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THE CARDIAC TRAINING EFFECT OF SELECTED COLLEGE MEN AS MEASURED BY THREE HEART RATE INTENSITY LEVELS BASED ON RESTING AND MAXIMUM HEART RATES

by

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The purpose of this investigation was to study the cardiac training effect of three heart rate intensities based on the percentages within the range of resting and maximum heart rates. It was designed to focus additional light on the amount of cardiac stress needed to cause the "training effect" to occur and the amount of work needed to achieve a physiological change as noted by the decrease in resting heart rate.

The subjects were 12 dependable college males who would complete the six weeks exercise program. The resting heart rate was obtained by attaching electrodes to the manubrium sterni and monitoring the subjects' resting heart rate after they rested a minimum of 30 minutes in a supine position. A maximum heart rate was also obtained by monitoring the heart rate as each subject ran on a treadmill at 7 mph and 0 per cent grade. The speed remained constant but the grade increased 2½ per cent after each minute of exercise until exhaustion. The 50, 60 and 70 per cent heart rate intensity levels were determined from the range between the resting and maximum heart rates.

The subjects were assigned to three groups of four and exercised on a treadmill at the 50 per cent heart rate intensity level for two weeks. An analysis of

variance of resting heart rates (F = 0.372) showed the groups to be equated after the initial two weeks of exercise. Group I, which exercised at only the 50 per cent heart rate intensity level for six weeks, showed no significant difference when an analysis of variance on resting heart rate was calculated (F = 0.655). Group II trained for two weeks at 50 per cent and four weeks at the 60 per cent heart rate intensity level. An analysis of variance on this group's resting heart rate showed a significant difference at the .01 level (F = 7.705). Group III exercised for two weeks at 50 per cent, the second two weeks at 60 per cent and the final two weeks at 70 per cent heart rate intensity level. A significant difference was noted in the resting heart rates of this group at the .01 level (F = 7.179).

A t test between pre-training resting heart rate and post two weeks resting rate of all subjects showed no significant difference (t = 1.939). A t test of Groups II and III at the conclusion of the fourth week of training showed a significant difference between pre-training and post four weeks resting heart rate at the .01 level (t = 6.401).

The second criterion used to determine if training effect occurred was the change in the exercise tolerance level while the heart rate intensity remained the same. The change that occurred did not suggest training because the two groups which exercised at the highest rates had less significant change than the Group I subjects which exercised at the lesser heart rate intensity level. The work tolerance evidently reflected the time needed for members of a group to accustom themselves to the exercise.

A case study evaluation was made of each subject. This made it possible to study more closely each subject in the investigation.

It was concluded from this investigation that no "training effect" occurred in Group I at the 50 per cent heart rate intensity level and that training effect did occur in the two groups which exercised at 60 per cent or higher. These data suggest that the critical threshold where "training effect" occurs is approximately 60 per cent between the resting and maximum heart rates.

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TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS

The heart rate is a readily available measure of what occurs internally and provides data that indicate various exercise conditions. Since heart rate is easily obtained, it is indeed fortunate that research has shown the heart rate to be an important variable in the response of the heart to the demands of exercise. The rate of the heart beat furnishes data that quite accurately reflect the degree of stress created by an exercise workload; conversely, it provides insight into the adequacy of physiological responses to exercise. (6)

The heart becomes more efficient with training and is able to provide greater circulation of blood while beating fewer times per minute. This training effect affords the heart a more powerful contraction, it empties itself to a greater degree at each systole, thus increasing stroke volume and cardiac output. As training progresses, the heart rate becomes slower for a standard amount of work. This greater efficiency of the heart enables a greater transport of food and oxygen to the cells of the body and also aids in the elimination of waste products which permits the individual to attain greater performance levels. (30)

A point of interest to the physical educator, the physiologist, and the coach is the amount of work needed to achieve these physiological changes and show that a "training effect" has occurred. (6) Karvonen concluded that a critical threshold value must be exceeded during any workout for there to be any improvement in the exercise tolerance of the heart. He believed the critical threshold value was expressed at a point 60 per cent between the resting and the maximal heart rate. For example, a subject with a resting heart rate of 75 and a maximal rate of 200 has a critical threshold of 75 + .60 (200 - 75) or 150 beats per minute. (6, 56, 57, 58)

I. THE PROBLEM

Researchers, comparing the heart rates of athletes and non-athletes, have observed that "training effect" does occur. The training effect is known to reduce the heart rate. This decrease occurs in both the resting heart rate and in the heart rate during a standard exercise. There is very limited research concerning the critical threshold where training effect occurs. The majority of observations and investigations in this realm are concerned with a very limited number of subjects and short periods of training time.

Statement of the problem. The purpose of this investigation was to study the cardiac training effect of three heart rate intensities based on the percentages within the range of resting and maximum heart rates.

Sub-problems. To aid in the solution of the major problem it was necessary to investigate three sub-problems: (1) to determine the level of exercise heart rate intensity for each subject, (2) to determine training effect at each level of intensity, and (3) to compare the training effect level at each intensity.

Importance of the study. The heart rate has been recognized as an important measure of the cardiac activity of the individual. Modern researchers (60) in the cardiovascular area consider the heart rate an excellent indicator of the severity of the exercise. By using a motor driven treadmill and direct monitoring of the heart rate, by a cardiotachometer and graphic EKG write out on physiograph paper, this study investigated cardiac training effect at three heart rate intensities. The heart rate intensity level that produces a training effect is located, according to Karvonen (56, 57, 58), at approximately 60 per cent between the resting heart rate and the maximum heart rate. This investigation will help physical educators, physiologists, and coaches to understand better the cardiac stress or the heart rate intensity level needed to produce the training effect.

