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Effect of various training frequencies on cardiorespiratory endurance

Jay Herbert Jackson

The University of Montana

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THE EFFECT OF VARIOUS TRAINING FREQUENCIES
ON CARDIORESPIRATORY ENDURANCE

By

Jay Herbert Jackson

B. A. Whitworth College, 1964

Presented in partial fulfillment of the requirements
for the degree of

Master of Science

UNIVERSITY OF MONTANA

1966

Approved by:

[Signatures]

Chairman, Board of Examiners

Dean, Graduate School

JUL 21 1966

Date
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J.H.J.
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CHAPTER I

THE PROBLEM

I. Introduction

The response of man's system to physical exercise is of primary concern to the field of Health, Physical Education, and Recreation. It is important to teach skills and activities which will aid in the maintainence of optimal health, the development of a sound body, and the enjoyment of leisure hours. In order to achieve these goals, the instructor must, if he or she is to be as efficient and as effective as possible, be cognizant of the systemic response to exercise. At present, the lack of hard physical labor and the expanding recreational horizons of the nation have made it doubly important for the physical educator, and the public in general, to have a working knowledge of the effects of repeated physical exercise or training. Through newer and faster methods of transportation, the increased number of and variety of outdoor recreational areas, and in some cases, local emergencies, individuals with not even a minimum amount of fitness are being thrust into environments where their ability to continue (endurance) may well mean life or death.
This study is concerned with that aspect of fitness which involves the ability to continue vigorous activity for an extended period of time, cardiorespiratory endurance.

Wolffe (25), in a report presented before the Scientific Regional Conference of the American College of Sports Medicine in 1963, states that physical exercise is an important modality in the prevention and management of disease; it is the only safe and effective method for improving health. Dr. Wolffe also indicates that despite contradictory data in medical literature, evidence is mounting from clinical and research sources that exercise, within each individual's capacity for effort, plays a major role in the prevention and treatment of atherosclerosis, one of the most common forms of arteriosclerosis. Morris and Heady, as reported by Wolffe (25), found the incidence of heart attack among sedentary workers, clerks, switchboard operators, and truck drivers, to be three times greater than that found among individuals engaged in physically active occupations such as laborers, miners, transport workers, and farmers.

Since man is responsible for his own level of fitness, and because the efficient use of time is important, it would be highly beneficial to have an under-
standing of the most efficient frequency of physical exercise (training) necessary to evoke changes in fitness (cardiorespiratory endurance).

II. The Problem

Statement of the Problem

The purpose of this study was to compare the effects of various frequencies of training upon the level of cardiorespiratory endurance.

Significance of the Study

The information to be found in the related literature which pertains to endurance and the effects of training frequency is both limited and conflicting. It was felt that this study would help to clarify this picture and would be significant in the following ways:

1. This information would be valuable to the ordinary individual seeking to maintain a high degree of endurance.

2. In light of the increasing amounts of leisure time being made available to the public, the application of this knowledge would benefit an individual through the development of a level of endurance which would allow him to perform his necessary duties and also enjoy his leisure hours.
3. Information of this type, which would aid in the improvement of existing training methods or the substantiation of them, would be of benefit to the Physical Education profession in general.

Limitations of the Study

1. The number of subjects was limited to twenty males.

2. The number of training sessions ranged from five to twenty-five.

3. It was not possible to completely regulate the health habits, outside activities, sleep and diet of the subjects.

4. There was room for a certain amount of subjective judgement on the part of the training subject as to when he could no longer continue to exercise.
CHAPTER II

REVIEW OF THE RELATED LITERATURE

I. BASIC ASSUMPTIONS

The study of training and its influence on the physiological functions of man is fundamental to the fields of Physiology of Exercise and Physical Education. Training, for the purposes of this study, is defined as regularly repeated exercise, performed with the intent of bringing about a favorable increase in the level of physical fitness. The phrase, "level of physical fitness", is used synonymously with general endurance, and is taken to mean the ability of one to continue any particular task for extended or prolonged periods of time. Specifically, the endurance or fitness evaluated in this study may be considered as cardiorespiratory endurance. It is generally observed and accepted that those who habitually commit themselves to exercise are able to exert greater efforts and resist fatigue more readily than sedentary individuals. This exercise, or training, causes progressive changes in many physiological responses. Various studies throughout the literature have indicated that the following areas are directly influenced by training (4):
1. Strength and neuromuscular coordination
2. Mechanical efficiency
3. Maximum oxygen consumption
4. Cardiac output and pulse rate
5. Ventilation
6. Aerobic and anaerobic performance
7. Recovery from exercise
8. Heat dissipation during exercise

II. GENERAL INFLUENCE OF TRAINING

Knehr, Dill and Neufeld (16) in their study on training and its effect on the working and resting man, trained subjects three times per week for a period of six months. They conducted bi-weekly checks on performance values and bi-monthly checks on resting values. The training was conducted on a track and was similar to that type which is experienced by middle distance runners. The results of this study indicated that training did not significantly alter most of the basal levels. The resting pulse, however, did show a decrease. The oxygen requirement for a given amount of work was found to decrease over the training period and there was a sixty per cent increase in the amount of work done. It was stated that if the rate of work output was increased while holding the duration constant, one would
reach a physiological limit which no amount of training could increase. Holding the rate of work output constant, however, would result in an increased duration through training. The researchers concluded that the capacity for aerobic work increases through an increased cardiac output and improved circulation to the working muscles, and further, that one of the most significant effects of training is the ability to accumulate an increased amount of lactate in the blood and yet continue.

Brouha (3) states that the homeostatic mechanisms become more efficient through training. In response to an equal amount of work, displacement from equilibrium is reduced and the rate of recovery increases. Training effects contribute to an increased capacity for muscular activity and include: increased strength; better neuromuscular coordination requiring less energy per work load; improved cardiovascular function resulting in a better oxygen supply and an increased amount of blood available for heat dissipation; and improved pulmonary ventilation permitting adequate oxygen and carbon dioxide exchange for a lower energy expenditure in respiratory mechanics.

In his introduction to the chapter on Physical Fitness and Performance, Consolazio (7) makes the
following statement concerning the fit individual:

"... the physically fit man performs a given grade of light, moderate, and exhausting work more efficiently and with less displacement of his physiological equilibria. He can establish steady states at higher grades of work, and if forced, he can displace his physiological equilibria further for a longer period of time. He has a more economical ventilation during work, is able to attain a greater maximal ventilation, has a greater mechanical efficiency as measured in terms of lower oxygen consumption for a given amount of external work, and is able to attain a greater maximum oxygen consumption. He has a lower RQ during exercise and a lower blood lactate for a given amount of exercise. He has the ability to push himself to a higher lactate before exhaustion and has a smaller increase in pulse rate for submaximal work. Finally, he has better recuperative powers in the sense that he can return to his normal steady state after an exhausting exercise more rapidly."

It is evident then, that a great number of items influence the level of endurance and that one would experience a great amount of difficulty in attempting to measure the extent of each in a single study. Consolazio (7) indicates that as early as 1940, it was felt that there was no single definition of fitness and that even today, there is no one test that can measure more than a few aspects of fitness.

Campney (5) in his doctoral study at the State University of Iowa, investigated the amount of work required to produce changes in cardiovascular fitness. He took eight college men of low fitness and trained them twice a week for ten weeks. The method of training in-
olved bench stepping, seventeen inches high at a rate of thirty steps per minute, and was all-out work except for the tenth, twentieth, and twenty-first bouts which were limited in time to that of the original pre-training test. The twenty-first bout came at the close of a five week period of de-training. The researcher concluded the following:

1. At the end of the first five week period, seven out of eight subjects had experienced cardiovascular improvement as measured by heart rate recovery.

2. At the end of the second five week period, two subjects continued to show improvement but the other six failed to make any further gains.

3. The duration of exercise increased for all eight subjects.

4. The net energy cost of work required to produce changes in heart rate recoveries ranged from 703.29 calories to 1,623.19 calories. This wide range of calorie cost corresponded to the wide range of total time for exercise bouts.

Henry (14) worked with thirty-three male subjects, eighteen competing athletes and fifteen athletically in-
dined and physically active males, in his study on the influence of athletic training on the resting cardiovascular system. The group of fifteen served as controls and participated only in their normal activities. The experimental group trained in their respective sports and were tested prior to and at the close of their seasons. The study failed to find evidence that training causes a decrease in the peripheral resistance resulting from improved vascularization. There was evidence of increased arterial elasticity and increased stroke volume associated with a compensatory decrease in heart rate. The author states that the resting heart rate has a significant validity as a test of the effect of athletic training (0.76).

