascular fitness.

Adams and Bernauer\textsuperscript{35} researched the influence of


different pace variations on the oxygen requirement of running a 4:37 min. mile. A motor driven treadmill was used to control the speed of running as nine experienced middle distance runners executed three mile runs. The pace variations were: steady, fast-slow-fast and slow fast. Heart rate and oxygen consumption measures were taken during rest, exercise and for a recovery period of thirty minutes.

The data revealed that no significant differences existed among the three pace variations for net oxygen intake during the runs. The oxygen debt values for the steady pace was significantly less than for the other two pace variations which exhibited no significant variations in that respect. Hence, a steady-state of exercise was demonstrated to be most economical for aerobic oxygen utilization and for the minimization of the involvement of anaerobic energy sources.

Slay used short, intensive and long, slower paced treadmill runs to study the anticipatory, exercise and recovery heart rates of trained and untrained subjects. Thirty trained and thirty untrained male subjects, who ranged in age from nineteen to twenty-five years, were

selected on the basis of their index scores on the Johnson and Robinson Short Form Harvard Step Test. Subjects with scores of eighty or above were placed in the high fitness group and subjects with scores of fifty or below were selected for the low fitness group.

Resting and anticipatory heart rates were recorded prior to both work bouts for both the fit and unfit subjects. Heart rates were recorded with an E and M solid wire cardiotachometer. A pilot study was performed to establish treadmill runs that would produce a heart rate of 180 beats/min. within fifteen to sixteen minutes and a run that would produce a heart rate of 180 beats/min. in approximately one minute. For the long run the grade was kept level and the speed varied from 4 to 5.5 mph for the unfit subjects and from 6 to 7 mph for the fit subjects. For all subjects in both fitness groups the short workout consisted of a treadmill setting of 10 miles per hour and 30 percent grade. Both runs were terminated when the exercise heart rates reached 180 beats/min. For the long treadmill run both the fit and unfit subjects' run times ranged from fifteen to sixteen minutes. For the short run the fit subjects exhibited a mean run time of 41.9 seconds with a range from 22 to 52 seconds. The unfit group's mean run time on the short run was 25.1 seconds and ranged from 19 to 31 seconds.
A five-minute period of supine resting was used to determine the resting heart rates and the anticipatory heart rates were recorded as the subject stood in the exercise position on the treadmill. The fit group had a mean resting rate of 74.9 beats/min. and an anticipatory rate of 109.5 beats/min. for the short workbout. For the long workbout the fit group had a mean resting rate of 75.4 beats/min. and a mean anticipatory rate of 88.8 beats/min. For the short workbout the unfit group demonstrated heart rate means of 80.4 and 115 beats/min. for resting and anticipatory paramiters respectively. Prior to the long workbout the unfit group's mean resting rate was 80.2 beats/min. and the anticipatory rate was 97 beats/min.

Heart rate in recovery was recorded every minute for a period of fifteen minutes. Heart rate recovery curves for both groups on the two workbouts were compared by a 2 x 15 split-plot arrangement of treatments analysis of variance. Analysis of variance was used to determine differences between the resting and anticipatory heart rates of both groups. The mean heart rates in recovery for the fit group at one, five, ten and fifteen minutes were 131, 105, 97 and 92 beats/min. for the short workbout and were 126, 101, 93 and 88 beats/min. for the long workbout. The mean heart rates for the unfit group at one, five, ten and fifteen minutes were 156, 121, 107 and 100
beats/min. for the short workbout and 150, 118, 102 and 97 beats/min. for the long workbout.

The results of the study indicated that the heart rates in recovery were significantly higher for the unfit group than they were for the fit group at the .01 level of confidence. For all subjects the long workbout produced significantly lower recovery heart rates than the short workbout at the .01 level of confidence. The difference in the recovery rates for the fit and unfit groups remained uniform following both workbouts. There was no significant interaction found between the type of workbout and the recovery heart rates, thus indicating that the recovery pattern following the short workbout remained uniformly higher than the long workbout curves for the total recovery period. The unfit subjects had a significantly higher resting rate and anticipatory rate prior to exercise on both workbouts. The results also indicated that the differences in heart rate recovery curves between the fit and unfit subjects were much more pronounced during the first five minutes of the recovery period.

The author concluded that "the heart rate recovery pattern is influenced by the nature of the workbout that produces a stress level of 180 beats per minute in both fit and unfit subjects." The resting heart rate was

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37 Ibid., p. 67.
apparently an indicator of physical fitness.

Elbel and Holmer\textsuperscript{38} studied the relationship between the pre-exercise pulse rate and the amounts of time required for the pulse to return to pre-exercise levels after two minutes of exercise. Forty-five male university subjects performed step-up exercise at a rate of thirty-six steps per minute for two minutes.

The pre-exercise heart rate mean was 68.9 beats/min. The mean increase in pulse rate was 80.66 beats/min. The deceleration of the pulse after exercise was rapid showing a drop of 15.2 beats from the exercise rate of 149.6 beats/min. in the first twenty-five seconds of recovery. The mean recovery rates were 97.8 and 92.3 for the recovery periods 1:30 and 3:30 minutes respectively.

The results illustrated that recovery time was insignificantly correlated with the pre-exercise pulse rates, \( r = .164 \). The pre-exercise heart rates and the increase in heart rates due to two minutes of exercise were not significantly related, \( r = -.201 \). There was a nonsignificant correlation, \( r = .213 \), found between the pulse rate taken fifteen seconds following exercise and the recovery time.

Falls and Weibers,\textsuperscript{39} when studying the influence of pre-exercise conditions on heart rate and oxygen uptake during and following bicycle ergometer exercise, used cold shower, hot shower, exercise warm-up and rest as variables. Five subjects rode the bicycle ergometer at 1080 Kgm/min. for five minutes and data were collected during work and during a five-minute recovery period.

The results indicated that exercise heart rate and recovery oxygen consumption were significantly lower after the cold shower treatment. There was also a significant interaction between subjects and pre-exercise conditions on the recovery heart rate. The lowest mean values for recovery oxygen uptake, exercise heart rate and recovery heart rate were found to be lowest for the cold shower and highest for the hot shower.

McArdle \textit{et al.},\textsuperscript{40} investigated the validity of the use of various post-exercise heart rate records as a method for the determination of exercise heart rates during light, moderate and heavy work. Ten male subjects whose mean age

\textsuperscript{39}Harold B. Falls and Jacob E. Weibers, "The Effects of Pre-exercise Conditions on Heart Rate and Oxygen Uptake During Exercise and Recovery," Research Quarterly, Vol. 36 (October, 1965), 243-252.

was twenty years performed bicycle exercise at work loads that produced a heart rate of 100, 120, 140, 160 or 180 beats/min. The desired heart rate was maintained for either thirty seconds or two minutes. Each subject performed ten trials; each trial was on a separate day. Heart rates were recorded by electrocardiogram during the last thirty seconds of exercise and continuously during a thirty-second recovery period. Heart rates were collected by counting the number of QRS needle excursions and the R to R intervals were estimated to determine fractions of a beat.

The study results indicated that the recovery heart rates after the thirty-second period were approximately the same as those after the two-minute period. Heart rate during the first fifteen seconds of recovery was on the average 5.0 percent below the exercise level. In the total thirty-second recovery period, the heart rate was 8.4 percent which amounted to an average drop of 15 beats/min. The authors pointed out that a delay of four seconds when performing a 10-second palpation of the recovery heart rate could result in underestimates of 5.7 percent in strenuous work and a maximum of 13.5 percent in moderate work. The authors concluded that the rate of recovery was not similar for all individuals, and that such variability could result in serious errors when the
post-exercise heart rate was to be used to indicate the heart rate attained during exercise.

In an early study of heart rate during and after exercise, Cotton and Dill\textsuperscript{41} used flat treadmill runs at speeds ranging from 4.5 to 11 mph to elicit steady state exercise in twelve subjects whose ages ranged from thirty to forty years. Heart rates were recorded for two consecutive ten-second periods immediately before exercise termination and immediately following exercise. Judgment errors in counting beat to beat calculations were considered negligible.

The results indicated that the heart rate fell very little in the first ten-second period and only six percent in the second ten-second period. The authors concluded that accurate exercise pulse rates could be predicted from heart rate recordings taken immediately after cessation of exercise.

Morehouse and Tuttle\textsuperscript{42} made a study of the post-exercise heart rate in subjects with normal and abnormal hearts after different types and intensities of exercise.

\textsuperscript{41}F. S. Cotton and D. B. Dill, "On the Relation Between the Heart Rate During Exercise and that of Immediate Post-Exercise Period," \textit{American Journal of Physiology}, Vol. 3 (April, 1935), 554-556.

Twenty male subjects participated in stool-stepping exercise at a rate of 20, 30, 40 and 50 steps/min. Ten male subjects lifted a twenty-five pound bar held at arm's length over the head at rates of 5, 10, 15, 20 and 25 lifts per minute.

The results demonstrated that the stepping recovery rate during the first few beats of recovery was directly related to the intensity of the exercise and the resting rate. The increase in post-exercise heart rate that was higher than the resting level was directly related to the intensity of the exercise and during mild exercise intensities, there existed an inverse relationship. The pulse ratio of individuals who demonstrated high resting rates was higher than subjects with low resting rates.

The authors concluded that the length of the recovery time was related to the intensity of the exercise and that it had no relationship to the resting pulse rate.

Brouha discussed cardiac debt and cardiac cost when studying the influence of muscular exercise on the cardiovascular system. The cardiac cost was described as the total number of heart beats above the resting rate.

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that was needed to perform any exercise and that this figure could be used for the comparison of different exercise workloads. Cardiac debt was labeled as the number of beats that were counted between the end of exercise and the return to the resting level.

The author concluded that a computation of cardiac cost and cardiac debt constituted a better stress indicator of work than did oxygen consumption. The sum figure was considered a measure of the total physiological requirements for a given workload. A three-minute recovery curve was considered adequate for the computation process.

In a continuation of a series of publications centered upon methods for determining physiological strain, Maxfield and Brouha dealt with total cardiac cost above zero and the total cardiac cost. Total cardiac cost above zero was defined as the cardiac cost, which was the sum of heart beats counted during the working period, plus the recovery cost, which was the sum of heart beats counted during the recovery period. The total cardiac above resting was described as the total cost above zero plus the resting cost.

A parabolic relationship was found to exist between

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*44 Mary E. Maxfield and Lucien Brouha, "Validity of Heart Rate as an Indicator of Cardiac Strain," *Journal of Applied Physiology*, Vol. 18 (November, 1963), 1099-1104.*
the work performed and the total and recovery cardiac costs together. Recovery cost was found to exhibit an almost linear relationship to the total cost in relation to cardiac stress. Pulse counts during the first three minutes of recovery were also linearly related to the total cost and the recovery cost. Thus, these three counts were considered to provide an adequate estimate of the degree of cardiac stress under any environmental conditions.

Nupp and Morehouse investigated exercise intensity and heart rate as variables in their search to develop a functional tool that could be employed by physicians, physical therapists and physical educators to detect and rehabilitate deteriorated heart conditions. The primary aim was to ascertain the utility of the heart rate for the aforementioned purpose. Sixteen sedentary males over thirty years of age took an exercise tolerance test on the bicycle ergometer prior to the reconditioning procedure. The results of the tolerance tests were used to establish the training program. Each subject pedaled for eight minutes, two to five times weekly, at his own tolerance level. As soon as each subject could pass the

\[\text{Nupp and Morehouse}^{45} \text{ investigated exercise intensity and heart rate as variables in their search to develop a functional tool that could be employed by physicians, physical therapists and physical educators to detect and rehabilitate deteriorated heart conditions. The primary aim was to ascertain the utility of the heart rate for the aforementioned purpose. Sixteen sedentary males over thirty years of age took an exercise tolerance test on the bicycle ergometer prior to the reconditioning procedure. The results of the tolerance tests were used to establish the training program. Each subject pedaled for eight minutes, two to five times weekly, at his own tolerance level. As soon as each subject could pass the}\]

tolerance test, he was released from the program.

The results of the study demonstrated that intensity of exercise was a better training stimulus than frequency and duration. The physiological stress as evidenced by the heart rate was the best method for adjusting training exercises because it measured more accurately the physiological output. In the exercise tolerance test, a one-minute period of exercise was necessary for the heart rate to adjust to a level requiring ten beats more in heart rate.

Suggs\textsuperscript{46} used three sets of experiments consisting of 137 individual runs to test the theory that any energy extracted from a muscle must ultimately be supplied by oxygen consumption. One experiment called for fourteen subjects to exercise at varied levels in order to elicit heart rates ranging from 108 to 180 beats/min. The other two experiments involved one subject who exercised over a wide range of workloads. Each set of data was divided into three categories that related to the intensity of the exercise as evidenced by steady state heart rates. The three categories were light—125 beats/min., medium—125-150 beats/min. and heavy—150 beats/min.

To summarize his findings the author said that

heart rate and oxygen supply had been shown to be linearly related both in transition and during the steady state.

Nagle and Bedecki\textsuperscript{47} used an all-out treadmill run to determine if the 180 beats/min. heart rate response signified physiological incompetence as was suggested by Balke.\textsuperscript{48} Forty-four subjects aged eighteen to thirty-six years participated in an all-out treadmill run to exhaustion. The treadmill speed was initially set at 3.5 mph, then increased to 4.5 mph after one minute and finally increased to 5.6 mph at the end of the third minute. The initial grade was 5 percent; at five minutes it was increased to 6 percent and thereafter increased 1 percent every two minutes until a 10 percent grade was achieved. With this procedure all subjects reached maximal work around ten to fifteen minutes.

All subjects were given a practice run that duplicated the test procedure. Resting heart rates were counted with an EKG preamplifier while the subjects remained seated for a five-minute period. The R wave deflections were used


to calculate heart rates. Expired air samples were taken the last minute of the run.

The Person r method was used to determine the coefficients of correlation between heart rate times and the criterion measure which was all-out run time. The correlations found for 150, 160, 170 and 180 heart rates were .69, .76, .77 and .85, respectively, indicating an increasingly significant relationship as the heart rates progressed higher. The 180 heart rate correlation was the only one found to be significant.

When the mean consumption and ventilatory efficiency of the four poorest and four best performers were plotted against heart rates, the oxygen consumption of the best performers leveled off at rates above 180 beats/min., while the oxygen consumption of the poorest performers increased in a straight line relationship with heart rate for the entire run. The authors concluded that the best performers made respiratory and circulatory adaptations that enabled them to attain maximum levels of oxygen consumption before the end of the exercise. On the other hand, the poorest performers indicated a lack of the aforementioned physiological efficiency and the ventilatory stress they experienced early in the run became the limiting factor.

In conclusion the authors felt that the 180 heart
rate test in treadmill running appeared to be a valid test of circulorespiratory capacity. The 180 heart rate was the point at which physiological incompetence occurred and this phenomenon was evidenced by: 1) excessive ventilation; 2) a respiratory exchange ratio demonstrating unity; 3) a sharp decrease in the ratio of oxygen consumed to the work done; and 4) a tendency for the oxygen consumption to level off between heart rates 170-180 which indicated an increase of anaerobic work. The authors also felt that there was evidence that the poorest runners could not adapt adequately to the run and a more gradual routine would be more suitable.

Alderman substituted a bicycle in his study of the reliability of the 180 heart rate response in bicycle ergometer work. Forty male college students took part in an exercise bicycle ergometer test riding at 100 front wheel revolutions per minute against an initial friction of .25 Kgm. with .50 Kgm. added each successive minute of exercise. The subjects rested for five minutes and then rode until their heart rates reached 180 beats/min. The post-exercise recovery period lasted until a heart rate of 100 beats/min. was attained.

The data revealed that the time scores increased progressively in reliability up to 160 beats/min. An increase of the criterion beyond 150 to 180 beats/min. did not increase the test score reliability. The authors concluded that heart rate increased in a linear fashion with workload up to 180 beats/min. and that 180 beats/min. did not constitute a maximum heart rate. They also felt that the average maximum heart rate was higher than 180 beats/min.

In another study concerning bicycle ergometer work which elicited the 180 heart rate response, Alderman tested a hypothesis that individual differences in heart rate response to two different work loads of bicycle ergometer exercise would tend to exhibit high generality with the same task. Forty male college subjects rode against a friction load that increased one-half kg each minute at a rate of 100 and 120 wheel revolutions per minute. The exercise was terminated when a heart rate of 180 beats/min. was achieved. Each test period was preceded by a five-minute rest period and followed by a post-exercise recovery period. The test-retest period was forty-eight hours which was followed by a second test-retest period three weeks later.

The intercorrelation between the exercise times to 180 beats/min. for the two work loads was .933. Thus, 87 percent of the individual difference variance in the heart rate response was common to the two work loads and the remaining 13 percent was specific to the particular work load. Thus, heart rate was shown to be constant in inter-individual bouts of exercise. In recovery from 180 beats/min. the subjects recovered to 140 and 105 beats/min. during the first and sixth minutes respectively.

Brooke et al., used a wide range of bicycle ergometer work to study the variability of exercise heart rate measurement. The authors mentioned that other studies had evidenced that thirty-second cardiotachometer heart rate counts showed a variance of plus or minus five beats when compared to an electrocardiogram count.

Six skilled male cyclists whose mean age was twenty-one years took two trials of riding through ten periods of exercise progressing from low to high intensity. The r to r distances were measured for 1, 5, 10, 20 and 40 beats and the minute rates were extrapolated.

The trial by trial reliability coefficients for 1, 5, 10, 20 and 40 beats were .964, .971, .976, .974 and .975 respectively. The ten beat recording gave the best

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trial by trial reliability coefficients. The ten beat count also gave the best within trial reliability coefficient (.997).

Davies and Harris\(^{52}\) conducted a series of studies investigating the physiological phenomenon surrounding the heart rate in transition from rest to exercise. Thirty-four subjects of different ages and sex participated in a series of treadmill experiments. In one series the subjects rested then ran for a six-minute exercise period during which oxygen consumption and heart rate were measured. In another series the subjects ran for eight minutes, rested sitting in a chair until their heart rates were within five beats of resting and then performed a higher level of treadmill exercise.

The data used were: 1) exercise heart rate—the steady state after four minutes; 2) pulse deficit (PD)—the number of beats counted during the first four minutes that fell short of the count during the second four minutes; 3) the pulse deficit index (PDI)—the lowest volume of oxygen at which the pulse deficit showed a decided upward swing; and 4) Leitlungopulsindex (LPI)—the rise in heart beats/min. for every liter per minute rise in oxygen.

\(^{52}\)L. T. M. Davies and E. A. Harris, "Heart Rate During Transition From Rest to Exercise, in Relation to Exercise Tolerance," *Journal of Applied Physiology*, Vol. 5 (September, 1964), 857-862.
The results indicated that the PDI showed a better correlation with maximum volume of oxygen than did working capacity. The authors pointed out that untrained subjects often exhibited emotional tachycardia prior to the start of exercise and the tachycardia resulted in errors when the pulse deficit was calculated. Dummy runs were suggested to eliminate the aforementioned emotional tachycardia.

Brouha and Gallagher when searching for a single method for the determination of physical fitness of boys concluded:

Research has shown that the initial heart rate of healthy young men does not have a significant relationship to an individual's physical fitness; his fitness depends on the rate at which his heart slows after exercise and not on how fast it may have been beating before he began work.53

Anderson,54 when discussing the varied considerations involved in the evaluation and measurement of physical work capacity, set forth the criteria to be considered when collecting data on energy expenditure in short and duration type exercise. He stated that submaximal exercise should be of 8 to 10 minutes duration and maximal work load should lead to exhaustion in a time from thirty seconds


to five minutes.

Koff et al.,\textsuperscript{55} used physically fit and unfit men for a comprehensive study of heart rate, oxygen consumption and ventilation during strenuous treadmill exercise. The authors were attempting to construct an expeditious method for the measurement of short term maximal exercise in normal and trained subjects.

The first group consisted of eight varsity athletes in excellent condition and twenty normal men who were not currently engaged in formal physical activities. The mean age was 24.6 years. Each subject ran on a treadmill at 5 mph and 18 percent grade for a maximum of ten minutes or until they could not continue due to fatigue. The subjects were allowed to hold the railing while running. The results of the run readily differentiated among those who were in training or who had a previous background of athletics. All eight trained subjects and six others with athletic backgrounds ran for ten minutes. Twelve of the fourteen remaining untrained subjects walked less than 180 seconds. The test did not discriminate among various levels of fitness. The mean resting heart rate for trained subjects was 76 beats/min. and for the

untrained subjects it was 78 beats/min. The mean exercise heart rate for the trained group was 171 beats/min. and for the untrained the mean maximum exercise heart rate was 177 beats/min.