II. LIMITATIONS OF THE STUDY

This study has the following limitations:

1. The study used only 12 subjects.
2. All subjects were male college students between 18

and 24 years of age.

3. The exercise period for each subject was 15 minutes per day, 5 days per week over a span of 6 weeks.

4. The training effect was studied by maintaining the heart rate during exercise at only the 50, 60, and 70 percentage levels between the resting heart rate and the maximum heart rate.

III. DEFINITION OF TERMS USED

Resting heart rate. The resting heart rate was established by monitoring the heart rate, using the EKG unit of the physiograph, of a subject after thirty minutes of rest in a supine position within a quiet area. When several tests were made of an individual subject, the lowest heart rate per minute was recognized as the minimum heart rate. Fifteen-second periods, marked on the paper of the physiograph recorder, determined to the nearest ¼ of a beat and multiplied by four, were considered as a one minute recording.

Maximum heart rate. Maximum heart rate was monitored by the EKG recording of the physiograph. This maximum rate was established by having the subject run on a motor driven treadmill at 7 mph and 0 per cent grade. After each one minute period of exercise the grade was increased by 2½ per cent with the speed remaining constant. This continued until the subject became exhausted and stopped running. The point where the heart rate reached its highest intensity was considered the maximum heart rate. Fifteen-second periods, as marked by the physiograph recorder, approximated to the nearest ¼ of a beat and multiplied by four, were considered a one minute recording.

Heart rate intensity. The term "heart rate intensity" was interpreted as the various heart rate percentage levels located between the established resting heart rate and the established maximum heart rate for each subject. The heart rate intensity level of 50 per cent exercise tolerance was established at the point located 50 per cent between the resting and maximum heart rates.

Critical threshold value. The critical threshold value was the amount of exercise tolerance needed to produce a training effect.

Submaximal. The term "submaximal" refers to exercise workload which approaches, but does not reach maximal intensity. The workload is terminated at 180 beats per minute in most submaximal exercise.

Training effect. The term "training effect" was concerned with changes made by the subject's heart rate. This change was noted by (1) decrease in resting heart rate at the conclusion of the investigation, and/or (2) increase in exercise tolerance to maintain the required percentage exercising levels.

CHAPTER II

REVIEW OF THE LITERATURE

Much has been written about physical conditioning, training, and improving the human organism. There has been very little investigation into the level of where this training threshold is located. This training threshold or training intensity level and related areas are discussed in the following review of the literature.

I. LITERATURE ON TRAINING EFFECT

There was considerable information in the literature that one of the differences between the trained athlete and untrained individual was the lower resting heart rate. Brouha reported the advantages of training in the following study:

> With training the heart becomes more efficient and is able to circulate more blood while beating less frequently. Contraction of the heart becomes more powerful, thus it empties itself more completely at each systole, and stroke volume and cardiac output are increased. For a standard amount of work the heart rate becomes slower as training progresses. These heart rate changes indicate a decreasing load on the cardiovascular adaptation to exercise. Slow heart rates are observed at rest and it is not exceptional for the resting pulse rate to be reduced by 10 to 20 beats per minute between the beginning and the end of a training period. This greater efficiency of the heart enables a larger blood flow to reach the muscles, insuring an increased supply of

> fuel and oxygen and permitting the individual to reach higher levels of performance. (30:409)

Ganong (8) found the difference between the untrained individual and the trained athlete to favor the trained athlete. He could potentially achieve greater cardiac output without their heart rate increasing to as great a degree as the untrained individual.

Henry (52) credited the lower heart rates in athletes to greater stroke volume at rest and increased arterial elasticity. Therefore, the athlete could potentially increase his cardiac output without increasing his heart rate as greatly as the non-athlete. Karvonen (57) found both the resting heart rate and the heart rate during a standard exercise to decrease when comparing the heart rates of athletes to non-athletes. This was also noted in individuals when they engaged in training programs. Steinhaus stated, "It is generally conceded that trained athletes have low resting pulse rates." (79:112) He also found that the sum total of permanent changes in the organism, due to "training", was in direct relation to the amount of training. (79) Tuttle and Walker gave the following analysis on training:

> It has been demonstrated that a season of physical training brings about alternations in the response of the heart. It has been shown that the heart of a physically well trained man has a slower resting rate, increases less as a result of exercise, and recovers more quickly after exercise than the heart of a healthy untrained individual. (86:78)

Robinson and others (76) found marked cardiac advantages in exercise performed by trained runners over the advantages of untrained men before reaching maximal heart rate and also in recovery capacity. According to Wahlund (87), the pulse rate will give a most suitable indication of the individual's working capacity. Karvonen (57) gave the pulse rate measure at rest as an assessment of the training or fitness of the cardiovascular system. The heart rate proved a good indicator of the relative stress of physical activity as it formed an approximate linear function of work intensity and oxygen consumption. (69) Maxfield and Brouha (67) reported that recovery heart rates provide a simple measure of the degree of cardiac stress induced in any environment. The pulse, in investigations by Malhotra and others (65), showed a high correlation to the energy expenditure of the individual. LeBlanc (62) suggested the heart rate may be used as an indirect measure in calorimeteric studies and as a fatigue index since the heart rate is directly affected by circulatory changes.

Recent work by Hyman (55) and Tharp (85), concerning investigations of the Q to First Heart Sound Interval (Q-1HSI), has received increasing attention. They are possible simple indexes of cardiovascular fitness but do not appear to offer a good substitute for the more strenuous test of cardiovascular fitness.