Tabakin, et al. (23), investigated the hemodynamic response of normal subjects to graded treadmill exercise. The subjects were twenty-five males, motivated to some degree by financial rewards. The measurements and techniques of measuring were as follows: cardiac output was measured by use of an indicator dilution technique; heart rate was taken and recorded by use of a telemedics RKG-100 FM electrocardiograph system; vascular resistance was recorded by use of direct intraarterial pressure valves; and expired air was collected to provide measurements of the minute volume of ventilation, oxygen utilization, and carbon dioxide elimination.
All measurements were taken at rest, during exercise, and during recovery. Subjects were required to work at treadmill grades of four, eight, twelve, and fourteen per cent, for a period of four to five minutes at the lower levels and two to three minutes at the higher ones. The results of the study indicated that the mean values for cardiac output tend to increase as the work load increases. There was an excellent correlation, 0.77, between cardiac output and oxygen utilization. However, there was seldom a uniform increase in cardiac output as work increased. The stroke volume was very unstable and did not appear to have a significant relationship with work load. The researcher concluded that an increase in heart rate alone may meet the demands of an increase in cardiac output.

III. SPECIFIC TRAINING STUDIES

It is a generally accepted fact that training, as defined earlier in this chapter, does in fact influence certain physiological responses, which in turn, influence one's ability to perform. The following studies indicate that which has been done in relation to type, quantity, and frequency of training and the resulting effect on the general endurance level.

Alost (1) used two different types of training, isometric and running, to observe the effects of initial

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cardiovascular condition, type of training program, and frequency of practice periods upon cardiovascular development. The subjects were college males. Their initial level of cardiovascular fitness was indicated by their pre-test scores on the Harvard Step Test. Training was either sixty seconds of isometric exercise or a one minute run, taken two, three, or five times per week. The twelve experimental groups used different combinations of the three variables and a three-way analysis of variance was used to analyse the results. There was no significant difference between the types of exercise used, but five days of exercise proved to be significantly better than two or three days per week in developing cardiovascular condition.

Christiansen, Hedman, and Saltin (6) studied the effects of intermittent and continuous running on two well-trained subjects. The subjects were tested on the treadmill at a speed of 12.4 miles per hour and were able to continue for thirty minutes using the interval method, and three to four minutes while running continuously. At the end of a continuous running period, the subjects were completely exhausted and needed a long recovery period. The use of the interval type of training allowed the subjects to complete a thirty minute period of exercise, twenty minutes of running and ten minutes of
rest, without exhaustion. The researchers indicated that the interval training caused only a slight increase in the lactic acid concentration of the blood which indicated almost total aerobic work.

Patton (19) used all-out and interval training techniques in a study that compared pre-training and post-training scores on four tests of work capacity. Three groups (all-out, interval, and control) trained on the treadmill for eight weeks. The results indicated a significant difference between both the experimental groups and the controls, but not with each other.

Cooper (8) compared the effects of short intensive and prolonged intensive exercise on treadmill performance and certain cardiorespiratory functions. Two exercise programs were compared on the basis of their contribution to cardiorespiratory fitness on two treadmill tests. Maximum breathing capacity, heart rate, and oxygen consumption during rest, exercise, and recovery were recorded. Both programs contributed to gains in cardiorespiratory fitness. The author concluded that the quality and intensity of exercise are more important than quantity and duration.

Durnin, Brockway and Whitcher (11) performed an extremely interesting study dealing with the effects of a short period of training of varying severity on physical
fitness. The authors list several of the weak points associated with the present literature concerning the effects of training: differences in the definitions of terms, i.e., training versus practice; a lack of contact with individuals or groups throughout a training period; size of studies in terms of the number of subjects used; and a lack of control, i.e., the training not being standardized. A group of twenty-four physically untrained males, randomly divided into three experimental and one control group, participated in daily walking for two consecutive periods of five days each. The training distances were ten, twenty, and thirty kilometers per day. Three treadmill tests (pre, during, and post-training) were administered at a rate of one hundred yards per minute, a grade of ten per cent, and for fifteen minutes. The values recorded were pulmonary ventilation, oxygen consumption, and heart rate. The results were divided into two sections: the within groups observations or the results from day to day, and the between groups observations. In the former, the only group to show a significant increase in pulmonary ventilation and oxygen consumption was the twenty kilometer group (significant at the .01 level). All groups experienced a significant (.01) lowering of the heart rate during exercise. The thirty kilometer group had con-
s istently significant recovery rates (.05). A comparison of the groups with each other indicated that only the twenty kilometer group had consistently significant results. The writers summarized the study in the following manner:

1. A submaximal test which involves large groups of muscles and which is easy to perform, in terms of skill, is the best.

2. The combined respiratory and circulatory data indicate that the twenty kilometer group improved its fitness while the others were less positive.

3. The heart rate data reinforces Taylor, Buskirk, and Henschel (24), in that the exercise pulse rate is a better indication of fitness than the recovery rate.

4. The training was from moderate to hard. The training group which increased significantly (twenty kilometers) was not doing the most work. Thirty kilometers may have been too much for the level of fitness of that group.

5. Rate seems to be more important than amount. Since the exercise heart rate was between one hundred twenty and one hundred thirty, duration may have had an effect.
Hanson (13) in a report to the seventy-ninth Annual Convention of the American Association of Health, Physical Education and Recreation, compared the results of five day a week and three day a week Physical Education programs on achievement scores in the Youth Fitness Battery. Thirteen hundred scores of the sixth grade boys and girls indicated that, at this particular level, five days a week were better than three in most items. Boys were superior to girls in most items. Peterson (20), at the same convention, reported on the effects of three varied exercise programs on the physical fitness of high school boys. Three groups of similar size met daily for hourly physical education classes. One spent twelve to fifteen minutes per day on calisthenics, one allotted two periods of fifty minutes each per week for calisthenics, and one group had none at all. In a nine item test, for all three groups, four items were not significant pre to post or between. Two (sit-ups and the jump-reach) were significant pre to post, but not between the groups.

Zeigler (26) used three training groups in his study concerning the frequency of maximum effort most favorable for the development of endurance. Undergraduate and graduate college males were divided into groups which trained for eighteen weeks at frequencies of once,
twice, and three times per week. The groups were equated on the basis of the subject's age, height, weight, and initial score on the bicycle ergometer. The results of the study indicated that the group training twice a week improved more than the others, i.e., Group Two showed an increase of sixty-one percent from pre to post testing evidenced by a mean increase of twenty-four seconds per subject. All three groups exhibited an increase in the duration of riding time. The researcher concluded that significant results began to occur as early as the fifth week and that an increase in the frequency of exercise seems to increase the variability of the group.
CHAPTER III

PROCEDURE OF THE STUDY

I. THE SUBJECTS

The subjects for this study were accepted as volunteers from two Orientation classes in Health and Physical Education at the University of Montana, Missoula. There were approximately thirty to thirty-five applicants in all and twenty of these were chosen. The basis for selection, following this initial application, was: availability of the individual for training and testing sessions, continued interest on each individual's part following an orientation session, and judgement on the part of this writer and his assistants as to whether or not the prospective subject would be able to stay on the treadmill (i.e., Did he have the necessary coordination to run at the training speed and not be subject to personal injury?). Sixteen of the subjects were involved in the experimental training program and four served as controls and were active only in the Orientation classes. All subjects were given an orientation as to the purpose of the study, the nature of the study, the expected physical behavior...
while not involved in testing or training, the procedure they would follow when reporting to training or testing sessions, and finally, the necessity and the value of their cooperation in making the study a success (Appendix B). The subjects had been initially motivated by a simple request for volunteers and a statement of purpose for the proposed study. Following their eventual selection, they were further motivated by the promise of top grades in Physical Education upon their diligent completion of the required testing and training.