A second group of forty-eight subjects ranging from highly trained to moderately trained ran a three-minute treadmill run at 5 mph and 18 percent grade followed after a twenty-second pause by a run at 6.5 mph and 25 percent grade. The subjects held on to the railing during the run. Heart rates were collected at 2.5 min. of the preliminary run and for thirty seconds after the subject signaled he was in his last thirty seconds during the maximal run. The duration of the maximal run ranged from 60 to 543 seconds, with a mean run time of 192 seconds. The sitting resting heart rate mean was 82 beats/min. During the submaximal run the mean exercise heart rate was 163 beats/min. and the oxygen consumption was 2.7 liters/min. During the maximal run the mean maximum heart rate was 186 beats/min. with a range of 162 to 204 beats/min. and the mean oxygen consumption was 3.2 liters/min. with a range of 1.8 to 4.8 liters/min. In the first minute of recovery, the mean heart rate was 150 beats/min.

The results of the study indicated that the procedure was an efficient method for the evaluation of short
duration maximal work. Comparisons of the coefficients of variation indicated that the final exercise heart rate during the maximal run was the least variable factor at 5 percent, while duration of the run showed to be the most variable at 82 percent. Oxygen consumption showed a variation of 35 percent. Since the rate of running was held constant and the time of running became the variable factor of the test, the authors hypothesized that possibly maximal mechanical efficiency and neuromuscular coordination might have been more important that physiological capacity for maximal exertion.

Wolf\textsuperscript{56} studied the electrocardiogram changes that occurred after muscular exercise in trained and untrained subjects. One-hundred two untrained subjects selected from physical education classes made up one group while twelve trained members of a university track team comprised the second group. The purpose was to determine whether or not the ECG could be used to differentiate and record variations in physical condition after exercise.

The untrained group performed a pre-training treadmill run of 5 mph and 8.6 percent grade followed by a post-training all-out treadmill run at 7 mph and 8.6 percent grade. The trained group took an all-out

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treadmill run at 10 mph at 8.6 percent grade prior to track practice and meet training daily for fourteen weeks. The all-out run was administered after the track season was over. Heart rates were tabulated by counting ECG R to R intervals. The trained subjects showed a post-exercise decrease in the amplitude of the P wave and an increase in the amplitude of the R, S and T waves. The untrained subjects demonstrated an increase in the P and S waves and a decrease in the R and T waves.

With regard to the physiological processes involved in oxygen consumption following exercise, a great deal of research has been devoted to the explanation of this repayment process. Various attempts have been made to formulate theories to explain the phenomenon of excess oxygen consumption during recovery from exercise.

Krogh and Lindhard were the first investigators to report that the excess oxygen consumption in recovery demonstrated an initial phase of rapid decline followed by a slower, more prolonged period. The investigators attributed both phases to the oxygen deficit observed during the transition from rest to work.

Hill et al.,\textsuperscript{58,59} in a series of studies, investigated excess oxygen in recovery and coined the term "oxygen debt." Two components of the oxygen repayment curve were recognized and both were attributed to the removal and resynthesis of lactic acid.

Margaria et al.,\textsuperscript{60} revised the earlier concepts concerning the oxygen debt theory. It was discovered that the oxygen debt following light exercise did not demonstrate an increase in blood lactate. It was concluded that lactic acid mechanisms did not play a significant part in muscular contraction except during very strenuous exercise where anaerobic processes are involved.

Oxygen debt was divided into an alactic fast portion and a slower long-lasting lactacid portion. The alactic portion was believed to be a linear function of the oxygen intake in exercise and thus related to the oxidation fuels that furnish the energy for the resynthesis of phosphagen split down in activity. The lactacid


portion of oxygen debt was stated to come into operation only when muscular contraction was carried out in anaerobic conditions and increased rapidly at the maximum work levels.

With reference to this process in trained and untrained subjects, the authors pointed out that the lag in the disappearance of lactic acid removal ran about six to eight minutes in trained individuals and was up to two or three times longer in the untrained.

Huckabee modified the oxygen debt theory further when the results of his research on the excess lactate demonstrated a good relationship between oxygen debt measurements and excess lactate concentrations.

Kayne and Alpert utilized anesthetized dogs in studying oxygen debt and lactate removal. The authors claimed a complete dissociation between lactate removal and oxygen debt.

Barnard et al. used tryptophan and guinolinic

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acid to inhibit gluconeogenesis and block the removal of lactate by the liver to study oxygen debt in dogs. The results supported the theory of the alactacid and lactacid mechanisms in the removal of lactic acid during oxygen debt.

Knuttgen\textsuperscript{64} used several submaximal steady-state exercise intensities to study oxygen debt in normal male and female subjects. Twelve subjects whose age ranged from seventeen to twenty-six years took part in a series of three experiments involving bicycle ergometer exercise. In the first series, all subjects rode at several steady-state fifteen-minute work loads that ranged from 48 to 98 percent of their aerobic capacities. In the second series, seven subjects rode at work loads that required 60 percent of their maximum oxygen consumptions. The subjects rode for periods of 15, 35, and 55 minutes. In the last series, five subjects rode at loads that called for 55 to 83 percent of their oxygen capacities. The duration of the rides were 15 and 55 minutes. Blood samples and oxygen consumption values were measured during bed rest, during exercise and during seven periods of a fifteen minute recovery period.

The results of the three series demonstrated that

there was a positive relationship between the intensity of the exercise and the length of time required for the repayment of the alactacid portion of the oxygen debt. The alactacid portion was always repaid within six minutes with the mean repayment time being approximately 3½ minutes. The fast component time was found to be shorter after the longer periods of work. A discrepancy which was found between oxygen deficit and oxygen debt led the author to conclude that the disparity between deficit and debt that was found supported the theory that exercise caused a general disturbance to the body that in turn influenced the recovery process significantly.

The author hypothesized that oxygen debt appeared to be a complex interaction of numerous factors related to the general bodily disturbance imposed on the resting homeostasis by exercise. The division of oxygen debt into an alactacid and lactacid portion was thought by Knuttgen to be overly simplistic.

Welch et al., 65 looked at the ventilatory response and its relation to oxygen debt during work and in recovery. Two well-conditioned subjects performed bicycle ergometer exercise at fifty RPM over a variety of work

loads that ranged from 300 to 2,250 Kgm/min. The riding
time ranged from three to nine minutes. Oxygen consump-
tion was measured during sitting rest and continuously
for thirty minutes of recovery. After the severe work
loads, additional oxygen consumption collections were made
for five minute intervals at 35-40, 45-50, and 55-60
minutes of recovery. A comparison of baseline data
representing complete rest and a baseline of mild steady-
state work was performed. The differences between the
two methods were not significant indicating that the
larger oxygen debts reported in the literature might have
been due to the use of BMR data. The BMR data can only
be used after prolonged rest.

The relationship between work intensity and
oxygen debt was practically linear up to work loads of
1,200 Kgm/min., wherein the oxygen debt increased more
rapidly than the rate of work. The rate of ventilation
was extremely high during the later stages of maximum
work and during the first few minutes of recovery.

The authors concluded that oxygen debt was com-
posed of many factors such as increased oxygen use by
respiratory muscles during hyperventilation, the increase
in oxygen use by heart muscle, high resistance breathing
apparatus and possibly hormones released during exercise
that elevates the recovery metabolic rate. The size of
most oxygen debt collections was concluded to be too large to account for the true size of the depleted energy stores and therefore, the use of oxygen debt as an estimate of anaerobic energy stores was questioned.

Stainsby and Barclay\textsuperscript{66} presented a discourse on the topic of exercise metabolism in which oxygen deficit, steady-state oxygen uptake and oxygen uptake in recovery were discussed. During initial exercise, the oxygen deficit was shown to be the result of oxygen uptake that continued to rise at a declining rate until the steady level was reached. This assumption was based on the hypothesis that energy exchange began at a fixed level the moment exercise began. It was postulated that errors could occur if the energy exchange did not begin at the steady-state when exercise started.

The steady level of oxygen uptake was explained as the energy exchange that occurred during sustained exercise which was due to both contractile activity and turnover of metabolite products. The depletion of substrate metabolites was considered not to be a part of steady-state oxygen consumption.

The recovery oxygen uptake was outlined as the

\textsuperscript{66}Wendell N. Stainsby and Jack K. Barclay, "Exercise Metabolism: O\textsubscript{2} Deficit, Steady Level O\textsubscript{2} Uptake and O\textsubscript{2} Uptake for Recovery," \textit{Medicine and Science in Sports}, Vol. 2 (Winter, 1970), 177-181.
oxygen used to provide ATP or to resynthesize the first power source. It was also considered to provide energy for metabolite turnover, replacement of ionic gradients and depleted metabolites such as lactate. The authors mentioned that the operation of the latter components had not been fully explored.

Margaria et al.,\textsuperscript{67} used thirty- to forty-second maximal treadmill runs to study the energy utilization process. Three subjects who previously demonstrated exhaustion in thirty to forty-second treadmill runs at 18 Km/hr. and 15 percent grade, ran at the same rate for ten-second periods with varying rest intervals until exhaustion or a steady-state was reached. On different days the subjects performed 2, 5, 10, 15 and 20 runs for the series of experiments and lactic acid concentrations were collected from three to five minutes after the end of exercise. Expired air was collected throughout some of the experiments.

Lactic acid accumulated very fast in the first runs in all subjects in all experiments and attained a steady-state after the fifth run. From then on no lactic acid production took place if the rest periods were thirty seconds. During the ten-second rest period

the lactic acid accumulation was 11 Mg/100 ml of blood and was 3 Mg/100 ml of blood during the twenty-second rest period. The net volume of oxygen in ml/kg/min. was 54.0 for the 10 second rest, 47.0 for the 20 second rest, and 41.0 for the 30 second rest.

The results of the study confirmed the fact that during supramaximal exercise the alactic energy mechanisms always preceded the lactacid mechanism and that the payment of the alactacid oxygen debt occurred at a very rapid rate during recovery.

Bruce et al., set up three groups of trained subjects to study anaerobic responses to severe maximal treadmill and bicycle ergometer exercise. Group A contained fifteen subjects who walked at 5 mph and 18 percent grade for three minutes before running at 6.5 mph and 25 percent grade. Group B was made up of four men who walked at 1.7 mph and 10 percent grade, at 3.4 mph at 14 percent grade and 5 mph at 18 percent grade before running to exhaustion at 6 mph and 22 percent grade. Group three, made up of four men, pedaled a bicycle ergometer without interruption until exhaustion. The load started at 150 Kpm and increased to 500, 1000, 1250,

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1500 and 1750 Kpm.

The results demonstrated that although similar levels of oxygen intake, heart rate were exhibited in both treadmill and bicycle exercise, the ventilatory and anaerobic responses were significantly greater during the treadmill runs. This was due to the entire body's being supported by the legs. The percentage of anaerobic metabolism was twenty-eight percent in the treadmill run and twenty percent in the bicycle ergometer exercise.

Cooper compared short intensive and prolonged intensive exercise programs on treadmill performance and cardiorespiratory functions. Thirty male subjects between seventeen and twenty-three years were equated on the basis of a treadmill test and then randomly assigned to three experimental groups. Group A participated in the 5BX Canadian Air Force plan for physical fitness. Group B took part in a thirteen station circuit training program. Group C was a control group and the members refrained from participating in any regular or systematic exercise activity.

Two treadmill tests were administered before the exercise program, after two and one-half weeks and at

the completion of the fifth week of training. All groups exercised five days a week for five weeks. The submaximal treadmill test consisted of a walk at 3.4 mph with an increase of grade of one percent per minute until a heart rate of 180 beats/min. was reached. The second treadmill run was a maximal work test that consisted of a run at 7 mph at 8.6 percent grade until muscular exhaustion set in. Heart rate was recorded by an electrocardiogram. After fifteen minutes of rest, the resting heart rates were recorded as the subjects stood on the treadmill. Working heart rates were recorded every minute during the submaximal walk and every thirty seconds during the maximal run. Recovery heart rates were recorded for a period of five minutes as the subject stood on the treadmill. After fifteen minutes of rest, a thirty-second resting oxygen sample was collected as the subjects stood on the treadmill. During the submaximal walk, oxygen was collected after one, five and ten minutes of exercise. During the maximal run, oxygen was collected at one, two and three minutes and during the last thirty seconds. Recovery oxygen samples were collected at one and five minutes after both treadmill exercises. The author stressed that the resting respiratory quotient figure has been shown to exhibit variation from basal rates due to variations in diet, alteration in rate and
depth of respiration due to mouthpiece influences, self consciousness and apprehension.

On the submaximal treadmill run, Group A (5BX) showed the greatest amount of gain at the end of nine weeks with a gain of 1.60 minutes; Group B (Circuit) gained 0.9 minutes and the control group lost 0.70 minutes. No significant difference was found between Groups A and B. For the maximal run, Group B again demonstrated the greatest mean gain of 1.02 minutes, while Group A gained a significant mean gain of 55 seconds. No significant difference was found to exist between the performance of Groups A and B.

The results of both final treadmill runs demonstrated that both exercise programs contributed to significant gains in cardiorespiratory fitness. Both experimental groups exhibited lower resting, exercise and recovery heart rates and oxygen consumption after the training period than did the control group.

The circuit training in general seemed to contribute more to cardiorespiratory fitness than did the standard 5BX program. When running was added as a fifth exercise to the 5BX program, the contribution to cardiorespiratory fitness was equal to the circuit training program. In reference to this point the author concluded: "It becomes apparent then, that the quality and intensity
of the exercise is more important than the quantity and duration."70

Issekutz and Rodahl71 investigated the functioning of the respiratory quotient during short duration exercise. Nineteen untrained men aged twenty-three to forty-five years and eight women aged fifty to sixty-three rode six different loads of bicycle ergometer work. The rides began at 300 Kpm/min. and were increased to 450, 600, 750, 900 Kpm/min. and finished with a ride at the individual's maximum oxygen uptake.

The authors noted that at a given submaximal work load, the oxygen uptake for trained and untrained subjects was approximately the same, while the increase in blood lactate depended upon each individual's aerobic capacity. Cerebro-cortically induced hyperventilation during work caused the RQ to rise and hypoventilation in recovery caused a drop in RQ. It was stressed that both hyperventilation and hypoventilation can influence the resting RQ calculations. Another explanation for the aforementioned phenomenon was a delayed circulatory response with an initial discrepancy between oxygen demand and oxygen supply, thus resulting in a greater percentage of the

70 Ibid., p. 133.

participation of anaerobic glycolysis in the first few seconds of exercise. The initial rise in RQ was considered to be caused by an increased formation of lactate. The drop in RQ during the second minute was attributed to the anaerobic glycolysis process being slowed down by the increasing oxygen supply, which meant that temporarily more lactic acid was eliminated than was being formed. The excess CO$_2$/O$_2$ uptake ratio seemed to represent the percentual participation of anaerobic glycolysis in the total energy expenditure instead of the particular fuel being oxidized. Excess CO$_2$ followed the anaerobic metabolism more closely than did the blood lactate accumulations. With reference to the recovery RQ, the authors concluded that the reason for extremely low RQ's being reported might have been due partly to a gradual decrease in the lactate pool while the bicarbonate pool was increasing.

deVries$^{72}$ discussed the role of the respiratory quotient during rest, exercise and in recovery. He stressed that in non-steady state exercise, the RQ does not truly reflect the current oxidation of foodstuffs. During work that is partially anaerobic, lactic acid accumulates forming a temporary alkalosis that is the

result of more carbon dioxide's being blown off than is being formed metabolically. With reference to this process, RQ's above 1.00 and as high as 1.30 had been observed in heavy exercise. Also, RQ's below .70 were observed in recovery which meant that the removal of lactate caused temporary alkalosis which was counteracted by hypoventilation.

In a follow-up study, Issekutz et al., 73 investigated the use of the respiratory quotient for the prediction of aerobic work capacities. Thirty-two untrained subjects, twenty-four men aged 20 to 45 and eight women aged 55 to 65, performed varying levels of bicycle ergometer work. The experimental rides were preceded by a five-minute warmup ride at 450 Kpm/min. for the men and 300 Kpm/min. for the women at fifty pedal revolutions a minute. The experimental rides began after a ten-minute rest and the loads were 450 Kpm/min. for the women and 600-900 Kpm/min. for the men. The experiments were continued at increasing workloads until the maximum oxygen uptake was reached. Oxygen uptake, carbon dioxide production and RQ were monitored continuously. Before the exercise and during the first two minutes, blood lactate

samples were collected. Maximum oxygen uptake was determined from oxygen uptake increases, pulse rate and an RQ that was 1.15 or higher during three and one-half to four minutes.

The authors assumed a resting RQ of .75 taking the assumed RQ, a nonmetabolic or excess RQ was calculated and thus the following formula was derived:

\[ \text{Excess } \text{CO}_2 = \text{total } \text{CO}_2 - .75 \times \text{O}_2 \]

Therefore excess \( \text{CO}_2 / \text{O}_2 \) = the work RQ - .75. This figure represented the participation of anaerobic metabolism in the total energy process.

The authors found a straight line relationship to exist between oxygen uptake and workload and the excess \( \text{CO}_2 \) or excess RQ also rose in logarithmical fashion. When the aerobic oxygen capacity was reached the excess RQ continued to rise indicating the increased participation of anaerobic metabolism. The authors based the use of the RQ for the assessment of aerobic work upon observations that part of the expired carbon dioxide was delivered from the bicarbonate pool due to lactic acid accumulations. The authors concluded that the use of excess RQ, if strictly controlled, was an accurate method for the assessment of aerobic work capacity. When the RQ measured after four minutes of exercise rose above 1.1, the assessment of oxygen uptake was as accurate as direct measures.
Margaria et al., ran two non-athletes and one trained Olympic middle distance runner on treadmill exhaustive runs to study the mechanisms of oxygen debt. The subjects ran at speeds that were designed to produce exhaustion in 2 to 10 minutes. The subjects then ran 4 to 5 times at each grade for varying fractions of the exhaustive time period. Recovery lactate and pyruvate samples were taken at 1, 3, 5, 8, 15, 30 and 40 minutes during recovery.

The authors concluded that the amount of alactacid oxygen debt contracted demonstrated a linear relationship to the intensity of the exercise and amounted to approximately 2.5 liters in an averaged sized athlete. The value of the alactacid portion of the oxygen debt was found to be one-half of the value of the lactacid portion. The lactacid portion of the oxygen debt was considered to come into play only after the alactacid portion is met and when the metabolic rates were at maximum. The alactacid portion of oxygen debt was shown to be directly related to the intensity and time of the exercise. The lactacid portion of the oxygen debt was proportionate to the amounts of lactic acid in the blood.

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after exercise. No lactate was found in the blood after intensive exercise of 10- to 15-second durations. The authors concluded that there is an alactacid mechanism which played an important role in anaerobic and exhaustive work. It was stated that the concept of "excess lactate" was deceiving because the results demonstrated that it was not removed at the same rate as oxygen debt payment.

Margaria et al.\textsuperscript{75} studied the role of lactic acid and anaerobic metabolism during strenuous treadmill exercise of short duration. Four male well-trained subjects, aged 24 to 27, were trained to dismount from a treadmill after running at a workload that was designed to produce exhaustion in less than forty seconds. The treadmill speed was 18 Km/hr. at an incline of from 10 to 25 percent. The subjects ran for periods of ten seconds each.

The purpose of the study was to determine whether or not heavy activity could be maintained over extended periods of time if the exercise was short duration interspersed with rest periods. This assumption was based upon the observation that lactic acid was only produced 10-15 seconds after heavy exercise began. It was found

that during short intensive exercise bouts interspersed with rest, the subjects were able to replenish the anaerobic energy power sources and only the alactic portion of the oxygen debt was formed which had a repayment half-time of about 20 to 30 seconds.

Hermansen discussed the varied aspects of the energy release in anaerobic work. The results of oxygen debt experiments with well-trained male and female 400 and 800 meter runners and 100 and 200 meter swimmers were compared with the oxygen debt data obtained from physical education students and untrained subjects.