II. LITERATURE ON MINIMUM HEART RATE

The resting heart rate in healthy men varies from 40 to 80 beats per minute. (40) DeVries (6) believed it almost meaningless to speak of a normal heart rate because the resting heart rate will vary from individual to individual. It also varies within the same individual during two or more observations under similar environmental conditions. He gave 78 beats per minute as the average heart rate at rest. The rate of 40 beats per minute in the highly trained endurance athlete or 100 beats per minute in the non-athlete are not abnormal however. The procedure to establish the resting rate often is not published in the literature and is used very infrequently in investigations. The resting rate may be established by having the subjects count their resting heart rate each morning before getting out of bed. (58) A second method is to have the subject recline for a given period of time before establishing this resting rate. McArdle and others (68), in an experiment of selected running events, determined the resting rate after the subjects reclined for a 10-minute rest period.

III. LITERATURE ON MAXIMUM HEART RATE

The maximal heart rate during strenuous work will vary with the age of the subject. Astrand (22) found the average heart rate for subjects between 4 years and 30 years of age to be approximately 200. The average values for older subjects showed a lower rate in relation to age. The highest pulse rates established while running on a treadmill were 183 for 40 year-old subjects, 168 for 55 year-old subjects, and only 160 for the 70 year-old subjects. Whether these values actually represent maximal heart rates is difficult to determine.

Exhaustion tests by Metheny and others (70) showed little difference between the maximum heart rate means and the extremes in the heart rates of male [194, 178-210] and female [197, 181-206] subjects. Reeves and others (75) also observed heart rates above 190 beats per minute in exhaustive work on a treadmill with a grade that varied between 8 per cent and 20 per cent.

Michael and Horvath (71) used a maximal tolerance test on 30 female subjects between 17 and 22 years of age. The subjects began exercising at a work load of 300 kpm per minute and this was increased 150 kpm per minute each minute until the subject could no longer exercise. The maximal heart rate level averaged 184 beats per minute, with a range from 170 to 202 beats per minute. They concluded that maximal work capacity could not be made from any single submaximal measurement.

Brouha and Radford (32) used the bicycle ergometer to investigate maximal heart rates of men and women. The female heart rates increased at a quicker pace than a male's heart rate. The heart rate increased roughly in proportion to the amount of work done. The higher heart rate in women at different work levels was due to a smaller stroke volume per beat.

Wyndham and others (88) investigated maximum levels of oxygen intake and maximum heart rate of trained men for 4 months. Their findings reported an average coefficient of variation of 4.3 per cent and 3.5 per cent respectively. When a researcher tries to measure maximal work tolerance a steady state is temporarily attained, but eventually a breakdown occurs as energy reserves are depleted and end-products are accumulated during this anaerobic condition. (41)

The pulse rate and respiratory rate are considered by Wahlund (87) to be the most suitable measure of work capacity. Most tests which cause increases in heart rate are developed for the purpose of measuring physical fitness. Investigations by Montoye (72) found the better trained athlete to have a lower maximum heart rate. This was not observed by Robinson and others (76) in a study using 5 premier distance runners and a group of untrained men. The first exercise consisted of a walk in which the runners' pulse rates averaged 111 beats per minute, while the untrained men reached an average of 134 beats per minute for the same workload. The second grade of exercise was difficult enough to cause the untrained men to reach a maximal heart rate that averaged 190 beats per minute, while the runners completed this task at an average of 171 beats per minute. The third and final task was not performed by the untrained men due to its difficulty. This task caused the 5 runners to reach an average maximal heart rate of 189 beats per minute or approximately the same as the untrained group reached at the second grade of exercise. The recovery time was also much more rapid for the trained athletes.

McArdle and others (68) used telemetry to record the cardiac response of trained and untrained subjects. They found no significant difference in the maximum heart rates of the trained and the untrained subjects.

Knehr and others (59) found the length of the exercise period of exhaustive type exercise to be of great importance.

> We find that a regime of training, which certainly increases physical fitness, does not alter the decline of heart rate following exercise to complete exhaustion within an approximately constant time limit of three to four minutes. A study of the decrement in heart rate after exercise of fixed intensity and duration would certainly show a more rapid pulse recovery during any effective period of training. Our data do not negate such findings nor do they run counter to the assumption that individual differences in performance can be related to decline of pulse rate after moderate exercise. They do seem to show that when complete exhaustion is reached in a given time, the rate of work varying, the pulse recovery curve remains unaffected by training. (59:155)

Astrand and Saltin (24) investigated maximal oxygen uptake and heart rate in various types of muscular activity.

They observed, in maximal running and cycling, the aerobic capacity and maximal heart rate to be the same, especially in well trained athletes.

The main objective of most tests of physical fitness was to measure fitness of the young, the old, the fit and the unfit. This was often achieved by the submaximal test using the bicycle ergometer, motor driven treadmill, and modified forms of the Harvard Step Test. Submaximal investigations were usually terminated when the heart rate reached 180 beats per minute.

IV. LITERATURE ON STRENUOUS WORKLOAD

Brooker (28) trained four groups of subjects (4 or 5 per group) after giving them submaximal exercise bouts on the bicycle ergometer. Group I was the control and engaged in normal exercise, but no exercise that was unusual. The subjects in Groups II, III, and IV were fitted with sternal electrodes and a transmitter; they exercised on the bicycle ergometer starting at 5 kg-m/sec and increasing by 1 kg-m/sec/min. Group II concluded their exercise when the heart rate reached 120 beats per minute, Group III at 150 beats per minute and Group IV a heart rate of 180 beats per minute. No training intensity occurred at or below a 120 heart rate. He found, in Groups III and IV, the relationship between change in efficiency and change in total heart rates exhibited a significant association. These negative correlations showed a regression of 41.22 per cent of the association in Group III and 81.18 per cent in Group IV. This means the coefficient of correlation is .641 for Group III and .901 for Group IV.