The twenty subjects were divided into five groups of four using a table of random numbers (17). This grouping was for purposes of eventual training and each group was numbered from one to five, with respect to the number of days per week it would train (Group #4 was the exception to this. It served as the control group for the study.). The physical characteristics of the subjects may be found in Appendix A and the characteristics by training groups, in terms of mean values, are shown in Table I.
TABLE I

PHYSICAL CHARACTERISTICS OF THE TRAINING GROUPS

<table>
<thead>
<tr>
<th>Groups</th>
<th>$\bar{X}$ Height in inches</th>
<th>$\bar{X}$ Weight in pounds</th>
<th>$\bar{X}$ Age</th>
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<tbody>
<tr>
<td>1</td>
<td>71.6875</td>
<td>168.250</td>
<td>18.0</td>
</tr>
<tr>
<td>2</td>
<td>72.750</td>
<td>166.500</td>
<td>18.25</td>
</tr>
<tr>
<td>3</td>
<td>66.625</td>
<td>139.250</td>
<td>18.25</td>
</tr>
<tr>
<td>4 (Control)</td>
<td>69.750</td>
<td>159.000</td>
<td>19.50</td>
</tr>
<tr>
<td>5</td>
<td>70.250</td>
<td>152.875</td>
<td>18.0</td>
</tr>
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MEANS  
70.2125 157.175 18.4

II. EQUIPMENT

Treadmill

The subjects were trained and tested on a treadmill designed and constructed by the Missoula Equipment Development Center, United States Forest Service. It has a continuous rubber belt for walking or running, the surface of which measures four feet by eighteen feet and which is turned over forty-two 1.9 inch rollers. The speed is regulated by increasing or decreasing the tension on the belt and is registered in yards per minute on a small speedometer at one end of the treadmill. The speed may be regulated from one-half to ten miles per hour and the speedometer was calibrated prior to the
initial testing phase. The grade level of the treadmill may be adjusted from zero per cent to fifty-one percent through the manipulation of a hand crank. Both the speed and the grade may be altered while the machine is in operation. By experimentation, it was determined that the level of the belt was increased or decreased one per cent by three full turns on the hand crank (18).

Radio-Electrocardiograph

The various heart rate levels of the subjects were indicated by use of a Telemedics RKG 100 Radio-Electrocardiograph system, consisting of the following pieces of equipment: disposable electrodes, a battery-operated transmitter, a portable radio receiver, and a recording instrument. This system is identical to that used by McDonald (18) and described by him as follows:

The electrodes. The electrodes consisted of a patch type adhesive bandage with an electrode paste reservoir, a metallic screen, and a contact snap fastener. In order to minimize muscle noise, the two electrodes were placed at the right and left fifth rib, slightly forward of the mid axillary line.

The radio transmitter. The frequency modulated radio transmitter was approximately one inch thick by three inches wide by four inches high and weighted ten ounces, including the batteries. Heart signals from the
electrodes were carried by thin flexible wires of the
subject's cable to the transmitter where they were a m-
plified and transmitted from an antenna included within
the unit.

The radio receiver. The desk model receiver was
operated from a standard 115 volt 60 cycle power line.
It was equipped with a channel selector switch which
channeled the EKG signal to a recording instrument.

The recording instrument. The Telemedics Car-
diotac 400R electrocardiograph was equipped with a meter
that actually indicated the average heart rate in beats
per minute. The peaks of the amplified heart complex
(EKG) were translated into distinct "beeps". A volume
control permitted setting the audible level. This
system was checked out daily prior to its use and was
found to produce consistent results throughout the study.

Air Collection, Sampling, and Measuring Equipment

Air Collection Equipment. Expired air was col-
lected and analyzed during both pre and post-testing.
While taking the Astrand-Ryhming Step test, the subject
wore a special face mask with a one-way valve which
allowed full inspiration and which in turn, channeled
the expired air through an attached length of flexible
hose and through a two-way valve. This second valve
could be set to allow the expired air to pass into the
room atmosphere and at the desired time, switched to enable the air to pass into a Douglas bag for temporary storage. When taking the treadmill test suggested by Taylor, Buskirk, and Henschel (24) for the measurement of maximum oxygen consumption, the subject was fitted with a special rubber mouth-piece and a nose clip, which allowed the expired air to be collected in much the same manner as previously mentioned. In both cases, the proximal pieces of equipment were kept in a near surgical state of cleanliness and the more distant valves and hoses were cleaned and aired daily.

**Sampling Equipment.** The expired air was collected in Douglas bags and samples were taken by passing this air over mercury into Baily bottles. The sampling was performed immediately following the collection and each bag was thoroughly mixed just prior to sampling. Each bottle was properly labeled and the contents analyzed within thirty to ninety minutes of collection.

**Measuring Equipment.** A 600 liter chain compensated gasometer was used to draw the expired air out of the Douglas bags. A meter stick attached to the gasometer indicated the height that the gasometer bell reached while the expired air was being collected from the bag. The volume of the expired air was obtained by multiplying the number of centimeters rise times the
gasometer conversion factor which was 5.158 liters per centimeter. The expired air was mixed by an electric fan located within the gasometer bell. The temperature of the expired air was obtained by reading a thermometer which was located within the bell (18).

Gas Analysis

The samples of expired air were analyzed by use of the Scholander Micrometer Gas Analyzer and in the manner suggested by Scholander (21):

A gas sample is introduced into a reaction chamber connected to a micrometer burette and is balanced by means of an indicator drop in a capillary against a compensating chamber. Absorbing fluids for carbon dioxide and oxygen can be tilted into the reaction chamber without causing any change in the total liquid content of the system. During absorption of gas, mercury is delivered into the reaction chamber from the micrometer burette so as to maintain the balance of the gas against the compensating chamber. Volumes are read in terms of micrometer divisions. The rinsing fluids and absorbents are accurately adjusted to have the same vapor tension.

III. TESTS

The subjects were pre-tested and post-tested with three tests of physical fitness listed by Consolazio, Johnson, and Pecora (7). The battery of tests included the Balke Treadmill Test of Optimal Work Capacity; the Treadmill Test for Measurement of Maximal Oxygen Consumption suggested by Taylor, Buskirk, and Henschel;
and the Astrand-Ryhming Step Test for the calculation of physical fitness during submaximal work. It was felt that these three tests would provide a good basis for the observation of any fluctuations in the endurance level from pre to post-testing.

The Balke Treadmill Test of Optimal Work Capacity

Previous work by Balke and associates (7) has indicated that an individual may not continue to perform work which is in excess of fifty per cent of his maximum output for much more than eight hours. The point at which work output becomes "optimal" is when energy output is balanced by oxygen intake. It has been shown that when the heart rate reaches 180 beats per minute, the cardiovascular and cardiorespiratory systems suffer a limitation. For this reason, the test is terminated when the pulse rate reaches this level. The suggested procedure for administering the Balke test (7) is as follows:

1. Have subject walk on treadmill at a rate of 3.4 ± 0.1 miles per hour on a level grade.
2. At the end of the first minute of testing, raise the grade to two per cent. At the close of each succeeding minute, raise the grade by an additional one per cent.
3. Stop the test when the heart beat reaches the 180 level.
4. Record the length of the test in minutes and seconds. The suggested scoring of the Balke test, in terms of physical performance, is seen in Table II.

**TABLE II.**

**SCORING THE BALKE TEST**

<table>
<thead>
<tr>
<th>Duration of test in minutes</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 and below</td>
<td>Very Poor</td>
</tr>
<tr>
<td>13 and 14</td>
<td>Poor</td>
</tr>
<tr>
<td>15 and 16</td>
<td>Fair</td>
</tr>
<tr>
<td>17</td>
<td>Average</td>
</tr>
<tr>
<td>18 and 19</td>
<td>Good</td>
</tr>
<tr>
<td>20 and 21</td>
<td>Very Good</td>
</tr>
<tr>
<td>22 and 23</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

The Treadmill Test for the Measurement of the Maximal Oxygen Consumption

Taylor, Buskirk, and Henschel (24) suggest that the test be given on a treadmill at a constant speed of seven miles per hour and with an increase in grade of two and one-half per cent from test to test (This is stated to be more satisfactory than using a constant grade and increasing the speed). The test is supposed to run for three minutes. This is considered to be the
optimal time to allow for the collection of a one minute sample of expired air, for maximal safety of the subject, and affords a maximum opportunity for each individual to complete the test. Suggested procedure for the maximal oxygen intake test is as follows:

1. Warm up subject at 3.5 miles per hour.
2. For men in fairly good condition, start the test at six per cent grade.
3. Collect expired air from one minute forty-five seconds into the test until two minutes forty-five seconds.
4. On the following testing day, increase the grade by two and one-half percent.
5. As soon as the results from one test day to the next fail to differ by \( \pm 0.150 \) ml., it may be assumed that a maximum has been obtained.

It should be noted that the coefficient of reliability for the test was found to be 0.95 in sixty-nine test-retest cases, and that maximal oxygen was influenced by room temperature and time of warm-up (24).

The Astrand-Ryhming Step Test for Physical Fitness During Submaximal Work

A submaximal step test, five minutes in length, was used in conjunction with the Astrand-Ryhming Nomogram
to provide a means for estimating the maximal oxygen consumption from submaximal work. As suggested by Astrand and Ryhming (2), the pulse rate was taken before, during and immediately following exercise; expired air was collected and analyzed; and the individual body weights recorded. The results were applied to the Nomogram in the following three ways:

1. The exercise pulse rate, obtained during the fifth minute of exercise, and the body weight, in kilograms, were used to predict a maximal oxygen intake.