The author pointed out that in exercise lasting for ten minutes or more, aerobic processes played the most important role, while during short exhaustive exercise of from one to two minutes anaerobic energy sources provide the greatest contribution. In relation to the length of work periods, the author stressed that work periods that were too long or too short did not yield maximum values. If work was halted after one minute, the values for oxygen debt and blood lactate were lower than for work periods of two to three minutes. With reference to the elevated uptake after exercise, the reasons given were: 1) to refill myoglobin stores of

muscles, 2) for the replenishment of dissolved oxygen in the tissue fluids, 3) for the regeneration of venous oxyhemoglobin and 4) to supply the oxygen needs of the working respiratory and heart muscles. The relationship between the oxygen deficit and the oxygen debt was considered to be a method for determining the efficiency of anaerobic work. The author noted that work being performed in near absolute anaerobic conditions resulted in an oxygen debt which was almost twice as large as the oxygen deficit.

It was pointed out that the limiting factor in prolonged severe exercise is the maximal amount of oxygen the individual can take in, transport and consume. The large difference between well-trained and untrained individuals in aerobic capacities has been well demonstrated. It was emphasized that the limiting factors for anaerobic work are less well known and that the range of variability between fit and unfit individuals had not been demonstrated.

It was found that ATP and phosphocreatine stores were increased by training and that the ability to produce lactic acid was also increased. The lactate mechanism was considered most important in the energy release system. The concept of oxygen debt was considered a valid mechanism for describing an individual's ability
to perform both short duration exhaustive anaerobic work and to release energy through aerobic mechanisms.

Cunningham and Faulkner\textsuperscript{77} studied aerobic and anaerobic metabolism before and after a training period. Eight male subjects between the ages of 23 and 41 years participated in the training program which consisted of five day per week sessions for a total of six weeks. A pilot study was performed earlier to determine the relative contributions of the aerobic and anaerobic energy sources to the performance of trained and untrained men in a short exhaustive run which demonstrated that the trained had longer run times, reached higher oxygen uptakes in the latter stages of the runs and had higher oxygen debts and blood lactate accumulations. The longitudinal study was performed to see how training would influence the aforementioned results.

The training program consisted of alternate days of interval training and distance runs. The interval training program required the subjects to run alternately and jog 220 yards until they were unable to maintain a constant run time; then the remaining distance needed to complete a total of 2.5 miles for the day was jogged. The distance training days started with a half-mile warm-up.

jog followed by a two-mile run at the fastest pace possible.

A maximum oxygen uptake test and the short exhaustive run were administered prior to and after the training period. The maximum oxygen uptake consisted of a series of progressive five-minute treadmill runs with ten minute rest intervals in between. The test was concluded when the subject reached a five-minute workload that he could not complete. For the short exhaustive run, a grade of 20 percent was set and the subjects ran without warm-up at 7 or 8 mph. The test was constructed so as to achieve a pre-training run time that ranged from 30 to 60 seconds. Continuous monitoring of gas volumes and respiratory rates was performed and was also done during a twelve-minute recovery period. The twelve-minute period was selected because previous data indicated the twelve-minute oxygen debt data to be 80 to 85 percent of the debts collected for a two-hour period.

After training the oxygen consumption was increased by a significant 8 percent. Compared to the pre-training short exhaustive run, the post-training run time increased 23 percent, the oxygen uptake increased 48 percent, the oxygen debt increased 9 percent and the post-exercise lactate concentration increased 17 percent. There were no significant changes in oxygen uptake in the initial 30
seconds of the post-training exhaustive run, but the 30 to 45 second oxygen and ventilation rates were significantly increased. From this finding the authors hypothesized that there were blood flow rate limiting factors in oxygen transport and/or utilization that training did not alter. The training program of level running also was considered to be a factor which might not have transferred specifically to the short run at 20 percent elevation. Warm-up was provided in the training and no warm-up was provided in the treadmill run. The increased oxygen and ventilatory data in the latter stages of the run were attributed to increased oxygen transport and increased oxidative capacity for phosphorylation. The training program did not enhance the efficiency of running on the treadmill.

The authors hypothesized that the increases found indicated that there was an increase in the amount of adenosine triphosphate produced by the processes of oxidative phosphorylation, glycolysis and by creatine phosphate. With these findings the authors felt that specific training programs could be designed to prepare man to perform highly specific muscular exercise tasks.
RESEARCH RELATED TO THE MOTOR DRIVEN

TREADMILL AS A RESEARCH INSTRUMENT

The motor driven treadmill has been utilized extensively as a device for training, testing and research. The advantages lie in the element of control the investigator has in controlling the varied combinations of speed and grade as well as the relatively stable position of the subject. The testing is not so subject to motivation as the workload must be maintained. On this subject Cooper\textsuperscript{78} maintains that treadmill testing was the ultimate tool used by exercise physiologists for testing physical fitness.

In most studies where treadmill walks are of long duration, most follow the basic procedure developed by Balke and Ware\textsuperscript{79} where the subjects walk at 3.4 plus or minus 0.1 mph with a one-percent increase in grade at one-minute intervals. The slight increase in grade enables the subject to make easily the functional adaptations to the increasing workload without bringing into play anaerobic energy sources. The treadmill test


demonstrated a reliability of .82.

Erickson et al.\textsuperscript{80} made a systematic study of treadmill walking at sixteen different combinations of speeds and grades that ranged from 2.5 to 4.0 mph and from 0 to 10 percent grade. The conclusions substantiated the advantage of the treadmill as an experimental instrument. Little training effects, accurate control of work loads and good reproductability were reported.

Several combinations of speed, elevation and duration of short intensive treadmill runs have been utilized. With reference to speed, Taylor et al. stated:

Seven miles an hour was chosen since it is the slowest speed at which all subjects appear to be forced to maintain a running stride (a few subjects will break their stride at 6 mph) and it is slow enough to insure that a wide range of capacity can be tested satisfactorily.\textsuperscript{81}

In relation to grade, 8.6 percent has been extensively used to elicit an all-out treadmill performance but variations from this figure have been common. On this point Cureton\textsuperscript{82} has asserted that the average male will


develop maximum blood flow at 7 miles per hour, 8.6 percent grade and that at speeds above 7 miles per hour, tensing up will occur in all but the best athletes.

Margaria et al., in a study of energy expenditure during running, compared the treadmill running efficiency of athletes and untrained subjects. Indirect calorimetric measurements were made on two athletes aged 28 and 29 as they performed treadmill runs at speeds ranging from 9 to 22 Km/hr. on grades that ranged from minus 20 to plus 15 percent.

The linear cost of running per kilogram of body weight was constant and independent of speed and related only to the treadmill incline. When the treadmill speed dropped to 8.5 Km/hr., walking seemed to be more efficient than running. The running mechanical efficiency of athletes during treadmill running was found to be only 5 to 7 percent higher than the running efficiency of untrained subjects.

Glassford et al., echoed the findings of other studies when comparisons were made between oxygen uptake

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obtained by prediction from two direct treadmill tests, one direct bicycle ergometer test and one indirect submaximal bicycle ergometer test. Twenty-four male subjects aged 17-33 took part in the study. The results indicated that the two direct treadmill tests, which employed a greater muscle mass, elicited eight percent higher maximal oxygen uptake values than those demonstrated by the direct bicycle ergometer test.

SUMMARY OF RELATED LITERATURE

The review of literature emphasized four areas: 1) studies that dealt with intensity versus duration for the development of cardiovascular fitness; 2) studies dealing with the varied aspects of heart rate and oxygen consumption before, during and after exercise and as means for the comparison of trained and untrained subjects; 3) research that related to the use of the motor driven treadmill as a research and training instrument.

When the question of intensity versus duration was reviewed, the majority of the research findings indicated that the duration-type training programs for the development of cardiovascular fitness were superior to the intensity type. By and large these studies dealt with training programs in which long duration cardiovascular training methods such as running were compared with
generalized training programs. When interval-type training was compared with the duration-type programs, the results became more equally divided. In either case both types of training programs resulted in significant improvements in the resting, exercise and post-exercise variables associated with cardiovascular fitness.

The concept that the quality and intensity of a training program was more important than the duration and quantity seemed to summarize the basic question of which approach was most desirable for the development of cardiovascular fitness. In this instance a blending of the best qualities of the two different approaches appeared to be the basic conclusion drawn from this question. Very specific training programs to yield training results for isolated physiological functions was proposed as a guide for research and coaching.

The research findings wherein trained and untrained subjects were compared were generally consistent. Untrained subjects uniformly exhibited less efficient pre-exercise, exercise and recovery physiological responses than did the trained subjects. This result is in agreement with the universal findings relating to this topic and was substantiated in both the intensity and duration-type training programs and research studies.
The heart rate was rather uniformly selected as the most valid criterion of exercise stress. However, maximum oxygen consumption was accepted as the ultimate test of cardiovascular capacity and fitness. Heart rate and oxygen consumption were both linearly related to the intensity and duration of the workload. The respiratory quotient during exercise generally increased in linear fashion with the workload and surpassed unity in the later stages of work and also during short exhaustive work bouts.

In most studies, pre-exercise resting heart rate or oxygen consumption and RQ were not considered to be reliable indicators or predictors of physical fitness and/or physiological competence due to the number of variables that influence these functions.

The question of the use of the 180 heart rate response as the limiting factor during exercise was supported by most studies, but a few studies indicated that heart rates above 180 were possible without physiological impedence. High heart rate levels were uniformly recommended for the accurate measurement of maximal oxygen consumption and it was stressed the high levels were necessary for conditioning to be most successful. Again high heart rates held over a duration of time were recommended for training, but a few authors pointed out that the question of the short intensive workout of
exercise as a training stimulus was as of yet unanswered.

The recovery parameters of heart rate and oxygen consumption variables were normally linearly associated with the intensity, duration, and stress of the exercise workloads. As such both variables were accepted as valid indicators of exercise stress. Some disparity occurred in the rates that these two variables returned to normal after exercise and these circumstances were centered around the question of intensity and duration of the workbouts. Both heart rate and oxygen consumption recovery curves were higher after exhausting work than in submaximal exercises. Short intensive exercise produced initially higher recovery values than did longer duration exercise.

The role and nature of oxygen debt were not clearly agreed upon by the authors of the studies reviewed. In the final analysis, the consensus of the latest research opinions was that oxygen debt was composed of a fast portion labeled alactacid debt and a slow portion called lactacid debt. The alactacid portion was most closely associated with the intensity of the exercise and the lactacid portion associated with the lactic acid accumulations in the blood as well as the intensity and duration of the exercise. The recovery respiratory quotient was shown to exhibit fluctuations well above unity immediately
after exercise followed by gradual returns to normal and subnormal values.

The motor driven treadmill was accepted as a valid and reliable research device that enabled both trained and untrained subjects to be compared with a minimum number of clouding variables in operation. The treadmill yielded higher heart rate and oxygen uptake values than did bicycle ergometer work.
CHAPTER III

PROCEDURE FOR THE STUDY

OVERVIEW OF PROCEDURES

Thirty male subjects were selected from forty-six subjects that were tested for cardiovascular fitness status on the Harvard Step Test (Short Form.)\(^1\) Two groups of fifteen subjects each, one representing high-average cardiovascular fitness and one exhibiting low-average cardiovascular fitness, were selected for study.

Two treadmill workbouts were established for both groups: one a high intensity run of one-minute duration and one, a long duration walk of fifteen minutes. The criterion for the termination of each workbout was a heart rate level of approximately 180 beats per minute as indicated by a fifteen-second recording on a Physiograph. Recovery heart rate and oxygen samples were taken four times during a sixteen minute recovery period with the subjects resting in a sitting position. The heart rate and gas samples were collected during the 1st, 6th, 11th


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and 16th minutes of the recovery period. Prior to each
workbout, a resting heart rate count and oxygen sample
were collected. The resting data was collected in order
to insure that each subject was in a resting state prior
to exercise. When the resting data proved to be too
high the exercise bout was re-scheduled.

SUBJECTS

The subjects in this study were composed of thirty
male students at Southwest Missouri State College in
Springfield, Missouri. The subjects ranged in age from
eighteen to twenty-five years, with a mean age of twenty-
one years. All subjects were recruited individually on a
voluntary basis.

The Harvard Step Test (Short Form) was used to
determine the high-average and low-average fitness groups.
The high-average cardiovascular fitness group consisted of
fifteen subjects whose index scores were seventy-five and
above. The low-average cardiovascular fitness group was
made up of fifteen subjects who exhibited index scores of
sixty-five and below. Subjects who demonstrated index
scores from sixty-six to seventy-four were excluded from
the study.
MEDICAL CLEARANCE

After each subject was recruited and prior to study participation, each subject was cleared through the use of a procedure established by the Investigator, the Director of the College Health Service, the College Research Committee and the Department of Health and Physical Education.

At the recruitment session, each subject was given a full verbal description of the study plus an Information Form to fill out, a Subject Signature Form (400-23) and a written Study Description Form (400-20). Upon return of the Information Form and the Subject Signature Form, Approval Forms were mailed to the Subject's Parents or Guardian, his Family Physician and the College Director of Health Services. The forms sent to the Parents or Guardian included a Cover Letter, a Study Description Form (400-20) and a Parental Signature Form (400-22). The Family Physician Forms included a Cover Letter, a Study Description Form (400-20) and a Physician's Medical Review Form (400-21). The Director of the College Health Services received a Cover Letter, a Study Description Form (400-20) and a Medical Review Form (400-21). No testing was initiated until receipt of

2 Samples of the clearance forms are provided in Appendix C.
the Information Form, the Subject Signature Form (400-23), the Parental or Guardian Form (400-22), the Family Physician Medical Review Form (400-21) and the Director of College Health Services Medical Review Form (400-21).

TESTING EQUIPMENT

Step Bench. A step platform 20 inches high, 24 inches wide and 24 inches deep was constructed to administer the Harvard Step Test (short form). A floor level extension projected from the rear of the platform for the investigator to stand on in order to prevent movement of the stepping platform. See Plate I.

Electric Metronome. The cadence for the step test was established through the use of a Franz Electric Metronome, Model LM 4.

Tape Recorder. The cadence and instructions for the execution of the step test were recorded on a capstan drive Telmar Tape Recorder, Model 201. The recording tape speed was 3 3/4 inches per second. See Plate I.

Quinton Treadmill. A Quinton Treadmill, Model 24-72, was used to provide the fifteen and one-minute

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4 Operation Manual, Martel Electronics, 2339 South Cotner Ave., Los Angeles, California.
workbouts for the high and low-fitness groups. The Quinton Treadmill was equipped with a belt two-feet wide and 124 inches long, with hand rails on three sides. The treadmill belt speed ranged from 1½ to 25 miles per hour and the speed was indicated by a tachometer, accurate to one percent. The belt braking system was magnetically operated and could be adjusted by a potentiometer to stop the belt in 1½ seconds from full speed. See Plate IV.

*E and M. Physiograph "Six".* An E and M six channel Narco-Biosystems Physiograph "six" was used to print out the heart rates on graph paper. The Physiograph was designed to pick up, amplify and trace the bioelectrical functioning of the heart muscle physiology. The Physiograph leads that were attached to the subject consisted of two surface plate electrodes placed at bipolar positions on the lateral chest wall and a ground indifferent surface electrode placed below the clavicle. The three body leads were connected to a cardiac preamplifier MK IV which was a medium gain, condensor-coupled preamplifier used for recording cardiac and other high-level bioelectrical physiological functions. The cardiac preamplifier possessed a sensitivity exceeding one millivolt of physiograph pen deflection, a frequency response

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of from 0.05 to 2,000 cps, an input impedance of eight meghms and a voltage gain of fifty. The cardiac pre-amplifier MK IV connected to an amplifier channel unit MK VII in the main physiograph unit. The MK VII amplifier had a sensitivity of approximately 40 millivolts per centimeter of physiograph pen deflection and a voltage gain of approximately 350.

The Physiograph channel consisted of three elements: the first element was a transducer for the conversion of the effect of physiological activity into proportional electrical signals which were fed into the amplifier. The second element was an amplifier which increased the signal strength while still maintaining the physiologically proportional relationships of the electrical signal. The third element was made up of a pen recorder, pen motor, an electrically driven stylus, an inking system and rectilinear recording paper which could be driven at varied speeds. The pen motor received the electrical signals from the amplifier and drove the direct inking recording pen. The recording movements of the inking pen on the recording paper were proportional to the heart physiological activity. The recording paper could be driven from .05 cm per second up to 5.0 cm per second. A second inking pen marked a constant horizontal line on the graph paper. When activated by an event marker
switch, the horizontal inking pen inscribed a vertical mark. This pen system allowed the operator to mark the recording for timing purposes. See Plate III.

**Gas Collection Equipment.** An adjustable head harness was constructed to hold a Warren E. Collins Triple "J" Valve and the rubber mouthpiece. The Triple J Valve was connected by 1½ inch flexible plastic tubing to a two-way valve. Douglas bags, that ranged in capacity from 200 to 60 liters, were attached to the two-way valve. The Douglas bags were supported by a metal stand placed at the left side of the treadmill. See Plates I and IV.

**Pulmo Analysor.** A Godart NV Pulmo Analysor, type 44A-2 was used to analyze the collected gas samples. The Analysor was a self-contained unit that was made up of an analyzing cell block, a Wheatstone bridge, a constant power source, a circulating pump and a sampling circuit. The Analyzor worked on the principle that gases conduct heat to a specific degree and the thermal conductivity of gases was measured as they passed over two adjacent, equally heated platinum wires. As room air and the gas from a collected sample were drawn over the

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7 Warren E. Collins Co., Inc., 220 Wood Road, Braintree, Massachusetts.


PLATE I
ADMINISTRATION OF THE HARVARD STEP TEST

PLATE II
ADJUSTABLE HEAD HARNESS, TRIPLE "J" VALVE,
FLEXIBLE TUBING AND TWO-WAY VALVE
platinum wires, they withdrew specific amounts of heat from them and in doing so altered their resistance, thereby creating an electrical imbalance in the Wheatstone bridge. The imbalance altered the current flowing through the wires to a degree that was proportional to the amount of gas present in the sample. A calibrated galvanometer, set up in units from zero to one-hundred, reflected the electrical imbalance. The Pulmo Analysor required a preliminary warm-up period of one hour and used soda lime to absorb carbon dioxide and anhydrous calcium chloride to dry the air. When either or both chemicals changed color, they were replaced. A current milliammeter dial insured a uniform flow of electrical current and was set at 200 for oxygen analysis and 150 for carbon dioxide analysis. A sensitivity selector dial was set at 1.0 for oxygen analysis and at 0.3 for carbon dioxide measurements. The millivoltmeter (galvanometer) was adjusted prior to each measurement by an electrical zero correction dial. The gas samples were channeled through the Analysor by a five-way valve which was set on $O_2$ for oxygen analysis and on $CO_2$ for carbon dioxide analysis. A one-liter meteorological balloon and a flexible rubber tube were used to introduce gas samples into the Analysor. As the pump pulled the gas sample across the bridge, the millivoltmeter needle reflected the change
in bridge temperature by moving downward from 100 on oxygen samples and upward from 0 on carbon dioxide samples. The readings from the millivoltmeter zero scale were referred to an oxygen and carbon dioxide calibration chart to determine gas percentages.

The Pulmo Analysor in question had been validated against a Scholander Micrometer Gas Analyzer and a Gallen Kamp-Lloyd Gas Analyzer for the establishment of the oxygen calibration scale. Known gas samples were used to test the Analysor for reliability.

Dry Gas Meter. Gas volume was measured by an American Dry Gas Meter Model 5-M-210. The Meter was graduated in units from 1/100 liters to 10,000 liters and was operated by a 1/10 hp Bodine Electric Evacuator Pump. The Douglas bag was fitted over the meter valve and the gas was drawn through the meter and out through a flexible plastic hose to the electric evacuator pump. The pump was operated at a setting of fifty for the measuring process which pulled the gas sample through the meter at a rate of sixty-eight to seventy liters per minute.

STPD Computation. Temperature and barometric


station pressure were derived through the use of an Eberbach Barometer and Centigrade Thermometer. The station temperature and barometric readings were introduced into a Warren E. Collins STPD Chart indicating factors for reducing the volume of moist gas to volume by dry gas at 0°, 760 mm. Reading down the barometric column and across to the temperature reading, the STPD correction factor was derived.

**Beam Scale.** A Douglas-Homs Full Capacity Beam Scale, Model 150 KHH, was employed to ascertain each subject's weight in kilograms. The Douglas-Homs Scale was sensitive to ± 25 grams.