Alderman (17) used 40 subjects for four separate bouts of bicycle ergometer exercising. Two bouts were at 45.45 rpm and two at 54.54 rpm. The resistance was increased each minute by the addition of ½ kilogram. The exercise bout was completed when the subject reached a heart rate of 180 beats per minute. The following data were collected concerning the amount of time required to reach the heart rate level:

> Each of the test-retests were averaged to give a representative performance for each work load. The intercorrelation between the exercise times to 180 beats/min. for the two work loads was r = .933 after correction for attenuation. Therefore, 87 percent of the individual difference variance in heart rate response was common to the two work loads, while only 13 percent was specific to a particular work load. (17:323)

Taylor (81) conducted submaximal and maximal tests to determine exercise tolerance. The submaximal walk was conducted on a treadmill at 108 meters per minute on 5 per cent grade for a duration of 4 minutes. Subjects then rested in sitting position for 4 minutes. The maximal run was conducted at a constant speed of 162 meters per minute; the initial grade of 5 per cent was elevated 1 per cent each minute, and concluded when the subject became exhausted.

Thus, speed, duration and grade were constant during the walk. Speed was constant during the run, but the grade was periodically increased without interrupting the experiment. The duration, timed to the nearest quarter-minute, expressed the fitness of the subject. Taylor (82) also found in another study that heart rate rose slightly throughout steady state exercising of 45 minute duration.

A Two-Step Exercise test apparatus of Masters and Rosenfield (66) was constructed so the subject ascended to the top of two 9-inch steps in two steps and descended the other side to complete one trip. The subject turned towards the examiner; this caused the subject to reverse his turn after each trip and prevented him from becoming dizzy. When the exercise was complete, the subject reclined immediately and electrode leads were connected to appropriate monitoring equipment.

The Balke Test (26) was a treadmill run which began at 3.3 mph on a horizontal plane. The treadmill was elevated 1 per cent at the end of each minute. This increase was so gradual that functional adaptation occurred within a few seconds. This continued until the subject reached a heart rate of 180 beats per minute. The poorest physical conditioned subjects attained 180 beats after 7 or 8 minutes, the average was 15 or 16 minutes and the best exceeded 23 minutes. Trained athletes set marks of 27 and 28 minutes. This test can also be conducted on the bicycle ergometer with the subjects beginning without any load and increasing at a constant amount. Dill (42) believed this was the best test available for studying individuals varying in age and fitness because: (1) the initial workload was minimal for old, young, and unfit, (2) the first minutes give the subject a warm-up, (3) maximal performance can be assessed in one experiment, and (4) with the bicycle ergometer, the blood pressure can be obtained easily.

Taylor and others (83) used two methods to study maximal oxygen intake. They used a constant treadmill speed of 7 mph and increased the grade in steps of 2½ per cent until the oxygen intake became constant. In the second method, the treadmill grade was set at zero and the subjects were asked to carry out the 3-minute run on successive days. Each day the speed was increased until the oxygen intake reached a plateau during the standard collection time. The exhaustive run conducted by Metheny and others (70) was on a treadmill at 7 mph and a grade held constant at 8.6 per cent.

The Sharkey and Holleman (78) study used 16 male volunteers from the required physical education program as subjects. These subjects were between 18 and 19 years of age and averaged 70.9 inches in height and 158.4 pounds in weight. They were randomly divided into a control and three training groups of 4 per group. Each subject was given a modified Astrand-Ryhming step test (23) and the Balke treadmill test (25) to determine his endurance. The control group engaged in fencing class during the experiment which was conducted 3 days per week for 6 weeks. The training consisted of 10 minutes of walking at a constant speed of 3.5 mph and a grade sufficient to elicit either 120, 150, or 180 heart beats per minute. The specific heart rate, monitored by telemetry, was reached within 2 minutes and remained for the duration of the exercise period. The analysis of prepost Balke treadmill test data showed high significant difference as did the Astrand-Ryhming nomogram that predicts aerobic capacity. The 180 beat group was significantly different from the other three groups. The 150 group was also significantly different from the 120 group and the controlled group. This study was concluded with the following statement:

> . . . this study indicates the need for exertion prompting heart rates above 150 beats/min. Further study using exercise intensities between Tr 150 and maximum exertion would be useful to help answer the question of a possible threshold training stimulus. The results of this investigation do not preclude the possibility that a submaximal stimulus might elicit optimal adjustments to endurance training. (78:703)

Edwards (89) reported on an investigation using 12 sedentary college women between 17 and 21 years of age in a treadmill training program. She attempted to enlighten the question, "'Where does an exercise become training?' or 'What work intensity is necessary for cardiovascular change?'"

(89:14) This study was composed of two groups of 6 subjects each. Group I subjects exercised at a heart rate of 125 beats per minute while Group II subjects trained at a heart rate of 145 beats per minute. The treadmill speeds were regulated during the training sessions to elicit the pre-determined heart rate. Basal and "all out" treadmill test variables for pre- mid- and post-training included: (1) time at heart rate 180, (2) maximal oxygen intake, (3) maximal heart rate, and (4) test run time. Group I showed significant increase in the running time required to obtain a heart rate of 180 beats per minute. Group II also increased their total run time, but the heart rate of 125 provided sufficient but not minimal workload for training effects to occur.