2. The exercise pulse rate and the amount of oxygen consumed, in liters per minute, during the fourth and fifth minutes of exercise were used to predict a maximal oxygen intake.

3. The post-exercise pulse rate or recovery rate, obtained during the period of fifteen to thirty seconds immediately following the cessation of exercise, was used to predict the exercise pulse rate. This predicted exercise pulse was then used, in conjunction with the body weight, to predict a maximal oxygen intake.
IV. TRAINING

The training selected for use in this study consisted of running on a motor driven treadmill at the specified rate of seven miles per hour for ten minutes (upper limit of exercise time per training bout). All subjects started out on a level grade. As each one successfully completed the ten minute run, the grade was increased by one per cent for the next session.

There were four experimental groups involved in the training phase of the study. The frequencies of the training sessions which were utilized are shown in Table III.

| TABLE III |

| GROUP TRAINING SCHEDULE |

<table>
<thead>
<tr>
<th>Group</th>
<th>M T W Th F</th>
<th>Days Per Week</th>
<th>Training Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>1</td>
<td>5 weeks</td>
</tr>
<tr>
<td>2</td>
<td>X X</td>
<td>2</td>
<td>5 weeks</td>
</tr>
<tr>
<td>3</td>
<td>X X X</td>
<td>3</td>
<td>5 weeks</td>
</tr>
<tr>
<td>4 (Control)</td>
<td>--none--</td>
<td>-</td>
<td>--none--</td>
</tr>
<tr>
<td>5</td>
<td>X X X X X X</td>
<td>5</td>
<td>5 weeks</td>
</tr>
</tbody>
</table>

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V. TESTING AND TRAINING PROCEDURE

The testing and training of the subjects was conducted during the Winter Quarter of 1966, in the Human Performance laboratory of the University of Montana. The pre and post—testing of the subjects required approximately two and one-half weeks before and after the five week training period. All testing and training sessions were conducted between the hours of seven o'clock in the morning and twelve o'clock noon.

Testing

Following the original orientation, all subjects were scheduled for pre—test sessions. The battery of three tests were administered in the following sequence. The Astrand—Ryhming Step Test was administered first and served as a warm—up for the Balke Test of Optimal Capacity, both being completed during the initial testing session. The first maximal oxygen consumption test was scheduled for the following session, and the second no sooner than two days later. If subsequent maximum oxygen tests were required, they were scheduled in identical fashion. An attempt was made to schedule the individual testing appointments at approximately the same time from test to test during both the pre and post—testing.
When reporting to the lab for the testing session, the subject immediately took his height and weight and assumed a reclining position for a period of ten minutes. During the rest period, the oral temperature and resting pulse rate were calculated (for additional personal and atmospheric data, see Appendix C). The electrodes were affixed in the prescribed manner and the telemetering system engaged. Following the rest period, the subjects took the Astrand-Ryhming test described earlier in the chapter. The bench height was forty centimeters. The rate was 22.5 steps per minute. Upon completion of the five minutes of exercise, the subjects again rested for approximately five minutes and then took the Balke Test of Optimal Capacity. The amount of time, in minutes and the nearest ten seconds, required to raise the subject's heart rate to one hundred and eighty beats per minute was recorded and the initial testing session was completed.

Upon arrival for the second session, the first maximum oxygen consumption test, the subject followed the same routine with the following exceptions and additions:

1. The initial rest period was five minutes in order to obtain the oral temperature. This data served as a check on the absence of a
fever, which could possibly have an inflationary effect of the maximum oxygen consumption.

2. The resting pulse was not taken.

3. Following the rest period, the subject was instructed to walk five good fast laps, similar in speed to the pace of the Balke test, around the indoor track located in the upper portion of the gymnasium. This exercise served as a warm-up for the maximum oxygen test. Upon completion of the warm-up, the subject again rested for five minutes and then prepared to be tested.

The selection of the initial test level for the maximum oxygen consumption test was based on the exercise heart rate during the fifth minute of exercise while taking the Astrand-Ryhming Step Test. If the individual's exercise heart rate was one hundred fifty beats per minute or lower, he started at a six per cent grade. All others started at a three and one-half per cent grade. This manner of selection is in accordance with that suggested by Taylor, Buskirk, and Henschel (24).
**Training**

When reporting for regular training sessions, the subject rested for a five minute period, during which the oral temperature and the resting pulse were taken. The room temperature was recorded and the subject then attempted to complete a ten minute run at his particular level of training.

Following the five week training period, all subjects were re-tested using identical testing procedures.
CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

I. Introduction

The following chapter presents an analysis and discussion of the results obtained while testing individuals who had trained at four different frequencies as well as the control group. This study was concerned with the effects of various frequencies of training on the general endurance level. More specifically, the writer was interested in the changes in that aspect of endurance which is measured by the cardiorespiratory response. The data resulting from this study may be found in Tables IV – XIV and will be discussed in this chapter.

II. Analysis of Results

According to the classification index suggested by Balke (7), the training groups ranged from very poor to poor, in terms of fitness levels, prior to training. The mean scores of each group and the general classification of each group are shown in Table IV.
TABLE IV

PRE-TRAINING RESULTS ON BALKE TEST

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean score in minutes</th>
<th>Classification of fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.333</td>
<td>Very poor</td>
</tr>
<tr>
<td>2</td>
<td>14.208</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>11.750</td>
<td>Very poor</td>
</tr>
<tr>
<td>4</td>
<td>13.208</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>11.333</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

In view of the low fitness level of the subjects in general, it was anticipated that they would react well to the training and that the achievements in training would vary in a direct relationship with the number of training sessions available to each group. The number of successful training sessions, i.e., running at the specified rate and grade for the full ten minutes, and the longest time run at the highest training level for each subject may be found in Appendix D. The same data for the different training groups, in terms of group means, are shown in Table V.
TABLE V

AVERAGE TRAINING INCREMENTS AND BEST TIMES

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of successful training sessions</th>
<th>Best group mean time at highest training level in minutes and seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.50</td>
<td>6:46</td>
</tr>
<tr>
<td>2</td>
<td>7.25</td>
<td>7:32</td>
</tr>
<tr>
<td>3</td>
<td>7.75</td>
<td>7:40</td>
</tr>
<tr>
<td>4 (Control)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>7.00</td>
<td>7:58</td>
</tr>
</tbody>
</table>

In spite of the unequal number of training bouts, Groups 2 and 3 had a mean number of successful sessions slightly greater than Group 5. The severity of the training was what could be classified as moderate, similar to the running of an eight minute mile. This, of course, involved an increasing work load as the grade was increased and thus became more difficult as the individual progressed.

An analysis of variance was performed on the data to see if there was a significant difference between the mean training achievements (Table VI). The "F" ratio needed to be 5.95 (9) in order to indicate significance at the .01 level of confidence. The "F" ratio on the analysis of variance of training achievements was significant well beyond the .01 level. The
analysis of variance formulation is shown in Appendix H.

**TABLE VI**

ANALYSIS OF VARIANCE FOR TRAINING ACHIEVEMENTS

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>&quot;F&quot; ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Between&quot; groups</td>
<td>3</td>
<td>191.300</td>
<td>63.767</td>
<td></td>
</tr>
<tr>
<td>&quot;Within&quot; groups</td>
<td>12</td>
<td>106.500</td>
<td>8.875</td>
<td>7.19*</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>297.800</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant beyond the .01 level.

A further test of significance, the Hartley Test (22), was performed on the training results in order to determine the location of the significant differences revealed by the analysis of variance. This test indicates significance at the .05 level of confidence and is based on the use of least significant differences. The results of the Hartley test are shown in Table VII and the significant differences are indicated by an asterisk (*). The numbers in parentheses are the least significant differences which may exist between those particular means and still be termed significant. If the actual difference is larger than this number, it
is judged significant. The suggested method for applying the Hartley test is found in Appendix H.

**TABLE VII**

**HARTLEY TEST FOR SIGNIFICANCE WITHIN THE TRAINING RESULTS**

<table>
<thead>
<tr>
<th>Group</th>
<th>$\bar{x}$</th>
<th>$\bar{x}$-2.50</th>
<th>$\bar{x}$-7.00</th>
<th>$\bar{x}$-7.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>7.75</td>
<td>5.25*</td>
<td>0.75</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.11)</td>
<td>(4.59)</td>
<td>(3.75)</td>
</tr>
<tr>
<td>2</td>
<td>7.25</td>
<td>4.75*</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.59)</td>
<td>(3.75)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7.00</td>
<td>4.50*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Indicates significance.

