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By
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* * * * *

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CHAPTER I

INTRODUCTION

Within recent years, interval training has been almost universally accepted as the best method of training athletes for endurance-type activities. The conventional training procedures have all but been abandoned except by the armed forces which still use basic calisthenics and marching to train their troops.

The scientific basis underlying any training procedure or method entails an understanding and application of the physiological overload principle.\(^1\) What this means, in essence, is that when the body is placed in a stressful situation, it compensates by adapting to this situation so that future application of the same stress result in less strain. The process of progressively increasing exercise stress on one or more systems of the living body for a period of time is referred to as conditioning or training.\(^2\)

The outcomes from a general conditioning program would be the following:

1. Increase of strength,

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2. Increase of muscular endurance,
3. Increased flexibility of muscles and tendons,
4. Better neuromuscular coordination,
5. Increased cardiovascular or cardiorespiratory endurance.

When an athlete is training for activities requiring strength, the exercise program should be one of a small number of repetitions with high resistance. This involves working a muscle near its maximum capacity by performing seven to ten repetitions which stress the muscle near the physiological overload zone. After the muscle has adjusted to the stress placed on it and the performer is able to increase the number of repetitions to twelve, then more resistance is added. This results in fewer repetitions and the addition of more stress to the working muscle group. As training progresses, less strain is experienced, and more resistance can again be added.

Activities resulting in more than twenty repetitions develop muscular endurance. Exercises such as using pulley weights, doing jumping jacks, or walking are types of activities that develop muscular endurance.

Flexibility is the range of motion about a joint and is dependent on the anatomical structure of the joint and the degree to which the muscles and tendons about the joint can be stretched. Activities such as sit reach, torso rolls, and back stretching are examples of flexibility exercises.

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3Mathews, pp. 319-322.  
4Ibid., p. 320.
Neuromuscular coordination refers to the ability to make smooth accurate voluntary movements of the body. This is mainly a function of the motor portion of the central nervous system. Neuromuscular coordination is developed primarily through practice of a specific activity.

Development of cardiorespiratory endurance involves a large number of repetitions with low resistance. Activities such as distance running or distance swimming involve maximum cardiovascular or cardiorespiratory function. Therefore, progressive cardiovascular stress or overload must be applied resulting in greater physiological adaptation with less strain. In a training program where cardiorespiratory endurance is the main objective, it is thought quality or intensity is more important than quantity or time spent doing a given activity.\(^5\) To illustrate this, if an untrained subject is given a test, such as the Harvard Step Test or maximum oxygen consumption, then is placed in a well-designed standardized training program for a given period of time, his work capacity will increase as measured after the training period by these tests. When the level of a subject’s physical condition reaches a plateau, increased time of work, i.e., greater distance of running, does not bring about any notable gain in his condition. However, if the work rate or quality is increased while the duration is held constant, then the

\(^5\)Heusner, p. 3.
subject will increase his work capacity to a higher level.
Improvement from one level to the next involves achieving
adaptation to graduated increases in intensity of the work.6

Presently, the most accepted training method of im-
proving cardiorespiratory function is interval training. The
important variables in an interval program are--

1. Distance the subjects are required to run,
2. The number of times the subjects run the es-
tablished distance,
3. The time which the coach or instructor requires
the subjects to cover the particular distance; i.e. eight 110 yards in sixteen seconds for each
run,
4. The amount of time allowed for rest between each
run,
5. The number of days each week the subjects exer-
cise (swim or run).

It is not known at the present time what possible
combinations of these variables would bring about the
greatest gains in the shortest time. Actually, with five
variables there would be an infinite number of combinations
when one considers changes in intensity.

The primary aim of the basic army physical training
program is to condition soldiers to be combat ready which re-
quires all phases of fitness. The army system of training
includes calisthenics, rifle drill, obstacle course drills,

6Ibid., p. 4.
and marching. One of the pronounced shortcomings in the army training program is the lack of activities which develop cardiorespiratory endurance. Marching is supposed to improve endurance, however, the type of conditioning that occurs from marching is mostly muscular endurance.

Interval training on the other hand is geared to the development of cardiorespiratory function because it stresses the cardiovascular system near the physiological overload zone.

The present practice of calisthenics, marching, combatives, and obstacle course work used by the armed services requires two to three fold the time required for interval training. It has also been established that because of the greater control in the quality of work which is the essence of interval training, greater gains in cardiorespiratory fitness would be noted from this type of conditioning over a conventional or recreational type training program and bring about these gains in a shorter period of time.

Statement of the problem

The purpose of this study was to determine the effects of interval training, a simulated army training of calisthenics and marching, and a recreational program of

of activities on the cardiorespiratory endurance of twenty-five men.

Three tests of fitness were used to evaluate the results of the conditioning programs. They were (1) maximum oxygen consumption, (2) the Harvard Step Test, and (3) the Army Physical Fitness Test.

Sub-problems. 1. To determine the relationship of maximum oxygen consumption to the Harvard Step Test, and the Army Physical Fitness Test.

2. To determine the effects of the interval and army training programs on maximal oxygen consumption for athletes, non-athletes with a \(\text{Vo}_2 > 46.50 \text{ ml./kg. body weight}\), and non-athletes with a \(\text{Vo}_2 < 46.50 \text{ ml./kg. body weight prior to training}\).

3. To determine the effect of interval and army training programs on the Harvard Step Test for athletes, non-athletes with a \(\text{Vo}_2 > 46.50 \text{ ml./kg. body weight}\), and non-athletes with a \(\text{Vo}_2 < 46.50 \text{ ml./kg. body weight prior to training}\).

4. To determine the effect of interval and army training programs on the Army Physical Fitness Test for athletes and non-athletes with a \(\text{Vo}_2 > 46.50 \text{ ml./kg. body weight}\), and non-athletes with a \(\text{Vo}_2 < 46.50 \text{ ml./kg. body weight prior to training}\).

Selection of criteria for measuring physical fitness

Maximum oxygen consumption. The ability to perform heavy work is dependent on the amount of oxygen the cardiorespiratory system is able to take up, transport, and deliver
to the working tissues. This is the best measure of physical fitness when stated in terms of \( \dot{V}O_2 \text{ ml./kg. body weight} \).^8

**The Harvard Step Test.** One of the best indexes in evaluating condition is recovery heart rate following heavy work. Recovery heart rate is even more meaningful when used to evaluate the progress of each individual in a training program.\(^9\) The Harvard Step Test is a valid test; it is easy to administer and requires minimal equipment.

**The Army Physical Fitness Test.** This test was selected primarily because the U. S. Army uses it to evaluate physical fitness of soldiers.

**Definition of terms**

**Interval training.** A system of conditioning where intervals of work and rest are used with the primary aim of developing cardiorespiratory function.

**Maximum oxygen consumption.** A measure of the aerobic work capacity of an individual. It is the maximum ability of the cardiorespiratory system to take up, transport, and deliver oxygen to the working tissues during maximal exercise.

**Athlete.** A person who participates in sport and is in excellent physical condition.

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Non-athlete. A person who does not participate in sport, however, his condition may range from poor to good.
CHAPTER II

REVIEW OF RELATED LITERATURE

Cardiovascular and cardiopulmonary tests have been experimented with in the United States since 1884 when an Italian physiologist, Angelo Mosso, invented the ergograph. It was Dr. Mosso's original premise that the ability of a muscle to do work was dependent on the ability of the circulatory system to deliver fuel to the working tissues and to carry away waste materials.

Since that time many tests have been developed to determine cardiopulmonary fitness. Among the early tests for cardiovascular efficiency was Crampton's Blood Ptosis Test. ¹ This test consists of comparing the values of reclining heart rate and blood pressure with the values of standing heart rate and blood pressure.

When this test was administered to a large number of high school students, Crampton found that a change from the reclining to the erect position resulted in an increase in heart rate of from 0 to 44 beats per minute. In addition, he found a variation in systolic pressure from +10 mm Hg to +10 mm

Hg. The conditioned students had a systolic blood pressure of 8 to 10mm Hg and showed no increase in heart rate upon standing. On the other hand, the students in poor condition had little if any systolic pressure rise and, in some cases, the pressure was even lower on standing with an increase in heart rate of as much as 44 beats per minute.

The Schneider Test was used to determine the efficiency of soldiers during World War I. This test was empirically devised by Schneider, and the items consist of—

a) Reclining pulse rate,
b) Systolic blood pressure,
c) Standing pulse rate,
d) Increased pulse rate after standing,
e) Difference in systolic blood pressure over reclining blood pressure,
f) Pulse rate increase just after exercise,
g) Return of pulse rate to standing normal after exercise.

Norms were established for this test, however, reliability on a test-retest basis has been variously reported. If the test is given with extreme care, reliability is about .86.3

Espenshade4 studied the effect of staircase running on fifty-three students at Wellesley College and correlated the results with the Schneider Test. The coefficient was .78 which indicates that the Schneider Test does measure endurance.


3Ibid., pp. 91-93.

Cureton obtained the following correlations with the Schneider Test: mile run, .65; two-mile run, .63; 1000-yard time minus (10 x 100 time), .55; three-mile steeple chase, .50; composite of four endurance runs, .81. These conflicting correlation results seem to indicate that the test is not very good in testing cardiorespiratory endurance.5

Gallagher and Brouha,6 Karpovich,7 and Mathews et al.8 have explained that the value of post-exercise heart rate during recovery after a standard hard exercise gives a good measure of an individual's physical fitness. This indicates that the better physical condition a person possesses, the more rapid will be his recovery heart rate, i.e., athletes in good condition have a faster recovery heart rate than individuals in poor condition. Also, the more exhaustive the work, the longer will be the recovery period.

Dill points out that physiological measurements show that an athlete, after maximal effort lasting ten seconds, may not be back to normal in an hour or possibly even


twenty-four hours, since there are indications that the process of recovery is not really complete in one day. Probably no sprinter can run 100-yards in his record time every day or perhaps every week.9

Astrand criticizes this use of recovery heart rate and defines fitness as the ability to do prolonged, heavy, muscular work and the ability of the cardiorespiratory system to take up, transport, and give off oxygen to the working tissues.10 He states,

Experience has shown that the investigation of different functions during recovery from heavy work does not give reliable information about the reaction of these systems to the work. For one and the same person the correlation, such as, the pulse rate during a constant work and pulse rate at a certain time after the end of work, is relatively high, but, the decline from a certain level of pulse rate follows with varying speed in one individual as compared with another, even if the physical condition is roughly the same. If the aim is to follow one and the same individual during a training period, recovery values can be used, but not in a comparison of physical fitness between different individuals.