Thirty subjects, 20 trained endurance athletes (10 runners and 10 swimmers) and 10 healthy non-trained subjects were used by Hartung (91) to determine if training specificity could be determined with respect to heart rate changes during exercise and in recovery. All subjects walked on a graded treadmill until their heart rate reached 170 beats per minute. The heart rates were determined by EKG at the end of each minute. Times were recorded for each subject to reach heart rates of 110, 130, 150, and 170 during exercise and 130 and 90 during recovery. He concluded the following from his investigation:

> . . . that heart rate response to exercise is specific as to the type of training and that general or non-specific training is not significantly better than no training. [and] . . . recovery heart rate is probably not valid as an indicator of cardiac efficiency or level of fitness. (91:15)

Humphrey and Falls (93) used the bipolar chest lead EKG recorded on a physiograph to determine whether the 180 heart rate employed in the Balke test (25) was a valid measure of maximal aerobic capacity. One minute expired air collections were taken when each female subject obtained a heart rate of 180 and continued until the subject terminated the exercise. The O_2 and CO_2 percentages were obtained with a Godart analyzer and calibrated against a micro-Scholander and Gallenkamp-Lloyd apparatus. The test was conducted at least three times and an average was obtained. The maximum heart rate data were greater than the values obtained at 180 beats per minute at the .05 level of significance. They concluded a heart rate cutoff point in excess of 190 heart beats per minute should be used, in progressive treadmill testing of young college females, instead of the often used 180 beats per minute.

In regard to oxygen uptake and heart rate during a period of exercise, the following was stated by Astrand and Rodahl:

> Under normal conditions there is in any given individual a roughly linear relationship between oxygen

> uptake and heart rate during submaximal work. The slope of the line changes with the state of physical training or physical fitness; a fit person is able to transport the same amount of oxygen at a lower heart rate than an unfit person. (1:617-8)

Durnin and others (46) reported on the changes in fitness associated with short training sessions. The training program involved daily walks of 10, 20, and 30 kilometers. During this training the heart rates were only 120 to 130 beats per minute. They observed significant changes in oxygen consumption and heart rate response to the workload. The 20 kilometer group made the better gains. The authors suggested that the 30 kilometer group was put to a task too severe for their fitness level.

Karvonen and others (58), in a longitudinal study, investigated the effect of various training schedules on pulse rate. Six previously untrained medical students ran on a horizontal treadmill for 30 minutes daily, 4-5 days per week for 4 weeks. One subject repeated the experiment after a five-week interval. The speed of the treadmill was adjusted to keep the pulse rate at a predetermined level. If the pulse rate decreased due to training, the speed of the treadmill was increased. When the pulse rate was increased by less than 60 per cent of the range between resting rate and the maximum obtainable by running, no training effect was observed on the heart rate. When the pulse rate was above the 60 per cent level, the heart rate during work did clearly decrease and training effect occurred.

The resting heart rate was determined every morning by each subject before he got out of bed. The maximal heart rate was determined by running at a submaximal speed until exhaustion. Within 15 seconds after the subjects stepped off the treadmill, a 10-second heart rate was recorded by using a stethoscope.

There are several advantages in using the treadmill over the bicycle ergometer to obtain research data. Erickson and others (47) gave five treadmill advantages: (1) The workload is always fixed without requiring the subject to keep cadence. (2) Training factors are at the very minimum. (3) A large total energy expenditure can be obtained. (4) The workload is adjusted to the subject's size automatically. (5) Our society and occupations necessitate walking, so this provides a method of evaluation of the handicap of many diseases and injuries. The best reason, especially for this country, is simply, "Everyone walks but not all ride bicycles." (47:740)

Campbell (35) used the peak of 180 heart beats per minute to study the effect of a season of basketball on resting and recovery heart rate. There was no significant difference in resting heart rate but a significant reduction in the post season treadmill performance and recovery time of the heart rate. Olds (74) also found no difference in condition after a five-month period of basketball as measured by efficiency tests. Evidence presented by Antel and Comming (19) showed that emotional factors can significantly alter submaximal work test based on heart rate alone. In nine emotionally stable boys, an increase in only 4-7 beats was noted in the range of 100-175 beats per minute. But an increase of over 25 beats per minute was noted in one emotionally labile patient. Emotional factors were credited with high pulse rate of young men during the preinduction medical examination. (31) Astrand and Saltin (24) used the 7 mph treadmill exercise described by Taylor and others (83) and increased the grade to study maximal oxygen uptake and heart rate in various types of muscular activity.

In an investigation of lumber workers, Lundgen (64) measured pulse rate by having the men stop on a signal and, while resting in a standing position, the first ten pulse beats were recorded with a stop watch. Karvonen also had his subjects step off the treadmill for approximately 15 seconds and a pulse rate of 10 seconds was taken. (58)

Cotton and Dill (36) used the cardiotachometer to examine the heart rate of strenuous exercise on a treadmill. During the ten seconds following cessation of exercise, the heart rate decreased approximately one beat per minute. These data indicate the possibility of predicting exercising heart rate, with reasonable accuracy, by obtaining the ten-second period following exercise.

The environmental conditions for studies of treadmill exercising showed some variation among researchers. Erickson and others (47) maintained a constant dry bulb temperature of 78° ± 2°F., humidity 50 ± 5 per cent of relative saturation, with lighting, noise and air movement held constant. Clothing consisted of shoes, socks, and cotton shorts. Taylor and others (83) conducted all tests in an air-conditioned laboratory maintained at 78° ± 2°F. and relative humidity of 45 to 60 per cent. Astrand and Rodahl (1) preferred room temperature between 19 and 20°C (66.2 to 68°F) and the relative humidity between 40 and 60 per cent. They also did not allow the oxygen content of the room to drop below 20.90 per cent.