The results of the Hartley test indicated that significant differences existed between the three, two, and five day per week groups and the one day per week group but not between each other. It was interesting to note that both the three day and the two day groups had means above that of the five day group.

**Comparison of the Pre-test and Post-test Results of Training**

The pre to post-test results of each individual subject were compared and the differences recorded.
The mean differences in terms of specialized training groups in each of the three tests are shown in Table VIII.

### TABLE VIII

**COMPARISON OF MEAN DIFFERENCES OF PRE-POST TEST SCORES**

<table>
<thead>
<tr>
<th>Group</th>
<th>Balke Test mean differences</th>
<th>Taylor Test mean differences</th>
<th>Astrand-Ryhming Step Test mean differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.750</td>
<td>0.056</td>
<td>0.0175</td>
</tr>
<tr>
<td>2</td>
<td>4.917</td>
<td>0.215</td>
<td>0.9550</td>
</tr>
<tr>
<td>3</td>
<td>5.125</td>
<td>0.052</td>
<td>0.6150</td>
</tr>
<tr>
<td>4</td>
<td>2.667</td>
<td>-0.054</td>
<td>-0.1450</td>
</tr>
<tr>
<td>5</td>
<td>7.000</td>
<td>0.136</td>
<td>0.2325</td>
</tr>
</tbody>
</table>

**The Balke Test**

The results of the Balke test indicated an increasing positive change in the work capacity of the groups in relation to the amount of training received by each (Appendix E). The fact that the controls showed a mean increase of 2.667 minutes in work capacity may be the result of pre-testing work on the treadmill and participation in the physical education class (the former being a rather small influence at best, and the latter a very large one). The control group was required to attend each session of the class and the instructor put the class through a program of warm-up calisthenics three days per week.
An analysis of variance was performed on the data to see if there was a significant difference between the mean differences of the pre and post Balke scores (Table IX). The "F" ratio on the analysis of variance test was barely significant at the .05 level of confidence. In order to obtain significance at this level, the "F" ratio needed to be 3.06 (9).

### TABLE IX

**ANALYSIS OF VARIANCE FOR BALKE TEST**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>&quot;F&quot; ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Between&quot; groups</td>
<td>4</td>
<td>42.218</td>
<td>10.554</td>
<td></td>
</tr>
<tr>
<td>&quot;Within&quot; groups</td>
<td>15</td>
<td>50.352</td>
<td>3.357</td>
<td>3.14*</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>92.570</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

This significance was further tested by use of the Hartley test in order to determine the location of the significant differences. The results of the Hartley test are shown in Table X.
TABLE X
HARTLEY TEST FOR SIGNIFICANCE WITHIN THE BALKE TEST

<table>
<thead>
<tr>
<th>Group</th>
<th>( \overline{X} )</th>
<th>( \overline{X} - 2.6670 )</th>
<th>( \overline{X} - 3.7500 )</th>
<th>( \overline{X} - 4.9170 )</th>
<th>( \overline{X} - 5.1250 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>7.000</td>
<td>4.3330*</td>
<td>3.2500*</td>
<td>2.0830</td>
<td>1.8750*</td>
</tr>
<tr>
<td></td>
<td>(2.5320)</td>
<td>(2.3640)</td>
<td>(2.1264)</td>
<td>(1.7440)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5.125</td>
<td>2.4580*</td>
<td>1.3750</td>
<td>0.2080</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.3640)</td>
<td>(2.1264)</td>
<td>(1.7440)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4.917</td>
<td>2.2500*</td>
<td>1.1670</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.1264)</td>
<td>(1.7440)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.750</td>
<td>1.0830</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.7440)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.667</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Indicates significance.

The significant differences indicated by this test existed between the five day a week training group and each of the other groups except the two day a week group, and between the three and two day a week groups and the control group. All of the significant differences, with the exception of the five-to-four and the five-to-one, were just barely so (within a range of 0.100 \( \pm \) 0.03).

A second test for determining the location of significant differences between means, Duncan's Multiple Range Test (10), was used to serve as a check on the findings of the Hartley test. This test is very similar, in construction and application, to the Hartley test.
In view of the small sample size used in this study, it was not expected that there would be complete agreement between these two tests. The results of the Duncan test did, in fact, agree with the Hartley test to the point of noting the large significant differences, namely the five-to-four and the five-to-one group differences.

**The Astrand-Ryhming Step Test**

The results of the Astrand-Ryhming test indicated a definite increase in the predicted maximal oxygen consumption (Appendix F). This positive influence of training was, however, not a progressive one with respect to the number of training sessions experienced as in the case of the Balke test. The mean differences of scores made on the Astrand-Ryhming step test from pre to post-testing are shown in Table VIII. The controls exhibited a mean loss of predicted maximal oxygen consumption of \(-0.145\) liters of oxygen per minute, this being fairly consistent with their lack of training. The results of the experimental groups, however, were quite unexpected. The two day a week group showed a mean increase of nearly one liter per minute and the three day a week group increased better than six tenths of a liter per minute. The one day a week group was seen to exhibit only a very minor positive change.
Possibly the most surprising results of all were registered by the five day a week group which showed less than one quarter of the increase exhibited by the two day a week group (0.2325).

An analysis of variance was performed on the data to see if there was a significant difference between the pre and post-test results of the Astrand-Ryhming step test (Table XI). The "F" ratio on the analysis of variance was highly significant beyond the .01 level of confidence. In order to obtain significance at this level, the "F" ratio needed to be at least 4.89 (9).

**TABLE XI**

**ANALYSIS OF VARIANCE FOR ASTRAND-RYHMING STEP TEST**

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>&quot;F&quot; ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Between&quot; groups</td>
<td>4</td>
<td>3.2180</td>
<td>0.8045</td>
<td></td>
</tr>
<tr>
<td>&quot;Within&quot; groups</td>
<td>15</td>
<td>1.6617</td>
<td>0.1108</td>
<td>7.27*</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>4.8797</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant beyond the .01 level.

As in the case of the Balke test, two tests of significance for locating the significant differences were applied to the results of the Astrand-Ryhming test. The Hartley test indicated a wide range of significance,
as shown in Table XII, and in this instance, the Duncan test showed a high degree of agreement, i.e., a seven to five ratio of significant differences from Hartley to Duncan.

TABLE XII
HARTLEY TEST FOR SIGNIFICANCE WITHIN THE ASTRAND-RYHMING TEST

<table>
<thead>
<tr>
<th>Group</th>
<th>$\bar{X}$</th>
<th>$\bar{X} - (-0.145)$</th>
<th>$\bar{X} - 0.0175$</th>
<th>$\bar{X} - 0.2325$</th>
<th>$\bar{X} - 0.6150$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.9550</td>
<td>1.1000*</td>
<td>0.9375*</td>
<td>0.7225*</td>
<td>0.3400*</td>
</tr>
<tr>
<td></td>
<td>(0.4486)</td>
<td>(0.4196)</td>
<td>(0.3780)</td>
<td>(0.3117)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.6150</td>
<td>0.7600*</td>
<td>0.5975*</td>
<td>0.3825*</td>
<td></td>
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<tr>
<td></td>
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<td>(0.3780)</td>
<td>(0.3117)</td>
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<td>0.3775</td>
<td>0.2150</td>
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<td>-0.1450</td>
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</table>

*Indicates significance.

The two day a week group differed significantly from all the other groups and the three day a week group was significantly different from the controls and experimental groups one and five. The multiple range test of Duncan's agreed with these findings with the exception of the two-to-three and the three-to-five differences.

The Taylor Test of Maximal Oxygen Consumption

The results of the actual maximum oxygen consump-
tion test differed from those of the predictive test (Astrand-Ryhming test) in terms of significance but not so very much in terms of mean differences (Table VIII). The individual results of pre and post-testing are found in Appendix G. Again there was no consistent relationship between the total number of exercise bouts and the ranking of the mean differences. The control group did indicate a slight loss of maximal oxygen intake (-0.054), which was consistent with the results of the Astrand-Ryhming test. The ranking of the experimental means changed somewhat, with the two day group again commanding the top spot and the three day group dropping from second to fourth position. The five day per week training group and the one day per week group retained the same positions relative to each other and both moved up to spots two and three respectively. The mean improvement in maximal oxygen consumption of the two day a week group was nearly twice that of the five day group and four times that of the one and three day groups.

An analysis of variance was run to see if there was a significant difference between the pre and post-test results of the Taylor Maximal Oxygen Consumption test (Table XIII). In order to be significant, the "F" ratio had to be at least 3.06 at the .05 level of
confidence (9). The obtained "F" ratio of 0.2745 was far from this value.