**Line Chart.** To calculate Respiratory Quotient (R.Q.), Metabolic Respiratory Quotient (MRQ) and the true oxygen percentage from analyses of expired air, a line chart was used. The Pulmo Analysor calibrated readings for oxygen and carbon dioxide readings were connected by a straight edge on the line chart and the points crossed on the true oxygen scale and R.Q. scale were read to the

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12Eberbach Corporation, Ann Arbor, Michigan.

13STPD Chart Cat. No. P453, Warren E. Collins, Inc., 220 Wood Road, Braintree, Massachusetts, 02184.


TESTING PROCEDURE

Step Test for Fitness Determination

The Harvard Step Test\textsuperscript{16} (short form) was used to determine the high-average and low-average fitness levels. Each subject was tested individually and the testing period was established so that food digestion, smoking and previous physical activity were controlled. A two-hour period was established for food digestion and the subject was instructed not to participate in any vigorous physical activity the day of the test. All subjects were asked to refrain from smoking for two hours prior to testing. Each subject's resting heart rate was counted for thirty-seconds as they remained seated and then they were given a detailed orientation to the test plus a short demonstration of the test execution. The subject was then given a short trial run to become familiarized with the stepping technique and the cadence. After the trial run, the subject was seated until he was in a resting state as indicated by a thirty-second heart count taken by a stethoscope. During the

resting period, the test procedures were reviewed again and any questions asked by the subject were answered. The test cadence was provided by a tape recorded playback of an electric metronome. The recording also contained verbal instructions as to when to start and stop and was sequenced as well to indicate to the investigator when to start and stop the post exercise count. In addition, the investigator held a stop watch in order to time those subjects who could not finish the five-minute period.

During the test, the investigator stood on the stabilizing board of the platform and held his arm in such a position so as to steady the subject in case he stumbled. The subject began the test when the recorded instructions indicated to do so and continued at a rate of thirty steps per minute for a period of five minutes, or until he was unable to maintain the cadence. The investigator communicated verbally with the subject so as to insure proper execution and cadence. At the end of five minutes, or at the time the subject failed to maintain cadence, the subject was instructed to sit down. The heart count was taken by the use of a stethoscope from one minute to one minute and thirty seconds after exercise. The pulse count after exercise and time of duration were recorded on the subject's work sheet. See
Plate I. The physical fitness index score was derived from the formula: 17

\[
\text{Index of Fitness} = \frac{\text{Time of stepping in seconds} \times 100}{5.5 \times \text{pulse rate}}
\]

The high-average fitness group included scores from 75 and above and the low-average fitness group included scores from 65 and below. The Harvard Step-up Test (Short Form) has been validated against the ten-minute pulse count and the coefficient of correlation was found to be highly significant \((r = .92)\). 18 The test-re-test coefficient of reliability for the one-pulse count was found by Karpovich to be .89. 19

Introduction to Test Procedure

After the completion of the step-up test and on the same day, each subject was familiarized with the testing area and the equipment to be used. The testing area was situated in a room 13\(\frac{1}{2}\) feet wide, 15 feet long with a 9 foot ceiling. The treadmill room was separated from the lab proper by double doors. The room had one external window and a 1\(\frac{1}{4}\) ton air conditioner.

The temperature during the testing periods ranged

17 Peter V. Karpovich, op. cit.
19 Peter V. Karpovich, Ibid.
from 22.5 to 27.2 degrees Centigrade. During the familiarization process, the treadmill, physiograph and gas collection equipment were shown and their operation explained. Each subject was given a short walk and run on the treadmill to acquaint him with the testing and safety procedures and the walking and running techniques. The walk trial lasted approximately 1 1/2 minutes with the speed set at 3 1/2 miles per hour and the elevation set at zero. For the trial run, the speed was increased to five miles per hour and the elevation set at 10 percent. The trial run lasted approximately one minute.

All testing was done by setting up individual appointments with each subject. At the time each appointment was made, the subject was given specific instructions concerning eating, smoking, and pre-test exercise. Prior to each testing period, the subject was questioned about his physical status for testing.

**Determination of Work Loads for the Fifteen Minute Walk**

Each subject was given a fifteen-minute trial walk in order to determine the work load necessary to reach a heart rate of approximately 180 beats per minute during the fifteenth minute of exercise.

The treadmill speed was held constant at 3 1/2 miles per hour for all subjects in both groups. During the trial walk, the determination of work load was
achieved by varying the elevation of the treadmill grade during the walk. After experimentation it was found that the best procedure was to allow the subject to walk for two minutes at zero grade and thereafter raise the grade 1 percent each minute. In addition to the predictive element, the practice sessions served two other purposes. One was to familiarize the subjects with the final testing procedure, i.e. safety procedures, oxygen collection methods and heart rate recording technique. The second purpose was to prevent undue anticipatory heart rate influences and hyperventilation while breathing through the oxygen collection equipment.

Each subject's resting heart rate was taken as he rested sitting in a chair placed on the treadmill. See Plate III. The heart rates attained during the fifteenth minute enabled the investigator to compute the terminal treadmill elevation necessary to attain the desired heart rate during the final minute of exercise. The trial walk data of minute by minute heart rates demonstrated a uniform increase with each percent of grade increase. This increase averaged approximately four to five beats for each percent of grade increase. Therefore, each individual's fifteenth minute heart rate and the treadmill elevation in percent were plotted on the subject's final workload chart. It was established
that all subjects needed to reach predetermined heart rates at the same times during the fifteen-minute walk if the desired rate of approximately 180 beats was to be attained in the last minute. Therefore, the only variable that had to be manipulated during the final fifteen minute walk for record was the percent of treadmill elevation necessary to elicit the desired heart rate in each subject.

At the conclusion of the final trial walk, an appointment was made with each subject for the final fifteen minute walk. At this time each subject was again instructed not to exercise or smoke for two hours prior to the testing period and the time for testing was set so that a minimum two-hour period intervened between the last meal and testing. The appointment was also set so as to be at approximately the same time of day as the trial walks. This procedure was followed after the completion of the sixty-second run trials as well.

**Determination of Work Loads for the Sixty Second Run**

The trial runs for the short intensive workbout were initiated after each subject had completed the long duration testing. The sixty-second run grade and speed determination required more trial runs than the fifteen-minute walk due to the fact that both treadmill elevation and speed were variables. The sixty-second time limit on
PLATE III

COLLECTION OF PRE-EXERCISE AND RECOVERY DATA

PLATE IV

ARRANGEMENT FOR THE TREADMILL EXERCISE BOUTS
the run and the fact that the heart rate recording could not be counted accurately until after the run served to compound the difficulty.

For all subjects, the first short run practice sessions consisted of two sixty-second runs. The treadmill elevation was set at 10 percent for the first run for all subjects and the speed was varied depending upon the group. The low-average fitness group speed was set at approximately five miles per hour and the high-average fitness group speed was set at approximately six miles per hour. The first run was used primarily as a familiarization run and the second was used more as a predictive run. Between the first and second trials, each subject sat in a chair placed upon the treadmill. The second trial was not begun until the subject's heart rate had returned to within ten beats of his resting rate. After the first practice session, the treadmill grade and speed for each subject became highly individualized.

Heart Rate Recording

The body attachments for heart rate recording consisted of two surface plate electrodes placed at bipolar positions to the heart and one ground indifferent surface electrode placed above the scapulae. The surface plate electrodes were placed on the lateral aspect of the chest wall at the level of the sixth rib. The placement
area was cleaned with alcohol to facilitate contact and electrode conducting paste was applied to the electrode. The electrodes were attached to the body with adhesive tape on all four sides of the plate. In addition, an adjustable rubber belt was positioned over the electrode plate knobs and adjusted to fit firmly around the chest. The adhesive tape and belt were necessary to control artifacts arising from movement of the muscles and fat under the contact surface. The input wires were attached to the electrode plates and then taped to the rubber belt to cut down on artifacts occurring from movement of the wires. The ground indifferent electrode was attached with the use of adhesive tape and was employed to control other recording artifacts.

All three wires leading from the subject were tied into a three and one-half foot long shielded input extension cable. The input cable consisted of two electrode wires and a ground which were plugged into the cardiac preamplifier with an input jack. The cardiac preamplifier was attached to a ceiling pipe above the treadmill and was placed in such a position that the input leads were of sufficient length to allow the subject to sit in a chair placed upon the treadmill.

The Physiograph was positioned at the immediate left side of the treadmill. The treadmill control panel
was placed on top of the Physiograph. This arrangement allowed the investigator to observe the subject, control the treadmill and record the heart rate. See Plates III and IV.

The resting, exercise and recovery heart rates were determined by counting full R to R peaks plus partial peaks of the QRS complex (ventricular contraction) on the moving rectilinear paper, as shown below in a sample electrocardiogram tracing:

Since the recordings were of only fifteen second duration, the intervals from the start of the count and the first R peak (QRS complex) and to the end of the count from the last R peak had to be interpolated in order to arrive at the minute count. The fifteen-second recording was taken during the last portion of each recording minute and this figure was multiplied by four to determine the minute count. The recording paper was marked for counting by the external event marking pen activated by the investigator. All timing was performed with a Minerva sweep-hand
stop watch that made two complete sweeps for each sixty seconds. For resting and recovery heart rate recording, a paper speed of one centimeter per second was sufficient to allow accurate counting. During exercise the paper speed was increased to two centimeters per second.

**Gas Collection Procedures**

For the resting, exercise and the recovery gas collection each subject wore an adjustable head harness that held the mouth piece of the Triple "J" Valve in the proper position. A nose clip was worn to prevent air loss during the collection periods. The output opening of the Triple "J" Valve was connected to a two-way valve by a one and one-half inch flexible plastic hose three feet in length. The two-way valve allowed the investigator to direct the expired air into a Douglas bag during the collection period. The two-way valve was attached to a frame for holding the Douglas bags and was located at the immediate left side of the treadmill. The two-way valve could easily be reached from the investigator's position at the Physiograph. The head harness and flexible tubing allowed each subject adequate freedom of movement on the treadmill. See Plates II and III.

All oxygen samples were taken for one-minute periods. Prior to each collection period, the subject was instructed to breathe normally. Sixty liter Douglas
bags were used to collect the resting and the last three recovery gas samples. The first recovery sample was collected in a 200 liter bag and the second recovery sample was collected in a 100 liter bag.

**Fifteen Minute Workout Data Collection**

Prior to testing for the fifteen-minute walk, each subject was questioned as to his readiness for the walk. Each subject was weighed prior to the workout. The weight was recorded on a lab scale to the nearest one-tenth kilogram. The weight was taken with the subject dressed in shorts without shoes. The preparation period for testing took approximately fifteen minutes.

The subject was seated on a chair placed upon the treadmill while the head harness was adjusted and the electrode leads attached to the input cable. The subject sat resting in the chair while the Physiograph recording was checked for clarity. After the subject had been sitting at rest for approximately five minutes, his resting heart rate was recorded. If the rate appeared significantly higher than had been previously recorded during preliminary testing, more recordings were taken. In the event a disparity of more than fifteen beats per minute was observed, the subject was not tested. During all recording the Physiograph paper was positioned so that the subjects could not see the heart rate recording process.
After completion of the resting heart rate count, the mouthpiece and nose clip were positioned for the gas collection. A two-minute period was allowed prior to the collection of the resting sample in order to blow out the ambient air trapped in the Triple "J" Valve and the flexible tubing. The one-minute resting sample was taken as the subject remained seated. Each subject was instructed to breathe normally during all of the gas collection periods.

Prior to the fifteen-minute walk, the treadmill was set on the starting grade that had been determined for each subject in the preliminary walks. For the high-average fitness group, the mean starting elevation was 1.47 percent with a range of 0 to 5 percent. For the low-average fitness group, the mean starting elevation was .47 percent with a range of 0 to 2 percent. Regardless of the starting grade, it was determined that all subjects should reach predetermined heart rate counts at specified intervals during the fifteen-minute walk session. The predetermined heart counts and intervals were as follows:

<table>
<thead>
<tr>
<th>Minute</th>
<th>Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
</tr>
<tr>
<td>7</td>
<td>140</td>
</tr>
<tr>
<td>9</td>
<td>150</td>
</tr>
<tr>
<td>11</td>
<td>160</td>
</tr>
<tr>
<td>13</td>
<td>170</td>
</tr>
<tr>
<td>15</td>
<td>180</td>
</tr>
</tbody>
</table>
With the treadmill speed held constant at \( \frac{3}{2} \) miles per hour, it was found that for each one percent of increase in elevation, there would be approximately a five beat increase in heart rate. Therefore, regardless of each subject's fitness level, it was necessary only to adjust the starting elevation so that the subject's heart rate corresponded to the predetermined rate early in the walk. Any variation of heart rate progressions, i.e. increasing too slowly or too quickly, was dealt with by doubling the 1 percent increase per minute or by not increasing the elevation for a period of time. The objective of this procedure was to insure a uniform increase in heart rate throughout the walk so that the subject would reach the terminal heart rate without bringing into play undue anaerobic power sources. The high-average fitness group had a mean of 3.07 trials and the range was 2.0 to 4.0 trials. The low-average fitness group mean was 2.60 trials and the range was 2.0 to 3.0 trials. Subjects who reached the final heart rates too early in the walk were retested.

To begin the fifteen minute walk, the subject was instructed to hold both guard rails and place his feet astride the treadmill belt. When the subject indicated that he was ready, the treadmill was started and as the subject began to walk, the stopwatch was activated. Each
subject was informed of the time at one minute intervals during the walk. At the termination of the walk, the subject was instructed to grasp the hand rails, and then the treadmill was stopped. At the same time the treadmill was stopped, the two-way valve was opened to start the collection of the first one-minute gas sample. A chair was placed immediately upon the treadmill so that the subject could rest. In the last fifteen seconds of the first minute of recovery, the recovery heart rate was taken. The three remaining gas samples and heart rate recordings were taken during the fifth to sixth minute, during the tenth to the eleventh minute and during the fifteenth to the sixteenth minute. At no time during the recovery period could the subject see the heart rate recording. See Plates III and IV.

The high-average fitness group reached a mean terminal treadmill elevation of 21.73 percent with a range of 15.0 percent to 26.0 percent. The low-average fitness group's mean terminal elevation was 14.8 percent and the range was from 11.0 to 21.0 percent. The speed for all subjects was held constant at 3½ miles per hour.

**Sixty Second Workbout Data Collection**

The same procedure that was used to prepare each subject for the fifteen-minute walk was employed for the sixty-second run preparations. The resting gas sample
and heart rate recordings were taken in the same manner.

Each subject's treadmill speed and starting elevation were set prior to the testing period. The high-average fitness group treadmill speed averaged 6.4 miles per hour and ranged from 5.5 to 8.0 miles per hour. The mean treadmill elevation for the high-average fitness group was 20.8 percent and the range was from 16.0 to 26.0 percent. The low-average fitness group's mean treadmill speed was 5.3 miles per hour with a range of 5.0 to 6.0 miles per hour. The mean treadmill elevation for the low-average fitness group was 18.33 percent and the range was from 13.0 to 22.0 percent.

Due to the interrelationship of the three variables—running time, treadmill speed and treadmill elevation, it was much more difficult to accurately predetermine each subject's proper workload in order to achieve the desired heart rate of approximately 180 beats per minute at the end of the one-minute period. It was found that a measurement of the R to R interval of the heart rate recording at thirty seconds into the run would indicate whether or not the load was appropriate. If the thirty-second R to R interval was too great, the treadmill was raised 1 to 2 percent for the last portion of the run. This procedure helped to eliminate wasted runs due to the subject's failure to reach a heart rate of at least 177
beats per minute. It was also essential that each subject be able to finish the one-minute interval so that the heart rate recording period and oxygen collection process would be simultaneous and that excessive hyperventilation be eliminated. The high-average fitness group required a mean of 4.93 trials with a range of from 2.0 to 7.0 trials. The low-average fitness group had a mean of 4.2 trials and a range of from 3.0 to 7.0 trials.

For the beginning of the sixty second run, each subject was instructed to hold both guard rails and place his feet astride the treadmill belt. When the subject indicated he was ready, the treadmill was started and when the subject began to run, the stop watch was activated. The running procedure was set up so that each subject held onto the guard rails until he reached his full running stride and then he let go for the remainder of the run. Also, the procedure called for the subject to grasp the rails if he began to fatigue unduly, lose his balance, or lose ground on the belt. In such an event, the treadmill was to be stopped immediately. Each subject understood clearly that he could make the decision to stop at any time he desired. The running time was given to each subject in fifteen second intervals and a preliminary command to grasp the guard rails was given at approximately three seconds before the stop
command. See Plate IV.

The sixteen-minute recovery period data collection followed exactly the procedures used in the fifteen-minute walk data collection.

GAS ANALYSIS PROCEDURE

Upon completion of both workbouts, a one and one-half hour period was allotted for gas analysis. Each gas sample bag was thoroughly kneaded prior to analysis to insure uniform mixing of gas within the Douglas bag. The Pulmo Analysor was allowed to warm up on the oxygen circuit one hour prior to use. All five bags of gas were analyzed first for oxygen by drawing off one liter samples in a one-liter meteorological balloon. The sample oxygen relative percentages indicated on the millivolt hundred unit scale were read to the nearest one hundredth. The reading was referred to the calibration table and the oxygen percentage was read again to the nearest one hundredth.

After completion of the five oxygen samples, the Analysor was set on the CO₂ circuit and the same procedure was followed for the carbon dioxide percentage determination.

The gas volume of each bag was measured by drawing the gas from each bag through a dry gas meter and the
volume then read to the nearest one-hundredth liter. The number of liters drawn off for percentage analysis was added to the figure determined from the gas meter.

The true oxygen content, metabolic respiratory quotient (MRQ) and respiratory quotient (RQ) were ascertained by plotting the calibration chart oxygen and carbon dioxide percentages on a line chart for calculating R.Q. and true $O_2$ from analysis of expired air. All gas samples were corrected for STPD through the use of room temperature and barometric readings. The STPD correction factor was derived from a table for reducing the volume of a moist gas to a volume by dry gas at $0^\circ$, 760 MM. Each minute volume of oxygen in liters was multiplied by the STPD correction factor to determine the corrected oxygen volume in liters. The final step was the division of the corrected oxygen volume by the subject's weight in kilograms. This step resulted in the determination of each subject's oxygen uptake in milliliters per kilogram of body weight per minute.

STATISTICAL ANALYSIS

The statistical matrix utilized in this study consisted of a three factor analysis of variance with a nested factor.\(^{20}\) The three factors consisted of

fitness categories, workbouts and recovery patterns. The subjects were nested under the fitness categories. The workbouts were a sixty-second run and a fifteen-minute walk. The recovery patterns were made up of data collected at one, six, eleven and sixteen minutes of the recovery period. The three recovery pattern data consisted of heart rate, oxygen consumption and respiratory quotient.

Comparisons were made of the three recovery patterns at the four levels outlined to determine whether or not significant differences existed between the high-average fitness and low-average fitness subjects after both workbouts.
CHAPTER IV

ANALYSIS AND PRESENTATION OF DATA

I. INTRODUCTION

The measures in this study consisted of resting, exercise and recovery data collected for fifteen high-average fitness subjects and fifteen low-average fitness subjects on a short, intensive treadmill run and a long duration treadmill walk. The resting data, that were used for base level comparisons only, consisted of heart rate and oxygen consumption. The exercise data were the terminal heart rates of 180 beats per minute that were attained in both workbouts. The recovery data were one-minute samples of oxygen consumption, heart rate and respiratory quotient taken at 1, 6, 11 and 16 minutes in the recovery period. The short intensive run was of sixty seconds duration and the walk was of fifteen minutes duration.

The statistical procedure utilized to analyze the recovery data was a three factor analysis of variance with a nested factor.