It should be emphasized that the results of the criticized tests certainly can give a high correlation to the individual's performance. The pulse rate, for example, is gradually reduced at rest, during work and recovery from such work during a period of training. Even if the work time is so short that energy is primarily delivered anaerobically, some correlation between the results obtained and the aerobic work capacity can be

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assumed. A good standard of physical condition presupposes a rapid adaptation of the circulatory and respiratory organs to the demand of work and the aerobic part is relatively small. The uncertainty of the results from similar indirect methods must, however, be fairly great and often impossible to avoid.  

Other factors that may affect the results of cardiac functional tests are the amount of rest before the test, the time following the last meal, and emotional factors which might appreciably affect the results.  

Gallagher and Brouha and their associates developed the Harvard Step Test in the Harvard Fatigue Laboratory during World War II. This test was constructed for the purpose of measuring the ability of the body to adapt itself to and recover from strenuous exercise. Essentially, the test classifies people into three groups; least fit, fit, and most fit. The validity of the Harvard Step Test was determined by endurance running on the treadmill, maximum heart rate per minute, and blood lactate levels. Studies on Harvard undergraduates showed that athletes scored higher with less variable scores than did non-athletes, and increased their scores with more training. If an athlete terminated training, his scores were correspondingly lower. 

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11 Ibid., p. 326.
12 Mathews, Stacy and Hoover, p. 363.
13 Gallagher and Brouha, p. 34.
There are two forms of the Harvard Step Test. They are the long form and the short form. In the long form, the subject steps up and down on a 20-inch bench at a cadence of thirty steps per minute. He continues this work for as long as he can up to five minutes. The pulse count is taken from one to one and one-half minutes, two to two and one-half minutes, and three to three and one-half minutes after cessation of the exercise. The physical efficiency is computed from the following formula:

\[
\text{Index} = \frac{\text{duration of exercise in seconds} \times 100}{2 \text{ (sum of the pulse counts in recovery)}}
\]

The standards based on data obtained from 8,000 college students are as follows:

- below 55: poor
- 55-64: low average
- 65-79: average
- 80-89: good
- above 90: excellent

The short form of the Harvard Step Test consists of the same procedure as the long form, however, the pulse count is only taken from one to one and one-half minutes after exercise. The scoring of the short form is as follows:

\[
\text{Index} = \frac{\text{duration of exercise in seconds} \times 100}{5.5 \times \text{pulse count}}
\]

Standards for the short form are:

- below 50: poor
- 50-80: average
- above 80: good

Justification for the use of recovery pulse rate as a measure of physical fitness has been offered by many experts.
such as A. V. Boch who in 1928 found that during exercise the pulse curve alone quite accurately measures the physical state.\(^{14}\)

Elbel and Green found that pulse rates following exercise in the step test were affected by the height of the bench, the duration of the exercises, and the cadence to be held. When any one of the factors was increased, the post-exercise heart rates also increased.\(^{15}\)

Taddonio and Karpovich, working with eighty-two trained trackmen, found that there is no significant correlation between scores made on the Harvard Step Test and the order of finish in three different types of running events; cross country, marathon, and sprints. They found that the marathon runners had the most difficulty with the Harvard Step Test, since they were not accustomed to lifting the legs high. The investigators found a significant rank difference correlation (rho) of .63 among non-experienced intramural cross-country runners and the score on the Harvard Step Test.


This indicates that the test is more reliable when administered to relatively non-experienced runners.16

Rodahl et al. studied 712 male and female students from age eight to twenty-two; he compared several aspects of physical fitness. Among the conclusions drawn, one statistically significant correlation was found to exist, between maximum oxygen uptake and a modification of the Harvard Step Test. The modification was a variation of the step height in relation to the height and weight of the individual.17

Michael and Gallen working with seventeen varsity basketball players administered a one-minute step test on a 17-inch bench at a pace of 36 steps per minute during a 16-week training period. They again gave the test during the post-season period at ten and twenty week intervals. The results indicated that the recovery pulse rate count made significant changes during the training period. Significance was found at the .05 level of confidence after three weeks of training and at the .01 level of confidence in six weeks. Minimum changes occurred after the six-week period. They also found that the pulse rate increased significantly ten weeks after the season ended. This indicates that the


conditioning levels are not maintained very long after the conditioning period ends. 18

Howell, Hodgsen and Sorenson equated two groups of seventeen subjects on the basis of the modified Harvard Step Test. The control group participated in regular physical education, while the experimental group took part in circuit (interval) training twice a week for a period of four weeks. At the end of the four-week period, all subjects were re-tested on the modified Harvard Step Test. The investigators concluded that circuit training over a four-week period twice a week caused a statistically significant improvement in the Step Test ($t = 4.94$). The control group had no significant improvement on the Step Test. 19

The Behnke Step Test was developed by members of the Experimental Diving Unit, Washington, D.C. This test was used primarily for the selection of candidates for Deep-Diving School. The test has two parts, the cardiovascular phase and the endurance phase. The cardiovascular phase consists of twenty step-ups in thirty seconds on an 18-inch bench. The sitting pulse is counted before the exercise, and pulse rate counts are taken during the periods 5-20 seconds


and 105-135 seconds after the completion of the step-ups. The cardiovascular score is computed as the total of the two post-exercise pulse rates. This scoring method provides a range of values between 54 which is good and 90 which is poor. The endurance phase consists of the same exercise as in the cardiovascular phase, but the exercise is continued to exhaustion or to the point where less of cadence occurs. Scoring is based on the number of seconds a person can maintain the exercise.20

Cook and Wherry, working with 120 naval enlisted men, ran correlations between the endurance phase of the Behnke Test, the Schneider Test, and the Harvard Step Test. The Behnke Test correlated .231 with the Harvard Step Test and .038 with the Schneider Test. The Harvard and the Schneider had a .082 correlation. This indicates that these tests which purport to measure the general trait of physical fitness do not accurately evaluate what they are supposed to measure. It was the conclusion of the investigators that one of the main reasons for this low correlation was the day to day variation in blood pressure and pulse rate.21

Fowler and Gardner, working with forty-six cardiac and fourteen muscular dystrophy patients at the University of


21Ibid., pp. 94-110.
California Medical Center at Los Angeles, administered a number of different tests to the above mentioned subjects in order to measure nine specific areas of motor performance. They found that children with congenital heart disease or asthma had marked decreases in physical working capacity but only slight changes from their predicted scores in most motor performance tests such as the Kraus Weber Test. Submaximal-work-load-cardiovascular tests had a low or insignificant relationship to most tests of motor skills and performance. Most motor-performance and cardiovascular tests were highly specific, showed little correlation to each other, and varied in relationship to height, weight, and physique. These variables played a minor role in the motor performance tests with the possible exception of the endurance events. Physical working capacity, however, correlated highly with many of these factors. Cardiovascular and motor performance tests had a similar relationship to age and sex. Both showed increases with age and a superiority of boys over girls. Physical working capacity had less overlap at the earlier ages and less fluctuation or decrease in performance especially among girls on motor performance tests.22

On the basis of the above mentioned study, fitness apparently depends on the character of the test, and a patient must be severely or acutely ill or have a neuromuscular disease before significant changes occur in motor fitness performance.

The Army Physical Efficiency Test was devised during World War II to measure the principal factors in general physical fitness which are strength, endurance, agility, and coordination. The original battery consisted of ten items, however, Esslinger and McGloy validated the test by selecting from a number of tests those items which showed the greatest differences between conditioned and non-conditioned troops. In order to facilitate administrative economy, the test was finally reduced to five different items and called the Army Physical Fitness Test. The test items are as follows:

1. pull-ups
2. squat jumps
3. push-ups
4. sit-ups
5. 300-yard shuttle run.

Variations of the test consist of a 250-yard shuttle run or a substitution of a one-minute squat thrust for the 300-yard shuttle run when the test must be done indoors.

Bookwalter, utilizing 1,269 army cadets as subjects, reported no relationship between the Harvard Step Test and the Army Physical Fitness Test. This would seem reasonable since the Harvard Step Test is an endurance-type (aerobic) activity whereas most of the items on the Army Physical Fitness Test are strength, agility, and coordination tests.


Fitness Test are strength (anaerobic) activities except for the 300-yard shuttle run.25

Henry and Berg felt that the tests developed during the World War II period were not valid in terms of what they were supposed to measure. Twenty-three freshmen track and basketball players were tested before and after the training and competitive season on the following items:

1. Time required to run 75 yards one day and 300 yards on subsequent days.
2. Stool stepping to exhaustion on an 18-inch bench at the rate of 40 steps per minute, scored as duration in time units.
3. Oxygen debt and carbon dioxide production per kilogram of body weight and their recovery heart rates expressed as time required for 50 per cent recovery after a 4-minute stool stepping test.

Results showed that the physiological measures of oxygen debt and carbon dioxide production are more effective measures of fitness than the other performance tests, however, there were some significant gains on the performance tests. It was the investigator's conclusion that work capacity can only be determined accurately by direct methods such as oxygen debt measurements, and that reduction in oxygen debt due to conditioning tended to show only a small positive correlation with individual improvement in performance.26

25Ibid., p. 201.

Maximum oxygen uptake

The first references relative to oxygen consumption were reported in a text by Bainbridge. Studies by Fletcher and Brown showed that exercise was dependent on oxygen supply to the muscle, and that muscular work almost immediately increases oxygen intake and consumption. Benedict and Ethcart postulated in 1913, as did Lindhard and Beethby in 1915, that oxygen consumption per minute varied almost directly with the amount of work being done in the same time, and the relationship was so close that the oxygen-consumption of the body during exercise could be taken as a measure of work intensity. This was the beginning of the oxygen debt concept, but it was not until 1922 that A. V. Hill and his associates studied oxygen consumption of athletes while they were running, and concluded from this study that the athlete went into debt for oxygen which had to be repaid during recovery. This initiated the present "oxygen debt" concept.

Within the past twelve years, however, maximal oxygen uptake has been measured and proven to be the best measure of fitness by such investigators as Åstrand and Rhyming, Asmussen, Karpovich, and Mathews. For example, in 1954, Åstrand and Rhyming said,

An individual's capacity for heavy prolonged muscular work will first of all be dependent upon the supply

---


of oxygen to the working muscles. In types of work which engage large groups of muscles, the limiting factor for maximal oxygen intake (aerobic capacity) will probably be the capacity and regulation of the oxygen transporting system. The aerobic capacity probably is the best measure of a person's physical endurance.