### TABLE XIII

**ANALYSIS OF VARIANCE FOR THE TAYLOR TREADMILL TEST RESULTS**

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>&quot;F&quot; ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Between&quot; groups</td>
<td>4</td>
<td>0.1636</td>
<td>0.0409</td>
<td></td>
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<tr>
<td>&quot;Within&quot; groups</td>
<td>15</td>
<td>2.2348</td>
<td>0.1490</td>
<td>0.275*</td>
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<tr>
<td>Total</td>
<td>19</td>
<td>2.3984</td>
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</table>

*Not significant at the .05 level.

### III. Discussion of the Results

Several different studies have indicated that there is a fairly rapid physiological response to the rigors of training.

Patton (19) used three groups of subjects, trained for eight weeks on the treadmill and found that both the all-out and the interval training groups improved significantly over the controls.

Cooper (8) compared the effects of two different exercise programs on the basis of their contributions to cardiorespiratory fitness and found that both programs made significant contributions within a five week period of training.
Campney (5) took one group of eight, low fitness, college males and trained them for ten weeks. The training was all-out bench stepping and the author reported that within the first five weeks, tests showed that seven out of eight had registered cardiovascular improvement, as measured by heart rate recovery.

Knehr, Dill, and Neufeld (16), trained fourteen subjects for six months, at a frequency of three days per week, in middle distance type running. Through bi-weekly tests on the treadmill, the study reported that the greatest decrease in the oxygen requirement occurred within eight weeks.

Brouha (4) indicates that through training, the following changes will occur:

1. Increased neuromuscular coordination may result in a decrease of energy expenditure, for a given task, of up to one quarter of that needed prior to training.

2. The heart becomes more efficient through training and the exercise heart rate decreases as training progresses.

3. Changes in the respiratory response are progressive and from four to six weeks are needed to reach maximum efficiency. For a given task, less oxygen is consumed and at high levels of exercise, the maximal oxygen intake
Durnin (11) and his associates found that a significant decrease in oxygen consumed and in exercise heart rate could be obtained in only ten days of moderate to difficult physical exercise and training.

In general then, the results obtained in this study involving a training period of five weeks, concur very well with those of previous investigators. As a group, the experimental subjects evidenced the following changes from pre to post-testing:

1. The oxygen consumed for a given amount of work (five minutes of exercise in the Astrand-Ryhming step test) was decreased, the mean decrease being one of -0.014 liters of oxygen per minute per subject.

2. The maximal oxygen consumption value showed a mean increase of 0.115 liters of oxygen per minute per subject.

3. The exercise heart rate, measured during the fourth and fifth minutes of exercise in the Astrand-Ryhming test, showed a definite reduction. The mean decrease per subject during the fourth minute of exercise was 14.5 beats per minute and the mean decrease during the fifth minute was 15.0 beats per minute.
4. There was no direct calculation of the energy cost but it was felt that a certain amount of the reduction in oxygen consumed for given amounts of work was directly related to an increase in neuromuscular coordination, hence mechanical efficiency, the increased coordination being directly responsible for a smaller amount of wasted motion and thus a smaller amount of fuel necessary to perform a given task.

The results of the Balke test indicated that work capacity, as measured by this test, could be altered in a positive manner in five weeks of training. The results were significant at the .05 level. Further analysis of the group means indicated that there was a significant difference to be found between the gains made by the five, three, and two day per week training groups and those made by the controls. It was interesting to note that significant differences also existed between five-to-three and five-to-one, but not between five-to-two or between three-to-two or between three-to-one. In terms of attempting to increase the optimal work capacity, for these particular subjects, the most equitable returns came from training at the frequency of two days per week.
The predictive test of maximal oxygen consumption, the Astrand-Ryhming Step test, provided results that were markedly different from those of the Balke test in terms of significance. Prior to training, a correlation of .546 was obtained between the Astrand-Ryhming test and the Balke test. This correlation indicates a lack of a very high degree of relationship between work capacity and predicted maximal oxygen consumption within this group of subjects. A second correlation was run with these same two tests but using the values from the Astrand-Ryhming step test in terms of milliliters of oxygen per gram per minute instead of the maximal oxygen score in liters per minute. This treatment of the data produced a somewhat higher correlation of .627, but still failed to indicate a very high degree of relationship. The method of calculation for the coefficient of correlation may be found in Appendix H. It was found that a difference existed from pre to post-testing which was significant well beyond the .01 level of confidence for the Astrand-Ryhming results. Through the application of the Hartley test, it was discovered that groups two and three were significantly different from all others (two was significantly better than three also) and that there was no difference between five, one, and four (controls). The
Astrand-Ryhming test also indicated a general decrease in the exercise pulse rate and the amount of oxygen consumed during exercise. All three values, the pulse rate, the amount of oxygen consumed, and the predicted maximal oxygen consumption, indicate a much more significant return, for this particular group of subjects, when training at the two day per week frequency.

The Taylor, Buskirk, and Henschel test of Maximal Oxygen Consumption gave no significant results. It did, however, indicate that the Astrand-Ryhming test tends to underestimate an actual maximal oxygen value and overestimate the amount of change therein. Prior to training, a correlation of .646 was found to exist between the Taylor test and the Astrand-Ryhming test. In terms of mean improvement, the results of the Taylor test found group two with the highest change in the maximal oxygen consumption. Again, it would appear that the practice of training twice a week is as good if not better than five.

In terms of actual achievement during training, the two day, three day, and five day per week groups were approximately even. In spite of the unequal number of training sessions, i.e., ten, fifteen, and twenty-five, the two day a week group did better than
the five day and came within 0.5 sessions of the three day a week group. All three groups made much more improvement than the one day a week group (significant beyond the .01 level of confidence).

Durnin, et al. (11) in their study on the effects of a short period of training of varying severity, used physically untrained subjects and exposed them to daily training for a period of ten days with one day of rest in the middle of that period. They made use of three experimental groups and had them training at ten, twenty, and thirty kilometers of walking per session. The results of this study were as follows:

1. "Within groups": the only group, from one test day to the next, to have a significant decrease in pulmonary ventilation and oxygen consumption, was the twenty kilometer group (significant beyond the .01 level). All experimental groups experienced a significant lowering of the heart rate during exercise.

2. "Between groups": the twenty kilometer group was the only one to have consistently significant results.

The authors concluded that the training group which made the most significant improvements wasn't the one doing the most work. Also, that the thirty kilometer training
sessions may have been too much for the level of fitness of that particular group.

Table XIV affords a summary of all data studied and a simple ranking of the groups in terms of their relative position in each instance.

**TABLE XIV**

**SUMMARY RANKING OF GROUPS**

<table>
<thead>
<tr>
<th>Position</th>
<th>Taylor test</th>
<th>Predicted maximal oxygen*</th>
<th>Astrand-Ryhming Step Test</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Exercise pulse rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxygen Balke* consumed test</td>
</tr>
<tr>
<td>First</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Second</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Third</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fourth</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fifth</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Significant beyond the .05 level.

The results of this study would appear to indicate the lack of a necessity for training every day of the week and the presence of a definite high rate of beneficial returns from a training frequency of two days per week. The comment of Durnin, et al. (11), regarding the fitness level of their subjects, should not be ignored when considering the results of this investigation.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

This study was conducted to observe the effects of various frequencies of training upon the level of cardiorespiratory endurance. Twenty students, enrolled in physical education activity classes at the University of Montana, were accepted as volunteers, to participate as subjects in an attempt to discover the training frequency which afforded the most beneficial returns relative to the amount of time involved.

Each subject was given a step test to predict the maximal oxygen consumption, a treadmill test to determine the actual maximal oxygen consumption, and a treadmill test of optimal work capacity. These tests served as pre-training points of reference. The subjects were randomly divided into five groups, consisting of four experimental groups and one control group. The experimental groups (one, two, three, and five) trained at frequencies consistent with their group reference number, i.e., group three trained at a frequency of three days per week. Group four served as the control group and was inactive except for a physical education class.
The training was similar for all groups. It involved running for a period of ten minutes, if possible, at grades. The treadmill speed was held constant at seven miles per hour.

Following the training period all subjects were re-tested, using the same test battery in the same order, to determine the effectiveness of the training program. The pre-training scores were graphed and the coefficient of correlation calculated for the three possible comparisons involving the three tests. The correlation between the actual and predicted maximal oxygen consumption was found to be .646, indicating a fair degree of commonality. The other two correlations, .546 of optimal work capacity to predicted maximal oxygen consumption, and .155 of optimal work capacity to actual maximal oxygen consumption, were less than fair and indicated a lack of the measurement of similar effects. The correlation of .546 between the predicted maximal oxygen consumption and optimal work capacity was probably as high as it was due to a similar basis of measurement, namely the exercise pulse rate.