Table I provides the means for groups, workbouts
<table>
<thead>
<tr>
<th>Groups</th>
<th>Heart Rate</th>
<th>Oxygen Uptake</th>
<th>Resp. Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Fitness</td>
<td>98.12</td>
<td>11.81</td>
<td>.94</td>
</tr>
<tr>
<td>Low Fitness</td>
<td>107.00</td>
<td>10.42</td>
<td>.94</td>
</tr>
<tr>
<td>Workouts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 Seconds</td>
<td>105.22</td>
<td>11.60</td>
<td>1.04</td>
</tr>
<tr>
<td>15 Minutes</td>
<td>99.90</td>
<td>10.62</td>
<td>.83</td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Minute</td>
<td>134.05</td>
<td>27.62</td>
<td>1.26</td>
</tr>
<tr>
<td>6th Minute</td>
<td>94.92</td>
<td>6.30</td>
<td>1.02</td>
</tr>
<tr>
<td>11th Minute</td>
<td>91.87</td>
<td>5.42</td>
<td>.78</td>
</tr>
<tr>
<td>16th Minute</td>
<td>89.42</td>
<td>5.10</td>
<td>.69</td>
</tr>
</tbody>
</table>
and recovery variables utilized in the various comparisons.

Table II presents the heart rate, oxygen consumption and respiratory quotient data for each fitness group for each interval in the recovery period following each exercise workout. The heart rate means were expressed in beats per minute, the oxygen uptake means were illustrated in milliliters of oxygen consumed (ml/kg/min), and the respiratory quotients in units and tenths of a unit. The reader may wish to refer to these tables for clarification purposes as well as to Graphs I, II, and III for group recovery curve comparisons.

Appendixes A and B contain mean figures for all the data collected on both groups and Appendixes D and E contain the data collected on each individual in the high-average and low-average fitness groups.

ANALYSIS OF HEART RATE DATA

Comparison of Fitness Levels on Recovery Heart Rate

In Table III it may be seen that the F-ratio of 10.46 for fitness levels exceeded the required F-ratio of 7.64 at the .01 level of probability. This result indicated that the high-average fitness group's recovery heart rate mean of 98.12 for both workbout was significantly lower than the recovery heart rate mean of 107.00
TABLE II

RECOVERY HEART RATE, OXYGEN UPTAKE AND RESPIRATORY QUOTIENT MEANS FOR THE HIGH-AVERAGE AND LOW-AVERAGE FITNESS GROUPS AFTER THE FAST AND SLOW WORKBOUTS

**Sixty Second Run**

<table>
<thead>
<tr>
<th>Group</th>
<th>1st Minute</th>
<th>6th Minute</th>
<th>11th Minute</th>
<th>16th Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>HR 132</td>
<td>02 30.17</td>
<td>RQ 1.50</td>
<td>HR 95</td>
</tr>
<tr>
<td>Low</td>
<td>HR 142</td>
<td>02 25.98</td>
<td>RQ 1.46</td>
<td>HR 99</td>
</tr>
</tbody>
</table>

**Fifteen Minute Walk**

<table>
<thead>
<tr>
<th>Group</th>
<th>1st Minute</th>
<th>6th Minute</th>
<th>11th Minute</th>
<th>16th Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>HR 123</td>
<td>02 29.58</td>
<td>RQ .99</td>
<td>HR 86</td>
</tr>
<tr>
<td>Low</td>
<td>HR 139</td>
<td>02 24.74</td>
<td>RQ 1.08</td>
<td>HR 98</td>
</tr>
</tbody>
</table>

**BOTH WORKBOUTS COMBINED**

<table>
<thead>
<tr>
<th>Group</th>
<th>1st Minute</th>
<th>6th Minute</th>
<th>11th Minute</th>
<th>16th Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>HR 128</td>
<td>02 29.88</td>
<td>RQ 1.24</td>
<td>HR 91</td>
</tr>
<tr>
<td>Low</td>
<td>HR 140</td>
<td>02 25.36</td>
<td>RQ 1.27</td>
<td>HR 99</td>
</tr>
</tbody>
</table>
GRAPH I

REST AND RECOVERY HEART RATE MEANS FOR THE HIGH-AVERAGE AND LOW-AVERAGE FITNESS SUBJECTS FOR BOTH WORKBOUTS

H.R.
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60

Period
Rest 1st Min. 6th Min. 11th Min. 16th Min.

• = High-Average Fitness, Fast Workbout
○ = Low-Average Fitness, Fast Workbout
■ = High-Average Fitness, Slow Workbout
□ = Low-Average Fitness, Slow Workbout
GRAPH II

REST AND RECOVERY OXYGEN UPTAKE OF THE HIGH-AVERAGE AND LOW-AVERAGE FITNESS SUBJECTS FOR BOTH WORKBOUTS

ML/O₂

Period

Rest 1st Min. 6th Min. 11th Min. 16th Min.

○ = High-Average Fitness, Fast Workbout
○ = Low-Average Fitness, Fast Workbout
● = High-Average Fitness, Slow Workbout
□ = Low-Average Fitness, Slow Workbout

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GRAPH III

REST AND RECOVERY RESPIRATORY QUOTIENT MEANS FOR THE HIGH-
AVERAGE AND LOW-AVERAGE FITNESS SUBJECTS FOR BOTH WORKBOUTS

R.Q.
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
.95
.90
.85
.80
.75
.70
.65
H L H L H L H L H L H L H L

REST 1st MIN. 6th MIN. 11th MIN. 16th MIN.

A = Fast Workbout  H = High-Average Fitness Group
B = Slow Workbout  L = Low-Average Fitness Group
TABLE III

ANALYSIS OF VARIANCE OF RECOVERY HEART RATE FOR FIFTEEN HIGH-AVERAGE AND FIFTEEN LOW-AVERAGE FITNESS SUBJECTS AT THE 1ST, 6TH, 11TH, AND 16TH MINUTES AFTER EXERCISE

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitness Levels (F)</td>
<td>4,725.94</td>
<td>1</td>
<td>4,725.94</td>
<td>10.46*</td>
<td>.01</td>
</tr>
<tr>
<td>Subjects w/n F</td>
<td>12,647.25</td>
<td>28</td>
<td>451.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workbout (W)</td>
<td>1,701.34</td>
<td>1</td>
<td>1,701.34</td>
<td>16.36*</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Workbout F x W</td>
<td>467.60</td>
<td>1</td>
<td>467.60</td>
<td>4.50*</td>
<td>.05</td>
</tr>
<tr>
<td>Subjects w/n FxW</td>
<td>2,911.18</td>
<td>28</td>
<td>103.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery (R)</td>
<td>80,228.11</td>
<td>3</td>
<td>26,742.70</td>
<td>912.10**</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Recovery</td>
<td>293.51</td>
<td>3</td>
<td>97.84</td>
<td>3.34**</td>
<td>.05</td>
</tr>
<tr>
<td>Subjects w/n FxR</td>
<td>2,462.75</td>
<td>84</td>
<td>29.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workbout x Recovery</td>
<td>18.45</td>
<td>3</td>
<td>6.15</td>
<td>&lt;1**</td>
<td>N.S.</td>
</tr>
<tr>
<td>F x W x R</td>
<td>14.25</td>
<td>3</td>
<td>4.75</td>
<td>&lt;1**</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

F needed for significance: *1 and 28 df, .05 level = 4.20
                                  .01 level = 7.64
**3 and 84 df, .05 level = 2.72
                                .01 level = 4.03

139
exhibited by the low-average fitness group.

Comparison of the Sixty Second Run and Fifteen Minute Walk

When both the high-average fitness and the low-average fitness groups' heart rate means were combined for the purpose of comparing the long walk with the short run, the resultant $F$ - ratio of 16.36 in Table III exceeded the required $F$ of 4.20 at the .01 level of probability. This factor signified that the over-all mean recovery heart rate of 105.2 following the sixty-second run for both groups combined was significantly higher than the long walk heart rate recovery mean of 99.9 for both groups. Thus the sixty-second exercise bout was more severe in terms of mean heart rate during recovery than the fifteen-minute walk.

Interaction of Fitness Level and Workout

As shown in Table III, the interaction for the high-average and low-average fitness groups and the slow and fast workbouts resulted in an $F$ ratio of 4.50 which was significant at the .05 level of probability. This result was interpreted to mean that the difference between the recovery heart rates for the slow and fast workbouts for the high-average fitness group was greater than the difference between the recovery heart rates produced by the fast and slow workbouts for the low-average
fitness group. The high-average fitness group showed a mean recovery rate of 102.2 following the fast run and a recovery mean heart rate of 94.1 following the slow walk which was a difference of 8.1. The low-average fitness group had a mean recovery of 108.3 following the fast workbout and a mean recovery rate of 105.7 following the slow workbout, a difference of 2.6. Thus the low-average fitness group was placed under more equal stress on both workbouts, whereas the high-average fitness group was not stressed nearly as much on the slow walk as on the fast run.

Comparison of Heart Rates for the Four Recovery Time Measures for all Subjects on Combined Workbouts

The comparison of the heart rates at the different recovery intervals for both groups combined on both workbouts resulted in an F ratio of 912.10 which was highly significant at the .01 level of probability. As shown in Table I, the mean heart rate for the first minute was 134.0, 94.9 for the sixth minute, 91.9 for the eleventh minute and 89.4 for the sixteenth minute. As shown in Graph IV, this pattern was highly linear and therefore no statistical comparisons were made as it was obvious that the highly linear decrease in heart rate accounted for the significant F-ratio. A leveling off from the 6th to 16th minutes is also readily apparent in the graphical illustration.
GRAPH IV

HEART RATE RECOVERY PATTERN FOR HIGH-AVERAGE AND LOW-AVERAGE FITNESS GROUPS AND SLOW AND FAST TREADMILL WORKOUTS COMBINED

Heart rate

145
140
135
130
125
120
115
110
105
100
95
90
85
80
75

Recovery period
1st Min. 6th Min. 11th Min. 16th Min.
Interaction Between Fitness Level and Recovery

The interaction of the high-average and low-average fitness groups' combined fast and slow workout heart rate recovery patterns for the four recovery periods was significant at the .05 level of probability. As shown in Table III, the F ratio of 3.34 exceeded the required F of 2.72 for 3 and 84 degrees of freedom. In Graph V, it may be seen that the difference between the high-average and low-average fitness groups at the first minute after exercise was much greater than the differences at the other intervals of recovery. This factor accounted for the significant interaction. In Table II, it shows that the high-average fitness group heart rate recovery means for both workouts combined were 127.7, 91.2, 88.3 and 85.3 for the 1st, 6th, 11th and 16th minutes, respectively, while the low-average fitness group demonstrated means of 140.4, 98.6, 95.4 and 93.6 for the same recovery periods. The differences between these two patterns were 12, 8, 7 and 8 beats for the 1st, 6th, 11th and 16th minutes, respectively.

Interaction of Workout and Recovery

The interaction of workout and recovery pattern produced an F ratio of <1 and, of course, was not significant. This result indicated that the difference between
GRAPH V

RECOVERY HEART RATE PATTERNS FOR THE HIGH-AVERAGE AND LOW-AVERAGE FITNESS GROUPS FOR THE SLOW AND FAST WORKOUTS COMBINED

Heart rate

Recovery period

1st Min. 6th Min. 11th Min. 16th Min.

○ = High-Average Fitness Group
○ = Low-Average Fitness Group
the fast and slow workbouts remained essentially uniform throughout the recovery period.

**Interaction of Fitness Level, Workout and Recovery**

The interaction of the high-average and low-average fitness groups, the fast and slow workbouts and the four recovery periods resulted in an F ratio of <1 which, as shown in Table III, was not significant. This result signified that the differences between the high-average and low-average fitness groups following the slow and fast workbouts remained fundamentally the same throughout the recovery period.

**ANALYSIS OF OXYGEN UPTAKE DATA**

**Comparison of Fitness Levels on Recovery Oxygen Uptake**

Table IV shows that the F-ratio of 12.56 for fitness levels exceeded the required F-ratio of 7.64 at the .01 level of probability. This factor disclosed that the high-average fitness oxygen uptake mean of 11.81 ml/kg/min. (Table I) was significantly higher than the oxygen uptake mean of 10.42 exhibited by the low-average fitness group for the recovery period following the fast and slow workbouts combined.

**Comparison of the Sixty-Second Run and Fifteen-Minute Walk**

When both the high-average fitness and the low-
TABLE IV

ANALYSIS OF VARIANCE OF RECOVERY OXYGEN UPTAKE
FOR FIFTEEN HIGH-AVERAGE AND FIFTEEN LOW-AVERAGE
FITNESS SUBJECTS AT THE 1ST, 6TH, 11TH,
AND 16TH MINUTES AFTER EXERCISE

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
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<tr>
<td>Fitness Levels (F)</td>
<td>116.33</td>
<td>1</td>
<td>116.33</td>
<td>12.56*</td>
<td>.01</td>
</tr>
<tr>
<td>Subjects w/n F</td>
<td>259.22</td>
<td>28</td>
<td>9.26</td>
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</tr>
<tr>
<td>Workbout (W)</td>
<td>58.09</td>
<td>1</td>
<td>58.09</td>
<td>32.81*</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Workbout F x W</td>
<td>0.91</td>
<td>1</td>
<td>0.91</td>
<td>&lt;1*</td>
<td>N.S.</td>
</tr>
<tr>
<td>Subjects w/n F x W</td>
<td>68.42</td>
<td>28</td>
<td>2.44</td>
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</tr>
<tr>
<td>Recovery (R)</td>
<td>21,848.35</td>
<td>3</td>
<td>7,282.78</td>
<td>2,167.49**</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Recovery</td>
<td>195.24</td>
<td>3</td>
<td>65.08</td>
<td>19.37**</td>
<td>.01</td>
</tr>
<tr>
<td>Subjects w/n F x R</td>
<td>282.20</td>
<td>84</td>
<td>3.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workbout x Recovery</td>
<td>2.25</td>
<td>3</td>
<td>0.75</td>
<td>&lt;1**</td>
<td>N.S.</td>
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</table>

(continued)
### TABLE IV (continued)

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<tr>
<th>Source of Variance</th>
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<th>Mean Square</th>
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<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>F x W x R</td>
<td>4.63</td>
<td>3</td>
<td>1.54</td>
<td>&lt;1**</td>
<td>N.S.</td>
</tr>
<tr>
<td>Subjects w/n F x W x R</td>
<td>212.51</td>
<td>84</td>
<td>2.53</td>
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<td></td>
</tr>
</tbody>
</table>

*F needed for significance: *1 and 28 df, .05 level = 4.20  
.01 level = 7.64  
**3 and 84 df, .05 level = 2.72  
.01 level = 4.03*
average fitness groups' oxygen uptake means were combined for the purpose of comparing the two workbouts, the F ratio of 23.81 achieved for this comparison exceeded the required F of 7.64 at the .01 level of probability. (See Table IV) This finding revealed that the oxygen uptake mean of 11.60 ml/kg/min. for the short run was significantly higher than the long walk mean of 10.62 ml/kg/min. The sixty-second run exercise was thus more severe in terms of oxygen uptake recovery than was the fifteen-minute walk.

**Interaction of Fitness Levels and Workout**

Table IV shows that the interaction for the high-average and low-average fitness groups and the fast and slow workbouts resulted in an F ratio of .37 which was nonsignificant. This finding indicated that the difference between the oxygen uptake for the slow and fast workbouts for the high-average fitness group remained the same as the difference between the two workbouts for the low-average fitness group. The high-average fitness group showed a mean of 12.36 ml/kg/min. on the fast run and a mean of 11.26 on the slow walk, a difference of 1.11 ml/kg/min. The low-average fitness group had a fast walk mean of 10.85 and a mean of 9.98 on the slow walk, which was a difference of .87 ml/kg/min.
Comparison of Oxygen Uptake for the Four Time Measures for all Subjects on Combined Workouts

When the oxygen uptakes for both groups combined were compared at the different recovery intervals, the F ratio achieved was 2,167.49 which was highly significant at the .01 level of probability. As shown in Table I, the mean oxygen consumption for the first minute was 27.62, 6.30 for the sixth minute, 5.42 for the eleventh minute and 5.10 ml/kg/min for the sixteenth minute. As pointed out in Graph VI, this pattern was highly linear and as a result no comparisons were made as it was clear that the highly linear decrease in oxygen consumption, especially from the first to sixth minute after exercise was responsible for the significant F ratio.

Interaction Between Fitness Level and Recovery

The interaction of the high-average and low-average fitness groups' combined fast and slow oxygen consumption recovery pattern for the four recovery periods was significant at the .01 level of probability. As shown in Table IV, the F ratio of 19.37 exceeded the required F of 4.03 for 3 and 84 degrees of freedom. In Graph VII it may be seen that the difference between the high-average and low-average fitness groups at the first minute after exercise was much greater than the differences
GRAPH VI

OXYGEN UPTAKE RECOVERY PATTERN FOR BOTH FITNESS GROUPS
AND BOTH WORKOUTS COMBINED

ML/O₂

0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Recovery period
1st Min. 6th Min. 11th Min. 16th Min.
GRAPH VII

OXYGEN UPTAKE MEAN RECOVERY PATTERNS FOR THE HIGH-AVERAGE AND LOW-AVERAGE FITNESS GROUPS FOR BOTH WORKOUTS COMBINED

ML/O₂

Recovery period

1st Min. 6th Min. 11th Min. 16th Min.

= High-Average Fitness Group

= Low-Average Fitness Group

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at the other recovery intervals. This first minute difference accounted for the significant interaction. Table II shows that the high-average fitness recovery means were 29.88, 6.50, 5.52 and 5.34 ml/kg/min for the 1st, 6th, 11th and 16th minutes, respectively, while the low-average fitness group demonstrated means of 25.36, 6.11, 5.31 and 4.87 ml/kg/min for the same recovery periods. The differences for these two patterns were 4.52 for the first minute, .39 for the sixth minute, .20 for the eleventh minute and .47 ml/kg/min for the sixteenth minute.

**Interaction of Workout and Recovery**

The interaction of workout and recovery pattern resulted in an F of <1 which, as seen in Table IV, was nonsignificant. This finding signified that the difference between the fast and slow workbouts remained uniform throughout the recovery period.

**Interaction of Fitness Level, Workout and Recovery**

The interaction of the high-average and low-average fitness groups, the fast and slow workbouts and the four recovery periods yielded an F ratio which was nonsignificant. Table IV shows that an F of 2.72 was necessary to produce significance for 3 and 84 degrees of freedom. This result signified that the differences
between the high-average and low-average fitness groups following the slow and fast work bouts remained fundamentally the same throughout the recovery period.

ANALYSIS OF
RESPIRATORY QUOTIENT DATA

Comparison of Fitness Levels on Recovery Respiratory Quotient

Table V shows that the F ratio of <1 for fitness levels failed to meet the required F ratio of 4.20 to be significant at the .05 level of probability. This finding denoted that there were no differences between the over-all recovery respiratory quotient means of the two fitness groups. The high-average fitness group respiratory quotient (RQ) mean was .938 and the low-average fitness RQ mean was .935.

Comparison of the Sixty-Second Run and the Fifteen-Minute Walk

In Table V it may be seen that the F ratio of 133.00 greatly exceeded the F of 7.64 at the .01 level of probability for the comparison of the short run with the long walk when both fitness groups were combined. This result demonstrated that the fast workout produced an over-all recovery RQ mean of 1.04 which was significantly higher than the mean of .83 produced by the long
TABLE V

ANALYSIS OF VARIANCE OF RECOVERY RESPIRATORY QUOTIENT

FOR FIFTEEN HIGH-AVERAGE AND FIFTEEN LOW-AVERAGE FITNESS

SUBJECTS AT THE 1ST, 6TH, 11TH, AND

16th MINUTES AFTER EXERCISE

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitness Levels (F)</td>
<td>0.00</td>
<td>1</td>
<td>0.00</td>
<td>&lt;1*</td>
<td>N.S.</td>
</tr>
<tr>
<td>Subjects w/n F</td>
<td>0.84</td>
<td>28</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workbout (W)</td>
<td>2.66</td>
<td>1</td>
<td>2.66</td>
<td>133.00*</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Workbout F x W</td>
<td>0.07</td>
<td>1</td>
<td>0.07</td>
<td>3.50*</td>
<td>N.S.</td>
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<tr>
<td>Subjects w/n F x W</td>
<td>0.70</td>
<td>28</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery (R)</td>
<td>11.62</td>
<td>3</td>
<td>3.87</td>
<td>387.00**</td>
<td>.01</td>
</tr>
<tr>
<td>Group x Recovery</td>
<td>0.03</td>
<td>3</td>
<td>0.01</td>
<td>&lt;1**</td>
<td>N.S.</td>
</tr>
<tr>
<td>Subjects w/n F x R</td>
<td>0.93</td>
<td>84</td>
<td>0.01</td>
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</tr>
<tr>
<td>Workbout x Recovery</td>
<td>1.59</td>
<td>3</td>
<td>0.53</td>
<td>125.45**</td>
<td>.01</td>
</tr>
</tbody>
</table>

(continued)
<table>
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<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>P</th>
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<tbody>
<tr>
<td>F x W x R</td>
<td>0.04</td>
<td>3</td>
<td>0.01</td>
<td>2.90**</td>
<td>.05</td>
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<tr>
<td>Subjects w/n F x W x R</td>
<td>0.36</td>
<td>84</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*F needed for significance: *1 and 28 df, .05 level= 4.20  
  .01 level= 7.64  
  **3 and 84 df, .05 level= 2.72  
  .01 level= 4.03*
interaction of fitness levels and workout

In Table V it is revealed that the interaction for the high-average and low-average fitness groups and the fast and slow workbouts resulted in an F ratio of 3.50 which was nonsignificant. This finding disclosed that the difference between the mean over-all recovery respiratory quotients following the fast and slow workbouts for the high-average fitness group remained the same as the difference between the RQ's following the two workbouts for the low-average fitness group. The high-average fitness group had a mean RQ of 1.06 on the fast run and a mean of .82 on the slow walk, which was a difference of .24. The low-average fitness group had a mean RQ of 1.02 for the fast run and a mean of .84 on the slow walk, which was a difference of .18.

comparison of respiratory quotients for the four time measures for all subjects on combined workbouts

The comparison of the respiratory quotient at the four recovery intervals for both groups combined on both workbouts resulted in an F ratio of 387.00 which was highly significant at the .01 level of probability. As shown in Table I, the mean RQ for the 1st minute was 1.26, 1.02 for the 6th minute, .78 for the 11th minute and .69
for the 16th minute. As can be seen in Graph VIII, this pattern was highly linear with a leveling off between the 11th and 16th minutes, and as a result, no further statistical comparisons were made as it was evident that the highly linear decrease was responsible for the significant F ratio.