They further state,

The maximal oxygen intake probably varies with the muscular mass, and the ratio of muscular mass to body weight should, in many instances, be an important factor in determining the individual's capacity for hard work. Thus maximum oxygen uptake per kilogram of body weight will give a good conception of physical fitness.29

Karpovich points out that when the body is at rest, it uses from 200 to 300 cc. of oxygen each minute. During heavy work the demand for oxygen may increase 20-fold over resting values. If exercise is moderate, the oxygen intake will rise gradually until a plateau is reached. This plateau is called the steady state. During steady state, oxygen intake is equal to oxygen demand. This balance is called aerobic work. When work exceeds oxygen intake, such as in sprints, the work is done anaerobically. Anaerobic work can only be performed for short periods.30

Oxygen debt is the ultimate limiting factor in exercise carried to exhaustion, and this represents the expenditure of chemical energy previously stored in the body. The


30Karpovich.
rate at which any given subject will accumulate an oxygen debt will depend on the intensity of the work he performs, however, conditioning can increase a person's oxygen debt capacity. An athlete who can take up more oxygen during exercise can do a greater amount of work than his non-conditioned counterpart. Figure 1 shows this relationship.

**FIGURE 1**

RELATIONSHIP OF MAXIMUM OXYGEN UPTAKE BETWEEN ATHLETES AND NON-CONDITIONED SUBJECTS

From this, it follows that oxygen debt is the limiting factor in work capacity. When an individual reaches his maximum oxygen debt tolerance, exhaustion occurs, and work must be either terminated or reduced considerably. However, the total amount of work an individual can perform is the

---

sum of his maximum attainable oxygen intake overtime plus his oxygen debt.32

Astrand points out that there are many physiological factors which directly determine one's maximal oxygen uptake:

1. Pulmonary ventilation
2. Minute volume of the heart
3. Rate of oxygen and carbon dioxide diffusion in the alveoli
4. Oxygen saturation of the blood
5. The rate of blood flow through the muscles
6. The conditions of oxygen diffusion in muscle capillaries, to the tissue
7. The hydrogen ion concentration of the blood
8. The hemoglobin content of the blood.33

Asmussen stated,

When a large proportion of the muscle in the organism is engaged in work, the circulatory and respiratory system will be the determining factor for the working capacity. When small muscle groups are engaged, it is the local circulation delivering the oxygen to the muscle fibers that sets the limit. In well-trained athletes, maximal oxygen uptakes above 4 liters per minute can be maintained for over an hour when large muscle groups are at work. The highest recorded oxygen uptake, 5.6 liters per minute, was achieved by a Swedish cross country skier.34

Mathews et al. explain that

The single most important factor in physical condition is the ability to take in oxygen. Maximal oxygen uptake is the most significant factor when we compare the athlete and the sedentary person.35

35Mathews, Stacy and Hoover, p. 324.
He concludes by stating, "The maximum oxygen uptake during exercise is probably the most valid measure we have of cardiovascular condition."\(^{36}\)

Heusner classifies exercise according to levels of oxygen requirements.

1. Aerobic work; oxygen demand is met
2. Anaerobic work; oxygen demand is not met.\(^{37}\)

Aerobic work consists of activity that is of low enough intensity that the subject's oxygen intake is sufficient to take care of oxygen requirements, and no significant oxygen debt occurs. Anaerobic work on the other hand is of sufficient intensity that oxygen requirements are greater than oxygen intake, therefore, oxygen debt develops.

Whenever a person undergoes anaerobic work, he develops two forms of oxygen debt.\(^{38}\) These are termed alactic or alactacid oxygen debt, and lactic or lactacid debt. Figure 1 shows a very rapid recovery for the first minute following exercise. The alactic acid debt is repaid quite rapidly, but there is no biological explanation for this. The repayment of the lactic acid debt occurs much more slowly, since the acid must be buffered to sodium lactate. This process requires one to two hundred times the period required to overcome alactic debt.\(^{39}\) It is probably this factor which

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\(^{36}\)Ibid., p. 362.  \(^{37}\)Heusner, p. 13.

\(^{38}\)Mathews, Stacy and Hoover, pp. 326-7.  \(^{39}\)Ibid.
would limit an athlete's performance if he had to compete in strenuous events within an hour of each other.

Karpovich points out that if an athlete's maximum oxygen intake is 4 liters per minute and the maximum oxygen debt he can accumulate is 15 liters, if he exercises at a rate requiring 5 liters per minute, the athlete will only be able to maintain this level of activity for 15 minutes.\(^\text{40}\)

The most reliable means of measuring physical fitness, then, is maximal oxygen uptake.\(^\text{41}\) The subject must be working at maximal capacity while expired air is collected for one minute. The volume and composition of the expired air allow determination of oxygen consumption.

Åstrand and Rhyming suggested that the individual's aerobic capacity per kilogram of body weight per minute will give a good measure of his physical fitness. They presented a nomogram which they claimed could be used to estimate an individual's maximum oxygen uptake within an error of \(\pm 6.7\) per cent from heart rate of oxygen uptake values measured during submaximal bicycle-riding or bench stepping.\(^\text{42}\) The nomogram was based on young subjects in good physical condition. Later studies by Åstrand extended the nomogram to

\(^\text{40}\)Karpovich, p. 61.


\(^\text{42}\)Åstrand and Rhyming, pp. 218-221.
include 129 male subjects in the age range from 20 to 69 years. He explained that a correction factor for increased age must be used in order to obtain the \( \pm 6.7 \) pre cent value.\(^{43}\)

Teraslinna and Ismail working with Astrand's nomogram report a correlation coefficient of .92 between the Astrand nomogram prediction and actual measured maximum oxygen uptake values which is somewhat better than that originally reported by Astrand.\(^{44}\)

Issekutz et al. measured the oxygen uptake and carbon dioxide output of thirty-two untrained subjects during submaximal work on the bicycle ergometer and attempted to assess maximal oxygen uptake by the calculation of work R. Q. (respiratory quotient) minus resting R. Q. They felt that R. Q. difference increases logarithmically with the work load, and that maximal oxygen uptake is reached at a R. Q. difference value of 0.40 during maximum work. By extrapolating the increase, they could predict the maximum oxygen uptake. Results show that they were able to predict maximum oxygen uptake within \( \pm 10 \) per cent.\(^{45}\)

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\(^{43}\) Astrand.


Falls et al. working with eighty-seven adult male subjects tried to estimate the maximum oxygen uptake of the subjects from results of the AAHPER Youth Fitness Test. They found that maximum oxygen uptake per kilogram of body weight can be estimated with reasonable validity on the basis of the AAHPER Youth Fitness Test. The 600-yard run-walk was the most related test item in the test battery to maximal oxygen uptake.46

de Vries and Klafs studied the relationship of five submaximal tests with maximum oxygen uptake using sixteen physical education major students. One of the tests was the Harvard Step Test. Using raw score data, they found a slightly negative correlation -.008, however, a significant correlation of .766 (beyond the .01 level of confidence) was found when the Harvard Step Test scores were compared to maximum oxygen consumption per kilogram of body weight.47

Army physical training

The army physical conditioning program is primarily concerned with the preparation of the individual to perform assigned military missions. The program entails conditioning


exercises, obstacle and confidence courses, posture training, mass games, team athletics, swimming, and life saving. These activities contribute to the progressive development of strength, endurance, agility, and coordination of the soldier.⁴⁸

There are three basic principles which regulate the execution of the army training program.

1. Moderate beginning. Physical conditioning should start with a moderate amount of exercise. This beginning should be geared to the current physical condition of the men. Nothing is gained by giving the men so much activity at the start that they suffer unduly from muscular soreness during the first weeks of exercise. Such a practice should be discouraged, for it results in an unfavorable attitude toward physical conditioning. This becomes evident in a tendency to perform the exercises improperly.

2. Gradual progression. As applied to physical conditioning, gradual progression is the increase of the amount of exercise designed to raise the level of physical fitness. For example, Drill One (par. 5 1 a) starts with 5 repetitions and is gradually increased to 12 repetitions over a 16-week cycle of training.

3. Overload principle. The degree of muscular development acquired is proportional to the demands made on the muscles. Little or no exercise results in a loss of strength and endurance. Moderate exercise merely uses the muscle tissue present in the body without creating a need for it to improve its functioning. The overload principle is: Muscle improvement and development is proportionate to the demand imposed on the muscles. Demand must increase as ability increases if improvement is to continue.⁴⁹


⁴⁹Ibid., pp. 8-9.
There are three stages in bringing soldiers to the desired physical condition:

1. **The Toughening Stage.** This stage is encountered when poorly-conditioned men exercise vigorously. The men go through a period of muscular stiffness, soreness, and recovery. Normally, this stage lasts from one to two weeks.

2. **The Slow Improvement Stage.** In this stage the improvement is fairly rapid at first but becomes progressively slower. This period lasts from six to sixteen weeks, depending on the age and previous conditioning of the men.

3. **The Sustaining Stage.** After passing through the toughening and slow improvement stages, the men reach a high level of fitness beyond which there is little improvement. The objective of training in the sustaining stage is to maintain men at this level of physical fitness.

The overall objective of the Army training program is to develop soldiers who are physically capable and ready to perform their duty assignment or combat role and to aid in the continuance of health and fitness through exercise. To reach this goal, physical conditioning activities must be aimed first at developing strength in adequate amounts to perform required duties and enough endurance to sustain activity over a long period of time.

The calisthenics program is aimed at the development of posture, strength, and endurance. Most of the posture calisthenics are stretching exercises such as toe touch, back extension, and windmill. Examples of strength calisthenics are push-ups, squat-jumps, and lunges. Some

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50Ibid., p. 10.  
51Ibid., pp. 5-10.
endurance exercises are jumping jack, stationary run, and diagonal squat thrust. There are thirty-six separate exercises grouped into three sets of twelve known as the "army daily dozen." (See Appendix A.)

In addition to the calisthenics, there is rifle drill (exercises with a rifle) obstacle course training, leg exercises, combatives, team games, relays, swimming, and marching.

**Interval training**

The forerunner to interval training was the fartlek system. This involved running that required strenuous, but untimed bursts of effort at a time when the athlete felt like running hard. This was followed by walking or jogging.

The body recovered while running slowly, but the athlete did not stop for the entire training distance. The fartlek (Swedish for speed play) system was developed in Scandanavia, and the great Finnish distance runners, Kohlemainen and Pikhala, used this training method effectively. The fartlek system had such merit that many American coaches are still using it to supplement their interval training methods.52

The first runner to use a non-systematized form of interval training, in 1932, was Kusecinski, a Polish distance runner who ran intervals after his cross country workout.53


53Ibid., p. 89.
Probably the first coach to use a system of interval training was Waldemar Gerschler, guided by a physiologist named Dr. Herbert Reindell. From 1935 to 1940, Gerschler trained Rudolph Harbig who set a number of European records. World War II brought an end to research in training methods, and it was not until after the war that research in interval training was continued.