V. LITERATURE ON ELECTRODE PLACEMENT

The method of attachment and placement of electrodes is very important in recording the heart rate during exercise. The obvious crux of the problem is the difficulty of keeping the electrodes in contact with the skin at all times. Kozar and Hunsicker (60) used the following method for attaching electrodes:

> (a) Any hair within the vicinity of the skin area to be utilized for placement was shaved clean; (b) the skin area was rubbed briskly with a towel and cleaned thoroughly; (c) Ace Adherent (aerosal) was sprayed very lightly over the area and patted softly with a towel to remove any excess adherent and speed up drying; (d) Eden Electrode Jelly was placed on the cupped surface of the electrode and the electrode was placed on the selected and prepared skin area; (e) Dr. Scholl's

> Corn Pad was applied to the dry side of the electrode. This technique attached the electrode firmly to the skin for a thirty-minute period. The heavy muscular involvement and excessive perspiration posed a problem of keeping the electrode in place. This was ultimately solved by using Dr. Scholl's Corn Pads to affix the electrode. (60:3)

The electrodes were placed on the manubrium process and between the fifth and sixth intercostal space below the left nipple. McArdle and others (69) placed their electrodes over the manubrium sterni and the fifth interspace on the left mid-auxillary line.

CHAPTER III

PROCEDURE

The heart rate has long been recognized as an important measure of the cardiac activity of the individual. The heart rate is also a readily available measure of what occurs within the subject and research has shown the heart rate to be an important variable in the response to exercise. By monitoring the rate of the heart it is possible for researchers to study the degree of stress created by the workload of a specific exercise.

The purpose of this investigation was to focus additional light on the amount of cardiac stress needed to cause the "training effect" to occur. This investigation was concerned with the amount of work needed to achieve a physiological change and thus show where a "training effect" occurs. The critical threshold where training effect occurs is located, according to Karvonen (56, 57, 58) at approximately 60 per cent between the resting heart rate and the maximum heart rate. This study was designed to assist physical educators, physiologists, and athletic coaches to understand better the cardiac stress or the heart rate intensity at three levels of workload within the range of resting and maximum heart rates.

I. DESIGN OF STUDY

This study was designed to investigate three heart rate intensity levels. All subjects were placed in three equated groups to exercise, for two weeks, at 50 per cent heart rate intensity level. The 50 per cent heart rate level was located midway between the resting and maximum heart rates. After two weeks of exercising the groups were again equated. Group I continued to exercise throughout the six weeks investigation at the 50 per cent intensity level. The exercise level of Groups II and III was increased to 60 per cent for the third and fourth weeks of the investigation. After completion of the fourth week of exercise, Groups II and III were again equated. Group II continued to exercise at the 60 per cent level for the fifth and sixth weeks. Group III was increased to 70 per cent for the final two weeks of the study. Figure 1 illustrates the heart rate intensity level and its duration for each group comprising the study.

II. PRELIMINARY INVESTIGATIONS

Preliminary investigations were conducted to determine the best or most practical methods to be used in this investigation. These investigations were limited to the selecting of methods which could be conducted with the best possible results using the equipment available in the Rosenthal