Interaction Between Fitness Level and Recovery

The interaction of the high-average and low-average fitness groups' combined fast and slow workbout respiratory quotients for the four recovery periods was nonsignificant. This finding showed that the differences in RQ's between the high-average and low-average fitness groups remained essentially the same throughout the four recovery intervals. In Table II it shows that the high-average fitness group RQ recovery means for both workbouts combined were 1.24, 1.03, .77 and .70 for the 1st, 6th, 11th and 16th minutes respectively, while the low-average fitness group displayed means of 1.27, 1.00, .78 and .69 for the same recovery intervals. The differences for these two patterns were .03 for the 1st minute, .02 for the 6th minute, .01 for the 11th minute, and .01 for the 16th minute.

Interaction of Workbout and Recovery

As shown in Table V, the interaction of workbout
GRAPH VIII

RESPIRATORY QUOTIENT MEAN RECOVERY PATTERN FOR BOTH FITNESS GROUPS AND BOTH WORKOUTS COMBINED

R.Q.
and recovery pattern yielded an F ratio of 125.45 which was significant at the .01 level of confidence. This result meant that the fast workbout recovery respiratory quotient means of 1.48 for the 1st minute, 1.15 for the 6th minute, .83 for the 11th minute and .71 for the 16th minute were significantly different from the slow workbout pattern of 1.03, .88, .72 and .68 for the same time periods. As may be seen in Graph IX, the slope of the fast workbout recovery pattern is much steeper for the first three time periods than the slope of the slow workbout, and it is clear that this factor accounted for the significant interaction found. The differences existed primarily at the 1st, 6th and 11th minute recovery periods.

Interaction of Fitness Level, Workbout and Recovery

The interaction of the high-average and low-average fitness groups, the fast and slow workbout and the four recovery periods resulted in an F ratio of 124.45 which, as shown in Table V, was highly significant at the .01 level of probability. In Table II and Graph X it may be seen that the difference between the RQ's of the high-average and low-average fitness groups at the end of the 1st minute following the slow workbout was greater than for the fast workbout. Conversely, the difference between the RQ's of the high-average and low-
GRAPH IX

FAST AND SLOW WORKOUT RECOVERY RESPIRATORY QUOTIENT
MEANS BOTH GROUPS COMBINED

R.Q.

0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
1.45
1.50
1.55

Recovery period
1st Min. 6th Min. 11th Min. 16th Min.

○ = Sixty Second Workout
● = Fifteen Minute Workout
GRAPH X
HIGH-AVERAGE FITNESS AND LOW-AVERAGE FITNESS GROUP

RESPIRATORY QUOTIENT MEAN RECOVERY PATTERNS FOR
THE FAST AND SLOW WORKOUTS

R.Q.
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65

Recovery period 1st Min. 6th Min. 11th Min. 16th Min.

= High-Average Fitness Group, Fast Workout

= High-Average Fitness Group, Slow Workout

= Low-Average Fitness Group, Fast Workout

= Low-Average Fitness Group, Slow Workout

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average fitness groups at the end of the 6th minute was
greater following the fast workout than for the slow
workout. These differences between the differences
accounted for the significant interaction.
CHAPTER V

SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS
AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to compare the heart rate, oxygen uptake and respiratory quotient recovery measures of high-average and low-average fitness subjects after sixty-second and fifteen-minute treadmill exercise bouts, both of which produced a terminal exercise heart rate of 180 beats per minute. Thirty male college subjects were selected from students at Southwest Missouri State College, Springfield, Missouri. The subjects were placed in a high-average or low-average fitness group of fifteen subjects each based upon their scores on the short form of the Harvard Step Test.

Each subject was given trial walks and runs on the two treadmill workbouts until a sufficient workload, based upon speed and elevation was achieved which would produce a terminal exercise heart rate of 180 beats per minute. Upon completion of the preliminary walks, each subject made one record walk for each workout, after which oxygen
uptake and heart rate data were collected in one minute samples at 1, 6, 11 and 16 minutes during the recovery period. Metabolic respiratory quotient and respiratory quotient values were determined for the same periods as the oxygen samples were analyzed. The fast and slow workbouts were administered during separate testing sessions.

The heart rate electocardiograms, oxygen samples and respiratory quotients were analyzed and derived in the Kinetoeenergetics Laboratory at Southwest Missouri State College, Springfield, Missouri. The statistical data were processed at the Computer Research Center at Louisiana State University, Baton Rouge, Louisiana. The statistical design was a three factor analysis of variance with a nested factor. For each of the three recovery variables under study, the following analyses were performed:

1. Comparison of fitness levels.
2. Comparison of the sixty-second run and fifteen-minute walk.
3. Interaction between fitness levels and workbouts.
4. Comparison of the four recovery time intervals for all subjects on both workbouts.
5. Interaction between fitness level and recovery intervals.
6. Interaction of workbout and recovery intervals.
7. Interaction of fitness level, workbout and recovery intervals.

FINDINGS

The findings of this study given in the order of the previously outlined statistical comparison were as follows:

1. Comparison of fitness levels:
   A. The overall recovery heart rate mean for the high-average fitness group was significantly lower than the heart rate recovery mean of the low-average fitness group at the .01 level of probability.
   B. The overall oxygen consumption recovery mean of the high-average fitness group was significantly higher than the overall oxygen consumption recovery mean of the low-average fitness group at the .01 level of probability.
   C. No significant difference was found to exist between the overall recovery respiratory quotient means of the high-average and low-
2. Comparison of the fast and slow workbouts:
   A. The overall heart rate recovery mean for the short workbout was significantly higher than the overall recovery mean for the long workbout at the .01 level of probability.
   B. The overall oxygen consumption recovery mean was significantly higher for the short workbout than for the long workbout at the .01 level of probability.
   C. The overall respiratory quotient recovery mean was significantly higher for the short workbout than for the long workbout at the .01 level of probability.

3. Interaction of fitness level and workbout:
   A. The interaction between fitness level and workbout in mean recovery heart rate was significant at the .05 level of confidence. The difference between the short and long workbout was greater for the high-average fitness group. The low-average fitness subjects were placed under proportionately greater stress for the long workbout than the high-average fitness subjects.
   B. There was no significant interaction between
fitness level and workout in oxygen consumption or respiratory quotients.

4. Comparison of the four time intervals for the three variables for all subjects on combined workbouts:

The differences between the four time intervals for heart rate, oxygen uptake and respiratory quotient were significant at the .01 level of confidence. All three variables demonstrated highly linear patterns for the four time periods. The recovery slopes of the three variables demonstrated the most acute decline from the immediate post-exercise levels during the 1st and 6th minute and then assumed a more gradual decline toward the resting levels.

5. Interaction between fitness level and recovery intervals:

A. The interaction between fitness level and recovery heart rate was significant at the .05 level of confidence. The higher heart rate of the low-average fitness group was much greater than the high-average fitness subjects in the first minute of recovery than at the other three recovery intervals.
B. The interaction between fitness level and recovery intervals for oxygen uptake was significant at the .01 level of probability. The oxygen uptake of the high-average fitness group was considerably greater than the low-average fitness group in the first minute of recovery than at the other three recovery intervals.

C. No significant interaction was found to exist between fitness level and recovery intervals in respiratory quotients.

6. Interaction of workbout and recovery intervals:
   A. No significant interaction was found to exist between workbout and recovery for heart rate or for oxygen uptake.
   B. The interaction between workbout respiratory quotient and recovery patterns was found to be significant at the .01 level of confidence. The respiratory quotient for the short workbout was much greater than for the long workbout at the first minute in recovery than at the other intervals.

7. Interaction of fitness level, workbout and recovery:
   A. No significant interaction was found to exist
between recovery patterns, workbouts and fitness groups in heart rate or oxygen uptake.

B. The interaction between recovery pattern, workbouts and fitness groups for respiratory quotients was significant at the .01 level of confidence. The difference between the respiratory quotients of the high-average and low-average fitness groups following the short and long workbouts was greater in the first minute after exercise than in the sixth minute after exercise.

**DISCUSSION OF FINDINGS**

The findings of this study revealed that there was a significant difference between the recovery heart rate and oxygen uptake total means of the high-average fitness and low-average fitness groups for the slow and fast workbouts. The high-average fitness group had a lower total heart rate recovery mean and also had a higher oxygen uptake recovery mean. The respiratory quotient recovery means for the same comparison were not significantly different. These findings were in agreement with some of the findings in similar studies but they were inconsistent in other respects. It was expected that the
high-average fitness group would exhibit a lower recovery heart rate when the fitness groupings were determined by the use of a step test which is based upon recovery heart rate. Taylor\(^1\) found similar results in the recovery heart rate means in the recovery data of high and low fitness subjects after maximal and sub-maximal treadmill runs. However, one difference must be considered: many of the studies such as the one just mentioned were based upon a maximum run on a standard exercise while the runs in this study were basically individualized, controlled from a time standpoint and terminated when a heart rate of 180 beats per minute was attained.

The same consideration must be observed in the interpretation of the finding that the high-average fitness group exhibited a significantly higher recovery oxygen consumption mean than the low-average fitness group. Many studies such as the one by Hartley \textit{et al.}\(^2\) show that low fitness subjects exhibit higher oxygen consumption.

\(^1\)Craig Taylor, "Some Properties of Maximal and SubMaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance," \textit{American Journal of Physiology}, Vol. 142 (September, 1944), 200-212.

recovery values after a standardized workload than high fitness subjects do. In this study it was evident that the high-average fitness subjects were performing a higher level of work at the termination of exercise and in the process were most likely developing a greater oxygen debt which accounted for the higher oxygen recovery mean. The high-average fitness subjects performed the short workbout at a mean treadmill grade of 20.8 percent and a speed of 6.4 mph; they walked the 3.5 mph long workbout to a final mean treadmill elevation of 21.7 percent. The low-average fitness group had means of 5.3 mph and a grade of 18.3 percent on the short workbout and a final grade of 14.8 percent on the long workbout.

The finding that there was no difference in the respiratory quotient recovery means between the two fitness groups on both workbouts combined is inconsistent with the literature wherein standard workbouts were used. The studies by Cureton, Bock, Steinhaus, and McNelly


were all in agreement that high fitness subjects have lower respiratory quotients than low fitness subjects. In the study by Cooper, fast treadmill exercise produced lower recovery respiratory quotients for the trained subjects while there was little difference between the recovery respiratory quotients of the trained and untrained for the slow treadmill exercise. It was established in this study that recovery heart rate, oxygen uptake and RQ demonstrated mainly linear patterns. The results of the study by Issekutz also exhibited a straight line relationship between workload, oxygen uptake and RQ. In this study the high-average fitness subjects were working at higher terminal workloads on both workbouts as well as working harder to attain the 180 heart rate than the low-average fitness group. It was thus hypothesized in this study that the high-average fitness group RQ of .94 indicated a higher level of physiological stress than the RQ of .94 demonstrated by the low-average fitness group. This hypothesis was further strengthened by the generally


accepted consensus of research findings which has shown that high fitness subjects demonstrate lower recovery heart rates and oxygen consumption. It was also shown in the study by Suggs that oxygen uptake and heart rate are linearly related, and as such the RQ is representative of the removal of carbon dioxide during the oxygen debt period. Since there were differences between the two fitness groups on the recovery heart rate and oxygen uptake, it adds strength to the belief that the identical respiratory quotients found actually represent different stress levels.

When both fitness groups and both workbouts were combined for the analysis of the recovery patterns, all three recovery variables demonstrated significantly linear recovery slopes. Both heart rate and oxygen uptake had the greatest departure from a pure linear pattern, or leveling off effect, between the first and sixth minute recovery points. This finding was in keeping with the well documented recovery patterns of these two variables once the immediate high level demands upon the circulo-respiratory system have ceased. The respiratory quotient recovery patterns exhibited an almost perfect linear recovery pattern without the leveling off effect between

the sixth and eleventh minute collection periods. The recovery patterns of these three variables agreed with the patterns that Cooper\(^{10}\) found after slow and fast treadmill runs. Both the heart rate and oxygen consumption curves dropped rapidly during the first two recovery intervals and then assumed a more gradual decline which were near, but still above, the resting values at the sixteenth minute of recovery. The rapid decline of heart rate in the first few minutes following exercise was in agreement with many studies such as the all inclusive study by Cardus and Spencer.\(^{11}\) The rapid decline of oxygen consumption in the oxygen uptake repayment curve was also in agreement with existing research such as was described in the study by Knuttgen.\(^{12}\) The respiratory quotient recovery curve assumed an almost perfect linear pattern that was slightly above the resting level at the eleventh minute and fell below the resting level at the sixteenth minute. This phenomenon

\(^{10}\) Cooper, op. cit.


has been observed by deVries, Issekutz, and Gould. deVries explained that the process represents the removal of lactate from circulation which causes a temporary alkalosis that is compensated for by hypoventilation in recovery.

The interaction between fitness levels and recovery intervals was significant for the heart rate and oxygen consumption variables and nonsignificant for the respiratory quotient variable. The low-average fitness group, in addition to showing a higher heart rate recovery pattern, demonstrated the greatest difference from the high-average fitness pattern at the conclusion of the first minute of recovery. This finding concurred with the findings of Slay, wherein the difference between the high and low fitness groups' recovery rates was significant, showing that the low fitness group exhibited


a higher heart rate during the first five minutes of recovery. In this study, at the conclusion of the sixteen-minute recovery period both groups were still well above resting values. The low-average fitness group had a resting heart rate of 69.1 and a sixteenth minute recovery rate of 93.6 while the high-average fitness group had a resting rate of 64.5 and a recovery rate of 85.3. This indicated that the high-average fitness group even though working at a higher level, recovered faster.

For oxygen uptake the high-average fitness group demonstrated a higher recovery pattern with the most pronounced difference occurring at the end of the first minute of recovery. It is speculated that the greater workload of the high-average fitness group accounted for the first minute difference and that the high-average fitness group developed a higher oxygen debt which accounted for the increased uptake. It is also possible that the high-average fitness group was able to utilize more oxygen during this period, which enabled them to recover faster as was indicated by the lower first minute recovery heart rate they exhibited. The insignificant interaction between fitness level and recovery showed that the differences between the high-average and low-average fitness groups' respiratory quotient recovery
patterns remained essentially the same throughout the recovery periods.

The fast workbout produced significantly higher recovery patterns for all three variables than did the long workbout. This finding contradicts some of the general statements in the literature that related to the question of short versus long duration exercise. The finding is in complete agreement on all three variables in question with the findings of Cooper¹⁸ and also agrees with the findings on heart rate by Shaw.¹⁹ It has been recognized that short intensive exercise is primarily anaerobic in nature and creates a greater oxygen debt than aerobic exercise. Since increased oxygen uptake follows oxygen debt and the respiratory quotient is a measure of the participation of anaerobic glycolysis,²⁰ it is easy to see why these two variables demonstrated a higher pattern. The insignificant interaction of workbout and recovery demonstrated that the heart rate and oxygen uptake differences between the slow and fast workbouts remained essentially the same throughout the recovery period. However, the interaction between workbout and recovery pattern for respiratory quotients was

¹⁸Cooper, op. cit.
¹⁹Slay, op. cit. p. 65.
²⁰Issekutz, op. cit., p. 610.
significant wherein the fast workbout RQ recovery pattern was much higher than the slow workbout at the 1st and 6th minute recovery intervals than at the 11th and 16th. This finding agrees with the findings concerning respiratory quotient reported in the literature. A similar finding was reported by Crakes21 who, when testing trained milers on an all-out treadmill run, found that the fastest runners had higher respiratory quotients. It is apparent that a faster workbout brings into play more anaerobic power which is reflected by higher recovery RQ values.

When the interaction of fitness level and workbout was investigated, it was found that the differences between the high-average fitness and low-average fitness groups on oxygen uptake and respiratory quotient remained uniform for both workbouts. However when heart rate was studied, the high-average fitness group was placed under less stress on the long workbout than on the fast workbout, while the low-average fitness group was placed under about equal stress on both workbouts. This finding, while possibly partially explaining the oxygen uptake and respiratory quotient inconsistencies found earlier, also conflicts with the assumption that the

180 beats per minute heart rate represents the limiting point of physiological working capacity. Astrand et al.,\textsuperscript{22} reported that during maximum exercise at 200 beats per minute or above, the diastolic filling of the heart allowed maximal stroke volume. Alderman\textsuperscript{23} concluded that the average maximum heart rate was higher than 180 beats per minute. The study by Nagle and Bedecke\textsuperscript{24} is representative of the studies that report physiological incompetency occurring at an exercise heart rate of 180 beats per minute. Shepard\textsuperscript{25} pointed out that in steady state exercise the pulse rate of young men tended to plateau at 170-180 beats per minute and very seldom exceeded a rate of 200. For this study it is apparent that the differences found in recovery heart rates indicated that the long workbout did not represent the


same level of stress for the high-average fitness group as it did for the low-average fitness group. It could also be possible that the long workbout was in reality more stressful anaerobically and/or aerobically to the low-average fitness group. This result also lends strength to both sides of the question of intensity versus duration for the development of cardiorespiratory fitness. For if in fact the fast workbout was more stressful to the high-average fitness group and both workbouts were equally stressful for the low-average fitness group it has implications for conditioning programs.

The insignificant interaction of workbout and recovery revealed that the differences between the fast and slow workbouts for heart rate and oxygen consumption remained uniform throughout the recovery period. However, for respiratory quotient a significant interaction was found which indicated that the differences between the two recovery patterns were not uniform throughout the recovery period. This finding is in agreement with the findings of other studies wherein anaerobic-type exercise workbouts produced higher recovery respiratory quotients especially immediately following exercise than those produced by aerobic workbouts.

The interaction of fitness level, workbout and recovery revealed that for heart rate and oxygen uptake,
the differences between the high-average fitness and low-average fitness groups on both workbouts remained essentially the same throughout the recovery period. However, for the respiratory quotient variable, the high-average and low-average fitness groups demonstrated different patterns for the short workbout than for the long workbout especially in the 1st and 6th minutes after exercise. The difference between the workbouts at the 1st and 6th minutes of recovery accounted for the significant interaction. The large difference between the 1st minute RQs of the high-average and low-average fitness groups coincides with the finding that the high-average fitness group was less stressed on the long workbout. Therefore, it was assumed that the low-average fitness group, being stressed more, developed a greater oxygen debt which accounted for the higher first minute RQ. This finding agrees with Henry where he pointed out that people with poor oxygen transport systems demonstrate large oxygen debts and slower rates of pay-off.