The first great runner to use a system of interval training was Emil Zatepek of Czechoslovakia who won three gold medals in the 1952 Olympic Games. His training was definitely interval in nature, but it would be considered old-fashioned by present standards.

Until the mid-1950's, interval training was used more or less on a trial and error basis. More emphasis was placed on quantity than on quality of the practice session. By 1953, the elements of interval training were standardized as to distance and pace of the slow and fast intervals. Also, the total time to be spent in a workout was replaced by a total distance to be covered or by the number of fast intervals to be completed. In other words, the athlete had a pre-determined daily work schedule to complete rather than running spontaneously when he was in the mood.

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54Ibid. 55Heusner, p. 2.
56Doherty, p. 87.
Doherty quotes from a paper presented by Professor Joseph Neckor in which he lists eight scientific bases for interval training.

1. Scientific studies confirm modern endurance training methods in their assumption that training by alternating periods of greater and lesser exertions does produce great development of related organ systems, such as metabolism, circulation, breathing, etc.

2. A low degree of intensity during the work phase (long distance running) produces a high level of adaptation of the circulatory system but a low level of adaptation to the muscular system.

3. A highest level of intensity during the work phase with long recovery periods and few repetitions (sprinting) produces a high-level of adaptation of the muscle system but a low-level adaptation of the circulatory system.

4. The intensity of work must be graded to individual capacities.

5. The intensity of the work must be great enough to obtain adaptation both in the muscle and the heart. This can be gained by an intensity of exercise of at least 60 per cent and at most 80 per cent of maximal capabilities.

6. Since the related systems function more economically during the later work periods, interval training should not be done in equal doses of intensity. Rather, the early work periods involve the least stress; later periods, the greatest stress.

7. Scientific studies confirm that the phase of exertion should be relatively short, depending, of course, upon the rate of work. "I am of the opinion that the work phase must not exceed 30 seconds, assuming correct intensity of exertion. Exertions longer than 1-1/2 minutes are certainly not successful. Despite these optimums, we can use longer and uninterrupted exertions to develop coordinations and other changes within muscles. They should not, however, be the main part of the training."

8. The exertion of the heart, as shown by stroke volume, is greatest immediately after the stopping of work. This period of greatest stroke-volume has a duration of from 30 to 60 seconds, depending upon the intensity of the work and individual adaptation. We conclude therefore that 30
seconds should be a minimum recovery interval and that, in general, the maximum should not be above three minutes. Frequency of pulse is one valid indicator of recovery. It should not be above 180 at any time and need not be below 120 to 130 at the beginning of the next run.57

When an athlete undergoes strenuous exertion such as that experienced during interval training, there is a marked initial increase in stroke volume. When he approaches exhaustion, the stroke volume begins to fall off in spite of maximal demands for more blood. This seems to come about as a result of elevated heart rate to the point that either diastolic filling is inadequate or peripheral resistance at various places in the vascular system is elevated. When exercise is terminated, stroke volume is again increased but to a higher level than was achieved initially. The duration of this increase in stroke volume lasts about thirty seconds. This serves as a direct stimulus for adaptation of the heart muscle to the stress of the severe exercise.58 It can be surmised, then, that the rest interval is not a recovery period but rather a period of adjustment. Recovery occurs after termination of the daily training period.

**Summation of the literature**

There is a general opinion among investigators that maximum oxygen uptake is the best measure of fitness. The varying reports relative to the Harvard Step Test and the

57Ibid., p. 107. 58Heusner, p. 4.
Army Physical Fitness Test would cause one to feel skeptical as to the value of the latter-mentioned tests.

It is generally concluded that the test for maximum oxygen uptake is the best test for fitness, however, it must be remembered that elaborate equipment is necessary to measure oxygen uptake. Most schools and colleges are not endowed with such elaborate equipment or the staff competent to make the evaluation. Though the Harvard Step Test, and in some instances, the Army Physical Fitness Test, may not be as definitive in measuring fitness as maximum oxygen uptake, they are readily available to physical educators.

Also, it must be remembered that the Harvard Step Test has been used extensively in assessing cardiorespiratory function and as a screening device to locate individuals who are low in cardiorespiratory function.

The literature contains the variables relative to interval training. There are too many to list, however, the most important variables are summarized below--

1. The work interval including distance and time
2. The recovery interval including distance, time, and type (resting, walking, or jogging)
3. Repeats of work and recovery intervals
4. Number of work days per week.

When a given standard or plateau is achieved, a change is made in one or two of the variables to a higher intensity level.
CHAPTER III

METHODS AND PROCEDURES

Description of the subjects

Eighteen non-athletes and seven athletes were selected as the subjects for this study. The athletes were in training prior to the beginning of the study. The average age in years of the twenty-five subjects was 20.36; the average height was 68.78 inches, and the average weight was 152.14 (69.07 kilograms). Twenty-two of the subjects were undergraduate students, two were graduate students, and one had graduated the previous year and was teaching college level physical education. All subjects were given a thorough medical examination to assure that they were in good health.

The twenty-five subjects were divided into three groups on the basis of maximum oxygen uptake by matching a high maximum \( \dot{V}O_2 \) with a low maximum \( \dot{V}O_2 \) until each group had eight members.* The mean and standard deviation for each group were then calculated to be sure the groups were equated.

The first group took part in an interval training program of running; the second group participated in a

*The interval group had nine members since it was assumed that this group might lose a number due to the strenuous activity of the program.
simulated army training program of calisthenics and marching, while the third group took part in recreational activities such as trampoline, swimming, archery, and golf for two hours each training day.

The Fitness Tests

**Maximum oxygen consumption**

The rate of oxygen consumption during exercise increases proportionally to the work performed. When the work load is severe, exercise can only be maintained for a relatively short period of time because the demand for oxygen is greater than the supply. At a given time during the short bout of exercise, the maximum ability of the cardiorespiratory system to take up oxygen is reached. The measure of oxygen consumption during one minute just prior to exhaustion is called the maximum \( \dot{V}O_2 \).

Maximum oxygen consumption represents the maximal rate of aerobic energy release for work and it is attained during the second, third, fourth, or fifth minute of exhaustive work in which the energy requirement of the exercise exceeds the maximal capacity for aerobic metabolism. The primary physiological factors that limit maximum oxygen consumption are the rate of oxygen transport by the circulation, the oxygen being used by the tissues, and the oxygen diffusing capacity of the lungs.
The maximal oxygen consumption is probably the best single physiological indicator of an individual's capacity for maintaining extreme heavy work.1 When exercise exceeds the ability of a subject to take up oxygen, the work must be terminated or sharply reduced.

Selection of work load. The subjects were oriented to laboratory procedures and equipment. The ergometer used to measure work was the Jaquet Universal Ergostat (bicycle ergometer). The bicycle could be calibrated from a low power output of 5 watts at 30 revolutions per minute to a high power output of 450 watts at 90 revolutions per minute. The proper rate of revolutions was maintained by the subject observing an electrical synchronized unit in front of the bicycle connected to the sprocket wheel. All subjects rode the bicycle for five minutes at a rate of 60 revolutions per minute at the pedals.

Most of the subjects were worked up to their maximum work tolerance in a series of three rides, however, when maximum work tolerance could not be determined in three rides, they were evaluated in four and in some cases five rides.

It was found that in some instances a subject had a higher \( \hat{V}O_2 \) for a lower work load. In this case, the work load was used that yielded the highest \( \hat{V}O_2 \).

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The collection of expired gas. While the subjects rode the bicycle ergometer, they wore a nose clip and breast plate which supported a mouth piece with a two-way valve. This allowed inhalation of room air and the expired air to be channeled into a 350-liter Collins Chain-Compensated spirometer. Expired volumes of gas were measured from a meter stick attached to the compensating chain of the spirometer. During the first and third minute of work, the spirometer was washed out with expired air from the subject to prevent contamination of the gas collected during the fifth minute.

Determination of maximal oxygen consumption. After the five-minute near-maximum ride on the bicycle ergostat, expired air from the spirometer was directed into a two-liter evacuated rubber sampling bladder. This gas was transferred to a Beckman E-2 Oxygen Analyzer for oxygen concentration readings. Room air concentration of oxygen was determined prior to the run and the expired oxygen readings were subtracted from this figure to determine oxygen extraction.

Harvard Step Test

The Harvard Step Test is designed to measure the ability of the body to adapt to and recover from strenuous work. The index of this test is based on one to one and one-half minute; two to two and two and one-half minute; and three to three and one-half minute recovery heart rate after the exercise.
The test entails stepping up and down on a 20-inch bench at a cadence of 30 steps per minute. The exercise is continued for five minutes or for as long as the subject can continue to maintain cadence.

A stop watch was used to time the work period and also to determine the time to take the post-exercise heart rates.

The Sanborn Viso Cardiette Model 51 was used to record post-exercise electrocardiograms. Heart rate was determined by counting the number of beats for fifteen seconds and multiplying by four.

**Army Physical Fitness Test**

The Army Physical Fitness Test measures the basic elements of strength, agility, and endurance. The test items are:

1. Pull-ups (total number)
2. Two-minute sit-ups (total number in two minutes)
3. Push-ups (total number)
4. Squat jumps (total number)
5. Three hundred yard shuttle-run (time in seconds)

Each test item has a possible 100 points and the total score is a sum of all the points achieved on the five test items.

The equipment used for the Army Physical Fitness Test is a horizontal bar for pull-ups and a stop watch to time the two-minute sit-ups and the 300-yard shuttle run.

The subjects were tested at maximum work tolerance to determine maximum oxygen uptake before and after training.
The post-training maximum work load was re-evaluated through a series of four rides. Also, index scores on the Harvard Step Test and scores on the Army Physical Fitness Test were recorded before the study began and again after the seven-week training period.

Conditioning Programs

The groups met every weekday for the training session. The total training period lasted seven weeks.

Interval training

Essentially this program aims at developing cardio-respiratory endurance through increased intensity of exercise. The following is an example of a typical interval workout:

8X440X1:15X5:00

In which

1. 8 is the number of repetitions
2. 440 is the running distance
3. 1:15 is the running time interval in minutes
4. 5:00 is the rest interval in minutes between each 440-yard run.