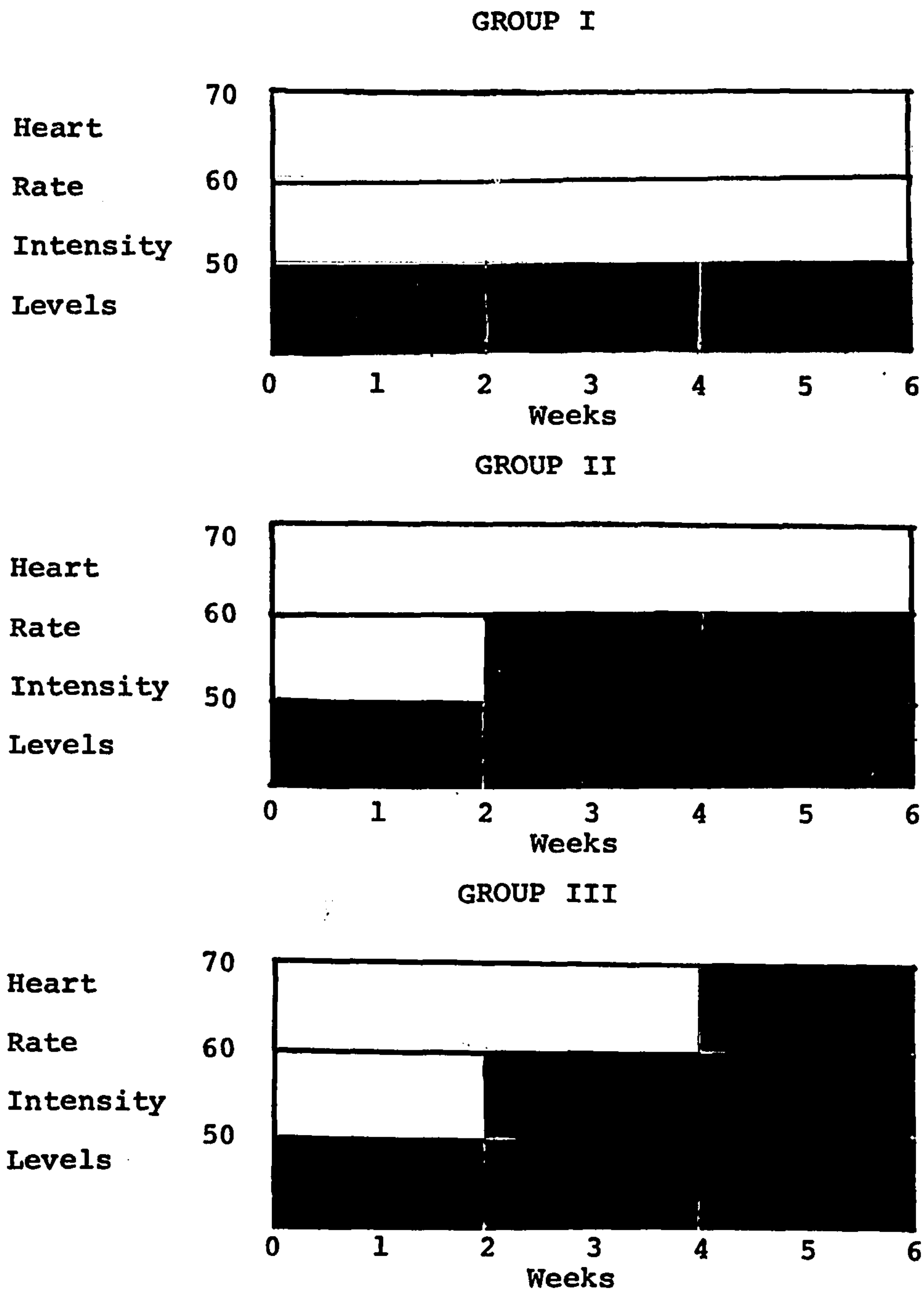


FIGURE 1

ILLUSTRATION OF THE HEART RATE INTENSITY
LEVEL AND THE DURATION OF EXERCISE
FOR EACH GROUP COMPRISING
THE STUDY

Research Laboratory at the University of North Carolina at Greensboro.

Subjects. The subjects used in the preliminary investigation included three graduate students at the University of North Carolina at Greensboro. Two of the subjects were doctoral candidates over age 30 who could not be used in the actual investigation because of possible decline in maximal heart rate due to aging. The third subject was a 24 year-old graduate student who was also used in the actual study. This subject was not subjected to activities which would jeopardize his eligibility of being a subject in the study.

Electrode attachment. Three different placements of the electrodes were used in this preliminary investigation. The skin was shaved, using a safety razor; the skin was cleaned and rubbed with an alcohol saturated towel; cleaned with an acetone solution; and the electrode paste was put in the capped portion of surface electrodes. The two surface electrodes were secured to the body with disposable, double-sided, adhesive washers.

The first arrangement of electrodes consisted of placing the two surface electrodes on the manubrium sterni approximately 1½ to 2 inches apart. Surgical tape was used to help secure the electrodes in place for the exercise period. The electrode wires were attached to the telemetry transmitter. The wires were neatly rolled up to prevent movement and were secured to the chest with surgical tape along with the telemetry transmitter. An elastic bandage was also placed around the subject to help limit the movement of the telemetry transmitter.

The second method investigated was the same as the first method except one surface electrode was placed on the manubrium sterni and the second was placed between the fifth and sixth intercostal space below the left nipple.

The third method used in the preliminary investigation was selected to be used in the study. This method consisted of preparing the surface as previously explained except the cleaning with acetone solution was omitted. Direct monitoring instead of telemetry was used and this made it necessary to use three surface electrodes. The three electrodes were placed on the manubrium sterni, one under the other as close as possible to each other. The top-most electrode was placed near the apex of the manubrium sterni. The electrode wires were rolled up and a rubber band was placed around each to prevent unnecessary movement. The wires were secured to the body by surgical tape. The three electrode wires were connected to the female connector of a shielded input extension cable which was plugged into the preamplifier input jack.

Telemetry and direct monitoring. The preliminary investigations were concerned with both telemetry and direct monitoring of the heart rate. The Physiograph Four and other equipment used were manufactured by the Narco Bio-Systems

Incorporated, Houston, Texas. The telemetry transmitter, connected to surface electrodes, was used to transmit the heart beat of the subjects in the preliminary investigation. This signal was picked up by biotelemetry receiver, then passed through a ni-gain preamplifier, and into the Physiograph Four recorder where the EKG and mean heart rate was graphically recorded periodically during exercise sessions. The cardiotachometer was used to observe visually the mean heart rate of each subject during the exercise periods.

The direct monitoring system consisted of using surface electrodes connected to the female connector of a shielded input extension cable. This cable was plugged into the hi-gain preamplifier and into the Physiograph Four where the EKG and mean heart rate were graphically recorded. The front panel of the cardiotachometer was also used to make visual observations of the heart rate during exercise and during rest. This direct monitoring system was selected as the method most reliable for the study.

Treadmill. The treadmill used in this preliminary investigation was manufactured by Quinton Instruments, Seattle, Washington. The treadmill had a speed range from 1 to 10 mph and an elevation range from 0 to 40 per cent. The preliminary investigation was concerned with methods to be used in obtaining a maximal heart rate and also the treadmill changes to be used in maintaining the constant heart rate during the exercise periods at three intensity levels.

The maximum heart rate test was concerned with the Balke Test (25) and also a test used by Taylor and others (83). With the electrodes attached and the Physiograph Four monitoring the heart rate, the subjects were given a maximal heart rate test. The Balke test was a treadmill run which began at 3.3 mph on a horizontal plane and increased the elevation one per cent at the end of each minute. The subject continued to exercise until he became exhausted and stepped off the treadmill.

The second method of obtaining maximal heart rate used a constant speed of 7 mph and increased the grade in steps of 2½ per cent until the subject stopped due to exhaustion. This method was selected as the best for the study conducted in this investigation due to the time that would be needed to test the subjects.

In the preliminary investigation various speeds and grades were used to maintain the heart rate required to keep the heart beat at the predetermined intensity level. After experimenting with various combinations it was decided to keep the grade of the treadmill constant at 2½ per cent and vary only the speed to keep the heart rate at the predetermined exercise intensity level.