The findings of this study revealed that the recovery variables heart rate, oxygen uptake and respiratory quotient demonstrated agreement in their indication of the exercise stress and the rate of recovery. The collection

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and determination of recovery oxygen uptake and respiratory quotient present difficulty due to the fact that the process is time consuming, complex and expensive. Therefore, it is significant to note that recovery heart rate can be used to indicate both the level of exercise stress and the rate of recovery.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The heart rate, oxygen uptake and respiratory quotient recovery patterns of high-average and low-average fitness subjects, following treadmill exercise terminated at a heart rate of 180 beats per minute, vary according to the intensity of the workbout used to achieve the 180 heart rate.

2. A workbout that produces a heart rate of 180 within one minute results in a higher heart rate, greater oxygen uptake and higher respiratory quotients during the recovery period after the cessation of exercise than a workbout in which the criterion heart rate is reached after fifteen minutes of exercise.

3. There is a high relationship between the heart
rate, oxygen uptake and respiratory quotient after the cessation of exercise as indicators of cardiovascular condition.

4. The use of the 180 heart rate as a measure of physiological incompetency, signifying the point at which all individuals have reached their maximum working capacity, is questioned when the physiological responses of persons of different fitness levels, engaging in anaerobic and aerobic exercises, are compared.

RECOMMENDATIONS

1. A study should be done wherein the maximum heart rate is used as the factor for the termination of the exercise bouts rather than a criterion heart rate of 180 beats per minute.

2. A similar study should be done to compare high, average and low fitness groups which have been categorized upon the basis of a maximal oxygen uptake treadmill walk.

3. Research of a similar nature should be done where standardized workbouts are employed for both levels of fitness.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS AND PUBLICATIONS


C. UNPUBLISHED MATERIALS


APPENDIX A

PERSONAL AND PERFORMANCE DATA FOR
THE HIGH AVERAGE FITNESS SUBJECTS

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APPENDIX B

PERSONAL AND PERFORMANCE DATA FOR
THE LOW AVERAGE FITNESS SUBJECTS

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Resting

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Exercise

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6th Minute

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11th Minute

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16th Minute

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<td>.64-.80</td>
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APPENDIX C

MEDICAL CLEARANCE FORMS

INFORMATION FORM

Date_______

Name_________________________Age____Height________Birthday_______

L. F. M.

SMS Address__________________________Phone__________

Home Address__________________________Phone__________

No. St. City State

Parents' or Guardian's Name__________________________

L. F. M.

Parents' Address__________________________Phone__________

No. St. City State

Family Physician's Name__________________________Phone__________

Physician's Address__________________________Phone__________

No. St. City State

Class Schedule_____ Semester 19____ Please indicate the hours that you would be free for exercise testing.

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Previous athletic experience: Sports__________________________

Years participated_________Location__________________________

School City State

Do you know of any injuries or physical health conditions, past or present that you have that would prevent you from engaging in such physical exercise as stair climbing or vigorous running? Yes____ No____. If yes, please describe

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the condition and give the approximate dates

Knee injury?  Yes___ No____, Heart Condition?  Yes___
No____.

How would you rate your physical condition (physical fitness for running)?  ___A. Excellent—able to run a mile around 6 minutes, ___B. Good—able to run a mile around 7 minutes, ___C. Fair—able to run a mile around 8 minutes, ___D. Poor—able to run a mile around 9 minutes, ___E. Very Poor—able to run a mile around 10 minutes.
Dear Dr.,

I am conducting a doctoral dissertation research project under the supervision of the Department of Health, Physical and Recreation Education at Louisiana State University. The study is to be conducted at Southwest Missouri State College in the Kinetoenergetics Laboratory of the Department of Health and Physical Education. The study is designed to compare the oxygen consumption and heart rate recovery curves of subjects of different fitness levels after high intensity and long duration treadmill runs. A brief description of the study is enclosed (Form 400-20).

______________________________ has expressed an interest in participating in the study as a subject. To assure that there are no contraindications to vigorous exercise in his medical history, we are asking you, the family physician, to complete H & PE Form 400-21, also enclosed, and return it in the postage paid envelope. If there are medical contraindications to his participation, would you please indicate their nature on Form 400-21.

Thank you very much for your cooperation.

Sincerely yours,

George E. Simpson, Assistant Professor
Department of Health and Physical Education
Dear Parent:

I am conducting a doctoral dissertation research project under the supervision of the graduate studies committee of the Department of Health, Physical and Recreation Education at Louisiana State University. The study is to be conducted at Southwest Missouri State College in the Kinetoenergetics laboratory of the Department of Health and Physical Education. The study is designed to compare the oxygen consumption and heart rate recovery curves of subjects of different fitness levels after high intensity and long duration treadmill runs. A brief description of the study is enclosed (Form 400-20).

____________________ has expressed an interest in participating in the study as a subject. Since this participation is not a requirement of his regular college program, I have deemed it desirable to secure parental or guardian approval before such participation. Pending such approval, I will seek the approval of your family physician and also the approval of the director of the college health service. If after reading the enclosed description of the study, you are willing to allow your son to participate will you please sign Form H & PE 400-21, also enclosed, and return it in the postage paid envelope.

Your son's participation will aid materially in the completion of the study, and I wish to thank you for your consideration and cooperation. If you desire further information before making a decision, please feel free to contact me.

Sincerely yours,

George E. Simpson, Assistant Professor
Department of Health and Physical Education
Description of Research Study: A Comparison of the oxygen consumption and heart rate recovery curves of subjects of different fitness levels after short and long duration treadmill runs.

Physical fitness in all its ramifications has been a topic of ever increasing interest and study in the United States as well as in other countries. The promotion of proper physical fitness attitudes and practices is one of the major objectives of the physical education profession. This concern, coupled with the concern of the medical profession, has led to cooperative efforts between the two fields in order to determine the most satisfactory manner in which physical fitness may be achieved. One of the problems of how best to achieve physical fitness evolves around the question of the contributions of long duration "endurance-type" exercise as opposed to short, intensive exercise.

It is an established fact that endurance type physical exercise, such as jogging for two miles, contributes to cardiovascular fitness (heart and blood vessels). However, most of the situations in which modern man is called upon to exert himself physically are of the explosive type such as running to catch a bus or playing a fast game of tennis. These short emergency type bursts of physical exertion call for a strong heart and circulatory system which have the capacity to adapt quickly to the stress involved.

The purpose of this research is to compare the post exercise oxygen consumption and heart rate recovery patterns of physically fit subjects with the same recovery patterns of unfit subjects after a 60-second treadmill run and after a 15-minute treadmill walk. The objective of the comparison is to investigate the relationship of both exercise programs to physical fitness as demonstrated by the oxygen and heart rate recovery patterns.
Each subject's medical history will be reviewed by the family physician. In addition, the college physician will review the subject's health exam records that are required prior to entrance in school and participation in physical education classes.

The first procedure will be the administration of a standard physical fitness test to determine each subject's fitness level. The test (Harvard Step-up Test) consists of stepping up and down on a 20 inch bench at a rate of 30 complete steps a minute for five minutes. At the end of the test a heart rate count, when compared to the norm scoring table, will determine his fitness level.

Preliminary to the treadmill exercise the subject's resting heart rate and resting oxygen consumption will be ascertained. Next, each subject will be given a 60-second trial run and a 15-minute trial walk on the motorized treadmill in order to familiarize him with the exercise routine, the treadmill, the oxygen analysis equipment and heart rate recording equipment. Both the run and walk routines may require a few trial runs (2 to 5) in order to progressively adjust the speed and treadmill grade combinations for each subject. These trial runs will start at low intensity and then increase to the specific intensity needed. At all times the subject's heart rate will be monitored through the use of a physiograph. All exercise will stop when a sub-maximal pulse rate of 180 beats a minute is reached, or at any time the subject wants to stop. This pulse rate is no greater than the pulse rate achieved in vigorous physical education classes and is universally used by exercise physiologists in physical fitness testing and research.

The final aspect of the study will consist of a 60-second treadmill run at a speed of about 5 to 8 mph and a grade of approximately 8 to 25 degrees, depending upon the subject, and a 15-minute treadmill walk at a speed of 3.5 mph with the increase of treadmill grade being that specifically determined for each subject in the trial runs, i.e., a one degree increase in grade each minute or 2 to 3 degree increments at 2-3 minute intervals. In both instances, the exercise will cease when the heart rate of 180 beats per minute is reached or
when the time limit is reached and then the pulse rate and oxygen consumption will continue to be monitored for an additional 16 minutes as the subject rests seated in a chair.

The treadmill runs represent exercise stress similar to that experienced in a vigorous physical education class. The investigator will be working under the guidance of Dr. Jack Nelson, Director of the Graduate Studies Program of the Department of Health, Physical Education and Recreation at Louisiana State University and this type research is along the line of research currently being conducted by Dr. Harold Falls, Director of the Kinetoeenergetics Laboratory at Southwest Missouri State College.

George E. Simpson, Assistant Professor
Department of Health & Physical Education
FORM 400-21

PHYSICIAN SIGNATURE FORM

Department of Health and Physical Education
Southwest Missouri State College
Springfield, Missouri
H & PE Form 400-21
Fall and Spring Semesters, _____

This is to certify that I have read H & PE Form 400-21
dated Fall and Spring Semesters, __________, describing
the general nature of a proposed research project. My
review of ______________________________________ medical
history does not reveal any factors which contraindicate
his participation in such research as a subject. It is
my understanding that the exercise stress is similar in
nature to that of a physical education exercise class.

__________________________ M.D.
Position_____________________
Address_____________________
____________________________
Date_________________________

Contraindications:
FORM 400-22

PARENT SIGNATURE FORM

Department of Health and Physical Education
Southwest Missouri State College
Springfield, Missouri
H & PE Form 400-22
Fall and Spring Semesters, ________

This is to certify that I have read H & PE Form 400-20
dated Fall and Spring Semesters, __________, and
I understand the general nature of the research in
which my son, __________________________ will
participate. It is my understanding that the exercise
involved is similar in nature and no more strenuous
than that of vigorous physical education classes. I
further understand his participation is not a require­
ment of any regular college courses, and that he is
participating on a voluntary basis. It is also under­
stood that he may voluntarily terminate his participa­
tion at any time that he does not wish to continue.

__________________________
Parent or Guardian of

__________________________
Date ______________________
This is to certify that I have read H & PE Form 400-20 dated Fall and Spring Semesters, _______________. From this reading and verbal conversation with the investigator I have an understanding of the nature of my proposed participation. It is my understanding that a review of my medical history will be made to insure that there are no contraindications to vigorous exercise. I further understand that my participation is on a voluntary basis, and that I may refuse to continue at any time I so desire.

______________________________
Date____________________________
APPENDIX D

ORIGINAL DATA FOR THE HIGH-AVERAGE FITNESS SUBJECTS

SS. NO. 1  AGE: 20.07  HT: 6'4"  WT: 75.4 KG.  INDEX SCORE: 88.0

60 SECOND RUN
TREADMILL SPEED 8.0 MPH  TREADMILL GRADE 19%
NO. OF TRIALS 5  EXERCISE HEART RATE 186

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>72.0</td>
<td>3.55</td>
<td>.70</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>143</td>
<td>32.39</td>
<td>1.50</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>109</td>
<td>9.23</td>
<td>1.18</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>103</td>
<td>4.72</td>
<td>.87</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>98</td>
<td>5.69</td>
<td>.70</td>
</tr>
</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 5-25%
NO. OF TRIALS 4  EXERCISE HEART RATE 184

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
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</tr>
<tr>
<td>11 MIN.</td>
<td>100</td>
<td>5.95</td>
<td>.73</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>92</td>
<td>4.35</td>
<td>.72</td>
</tr>
</tbody>
</table>
SS. NO. 2 AGE: 21.01 HT. 5'11" WT. 70.00 KG. INDEX
SCORE: 75.7

60 SECOND RUN
TREADMILL SPEED 7.0 MPH  TREADMILL GRADE 18%
NO. OF TRIALS 6  EXERCISE HEART RATE 183

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>67.0</td>
<td>4.92</td>
<td>.82</td>
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<tr>
<td>1 MIN.</td>
<td>148</td>
<td>26.90</td>
<td>1.58</td>
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<tr>
<td>6 MIN.</td>
<td>109</td>
<td>8.86</td>
<td>1.08</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>111</td>
<td>7.26</td>
<td>.85</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>106</td>
<td>6.50</td>
<td>.77</td>
</tr>
</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 3-17%
NO. OF TRIALS 4  EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>67.0</td>
<td>4.92</td>
<td>.82</td>
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<tr>
<td>1 MIN.</td>
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<td>22.75</td>
<td>1.00</td>
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<td>6 MIN.</td>
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</tr>
<tr>
<td>11 MIN.</td>
<td>89</td>
<td>4.39</td>
<td>.71</td>
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<tr>
<td>16 MIN.</td>
<td>86</td>
<td>4.61</td>
<td>.82</td>
</tr>
</tbody>
</table>
S.S. NO. 3 AGE: 23.03 HT: 5' 8 3/4" WT: 70.1
KG. INDEX SCORE: 79.0

60 SECOND RUN
TREADMILL SPEED 7.5 MPH
TREADMILL GRADE 18%
NO. OF TRIALS 7
EXERCISE HEART RATE 182

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>74.5</td>
<td>3.74</td>
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<td>1 MIN.</td>
<td>132</td>
<td>27.19</td>
<td>1.35</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>97</td>
<td>5.09</td>
<td>1.15</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>100</td>
<td>5.21</td>
<td>.78</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>100</td>
<td>5.57</td>
<td>.72</td>
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</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH
TREADMILL GRADE 2-24%
NO. OF TRIALS 4
EXERCISE HEART RATE 179

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
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<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>74.5</td>
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<td>.93</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>97</td>
<td>4.41</td>
<td>1.09</td>
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<td>11 MIN.</td>
<td>95</td>
<td>4.45</td>
<td>.75</td>
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<tr>
<td>16 MIN.</td>
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<td>3.80</td>
<td>.83</td>
</tr>
</tbody>
</table>
SS. NO. 4 AGE: 21.02 HT: 5'9" WT: 68.6 KG. INDEX
INDEX SCORE: 75.7

60 SECOND RUN
TREADMILL SPEED 6.0 MPH TREADMILL GRADE 21%
NO. OF TRIALS 5 EXERCISE HEART RATE 180

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>60.0</td>
<td>3.86</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>133</td>
<td>31.28</td>
<td>1.47</td>
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<tr>
<td>6 MIN.</td>
<td>93</td>
<td>7.55</td>
<td>1.26</td>
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<tr>
<td>11 MIN.</td>
<td>89</td>
<td>5.61</td>
<td>.90</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>86</td>
<td>5.83</td>
<td>.71</td>
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</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH TREADMILL GRADE 0-15%
NO. OF TRIALS 3 EXERCISE HEART RATE 181

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>60.0</td>
<td>3.86</td>
<td>.73</td>
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<tr>
<td>1 MIN.</td>
<td>123</td>
<td>27.88</td>
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</tr>
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<td>6 MIN.</td>
<td>79</td>
<td>5.68</td>
<td>.94</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>77</td>
<td>4.60</td>
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<td>16 MIN.</td>
<td>71</td>
<td>4.66</td>
<td>.69</td>
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</table>
SS. NO. 5 AGE: 20.00 HT: 5'11" WT: 67.4 KG. INDEX SCORE: 85.2

60 SECOND RUN

<table>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>63.5</td>
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<td>.71</td>
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<tr>
<td>1 MIN.</td>
<td>131</td>
<td>34.00</td>
<td>1.33</td>
</tr>
<tr>
<td>6 MIN.</td>
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<td>4.79</td>
<td>1.22</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>96</td>
<td>5.77</td>
<td>.75</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>88</td>
<td>6.56</td>
<td>.58</td>
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</table>

15 MINUTE WALK

<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>63.5</td>
<td>4.01</td>
<td>.71</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>134</td>
<td>26.74</td>
<td>.94</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>92</td>
<td>5.19</td>
<td>.89</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>89</td>
<td>4.57</td>
<td>.63</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>84</td>
<td>4.93</td>
<td>.60</td>
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</table>
SS. NO. 6  AGE:  20.01  HT:  5'6"  WT:  69.0  KG.  INDEX  SCORE:  79.0

**60 SECOND RUN**

<table>
<thead>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>63.5</td>
<td>4.87</td>
<td>.68</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>129</td>
<td>26.00</td>
<td>1.61</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>102</td>
<td>6.70</td>
<td>.92</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>96</td>
<td>5.60</td>
<td>.63</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>84</td>
<td>5.79</td>
<td>.58</td>
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</tbody>
</table>

**15 MINUTE WALK**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
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<td>4.87</td>
<td>.68</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>125</td>
<td>31.69</td>
<td>.96</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>77</td>
<td>4.96</td>
<td>.79</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>79</td>
<td>4.63</td>
<td>.69</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>75</td>
<td>4.51</td>
<td>.69</td>
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</table>
SS. NO. 7  AGE: 21.04  HT: 6'1"  WT: 76.1  KG. INDEX
SCORE: 97.4

60 SECOND RUN

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>59.5</td>
<td>3.52</td>
<td>.84</td>
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<td>1 MIN.</td>
<td>122</td>
<td>29.67</td>
<td>1.60</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>81</td>
<td>7.44</td>
<td>1.25</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>81</td>
<td>6.00</td>
<td>.97</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>78</td>
<td>5.90</td>
<td>.73</td>
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</table>

15 MINUTE WALK

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>59.5</td>
<td>3.52</td>
<td>.84</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>119</td>
<td>31.58</td>
<td>1.09</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>86</td>
<td>5.77</td>
<td>.99</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>81</td>
<td>3.81</td>
<td>.82</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>79</td>
<td>3.80</td>
<td>.79</td>
</tr>
</tbody>
</table>
SS. NO. 8 AGE: 18.05 HT. 5'10½" WT: 71.4 KG.
INDEX SCORE: 80.2

**60 SECOND RUN**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Heart Rate</th>
<th>Oxygen ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>54.5</td>
<td>4.02</td>
<td>.79</td>
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<tr>
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<td>128</td>
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<td>6.65</td>
<td>1.33</td>
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<tr>
<td>11 MIN.</td>
<td>75</td>
<td>6.03</td>
<td>.92</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>73</td>
<td>5.44</td>
<td>.82</td>
</tr>
</tbody>
</table>

**15 MINUTE WALK**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Heart Rate</th>
<th>Oxygen ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>54.5</td>
<td>4.02</td>
<td>.79</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>91</td>
<td>30.48</td>
<td>1.05</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>69</td>
<td>5.88</td>
<td>1.03</td>
</tr>
<tr>
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<td>66</td>
<td>4.28</td>
<td>.85</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>69</td>
<td>3.64</td>
<td>.78</td>
</tr>
</tbody>
</table>
SS. NO. 9   AGE: 22.05   HT: 5'7"   WT: 76.4 KG. INDEX
SCORE: 83.9

**60 SECOND RUN**

TREADMILL SPEED 6.0 MPH   TREADMILL GRADE 26%

NO. OF TRIALS 6   EXERCISE HEART RATE 183

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>56.5</td>
<td>2.93</td>
<td>.86</td>
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<td>1 MIN.</td>
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<td>33.99</td>
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<td>6 MIN.</td>
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<td>8.12</td>
<td>1.35</td>
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<td>99</td>
<td>6.17</td>
<td>.90</td>
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<tr>
<td>16 MIN.</td>
<td>99</td>
<td>5.80</td>
<td>.67</td>
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</tbody>
</table>

**15 MINUTE WALK**

TREADMILL SPEED 3.5 MPH   TREADMILL GRADE 0-24%

NO. OF TRIALS 4   EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>56.5</td>
<td>2.93</td>
<td>.86</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>126</td>
<td>29.34</td>
<td>.95</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>76</td>
<td>5.70</td>
<td>.81</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>80</td>
<td>5.78</td>
<td>.66</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>76</td>
<td>4.38</td>
<td>.59</td>
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</tbody>
</table>
SS. NO. 10  AGE: 20.08  HT: 5'11½"  WT: 73.3 KG.
INDEX SCORE: 95.7

60 SECOND RUN
TREADMILL SPEED 5.5 MPH  TREADMILL GRADE 22%
NO. OF TRIALS 5  EXERCISE HEART RATE 179

<table>
<thead>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
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<td>1 MIN.</td>
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<td>7.07</td>
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<td>80</td>
<td>6.26</td>
<td>.86</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>74</td>
<td>5.28</td>
<td>.72</td>
</tr>
</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 1-21%
NO. OF TRIALS 3  EXERCISE HEART RATE 180