The data were analyzed by analysis of variance techniques in order to test the hypothesis that there was no significant change in the physiological responses from pre to post-testing. The results were further
treated to determine the specific location of any significance in terms of mean differences. The Hartley test of least significant differences and the Duncan Multiple Range test were used to accomplish this latter purpose. Both are constructed to detect significance at the .05 level of confidence.

The analysis of variance test on the optimal work capacity data indicated significance at the .05 level. Further analysis revealed significant differences between the following means: five-to-three, five-to-one, five-to-four, three-to-one, and two-to-one.

The analysis of variance test on the step test data indicated a very high degree of significance, well beyond the .01 level of confidence. Further analysis by the Hartley test revealed the following significant differences between means: two-to-three, two-to-four, two-to-one, two-to-five, three-to-five, three-to-one, and three-to-four.

The results of the treadmill test of actual maximal oxygen consumption failed to yield significance when tested by analysis of variance.

An analysis of variance test on the training data proved that there was significance beyond the .05 level and further, that there was a significant difference between the results of training five, three, or two
days and only one day; but not between five days, three
days, and two days.

II. CONCLUSIONS

On the basis of the results found in this study, the following conclusions have been made:

1. For the particular subjects involved in this study, training at this specific level was either not intense enough or of a long enough duration to bring about significant alterations in cardiorespiratory endurance, as measured by maximal oxygen consumption.

2. Considering the initial level of cardiorespiratory endurance possesed by these subjects, it seems that training twice a week would be as beneficial as three times or five times.

3. In the case of certain individuals, five days a week training may be too severe to allow adaptation by the systems involved.

4. The maximal oxygen consumption as predicted by the Astrand-Ryhming step test tends to be lower than the actual maximum consumption.

5. At this level of fitness and this intensity of training, the optimal work capacity (as measured by the Balke test) is increased in
a direct relationship to the number of training exposures.

III. RECOMMENDATIONS

In view of the findings and conclusions of this study, the following recommendations have been made:

1. Further studies should be conducted along these lines, perhaps making comparisons of several different fitness levels with one particular frequency in order to discover the most desirable frequency of training at high levels of fitness.

2. It might be beneficial to study one frequency at a time, using more subjects and thus obtaining a more reliable insight into the effects of this frequency.

3. It would be desirable, in future research, to have more direct control of the outside habits and activities of the subjects in order to obtain a more definite result of training.

4. It might also be rewarding to study one particular frequency of training and to vary the intensity of training within that frequency.

5. It is recommended that much more work be done in this area in order that the profession might have a sound basis for the recommendation of training programs.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY


### APPENDIX A

**PHYSICAL CHARACTERISTICS OF THE SUBJECTS**

<table>
<thead>
<tr>
<th>Subjects (Training group)</th>
<th>Height in inches</th>
<th>Weight in pounds</th>
<th>Age in years</th>
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<td>180.0</td>
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<td>B.H. (3)</td>
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</tr>
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<td>R.K. (2)</td>
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<td>184.0</td>
<td>18</td>
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<tr>
<td>D.L. (4)</td>
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<td>188.0</td>
<td>23</td>
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<tr>
<td>M.M. (5)</td>
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<td>156.5</td>
<td>18</td>
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</tr>
<tr>
<td>W.M. (5)</td>
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<td>18</td>
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<tr>
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<td>150.0</td>
<td>18</td>
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<tr>
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<td>160.0</td>
<td>18</td>
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<td>R.R. (5)</td>
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<td>19</td>
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<td>19</td>
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**MEANS**

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APPENDIX B

HUMAN PERFORMANCE LABORATORY

January 6, 1966

Gentlemen:

We appreciate your willingness to participate in this investigation. Since the study involves metabolic measures, we must ask you to comply with the following regulations:

- Do not eat or drink (water o.k.) within three hours of a test.
- Get a good night's sleep before a test.
- Refrain from vigorous exercise on the day of the test.

During the training phase of the study it will be necessary for you to avoid regular strenuous exercise other than that involved in the investigation. Failure to comply with this regulation would confuse the outcome of the study. Therefore, we ask that you remove yourself if you do not feel you will be able to avoid regular strenuous activity. (Strenuous exercise is that which prompts rapid pulse and breathing rates.)

During the training phase you will be scheduled for a specific time. Please be prompt and we will do our best to keep the sessions brief. If you cannot attend the session for any reason, let us know, in advance, if possible.

Again, we thank you for your interest and cooperation.

Sincerely,

Dr. Brian Sharkey
Mr. Jay Jackson

Training schedule ___________

[Detach and return this stub.]

Name____________________ Age____ Ht.____ Wt.____ Class____

Previous athletic history

Have you any medical reason to avoid STRENuous physical activity? Yes No If yes, indicate reason________________________

Date of last physical examination________________________

Dorm__________________ Room # ___________ Phone #____________
APPENDIX C
HUMAN PERFORMANCE LABORATORY

Subject____________________ Date_________ Treatment________

Control Data:  Rm temp___ Bar pr___ Rel hum___ Oral temp___
Body wt___ Ht___ Rest Pulse___ ___ ___ ___ Blood pr___
Last food___ Drink(not H2O)___ Hrs slp___ Last ex________
Other____________________________________________________

Experimental Data:


Ventilation: Gasometer factor (GF)_______ Meter factor_______
Conversion factor (derived from bar pr & temp of gas)= CF_______

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<th>VR in</th>
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Gas Analysis:

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<th>T-O2</th>
<th>VR</th>
<th>CO2/min</th>
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Comments:
APPENDIX D

TRAINING DATA

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<tr>
<th>Subject</th>
<th>Number of Successful sessions</th>
<th>Best time at last level</th>
<th>Subject</th>
<th>Number of Successful sessions</th>
<th>Best time at last level</th>
</tr>
</thead>
<tbody>
<tr>
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<td>B.R.</td>
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<td>6:00</td>
</tr>
<tr>
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<td>D.T.</td>
<td>9</td>
<td>10:00</td>
</tr>
<tr>
<td>T.S.</td>
<td>3</td>
<td>5:20</td>
<td>R.M.</td>
<td>10</td>
<td>10:00</td>
</tr>
<tr>
<td>B.V.</td>
<td>3</td>
<td>7:20</td>
<td>R.K.</td>
<td>6</td>
<td>4:10</td>
</tr>
<tr>
<td><strong>Means</strong></td>
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## APPENDIX E

### PRE-POST TEST RESULTS OF BALKE TEST

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<thead>
<tr>
<th>Subject</th>
<th>Group 1 Pre-test* (minutes)</th>
<th>Group 1 Post-test (minutes)</th>
<th>Difference (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.R.</td>
<td>10.167</td>
<td>16.000</td>
<td>5.833</td>
</tr>
<tr>
<td>L.C.</td>
<td>12.667</td>
<td>15.333</td>
<td>2.667</td>
</tr>
<tr>
<td>T.S.</td>
<td>9.883</td>
<td>12.333</td>
<td>2.500</td>
</tr>
<tr>
<td>B.V.</td>
<td>12.667</td>
<td>16.667</td>
<td>4.000</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>11.333</strong></td>
<td><strong>15.083</strong></td>
<td><strong>3.750</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.R.</td>
<td>10.667</td>
<td>15.333</td>
<td>4.667</td>
</tr>
<tr>
<td>D.T.</td>
<td>17.500</td>
<td>23.833</td>
<td>6.333</td>
</tr>
<tr>
<td>R.M.</td>
<td>16.333</td>
<td>22.333</td>
<td>6.000</td>
</tr>
<tr>
<td>R.K.</td>
<td>12.333</td>
<td>15.000</td>
<td>2.667</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>14.208</strong></td>
<td><strong>19.125</strong></td>
<td><strong>4.917</strong></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Subject</th>
<th>Group 3</th>
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</thead>
<tbody>
<tr>
<td>M.W.</td>
<td>12.500</td>
<td>16.667</td>
<td>4.167</td>
</tr>
<tr>
<td>J.S.</td>
<td>8.167</td>
<td>10.333</td>
<td>2.167</td>
</tr>
<tr>
<td>B.H.</td>
<td>14.333</td>
<td>22.000</td>
<td>7.667</td>
</tr>
<tr>
<td>D.M.</td>
<td>12.000</td>
<td>18.500</td>
<td>6.500</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>11.750</strong></td>
<td><strong>16.875</strong></td>
<td><strong>5.125</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group 4</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C.M.</td>
<td>12.667</td>
<td>15.667</td>
<td>3.000</td>
</tr>
<tr>
<td>B.T.</td>
<td>14.667</td>
<td>19.833</td>
<td>5.167</td>
</tr>
<tr>
<td>B.Z.</td>
<td>14.000</td>
<td>15.500</td>
<td>1.500</td>
</tr>
<tr>
<td>D.L.</td>
<td>11.500</td>
<td>12.500</td>
<td>1.000</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>13.208</strong></td>
<td><strong>15.875</strong></td>
<td><strong>2.667</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group 5</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R.R.</td>
<td>12.333</td>
<td>17.833</td>
<td>5.500</td>
</tr>
<tr>
<td>M.M.</td>
<td>16.500</td>
<td>25.500</td>
<td>9.000</td>
</tr>
<tr>
<td>W.M.</td>
<td>8.000</td>
<td>14.667</td>
<td>6.667</td>
</tr>
<tr>
<td>D.M.</td>
<td>8.500</td>
<td>15.333</td>
<td>6.833</td>
</tr>
<tr>
<td><strong>Means</strong></td>
<td><strong>11.333</strong></td>
<td><strong>18.333</strong></td>
<td><strong>7.000</strong></td>
</tr>
</tbody>
</table>