Generally, two sets of intervals were executed during each workout. The distances used in this study were 110, 220, 440, and 880 yards. All subjects ran the prescribed distance for any given daily workout. Throughout the training period, intensity was developed by increasing the number of
repetitions or increasing the distance, or decreasing the running time or decreasing the rest time.

Before each practice session, the group did some warm-up exercises such as push-ups, sit-ups, and stretching exercises. After each set of intervals, recovery heart rates were recorded during the first, third, and fifth minute.

Heart rates were taken by palpation of the carotid artery at the end of the first, third, and fifth minute following an interval set for a period of five minutes (see Figures 2 and 3). The daily workout schedule is contained in Appendix A.

Army training

The Army training program is quite extensive and not adaptable to this study, therefore, a simulated Army training program of calisthenics and marching was devised for the seven-week training period. Calisthenics were performed daily and marching distance was increased from two miles to twelve miles during the training period (see Appendix A). Three-fourths of the marching was at a cadence of 120 steps per minute (quick time), and one-fourth was done at a cadence of 180 steps per minute (double time).

Heart rates were recorded by palpation of the carotid artery for a period of five minutes following calisthenics and marching during the first, third, and fifth minute
INTERVAL TRAINING GROUP
REGRESSION ANALYSIS FOR RECOVERY HEART RATES TAKEN DURING FIVE MINUTES
FOLLOWING RUNNING TWO SETS OF 110 AND 220 YARDS

FIGURE 2
INTERVAL TRAINING GROUP

REGRESSION ANALYSIS FOR RECOVERY HEART RATES TAKEN DURING FIVE MINUTES FOLLOWING RUNNING TWO SETS OF 440 YDS AND ONE SET OF 880 YDS

FIGURE 3
following exercise by each subject (see Figure 4). The entire program is contained in Appendix A.

The recreational group

The recreational group met for two hours a day, five days per week to participate in recreational activities such as golf, swimming, archery, trampoline, scuba, tumbling, and gymnastics. The daily activities are listed in Appendix A.
ARMY TRAINING GROUP

REGRESSION ANALYSIS FOR RECOVERY HEART RATES TAKEN FOR FIVE MINUTES FOLLOWING SETS OF CALISTHENICS AND MARCHING

FIGURE 4
THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE EFFECT OF INTERVAL TRAINING IN RUNNING, A SIMULATED ARMY TRAINING PROGRAM OF CALISTHENICS AND MARCHING, AND A RECREATIONAL PROGRAM OF ACTIVITIES ON TWENTY-FIVE SUBJECTS. EIGHTEEN WERE NON-ATHLETES, AND SEVEN WERE ATHLETES.

DESCRIPTION OF THE DATA


TO DETERMINE WHETHER CHANGES OCCURRED AS A RESULT OF THE THREE ACTIVITY PROGRAMS IN EACH OF THE THREE TESTS (MAXIMUM $\dot{V}O_2$ ML./KG. BODY WEIGHT, HARVARD STEP TEST, AND ARMY
Physical Fitness Test) the mean differences were tested using the $t$ test as described by Edwards.¹

In order to further evaluate the progress made by the interval and army groups, recovery heart rates were analyzed by regression analysis.

The relationship of one test to another (maximum $\dot{V}O_2$ ml./kg. body weight, Harvard Step Test and Army Physical Fitness Test) was demonstrated using correlation analysis.

As the sample contained both well-conditioned athletes and non-athletes, the question was posed as to whether well-conditioned subjects reacted to the exercise stress differently than the subjects who were in poor condition at the beginning of the experiment. As a result, the data were subjected to further statistical analysis in order to lend better understanding to this question. Detailed description of the analysis appear later in the chapter.

Statistical Analysis

To determine whether changes occurred as a result of the three activity programs on each of the three tests the mean differences were analyzed for significant changes.

Mean differences among the three groups

Maximum oxygen uptake per kilogram body weight.
Table 1 contains the data before and after training for the three groups (interval, army, and recreation) for maximum \( \dot{\text{VO}}_2 \text{ ml./kg. body weight} \). The analyses demonstrate that the army and recreation training groups did not improve significantly in their ability to take up oxygen. The internal group, however, had a significant gain in maximum \( \dot{\text{VO}}_2 \) (\( P < .05 \)). Probability levels for the various degrees of freedom were obtained from Snedecor.\(^2\)

**TABLE 1**

**MEAN DIFFERENCES IN MAXIMUM \( \dot{\text{VO}}_2 \text{ ml./kg. BODY WEIGHT FOR THE THREE GROUPS**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Before</th>
<th>After</th>
<th>Diff.</th>
<th>( \sqrt{\text{Diff.}} )</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td>9</td>
<td>48.64</td>
<td>51.36</td>
<td>2.72</td>
<td>.963</td>
<td>2.829 &lt; .05</td>
<td></td>
</tr>
<tr>
<td>Army</td>
<td>8</td>
<td>50.66</td>
<td>49.86</td>
<td>.786</td>
<td>1.296</td>
<td>.614 N.S.</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>8</td>
<td>49.14</td>
<td>45.86</td>
<td>-3.28</td>
<td>1.927</td>
<td>1.702 N.S.</td>
<td></td>
</tr>
</tbody>
</table>

Mean differences among the three groups on the Harvard Step Test. Table 2 contains the data for the three groups before and after training for the Harvard Step Test. The analyses show that significant gains were made by the interval (\( P < .01 \)) and army (\( P < .01 \)) training groups. The recreational group did not show significant improvement.

TABLE 2
MEAN DIFFERENCE IN HARVARD STEP TEST
INDICES FOR THE THREE GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>M_Below</th>
<th>M_After</th>
<th>Diff.</th>
<th>D(Diff.)</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td>7</td>
<td>81.09</td>
<td>95.01</td>
<td>13.92</td>
<td>2.35</td>
<td>5.92</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Army</td>
<td>8</td>
<td>81.42</td>
<td>98.0</td>
<td>16.58</td>
<td>2.73</td>
<td>6.07</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Recreation</td>
<td>7</td>
<td>71.50</td>
<td>78.78</td>
<td>7.28</td>
<td>2.978</td>
<td>2.445</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Mean differences among the three groups on the Army Physical Fitness Test. Table 3 contains the data for the three groups on the before and after training results for the Army Physical Fitness Test. The analyses show that significant improvement was made by the interval (P < .01), army (P < .01), and recreational (P < .05) groups.

TABLE 3
MEAN DIFFERENCE ON THE ARMY PHYSICAL FITNESS TEST FOR THE THREE GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>M_Before</th>
<th>M_After</th>
<th>Diff.</th>
<th>D(Diff.)</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td>6</td>
<td>314</td>
<td>356.17</td>
<td>42.17</td>
<td>9.645</td>
<td>4.372</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Army</td>
<td>6</td>
<td>291</td>
<td>342</td>
<td>51</td>
<td>8.795</td>
<td>5.799</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Recreation</td>
<td>3</td>
<td>228</td>
<td>265.3</td>
<td>37.3</td>
<td>7.921</td>
<td>4.710</td>
<td>&lt; .01</td>
</tr>
</tbody>
</table>

Regression analysis

Recovery heart rates were recorded each training day for the interval and army groups and since recovery heart rate is one of the best measures of fitness status, regressions were calculated to accurately determine the progressive
fitness of the two groups during the training period. Regressions for recovery heart rate are presented in Figure 2 (page 44), Figure 3 (page 45), and Figure 4 (page 47).

General observation of the figures indicates that the interval group was stressed considerably more with respect to cardiorespiratory function than the army group as depicted by the higher mean recovery heart rates for any given practice session. None of the regressions were significant from zero.

**Correlation among the three fitness tests**

Only sixteen subjects finished all three fitness tests during the post-training period because of injury, illness, or muscular soreness. These data were used for calculating correlation coefficients.

The raw score formula as described by Edwards\(^3\) was used to determine correlation coefficient \((r)\) among the three tests of fitness. Significance of the correlations was determined by the \(t\) test (calculations are contained in Appendix B).

Table 4 shows the interrelationship among the three tests of physical fitness. The \(r\) between the Harvard Step Test and maximum \(\dot{V}O_2\) ml. per kilogram of body weight was 0.654 with a \(t\) of 3.593 which was significant beyond the .01 level of confidence.

\(^3\)Edwards, pp. 136-137.
### TABLE 4

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>r</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard Step Test and Max. $\dot{V}O_2$ ml./kg. body Wt.</td>
<td>16</td>
<td>0.654</td>
<td>3.229</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Army Physical Fitness Test and Max. $\dot{V}O_2$ ml./kg. body Wt.</td>
<td>16</td>
<td>0.693</td>
<td>3.593</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Harvard Step Test and Army Physical Fitness Test</td>
<td>16</td>
<td>0.664</td>
<td>3.320</td>
<td>&lt; .01</td>
</tr>
</tbody>
</table>

The $r$ between the Army Physical Fitness Test and maximum $\dot{V}O_2$ ml. per kilogram of body weight was 0.693 with a $t$ of 3.593 which was significant beyond the .01 level of confidence.

The $r$ between the Harvard Step Test and the Army Physical Fitness Test was 0.664 with a $t$ of 3.320 which is also significant beyond the .01 level of confidence.

**Effect of Training on Athletes and Non-Athletes**

As was mentioned earlier in the chapter, the question was posed as to whether or not poorly-conditioned subjects reacted in a different manner to the exercise stress than the conditioned individuals. The subjects were placed into one group regardless of the two conditioning programs in which they participated ($N = 17$).
The subjects were then divided in accordance with two criteria for further statistical analysis: (1) whether an athlete or a non-athlete, and (2) those non-athletes whose maximum \( \dot{V}O_2 \) ml./kg. body weight exceeded 46.50 ml. and those non-athletes who had a maximum \( \dot{V}O_2 \) less than 46.50 ml./kg. body weight. This latter division was made so more detailed information concerning the reaction of the poorly fit subjects in the study could be determined. In summary, the twenty-five subjects were regrouped as follows:

1. Athletes were selected from both the interval program and the army program and placed in one group \( (N = 5) \).

2. Non-athletes in the interval program and army program with \( \dot{V}O_2 \) ml./kg. body weight 46.50 ml. \( (N = 6) \).

3. Non-athletes in the interval program and army program with \( \dot{V}O_2 \) ml./kg. body weight 46.50 ml./kg. body weight \( (N = 6) \).