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>62.0</td>
<td>5.37</td>
<td>.75</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>123</td>
<td>31.20</td>
<td>.90</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>85</td>
<td>5.59</td>
<td>.78</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>77</td>
<td>5.46</td>
<td>.61</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>74</td>
<td>5.03</td>
<td>.54</td>
</tr>
</tbody>
</table>
SS. NO. 11 AGE: 18.06 HT: 5'11\frac{1}{4}" WT: 81.6 KG
INDEX SCORE: 102.9

### 60 SECOND RUN

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>65.0</td>
<td>4.02</td>
<td>.79</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>138</td>
<td>29.35</td>
<td>1.40</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>92</td>
<td>7.30</td>
<td>1.37</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>96</td>
<td>6.65</td>
<td>.96</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>89</td>
<td>5.57</td>
<td>.83</td>
</tr>
</tbody>
</table>

### 15 MINUTE WALK

<table>
<thead>
<tr>
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<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
<td>65.0</td>
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<td>.79</td>
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<td>116</td>
<td>32.70</td>
<td>.94</td>
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<tr>
<td>6 MIN.</td>
<td>88</td>
<td>6.10</td>
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<td>11 MIN.</td>
<td>80</td>
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<td>.75</td>
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<td>80</td>
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<td>.69</td>
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</table>
SS. NO. 12  AGE: 18.03  HT:  6'2" WT:  74.6 KG, INDEX SCORE: 109.1

60 SECOND RUN

TREADMILL SPEED 6.5 MPH  TREADMILL GRADE 25%
NO. OF TRIALS 3  EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
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<tr>
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<td>1.77</td>
</tr>
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<td>6 MIN.</td>
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<td>10.75</td>
<td>1.30</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>100</td>
<td>8.88</td>
<td>.85</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>95</td>
<td>7.63</td>
<td>.73</td>
</tr>
</tbody>
</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 4-26%
NO. OF TRIALS 3  EXERCISE HEART RATE 178

<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
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<td>.70</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>138</td>
<td>35.45</td>
<td>1.08</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>91</td>
<td>7.92</td>
<td>.82</td>
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<tr>
<td>11 MIN.</td>
<td>87</td>
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<td>.71</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>87</td>
<td>6.10</td>
<td>.63</td>
</tr>
</tbody>
</table>
SS. NO. 13  AGE: 20.04  HT: 5'9½''  WT: 61.2 K.G.
INDEX SCORE: 79.8

60 SECOND RUN

TREADMILL SPEED 6.0 MPH  TREADMILL GRADE 25%
NO. OF TRIALS 4  EXERCISE HEART RATE 180

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
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<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>69.5</td>
<td>4.03</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>147</td>
<td>28.33</td>
<td>1.91</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>105</td>
<td>8.15</td>
<td>1.34</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>101</td>
<td>7.17</td>
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<tr>
<td>16 MIN.</td>
<td>99</td>
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</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 1-21%
NO. OF TRIALS 2  EXERCISE HEART RATE 179

<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>69.5</td>
<td>4.03</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>138</td>
<td>32.40</td>
<td>1.09</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>94</td>
<td>7.01</td>
<td>.77</td>
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<tr>
<td>11 MIN.</td>
<td>89</td>
<td>6.46</td>
<td>.66</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>86</td>
<td>6.01</td>
<td>.60</td>
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</table>
SS. NO. 14  AGE: 19.09  HT: 6'3½"  WT. 69.5 KG. INDEX SCORE: 104.9

60 SECOND RUN

TREADMILL SPEED 6.0 MPH  TREADMILL GRADE 17%

NO. OF TRIALS 3  EXERCISE HEART RATE 179

<table>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>58.5</td>
<td>4.22</td>
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</tr>
<tr>
<td>1 MIN.</td>
<td>110</td>
<td>33.89</td>
<td>1.23</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>82</td>
<td>5.18</td>
<td>.92</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>86</td>
<td>4.56</td>
<td>.63</td>
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<td>16 MIN.</td>
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<td>4.78</td>
<td>.59</td>
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</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 0-21%

NO. OF TRIALS 3  EXERCISE HEART RATE 182

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>58.5</td>
<td>4.22</td>
<td>.72</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>87</td>
<td>28.66</td>
<td>.98</td>
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<tr>
<td>6 MIN.</td>
<td>72</td>
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<td>.78</td>
</tr>
<tr>
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<td>76</td>
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<td>.67</td>
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<td>76</td>
<td>4.35</td>
<td>.60</td>
</tr>
</tbody>
</table>
SS. NO. 15 AGE: 18.08 HT: 6'2" WT: 85.4 KG. INDEX SCORE: 76.8

**60 SECOND RUN**

TREADMILL SPEED 6.0 MPH  
TREADMILL GRADE 16%

**NO. OF TRIALS 2**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>80.5</td>
<td>5.09</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>119</td>
<td>29.56</td>
<td>1.20</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>88</td>
<td>7.06</td>
<td>.94</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>76</td>
<td>4.36</td>
<td>.68</td>
</tr>
<tr>
<td>16 MIN.</td>
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<td>5.13</td>
<td>.68</td>
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</table>

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**15 MINUTE WALK**

TREADMILL SPEED 3.5 MPH  
TREADMILL GRADE 2-20%

**NO. OF TRIALS 2**

<table>
<thead>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
<td>80.5</td>
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</tr>
<tr>
<td>1 MIN.</td>
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</tr>
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<td>6 MIN.</td>
<td>95</td>
<td>5.17</td>
<td>.88</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>95</td>
<td>5.56</td>
<td>.76</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>92</td>
<td>5.23</td>
<td>.77</td>
</tr>
</tbody>
</table>
APPENDIX E

ORIGINAL DATA FOR THE LOW-AVERAGE FITNESS SUBJECTS

SS. NO. 1 AGE: 24.03 HT: 6'1" WT: 78.0 KG. INDEX SCORE: 55.3

60 SECOND RUN

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>77.5</td>
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<td>.70</td>
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<tr>
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<td>1.07</td>
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<td>11 MIN.</td>
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<td>5.63</td>
<td>.71</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>88</td>
<td>5.08</td>
<td>.72</td>
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15 MINUTE WALK

<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>77.5</td>
<td>4.27</td>
<td>.70</td>
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<tr>
<td>1 MIN.</td>
<td>137</td>
<td>22.47</td>
<td>.90</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>95</td>
<td>4.55</td>
<td>.89</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>95</td>
<td>3.25</td>
<td>.84</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>94</td>
<td>4.55</td>
<td>.65</td>
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</table>
SS. NO. 2 AGE: 22.08 HT: 5'10 3/4" WT: 100.5
KG. INDEX SCORE: 36.3

60 SECOND RUN
TREADMILL SPEED 6.0 MPH TREADMILL GRADE 16%
NO. OF TRIALS 5 EXERCISE HEART RATE 185

<table>
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<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
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<tr>
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</tr>
<tr>
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<td>108</td>
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<td>1.20</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>108</td>
<td>5.39</td>
<td>.93</td>
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<tr>
<td>16 MIN.</td>
<td>106</td>
<td>5.00</td>
<td>.80</td>
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15 MINUTE WALK
TREADMILL SPEED 3.5 MPH TREADMILL GRADE 0-15%
NO. OF TRIALS 3 EXERCISE HEART RATE 183

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>68.0</td>
<td>3.37</td>
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<tr>
<td>1 MIN.</td>
<td>146</td>
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<td>6 MIN.</td>
<td>109</td>
<td>5.25</td>
<td>.93</td>
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<tr>
<td>11 MIN.</td>
<td>101</td>
<td>3.37</td>
<td>.70</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>98</td>
<td>3.27</td>
<td>.67</td>
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</table>
SS. NO. 3  AGE: 21.04  HT: 6'2"  WT: 115.0  KG. INDEX 
SCORE: 39.1

**60 SECOND RUN**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
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<td>92</td>
<td>4.57</td>
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</tr>
<tr>
<td>16 MIN.</td>
<td>97</td>
<td>4.52</td>
<td>.75</td>
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**15 MINUTE WALK**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
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<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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<tbody>
<tr>
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<td>.68</td>
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<tr>
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<td>78</td>
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SS. NO. 4  AGE: 25.02  HT: 5'10½"  WT: 72.4 KG. INDEX SCORE: 47.0

60 SECOND RUN

TREADMILL SPEED 5.5 MPH  TREADMILL GRADE 20%

NO. OF TRIALS 7  EXERCISE HEART RATE 181

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
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<th>R.Q.</th>
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<tr>
<td>REST</td>
<td>80.5</td>
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<td>.72</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>144</td>
<td>22.79</td>
<td>1.65</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>107</td>
<td>8.49</td>
<td>1.24</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>103</td>
<td>6.91</td>
<td>.92</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>102</td>
<td>6.63</td>
<td>.71</td>
</tr>
</tbody>
</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 0-12%

NO. OF TRIALS 3  EXERCISE HEART RATE 177

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>80.5</td>
<td>4.62</td>
<td>.72</td>
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<tr>
<td>1 MIN.</td>
<td>140</td>
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</table>
SS. NO. 5  AGE: 22.06  HT: 5'11"  WT: 74.0 KG.

INDEX SCORE: 44.1

60 SECOND RUN

TREADMILL SPEED 5.0 MPH  TREADMILL GRADE 22%
NO. OF TRIALS 6  EXERCISE HEART RATE 179

<table>
<thead>
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<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>65.5</td>
<td>3.88</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>137</td>
<td>26.61</td>
<td>1.54</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>104</td>
<td>10.90</td>
<td>1.20</td>
</tr>
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<td>96</td>
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15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 0-18%
NO. OF TRIALS 3  EXERCISE HEART RATE 178

<table>
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<tr>
<th>TIME PERIOD</th>
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<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>65.5</td>
<td>3.88</td>
<td>.73</td>
</tr>
<tr>
<td>1 MIN.</td>
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<td>29.80</td>
<td>1.23</td>
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<tr>
<td>6 MIN.</td>
<td>95</td>
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<td>11 MIN.</td>
<td>86</td>
<td>5.46</td>
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<tr>
<td>16 MIN.</td>
<td>88</td>
<td>5.36</td>
<td>.62</td>
</tr>
</tbody>
</table>
SS. NO. 6  AGE:  20.00  HT:  5'7"  WT:  67.7  KG.  INDEX  
SCORE:  52.0

60 SECOND RUN

TREADMILL SPEED  5.0 MPH   TREADMILL GRADE  20%

NO. OF TRIALS  3

EXERCISE HEART RATE  180

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>62.5</td>
<td>3.47</td>
<td>.81</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>142</td>
<td>25.32</td>
<td>1.67</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>99</td>
<td>6.73</td>
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</tr>
<tr>
<td>11 MIN.</td>
<td>94</td>
<td>6.18</td>
<td>.84</td>
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<tr>
<td>16 MIN.</td>
<td>93</td>
<td>5.06</td>
<td>.73</td>
</tr>
</tbody>
</table>

15 MINUTE WALK

TREADMILL SPEED  3.5 MPH   TREADMILL GRADE  1-14%

NO. OF TRIALS  2

EXERCISE HEART RATE  182

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>62.5</td>
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<td>94</td>
<td>5.26</td>
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<tr>
<td>16 MIN.</td>
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<td>5.10</td>
<td>.67</td>
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</table>
SS. NO. 7 AGE: 20.07 HT: 5'11" WT: 69.5 KG.
INDEX SCORE: 63.0

**60 SECOND RUN**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.73</td>
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**15 MINUTE WALK**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>62.5</td>
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SS. NO. 8 AGE: 22.08 HT: 5' 8 3/4" WT: 67.4 K.G.
INDEX SCORE: 50.8

60 SECOND RUN

<table>
<thead>
<tr>
<th>TREADMILL SPEED</th>
<th>TREADMILL GRADE</th>
<th>NO. OF TRIALS</th>
<th>EXERCISE HEART RATE</th>
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</thead>
<tbody>
<tr>
<td>5.5 MPH</td>
<td>18%</td>
<td>4</td>
<td>179</td>
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<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>77.0</td>
<td>4.86</td>
<td>.85</td>
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<td>1.29</td>
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<td>.58</td>
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15 MINUTE WALK

<table>
<thead>
<tr>
<th>TREADMILL SPEED</th>
<th>TREADMILL GRADE</th>
<th>NO. OF TRIALS</th>
<th>EXERCISE HEART RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 MPH</td>
<td>1-16%</td>
<td>2</td>
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<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/Min</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
<td>77.0</td>
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<td>.85</td>
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<td>1 MIN.</td>
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<td>106</td>
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<td>11 MIN.</td>
<td>96</td>
<td>5.13</td>
<td>.78</td>
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<tr>
<td>16 MIN.</td>
<td>92</td>
<td>4.98</td>
<td>.74</td>
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</table>
SS. NO. 9  AGE: 19.10  HT: 5'10"  WT: 73.1 KG.
INDEX SCORE: 62.7

60 SECOND RUN
TREADMILL SPEED 5.5 MPH  TREADMILL GRADE 21%
NO. OF TRIALS 4  EXERCISE HEART RATE 177

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>64.0</td>
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<td>16 MIN.</td>
<td>93</td>
<td>5.88</td>
<td>.70</td>
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</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 2-21%
NO. OF TRIALS 2  EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.00</td>
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<td>11 MIN.</td>
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<td>6.35</td>
<td>.67</td>
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<td>16 MIN.</td>
<td>88</td>
<td>5.43</td>
<td>.64</td>
</tr>
</tbody>
</table>
SS. NO. 10  AGE: 22.00  HT: 6'1\(\frac{1}{2}\)"  WT: 84.0 KG
INDEX SCORE: 36.8

**60 SECOND RUN**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>80.5</td>
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<td>.81</td>
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<td>1 MIN.</td>
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<td>1.47</td>
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<td>1.08</td>
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<td>11 MIN.</td>
<td>106</td>
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<td>.88</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>103</td>
<td>5.33</td>
<td>.66</td>
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</table>

**15 MINUTE WALK**

<table>
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<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>80.5</td>
<td>4.37</td>
<td>.81</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>141</td>
<td>26.39</td>
<td>1.09</td>
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<td>6 MIN.</td>
<td>109</td>
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<td>.71</td>
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<td>4.99</td>
<td>.69</td>
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</tbody>
</table>
SS. NO. 11 AGE: 22.00 HT: 5'7" WT: 89.5 KG. INDEX SCORE: 29.2

60 SECOND RUN

TREADMILL SPEED 5.0 MPH TREADMILL GRADE 13%

NO. OF TRIALS 4 EXERCISE HEART RATE 179

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.28</td>
</tr>
<tr>
<td>6 MIN.</td>
<td>91</td>
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<td>1.00</td>
</tr>
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<td>11 MIN.</td>
<td>93</td>
<td>4.03</td>
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<tr>
<td>16 MIN.</td>
<td>89</td>
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<td>.75</td>
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</tbody>
</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH TREADMILL GRADE 0-12%

NO. OF TRIALS 2 EXERCISE HEART RATE 182

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>78.5</td>
<td>3.77</td>
<td>.77</td>
</tr>
<tr>
<td>1 MIN.</td>
<td>145</td>
<td>22.21</td>
<td>1.17</td>
</tr>
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<td>6 MIN.</td>
<td>102</td>
<td>5.32</td>
<td>.96</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>101</td>
<td>4.47</td>
<td>.89</td>
</tr>
<tr>
<td>16 MIN.</td>
<td>98</td>
<td>5.35</td>
<td>.77</td>
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</tbody>
</table>
SS. NO. 12  AGE:  25.09  HT:  5'8"  WT.  76.2  KG.

INDEX SCORE:  33.7

60 SECOND RUN

TREADMILL SPEED 5.0 MPH  TREADMILL GRADE 19%
NO. OF TRIALS 3  EXERCISE HEART RATE 181

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>68.0</td>
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<tr>
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<td>27.95</td>
<td>1.34</td>
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<td>99</td>
<td>6.73</td>
<td>.99</td>
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<td>16 MIN.</td>
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<td>4.49</td>
<td>.65</td>
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</table>

15 MINUTE WALK

TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 0-14%
NO. OF TRIALS 3  EXERCISE HEART RATE 180

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>68.0</td>
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<td>94</td>
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<td>16 MIN.</td>
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<td>.61</td>
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</table>
SS. NO. 13 AGE: 21.02 HT: 6'1" WT: 100.3 KG.
INDEX SCORE: 44.4

### 60 SECOND RUN

**TREADMILL SPEED 5.5 MPH**

**TREADMILL GRADE 19%**

**NO. OF TRIALS 5**

**EXERCISE HEART RATE 178**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
<td>REST</td>
<td>54.0</td>
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<tr>
<td>16 MIN.</td>
<td>79</td>
<td>5.37</td>
<td>.66</td>
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</tbody>
</table>

### 15 MINUTE WALK

**TREADMILL SPEED 3.5 MPH**

**TREADMILL GRADE 0-19%**

**NO. OF TRIALS 3**

**EXERCISE HEART RATE 178**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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<tbody>
<tr>
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<td>.77</td>
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<tr>
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<td>4.65</td>
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</table>
SS. NO. 14  AGE: 21.07  HT: 5'10\frac{1}{2}"  WT: 90.5  KG.
INDEX SCORE: 29.1

60 SECOND RUN

<table>
<thead>
<tr>
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<th>HEART RATE</th>
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<th>R.Q.</th>
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<tr>
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<td>1.24</td>
</tr>
<tr>
<td>11 MIN.</td>
<td>92</td>
<td>5.99</td>
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<tr>
<td>16 MIN.</td>
<td>97</td>
<td>5.64</td>
<td>.64</td>
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15 MINUTE WALK

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
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</thead>
<tbody>
<tr>
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<td>1.29</td>
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<tr>
<td>11 MIN.</td>
<td>92</td>
<td>5.32</td>
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<tr>
<td>16 MIN.</td>
<td>91</td>
<td>4.35</td>
<td>.68</td>
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</tbody>
</table>
SS. NO. 15  AGE: 22.00  HT: 5'9"  WT: 82.3 KG.
INDEX SCORE: 35.4

60 MINUTE RUN
TREADMILL SPEED 5.0 MPH  TREADMILL GRADE 17%
NO. OF TRIALS 3  EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6 MIN.</td>
<td>102</td>
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<td>1.04</td>
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<td>11 MIN.</td>
<td>99</td>
<td>4.92</td>
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<tr>
<td>16 MIN.</td>
<td>102</td>
<td>4.81</td>
<td>.74</td>
</tr>
</tbody>
</table>

15 MINUTE WALK
TREADMILL SPEED 3.5 MPH  TREADMILL GRADE 0-11%
NO. OF TRIALS 2  EXERCISE HEART RATE 178

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>HEART RATE</th>
<th>OXYGEN ML/KG/MIN</th>
<th>R.Q.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REST</td>
<td>81.5</td>
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<td>.71</td>
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<tr>
<td>1 MIN.</td>
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<td>4.18</td>
<td>.71</td>
</tr>
<tr>
<td>16 MIN.</td>
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<td>2.97</td>
<td>.70</td>
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VITA

The author was born in Kirksville, Missouri, on July 24, 1934. His elementary and high school education were acquired in Columbia, Missouri.

He received the Bachelor of Science degree in 1957 with a major in Physical Education and a minor in Biological Science. The degree was awarded by Southwest Missouri State College, Springfield, Missouri.

The author served two years as an infantry officer in the United States Army. He was awarded the Master of Science Degree by Louisiana State University in 1960 with a major in Health. The author was employed during this period as a Graduate Teaching Assistant in the Department of Health, Physical and Recreation Education at Louisiana State University.

Following this period, he taught one year at the University of Kansas City and four years as an instructor of Physical Education at Southwest Missouri State College, Springfield, Missouri.

In September, 1965, the author returned to Louisiana to begin work toward the Doctor of Education Degree with a major in Physical Education and a minor in
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The author is presently Assistant Professor of Health and Physical Education in the Department of Health and Physical Education at Southwest Missouri State College, Springfield, Missouri.
Candidate: George E. Simpson

Major Field: Physical Education

Title of Thesis: Oxygen Consumption and Heart Rate Recovery Curves of Subjects of Different Fitness Levels After Short and Long Duration Treadmill Runs

Approved:

Jack K Nelson
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

Jane Adams
Hein E Jent

J. Drury

Ralph E Stabin

Date of Examination:

November 30, 1971