*Values expressed in minutes and decimal fractions thereof.

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### APPENDIX F

**PRE-POST TEST RESULTS OF ASTRAND-RYHMING TEST**

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Subject</th>
<th>Pre-test*</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.R.</td>
<td>3.52</td>
<td>3.73</td>
<td>0.21</td>
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</tr>
<tr>
<td>L.C.</td>
<td>3.45</td>
<td>3.20</td>
<td>-0.25</td>
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</tr>
<tr>
<td>T.S.</td>
<td>2.70</td>
<td>2.45</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>B.V.</td>
<td>2.65</td>
<td>3.01</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Means</td>
<td>3.08</td>
<td></td>
<td>0.0175</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 2</th>
<th>Subject</th>
<th>Pre-test*</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.R.</td>
<td>3.05</td>
<td>3.68</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>D.T.</td>
<td>3.48</td>
<td>4.21</td>
<td>0.73</td>
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<tr>
<td>R.M.</td>
<td>2.72</td>
<td>4.28</td>
<td>1.56</td>
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</tr>
<tr>
<td>R.K.</td>
<td>3.00</td>
<td>3.90</td>
<td>0.90</td>
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<tr>
<td>Means</td>
<td>3.06</td>
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<td>0.9550</td>
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<table>
<thead>
<tr>
<th>Group 3</th>
<th>Subject</th>
<th>Pre-test*</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.W.</td>
<td>2.73</td>
<td>3.16</td>
<td>0.43</td>
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<tr>
<td>J.S.</td>
<td>2.10</td>
<td>2.68</td>
<td>0.58</td>
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</tr>
<tr>
<td>B.H.</td>
<td>2.92</td>
<td>3.41</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>D.M.</td>
<td>2.18</td>
<td>3.14</td>
<td>0.96</td>
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<tr>
<td>Means</td>
<td>2.48</td>
<td></td>
<td>0.6150</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 4</th>
<th>Subject</th>
<th>Pre-test*</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.M.</td>
<td>3.40</td>
<td>3.08</td>
<td>-0.32</td>
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</tr>
<tr>
<td>B.T.</td>
<td>3.00</td>
<td>3.32</td>
<td>0.32</td>
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</tr>
<tr>
<td>B.Z.</td>
<td>3.32</td>
<td>3.20</td>
<td>-0.12</td>
<td></td>
</tr>
<tr>
<td>D.L.</td>
<td>3.35</td>
<td>2.89</td>
<td>-0.46</td>
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</tr>
<tr>
<td>Means</td>
<td>3.27</td>
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<td>0.1450</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 5</th>
<th>Subject</th>
<th>Pre-test*</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.R.</td>
<td>3.10</td>
<td>2.87</td>
<td>-0.23</td>
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</tr>
<tr>
<td>M.M.</td>
<td>4.00</td>
<td>4.23</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>W.M.</td>
<td>2.15</td>
<td>2.61</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>D.M.</td>
<td>2.75</td>
<td>3.22</td>
<td>0.47</td>
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</tr>
<tr>
<td>Means</td>
<td>3.00</td>
<td></td>
<td>0.2325</td>
<td></td>
</tr>
</tbody>
</table>

*Values expressed in predicted liters of oxygen consumed per minute.*

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APPENDIX G

PRE-POST TEST RESULTS OF TAYLOR, BUSKIRK, AND HENSCHEL TEST

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test*</td>
<td>Post-test</td>
<td>Difference</td>
<td>Pre-test*</td>
<td>Post-test</td>
</tr>
<tr>
<td>J.R.</td>
<td>4.317</td>
<td>4.437</td>
<td>0.120</td>
<td>B.R.</td>
<td>3.591</td>
</tr>
<tr>
<td>L.C.</td>
<td>4.048</td>
<td>4.229</td>
<td>0.181</td>
<td>D.T.</td>
<td>3.755</td>
</tr>
<tr>
<td>B.V.</td>
<td>3.577</td>
<td>3.790</td>
<td>0.213</td>
<td>R.K.</td>
<td>4.198</td>
</tr>
<tr>
<td>Means</td>
<td>4.056</td>
<td></td>
<td>0.056</td>
<td>Means</td>
<td>3.835</td>
</tr>
</tbody>
</table>

*Values expressed in actual liters of oxygen consumed per minute.
APPENDIX H

STATISTICAL ANALYSIS

Formula for Correlation of Pre-test Results on the Balke, Astrand-Ryhming, and Taylor, Buskirk, and Henschel Tests:

\[ r = \frac{N \sum XY - \left( \sum X \sum Y \right)}{\sqrt{\left[ N \sum X^2 - \left( \sum X \right)^2 \right] \left[ N \sum Y^2 - \left( \sum Y \right)^2 \right]}} \]

where:
\[ N = \text{total number of subjects in sample population} \]
\[ X, Y = \text{raw or obtained scores on the tests} \]
\[ \sum XY = \text{sum of the products of raw scores} \]
\[ \sum X, \sum Y = \text{sum of scores} \]
\[ \sum X^2, \sum Y^2 = \text{sum of squared scores} \]
\[ (\sum X)^2, (\sum Y)^2 = \text{sum of scores, squared} \]

Analysis of Variance Formula:

Total sum of squares -

\[ \sum x^2 = \sum x^2 - \frac{(\sum X)^2}{N} \]

where:
\[ \sum x^2 = \text{total sum of squares} \]
\[ \sum x^2 = \text{sum of the squares of individual scores} \]
\[ (\sum X)^2 = \text{sum of the individual scores, squared} \]
\[ N = \text{total number of subjects in the sample} \]
APPENDIX H (CONT'D)

The "Between" sum of squares -

\[ \sum x^2 = \left[ \sum \left( \frac{\sum x^2}{n} \right) \right] - \frac{(\sum x)^2}{N} \]

where:
\[ \sum x^2 = \text{"Between" sum of squares} \]
\[ \sum \left( \frac{\sum x^2}{n} \right) = \text{summation of the ratio of the sum of individual scores, squared, and divided by the number of subjects within each particular group} \]
\[ \frac{(\sum x)^2}{N} = \text{the ratio of the total sum of the individual scores, squared, to the total number of subjects in the population} \]

The "Within" sum of squares -

\[ \sum x^2 = \sum x^2 - \frac{(\sum x)^2}{n} \]

where:
\[ \sum x^2 = \text{"Within" sum of squares} \]
\[ \sum x^2 = \text{sum of the squared individual scores} \]
\[ \frac{(\sum x)^2}{n} = \text{the ratio of the sum of the individual scores, squared, to the number of subjects within each group} \]

The "F" test -

\[ F = \text{the ratio of the "between" groups mean square to the "within" groups or error mean square, where the mean square is obtained by dividing the specific sum of squares by the accompanying number of degrees of freedom.} \]
APPENDIX H (CONT'D)

Hartley Test for Comparison of Mean Differences Formula:

\[ D = \sqrt{\frac{\text{Error or "within" mean square}}{a(a-1)/2}} \]

where:

- \( D \) = the square root of the ratio of the error or "within" groups mean square to the total possible number of comparisons of means, i.e., the possible number of combinations of \( a \) means taken two at a time.

\( D \) is then multiplied by the respective values of \( Q \), taken from Table 10.6.1 (22) and based on the associated degrees of freedom and the number of means \( a \), to arrive at the least significant difference for comparison with each mean difference.