**Athletes before and following conditioning** (selected from both interval and army groups). Table 5 contains the results of the effect of training on the athletes for the three fitness tests (maximum \( \dot{V}O_2 \) ml./kg. body weight, Harvard Step Test, and Army Physical Fitness Test). It was found that they did not make significant gains in their ability to take up oxygen or to perform on the Harvard Step Test, however, they did make significant improvement on the Army Physical Fitness Test \( (P < .01) \).
TABLE 5

ATHLETES BEFORE AND AFTER CONDITIONING ON
THE THREE FITNESS TESTS

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>Before</th>
<th>After</th>
<th>Diff.</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. ( \dot{V}O_2 )</td>
<td>5</td>
<td>56.05</td>
<td>55.38</td>
<td>.67</td>
<td>9.69</td>
<td>.069 N.S.</td>
</tr>
<tr>
<td>Harvard Step Test</td>
<td>5</td>
<td>94.8</td>
<td>103.34</td>
<td>8.54</td>
<td>3.494</td>
<td>2.444 N.S.</td>
</tr>
<tr>
<td>Army Physical Fitness Test</td>
<td>5</td>
<td>356</td>
<td>387</td>
<td>31</td>
<td>5.476</td>
<td>5.661 &lt; .01</td>
</tr>
</tbody>
</table>

The data for the recreational group were not used in these calculations (\( N = 8 \)).

Non-athletes before and following training with \( \dot{V}O_2 > 46.50 \text{ ml./kg. body weight prior to the experiment} \) (selected from both interval and army groups). Table 6 contains the results of the effect of training for the three fitness tests on the non-athletes with a \( \dot{V}O_2 > 46.50 \text{ ml./kg. body weight prior to conditioning} \). It demonstrates that these subjects did not improve significantly in their ability to take up oxygen, however, they did make significant gains on the Harvard Step Test (\( P < .01 \)) and the Army Physical Fitness Test (\( P < .01 \)).

Non-athletes before and following training with \( \dot{V}O_2 < 46.50 \text{ ml./kg. body weight prior to the experiment} \) (selected from both interval and army groups). Table 7 contains the results of the effect of training for the three fitness tests on the non-athletes with a \( \dot{V}O_2 < 46.50 \text{ ml./kg. body weight before conditioning} \). It shows that these subjects had
significant gains in maximum oxygen consumption (P < .05), the Harvard Step Test (P < .01), and the Army Physical Fitness Test (P < .01).

**TABLE 6**

**NON-ATHLETES BEFORE AND FOLLOWING TRAINING WITH**

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>MBefore</th>
<th>MAfter</th>
<th>Diff.</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. VO$_2$</td>
<td>6</td>
<td>50.12</td>
<td>50.84</td>
<td>.72</td>
<td>.329</td>
<td>.457</td>
</tr>
<tr>
<td>Harvard Step Test</td>
<td>5</td>
<td>74.35</td>
<td>95.64</td>
<td>21.29</td>
<td>2.857</td>
<td>.185</td>
</tr>
<tr>
<td>Army Physical Fitness Test</td>
<td>3</td>
<td>240</td>
<td>303.67</td>
<td>63.67</td>
<td>9.990</td>
<td>6.373</td>
</tr>
</tbody>
</table>

P for .05 2.571
P for .02 3.365 for 5 df
P for .01 4.032

**TABLE 7**

**NON-ATHLETES BEFORE AND FOLLOWING TRAINING WITH**

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>MBefore</th>
<th>MAfter</th>
<th>Diff.</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. VO$_2$</td>
<td>6</td>
<td>43.69</td>
<td>46.56</td>
<td>2.87</td>
<td>.9166</td>
<td>3.131</td>
</tr>
<tr>
<td>Harvard Step Test</td>
<td>6</td>
<td>74.7</td>
<td>91.42</td>
<td>16.72</td>
<td>1.551</td>
<td>10.780</td>
</tr>
<tr>
<td>Army Physical Fitness Test</td>
<td>5</td>
<td>296.6</td>
<td>346.40</td>
<td>49.80</td>
<td>11.019</td>
<td>4.519</td>
</tr>
</tbody>
</table>

P for .05 2.776
P for .02 3.747 for 4 df
P for .01 5.841
Discussion

The analysis of the data demonstrates that interval training was the only training method among the three training programs used in this study which brought about a significant increase in maximum \( \dot{V}O_2 \) ml./kg. body weight. The army and the recreational training programs apparently did not stress the cardiorespiratory system of the subjects enough to bring about a significant gain in maximum oxygen consumption.

Improvement on the Harvard Step Test was found to be significant for the groups trained by the interval or army conditioning method. The recreational activities program, however, did not produce significant changes. This would indicate that a program of recreational activities is not of sufficient intensity to bring about significant gains on the Harvard Step Test in a seven-week program.

The interval, army, and recreation groups improved significantly in their ability to perform the Army Physical Fitness Test.

The computations for mean changes to determine maximum oxygen uptake difference due to training for the non-athletes with a \( \dot{V}O_2 > 46.50 \) ml./kg. body weight and athletes who took part in the interval and army training programs show that they did not change significantly. The non-athletes with a \( \dot{V}O_2 < 46.50 \) ml./kg. body weight prior to training who participated in the interval and army programs were stressed
enough to make a significant gain in maximum oxygen consumption. This would indicate that maximum oxygen consumption for individuals in poor condition would improve significantly during seven weeks of training.

The results of the Harvard Step Test show that the non-athletes with $\dot{V}O_2 > 46.50$ ml./kg. body weight and the non-athletes with a $\dot{V}O_2 < 46.50$ ml./kg. body weight made significant gains, however, the athletes did not change significantly. Apparently, they were not stressed enough by the seven-week conditioning programs with respect to performing the Harvard Step Test.

For the Army Physical Fitness Test significant improvement was made by the non-athletes with a $\dot{V}O_2 > 46.50$ ml./kg. body weight, the non-athletes with a $\dot{V}O_2 < 46.50$ ml./kg. body weight, and the athletes. This indicates that the interval or army training method is sufficient to bring about improvement on this test.

The correlation coefficients among the three fitness tests (maximum oxygen uptake, Harvard Step Test, and Army Physical Fitness Test) indicate that they are related in what they measure, however, this does not mean that they can be substituted for each other in order to achieve the same results. The coefficient of determination ($r^2$) indicates that the amount of variation of the $x$ variable associated with that of the $y$ is such that the predictive value is not
sufficient to predict one variable when knowing the true value of the other.

The review of the literature relative to conditioning favors interval training for cardiorespiratory development. The results of this study would tend to substantiate this concept. In a well-designed interval training program there may be occasional slight decreases in heart rate which would indicate a plateau and, therefore, intensity must be increased to bring about further stress to the cardiovascular system.

Figure 2 (page 44), set two of 110 yards; Figure 3 (page 45), set one and two of 440 yards as well as one set of 880 yards show that, for the most part, the heart rates decreased during the training period even though intensity was increased for a given distance. This would indicate that the intensity of the interval training program was not followed carefully, and that the subjects were at a plateau of stress for the above mentioned distances. Figure 2 (page 44), set one of 110 yards; set one and two of 220 yards, show that the subjects were being stressed to a greater degree during the training period.

The simulated army training program did not stress the cardiovascular system to any great extent as can be seen in


Figure 4 (page 47). First and third-minute recovery heart rates were much higher for the interval trained group which would most likely be the reason why the interval group made significant improvement while the army group did not improve significantly.

The significant correlation coefficients among the three tests bring into question the findings of Karpovich and Cook\(^6\), \(^7\) who determined that there was no relationship between maximum oxygen uptake and the Harvard Step Test. The results of this study also raise questions as to the findings of Bookwalter\(^8\) who determined that there was no relationship between scores on the Harvard Step Test and the Army Physical Fitness Test. The results of this study, on the other hand, would substantiate the findings of Rodahl,\(^9\)


Howell et al.\textsuperscript{10} and de Vries and Klafs\textsuperscript{11} who found a significant relationship between the tests of maximum oxygen uptake and the Harvard Step Test.

All computations and tables are contained in Appendix C.


CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Maximum oxygen uptake was determined on twenty-five subjects who rode a bicycle ergometer for five minutes at a maximum work load at the beginning of the study.

The open circuit method for determining oxygen consumption was used in which the subject breathed room air and the exhaled air was channeled into a spirometer. Two Tissot-type spirometers with capacities of 350 or 120 liters, depending on the amount of ventilation of the subject, were used to collect the expired air during the fifth minute of maximum work. To analyze the exhaled gas, a Beckman Oxygen Analyzer was used. Gas was taken immediately after each experiment in a two-liter rubber bladder and passed through the oxygen analyzer to determine oxygen concentration.

Scores were obtained on the Army Physical Fitness Test and Harvard Step Test before the training programs.

Three groups were formed by matching high and low \( \dot{V}O_2 \) for each group until the group had eight members. The mean and standard deviation for each group was then calculated to assure that they were matched. One group participated in an
interval training program which consisted of intervals of hard running at distances of either 110 yards, 220 yards, 440 yards, or 880 yards. Intensity during the training period was increased by changing the number of running intervals, decreasing the running time of a given interval or decreasing the rest time between intervals.

Generally, there were two sets of intervals for each training day. Recovery heart rates were recorded for five minutes after each set of intervals (see Appendix A).

The second group took part in a simulated army program of training. Calisthenics and marching were used to condition this group. The army uses three sets of calisthenics which are performed on alternate days. Daily marching distance increased from two miles at the beginning of the study to twelve miles at the end. A mile of marching was added about every four days.

The recreation group participated in activities such as archery, golf, scuba, swimming, trampoline, and volleyball.

The total training period was seven weeks in length.

After the training period was over, the subjects were again tested on the bicycle ergometer at their post-training maximum work tolerance. Maximum oxygen uptake was recorded along with index scores on the Harvard Step Test, and scores on the Army Physical Fitness Test.
In order to determine whether significant changes occurred as a result of training, the \( t \) test was used.

To determine whether there was any relationship among maximum oxygen uptake, the Army Physical Fitness Test, and the Harvard Step Test, correlation coefficient \( (r) \) was used.

Regression analysis was calculated for post-exercise recovery heart rates for the interval and army trained groups.

Conclusions

On the basis of the data obtained in this study, the following conclusions were reached:

1. A seven-week conditioning program of interval training significantly improved the ability of subjects to take up oxygen unless he was an athlete or in excellent physical condition prior to training.

2. A seven-week conditioning program of simulated army training or a program of recreational activities did not significantly improve the ability of subjects to take up oxygen unless they were in poor condition prior to training.

3. A seven-week conditioning program of interval or army training significantly improved the ability of subjects to perform on the Harvard Step Test unless they were athletes.

4. Seven weeks of recreational activities did not significantly improve the ability of subjects to perform on the Harvard Step Test.
5. A seven-week conditioning program of interval training, army training, or a program of recreational activities significantly improved the ability of subjects to perform the Army Physical Fitness Test.

6. The correlation of maximum $\dot{V}O_2$ ml./kg. of body weight and the Army Physical Fitness Test was .69. Significance from the obtained $t$ was beyond the .01 level of confidence indicating that results on the Army Physical Fitness Test and maximum $\dot{V}O_2$ ml./kg. of body weight are associated.

7. The correlation of maximum $\dot{V}O_2$ ml./kg. of body weight and the Harvard Step Test was .65. Significance from the calculated $t$ was beyond the .01 level of confidence demonstrating that results on the Harvard Step Test and maximum $\dot{V}O_2$ ml./kg. of body weight are associated.

8. The correlation of the Harvard Step Test and the Army Physical Fitness Test was .66. Significance from the obtained $t$ was beyond the .01 level of confidence indicating that results on the two tests are associated.

**Recommendations**

As the result of the data obtained in this study, it is recommended that—

1. A heterogeneous group with more subjects be selected at random and placed in a conditioning program involving interval and/or army-type training in order to better understand the conditioning process.
2. A more controlled program of interval training be maintained in future studies as to number of repetitions, distance, running time, and rest interval in order to better evaluate intensity of the exercise.

3. Periodic tests be given during the training period to determine when a plateau is reached in order to increase the intensity of the exercise program so that the greatest benefit can be attained from training.
APPENDIXES
### APPENDIX A

#### ARMY CALISTHENICS PROGRAM

<table>
<thead>
<tr>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Jumping jacks</td>
<td>High jumper</td>
<td>Lunger</td>
</tr>
<tr>
<td>2. Leg V's</td>
<td>Bender and reach</td>
<td>Turn and bounce</td>
</tr>
<tr>
<td>3. Leg over</td>
<td>Squat thrust</td>
<td>Diag. squat thrust</td>
</tr>
<tr>
<td>4. Hurdle seats</td>
<td>Rowing exercise</td>
<td>V-up</td>
</tr>
<tr>
<td>5. Sit-ups</td>
<td>Squat bender</td>
<td>Squat stretch</td>
</tr>
<tr>
<td>6. Straight leg kick</td>
<td>Push-ups</td>
<td>One-legged push-up</td>
</tr>
<tr>
<td>7. Bicycle</td>
<td>Body twist</td>
<td>Lunge and bend</td>
</tr>
<tr>
<td>8. V-up-legs straight</td>
<td>Squat jumper</td>
<td>Leg circular</td>
</tr>
<tr>
<td>9. Leg spreader</td>
<td>Trunk twister</td>
<td>2 high jumper</td>
</tr>
<tr>
<td>10. Rocker</td>
<td>Stationary run</td>
<td>Turn and bend</td>
</tr>
<tr>
<td>11. Bounding ball</td>
<td>8 count push-up</td>
<td>Leg thrust dip</td>
</tr>
<tr>
<td>12 Mountain climb</td>
<td>Bottoms up</td>
<td>Back bender</td>
</tr>
<tr>
<td>Day</td>
<td>Interval</td>
<td>Army Calisthenics</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>-------------------</td>
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<tr>
<td>1</td>
<td>8X220X:36X3:00</td>
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</tr>
<tr>
<td>2</td>
<td>- -</td>
<td>- -</td>
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<tr>
<td>3</td>
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<td>26</td>
<td>- -</td>
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</tr>
<tr>
<td>33</td>
<td>- -</td>
<td>- -</td>
</tr>
</tbody>
</table>
### APPENDIX B

#### SUMMARY OF DATA

<table>
<thead>
<tr>
<th>Subject</th>
<th>Max. VO$_2$ (mL/kg) Before &amp; After Trng.</th>
<th>Max. VO$_2$ (liters) Before &amp; After Trng.</th>
<th>Harvard Step Test Index Before &amp; After Trng.</th>
<th>Army Physical Fitness Test Before &amp; After Trng.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB</td>
<td>51.58 52.70</td>
<td>3.70 3.84</td>
<td>96.1 94.3</td>
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<tr>
<td>RD</td>
<td>53.65 44.20</td>
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<td>72.8 85.2</td>
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<td>WD</td>
<td>57.79 55.43</td>
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<td>78.1 94.3</td>
<td>353 389</td>
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<tr>
<td>JF</td>
<td>45.43 45.93</td>
<td>3.64 3.69</td>
<td>68.1 -</td>
<td>266 -</td>
</tr>
<tr>
<td>RF</td>
<td>46.26 48.87</td>
<td>2.91 3.14</td>
<td>76.1 88.2</td>
<td>266 301</td>
</tr>
<tr>
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<td>4.02 3.41</td>
<td>78.9 90.4</td>
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<td>4.39 3.90</td>
<td>141.5 145.6</td>
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<td>90.3 84.3</td>
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<td>JK</td>
<td>42.76 47.65</td>
<td>3.25 3.44</td>
<td>75.0 83.3</td>
<td>- -</td>
</tr>
<tr>
<td>DL</td>
<td>46.49 48.91</td>
<td>2.45 2.62</td>
<td>66.9 89.8</td>
<td>228 300</td>
</tr>
<tr>
<td>DeL</td>
<td>51.45 44.20</td>
<td>3.38 2.87</td>
<td>75.6 74.3</td>
<td>302 355</td>
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<td>RM</td>
<td>46.46 44.05</td>
<td>3.41 3.40</td>
<td>72.5 78.9</td>
<td>221 -</td>
</tr>
<tr>
<td>TN</td>
<td>54.10 54.42</td>
<td>3.23 3.36</td>
<td>76.1 89.8</td>
<td>297 -</td>
</tr>
<tr>
<td>MR</td>
<td>47.96 50.92</td>
<td>2.59 2.89</td>
<td>80.6 96.7</td>
<td>353 434</td>
</tr>
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<td>ES</td>
<td>57.25 57.25</td>
<td>3.86 3.86</td>
<td>73.1 89.3</td>
<td>355 401</td>
</tr>
<tr>
<td>RS</td>
<td>52.18 46.36</td>
<td>3.35 3.10</td>
<td>85.2 114.5</td>
<td>238 -</td>
</tr>
<tr>
<td>CS</td>
<td>48.60 48.74</td>
<td>3.81 3.84</td>
<td>71.7 85.2</td>
<td>249 308</td>
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<td>JS</td>
<td>47.55 48.18</td>
<td>3.67 3.73</td>
<td>- -</td>
<td>241 -</td>
</tr>
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<td>HW</td>
<td>40.62 46.42</td>
<td>2.72 3.13</td>
<td>73.5 92.0</td>
<td>281 311</td>
</tr>
<tr>
<td>MU</td>
<td>49.32 55.51</td>
<td>3.09 3.44</td>
<td>75.0 92.0</td>
<td>355 386</td>
</tr>
<tr>
<td>DW</td>
<td>40.94 41.57</td>
<td>3.57 3.68</td>
<td>67.6 88.2</td>
<td>176 253</td>
</tr>
</tbody>
</table>
APPENDIX C

Statistical Formula for Calculating \( t \)
\[ m^2 = \bar{d}^2 - \frac{(\bar{d})^2}{N} \]

\[ Sd = \frac{\sum d^2}{N-1} \]

\[ \sqrt{\bar{d}} = \frac{Sd}{N} \]

\[ t = \frac{\text{mean difference}}{\sqrt{\bar{d}}} \]

Maximum \( \dot{V}O_2 \) ml./kg. Body Weight

Interval Group

<table>
<thead>
<tr>
<th>( N )</th>
<th>( \bar{d}^2 )</th>
<th>( Sd )</th>
<th>( \bar{d}d )</th>
<th>( t )</th>
<th>for 8 degrees of freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>67.17</td>
<td>2.89</td>
<td>.963</td>
<td>2.829</td>
<td>.05 = 2.306</td>
</tr>
<tr>
<td>48.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.02 = 2.896</td>
</tr>
<tr>
<td>51.36</td>
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<td></td>
<td></td>
<td></td>
<td>.01 = 3.355</td>
</tr>
<tr>
<td>21.44</td>
<td></td>
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<tr>
<td>118.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Maximum \( \dot{V}O_2 \) ml./kg. Body Weight

**Army Group**

\[
\begin{align*}
N &= 8 \\
\bar{M}^1 &= 50.66 \\
\bar{M}^2 &= 49.86 \\
\bar{d} &= 6.26 \\
\bar{d}^2 &= 98.80
\end{align*}
\]

\[
\begin{align*}
\bar{S}_d &= 3.666 \\
\bar{S}_d^2 &= 1.296 \\
t &= .614 \\
& \text{for 7 degrees of freedom}
\end{align*}
\]

\[
\begin{align*}
.05 &= 2.365 \\
.01 &= 3.355
\end{align*}
\]

---

**Recreational Group**

\[
\begin{align*}
N &= 8 \\
\bar{M}^1 &= 49.14 \\
\bar{M}^2 &= 45.86 \\
\bar{d} &= 26.26 \\
\bar{d}^2 &= 294.61
\end{align*}
\]

\[
\begin{align*}
\bar{S}_d &= 5.449 \\
\bar{S}_d^2 &= 1.927 \\
t &= 1.702 \\
& \text{for 7 degrees of freedom}
\end{align*}
\]

\[
\begin{align*}
.05 &= 2.365 \\
.01 &= 3.355
\end{align*}
\]

---

**Harvard Step Test**

**Interval Group**

\[
\begin{align*}
N &= 8 \\
\bar{M}^1 &= 81.09 \\
\bar{M}^2 &= 95.01 \\
\bar{d} &= 111.4 \\
\bar{d}^2 &= 1862.17
\end{align*}
\]

\[
\begin{align*}
\bar{S}_d &= 6.646 \\
\bar{S}_d^2 &= 2.35 \\
t &= 5.92 \\
& \text{for 7 degrees of freedom}
\end{align*}
\]

\[
\begin{align*}
.05 &= 2.365 \\
.01 &= 3.355
\end{align*}
\]
Harvard Step Test

Army Group

\[ N = 8 \quad \sigma d^2 = 414.2 \]
\[ M^1 = 81.42 \quad Sd = 7.69 \]
\[ M^2 = 98.0 \quad S\bar{x}d = 2.73 \]
\[ \Sigma D = 132.5 \quad t = 6.07 \]
\[ \Sigma D^2 = 2608.73 \quad \text{for 7 degrees of freedom} \]

Recreational Group

\[ N = 7 \quad \sigma d^2 = 373.99 \]
\[ M^1 = 71.50 \quad Sd = 7.88 \]
\[ M^2 = 78.78 \quad S\bar{x}d = 2.978 \]
\[ \Sigma D = 51 \quad t = 2.445 \]
\[ \Sigma D^2 = 745.56 \quad \text{for 6 degrees of freedom} \]

Army Physical Fitness Test

Interval Group

\[ N = 6 \quad \sigma d^2 = 2786.83 \]
\[ M^1 = 314.0 \quad Sd = 23.62 \]
\[ M^2 = 356.17 \quad S\bar{x}d = 9.645 \]
\[ \Sigma D = 253 \quad t = 4.372 \]
\[ \Sigma D^2 = 13,455 \quad \text{for 5 degrees of freedom} \]

\[ .05 = 2.571 \]
\[ .01 = 4.032 \]
### Army Physical Fitness Test
#### Army Group

<table>
<thead>
<tr>
<th>N</th>
<th>6</th>
<th>$\sum d^2 = 2,314$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M^1$</td>
<td>291</td>
<td>$Sd = 21.54$</td>
</tr>
<tr>
<td>$M^2$</td>
<td>342</td>
<td>$S\bar{d} = 8.795$</td>
</tr>
<tr>
<td>$\Sigma D$</td>
<td>306</td>
<td>$t = 5.799$</td>
</tr>
<tr>
<td>$\Sigma D^2$</td>
<td>17,920</td>
<td>for 5 degrees of freedom</td>
</tr>
</tbody>
</table>

$.05 = 2.571$
$.01 = 4.032$

### Army Physical Fitness Test
#### Recreation Group

<table>
<thead>
<tr>
<th>N</th>
<th>3</th>
<th>$\sum d^2 = 172.70$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M^1$</td>
<td>228</td>
<td>$Sd = 9.292$</td>
</tr>
<tr>
<td>$M^2$</td>
<td>265.3</td>
<td>$S\bar{d} = 7.921$</td>
</tr>
<tr>
<td>$\Sigma D$</td>
<td>112</td>
<td>$t = 4.71$</td>
</tr>
<tr>
<td>$\Sigma D^2$</td>
<td>4,354</td>
<td>for 2 degrees of freedom</td>
</tr>
</tbody>
</table>

$.05 = 4.303$
$.01 = 9.25$

### Maximum $\dot{V}O_2$ ml./kg. Body Weight
#### Athletes

<table>
<thead>
<tr>
<th>N</th>
<th>5</th>
<th>$\sum d^2 = 81.11$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M^1$</td>
<td>56.05</td>
<td>$Sd = 20.28$</td>
</tr>
<tr>
<td>$M^2$</td>
<td>55.38</td>
<td>$S\bar{d} = 9.69$</td>
</tr>
<tr>
<td>$\Sigma D$</td>
<td>3.35</td>
<td>$t = .069$</td>
</tr>
<tr>
<td>$\Sigma D^2$</td>
<td>83.35</td>
<td>for 4 degrees of freedom</td>
</tr>
</tbody>
</table>

$.05 = 2.776$
$.01 = 5.841$
### Maximum \( \dot{V}O_2 \) ml./kg. Body Weight

**Non-Athletes Max. \( \dot{V}O_2 \) 46.50 ml./kg.**

<table>
<thead>
<tr>
<th>N  = 6</th>
<th>( \Sigma d^2 = 78.43 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M^1 = 50.12 )</td>
<td>( S_d = 8.94 )</td>
</tr>
<tr>
<td>( M^2 = 50.84 )</td>
<td>( S_{\Delta d} = 1.20 )</td>
</tr>
<tr>
<td>( \Sigma D = 4.40 )</td>
<td>( t = 0.060 )</td>
</tr>
<tr>
<td>( \Sigma D^2 = 81.66 )</td>
<td>for 5 degrees of freedom</td>
</tr>
</tbody>
</table>

\[ \text{.05} = 2.70 \]
\[ \text{.02} = 3.365 \]
\[ \text{.01} = 4.032 \]

---

### Maximum \( \dot{V}O_2 \) ml./kg. Body Weight

**Non-Athletes \( \dot{V}O_2 \) 46.50 ml./kg. Body Weight**

<table>
<thead>
<tr>
<th>N  = 6</th>
<th>( \Sigma d^2 = 25.15 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M^1 = 43.69 )</td>
<td>( S_d = 2.243 )</td>
</tr>
<tr>
<td>( M^2 = 46.56 )</td>
<td>( S_{\Delta d} = 0.9166 )</td>
</tr>
<tr>
<td>( \Sigma D = 17.19 )</td>
<td>( t = 3.131 )</td>
</tr>
<tr>
<td>( \Sigma D^2 = 74.40 )</td>
<td>for 5 degrees of freedom</td>
</tr>
</tbody>
</table>

\[ \text{.05} = 2.571 \]
\[ \text{.01} = 4.032 \]
Statistical Formula for Calculating Raw Data
Correlation Coefficient (r)

\[
\begin{align*}
\sum x^2 &= \frac{\sum x^2}{N} - \left(\frac{\sum x}{N}\right)^2, \\
\sum y^2 &= \frac{\sum y^2}{N} - \left(\frac{\sum y}{N}\right)^2, \\
\sum xy^2 &= \frac{\sum xy}{N} - \left(\frac{\sum xy}{N}\right)^2, \\
r &= \frac{\sum xy^2}{(\sum x^2)(\sum y^2)}, \\
t &= \frac{r \sqrt{N-2}}{\sqrt{1-r^2}}
\end{align*}
\]

VALUES FOR MAXIMUM VO_2 ml./kg., HARVARD STEP TEST
AND ARMY PHYSICAL FITNESS TEST

<table>
<thead>
<tr>
<th>Subject</th>
<th>VO_2 ml./kg.</th>
<th>Army PFT Score</th>
<th>Harvard Step Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS</td>
<td>48.60</td>
<td>249</td>
<td>85.2</td>
</tr>
<tr>
<td>JK</td>
<td>42.6</td>
<td>149</td>
<td>75</td>
</tr>
<tr>
<td>MR</td>
<td>47.96</td>
<td>353</td>
<td>80.6</td>
</tr>
<tr>
<td>HW</td>
<td>40.36</td>
<td>281</td>
<td>73.5</td>
</tr>
<tr>
<td>MU</td>
<td>49.28</td>
<td>355</td>
<td>75</td>
</tr>
<tr>
<td>CH</td>
<td>48.42</td>
<td>295</td>
<td>78.5</td>
</tr>
<tr>
<td>DW</td>
<td>40.94</td>
<td>176</td>
<td>67.6</td>
</tr>
<tr>
<td>CS</td>
<td>52.18</td>
<td>238</td>
<td>71.7</td>
</tr>
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<td>TN</td>
<td>54.10</td>
<td>297</td>
<td>76.1</td>
</tr>
<tr>
<td>RF</td>
<td>46.26</td>
<td>266</td>
<td>76.1</td>
</tr>
<tr>
<td>DL</td>
<td>46.49</td>
<td>228</td>
<td>66.9</td>
</tr>
<tr>
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<td>34.19</td>
<td>104</td>
<td>33.7</td>
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<tr>
<td>RD</td>
<td>53.65</td>
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<td>46.29</td>
<td>258</td>
<td>77.7</td>
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<tr>
<td>DeL</td>
<td>51.45</td>
<td>322</td>
<td>74.6</td>
</tr>
<tr>
<td>RM</td>
<td>46.46</td>
<td>221</td>
<td>72.5</td>
</tr>
</tbody>
</table>

\[x = 749.39 \quad x = 4,075 \quad x = 1,157.50\]
\[x^2 = 35,515.11 \quad x^2 = 1,109,385 \quad x^2 = 85,632.81\]
r Between Maximum VO\(_2\) ml./kg. of Body Weight and Harvard Step Test

\[\begin{align*}
\sum x &= 749.39 \\
\sum x^2 &= 35,515.11 \\
\sum y &= 1,157.50 \\
\sum y^2 &= 85,532.81 \\
\sum x^2 &= 416.02 \\
\sum y^2 &= 1,894.92 \\
\sum xy &= 580.65 \\
\sum x^2 &= 416.02 \\
r &= 0.654 \\
t &= 3.229 \quad .01
\end{align*}\]

r Between Maximum VO\(_2\) ml./kg. Body Weight and Army Physical Fitness Test

\[\begin{align*}
\sum x &= 749.43 \\
\sum x^2 &= 35,515.11 \\
\sum y &= 4,075 \\
\sum y^2 &= 1,109,385 \\
\sum x^2 &= 412.38 \\
\sum y^2 &= 71,533 \\
\sum xy &= 3,764.48 \\
r &= .6931 \\
t &= 3.5928 \quad .01
\end{align*}\]
Between Harvard Step Test and Army Physical Fitness Test

\[ \Sigma x = 1,157.50 \]
\[ \Sigma x^2 = 85,632.81 \]
\[ \Sigma y = 4,075 \]
\[ \Sigma y^2 = 1,109,385 \]
\[ \Sigma x^2 = 1,894.92 \]
\[ \Sigma y^2 = 71,533 \]
\[ \Sigma xy^2 = 7,734 \]
\[ r = 0.6642 \]
\[ t = 3.320 \quad .01 \]
# APPENDIX D

## POST-EXERCISE RECOVERY HEART RATES

<table>
<thead>
<tr>
<th>Day</th>
<th>Interval Training</th>
<th>Army Training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st Set</td>
<td>2nd Set</td>
</tr>
<tr>
<td></td>
<td>1st 3rd 5th</td>
<td>1st 3rd 5th</td>
</tr>
<tr>
<td>1</td>
<td>137 128 110</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>157 125 113</td>
<td>157 125 113</td>
</tr>
<tr>
<td>3</td>
<td>166 137 117</td>
<td>162 137 119</td>
</tr>
<tr>
<td>4</td>
<td>157 118 114</td>
<td>151 119 116</td>
</tr>
<tr>
<td>5</td>
<td>155 134 123</td>
<td>154 128 119</td>
</tr>
<tr>
<td>6</td>
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<td>7</td>
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<td>8</td>
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<td>149 135 117</td>
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<td>124 124 120</td>
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<td>17</td>
<td>144 120 114</td>
<td>145 121 115</td>
</tr>
<tr>
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<td>150 128 121</td>
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</tr>
<tr>
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<td>152 129 125</td>
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<td>153 130 119</td>
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</tr>
<tr>
<td>26</td>
<td>140 123 114</td>
<td>134 118 114</td>
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</tr>
<tr>
<td>28</td>
<td>128 118 116</td>
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</tbody>
</table>
BIBLIOGRAPHY
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