III. THE SUBJECTS

The major concern in selecting the subjects was to obtain dependable subjects who would continue the exercise to the completion of the exercise program. Each subject was questioned about his daily activity and was cautioned about engaging in vigorous daily activity during the study.

Fitness of subjects. Each subject used in the study had been examined by a physician of his choice prior to his enrollment for the fall semester. All subjects were found to be in good physical condition by their examining physician. Five of the subjects had also been examined at the University of North Carolina at Greensboro Health Center during the fall semester of the school year. One of the physicians at the Health Center suggested that each subject be asked to sign an "Exercise Permit" card before participating in the study. An example of the "Exercise Permit" is illustrated in the Appendix.

Number of subjects. This study involved 12 subjects randomly assigned to three groups of 4 each. Each member within a group participated in the same intensity level training program.

Age of subjects. It was necessary to select subjects below 30 years of age to eliminate the factor of declining maximum heart rate due to age. When the final selection was made the subjects were all college males between 18 and 24 years of age. The average age of the subjects was 19.9 years.

Size of subjects. The height of the subjects ranged from 5'6½" (169.3 cm) to 6'1" (185.5 cm) and averaged 5'11" (180.1 cm). The weight of the 12 selected subjects ranged from 124 pounds (56.25 kg) to 180 pounds (81.65 kg) and averaged 158¼ pounds (71.78 kg).

Reward to subjects. Each subject was promised a sum of $25 as payment upon his completion of the study. All subjects completed the exercise program and each subject was paid the sum of $25.

Control over subjects. The participants were college students subject to regular institutional activity. The subjects were instructed to continue their normal day-by-day activity outside the laboratory exercise period; they were also cautioned from time to time about engaging in vigorous daily activity during the study.

IV. EQUIPMENT

The physiologically oriented equipment used in this study was located in the Rosenthal Research Laboratory on the campus of the University of North Carolina at Greensboro. Equipment which could not be reused, such as paper, disposable, double-sided, adhesive washers, and electrode paste, was furnished by the author.

Physiograph. The equipment used to directly monitor the heart rate of each subject was manufactured by Narco Bio-Systems Incorporated, Houston, Texas. The Physiograph Four and necessary equipment used for direct monitoring are listed in the Appendix. The descriptive name of the equipment, the part or model number and the manufacturer are supplied in this collection data.

Treadmill. The treadmill used in this study was manufactured by the Quinton Instruments, Seattle, Washington. The treadmill was model 18-49C and had a speed range from 1 to 10 mph and an elevation range from 0 to 40 per cent. This information is also supplied in the equipment listing in the Appendix.

V. RESTING HEART RATE

The resting heart rate was monitored on four occasions during the study. These four resting heart rates were referred to as (1) pre-training resting heart rate, (2) post 2 weeks training resting heart rate, (3) post 4 weeks training resting heart rate, and (4) post 6 weeks training resting heart rate. An illustration of resting heart rate procedure may be found in Figure 5 of the Appendix.

Pre-training resting heart rate. The pre-training resting heart rate was the initial data collected on the subjects. Therefore, it was necessary to prepare the subjects for the placement of electrodes on the manubrium sterni. The skin was shaved if necessary, then an alcohol saturated towel was used to clean the surface for the placement of the electrodes. The surface was rubbed with the alcohol saturated towel until it began to sting. This was an indication that the outer layer of skin had been rubbed off.

Disposable, double-sided, adhesive washers were then placed on three surface electrodes and each electrode was filled with electrode paste. Extreme care was taken filling the surface electrodes to prevent any air spaces in the electrode paste. The paste was then smoothed and the excess removed prior to the protective cover being removed from the electrode washer. The surface electrodes were then attached to the clean manubrium sterni beginning at the apex and continuing downward until all three electrodes were in place. This is illustrated in Figure 3 in the Appendix. The amount of resistance was kept below 20,000 ohms or the electrodes were removed, the skin recleaned, and the electrodes reattached. The two surface electrodes with the lowest resistance were connected to the shielded input extension cable in positions 1 and 2. The electrode with the most resistance was placed in the ground (G) connection. The topmost of the least resistance electrodes was placed in position 1 while the other was placed in position 2. This made the R spike of the EKG higher and more easily obtained and counted. If these two were reversed the R and S spikes would be of approximately the same magnitude and the readout would be more difficult to count.

The subject maintained a supine position for a minimum period of 30 minutes. The male connection was then attached to the hi-gain preamplifier which was connected to the Physiograph Four. This input into the Physiograph Four was made into a channel amplifier which was connected to a rectilinear recording channel and gave a beat by beat tracing of the subject's heart rate. The paper speed was controlled at 0.2 cm/sec by the chart drive assembly in the unit. The time and event channel was set to record each five seconds of time on the recording paper. An illustration of a subject and equipment is shown in Figure 4 in the Appendix.

The input data brought into the channel amplifier were also relayed into the cardiotachometer assessory unit of the Physiograph Four. This was also connected to a rectilinear recording channel and supplied a readout of the mean heart rate during the recording of the resting rate. Upon the completion of the 30 minutes minimum rest and the 5 or more minutes of recording time the subject was informed he had concluded his rest period.

The environmental conditions in the laboratory were controlled by two air conditioners that also controlled the humidity of the room. After cessation of the rest period the electrodes were removed and a lotion was applied to the area of the manubrium sterni. The lotion was used to prevent chafing or contusional effects of day-by-day preparation of the area.

When the data were collected from the 12 subjects, it was necessary to randomly divide them into three groups. It was noted that three subjects had resting rates below 50 beats per minute; three subjects had resting rates between 51 and 55 beats; five subjects ranged from 61 to 66 beats per minute and a lone subject's resting rate was 75 beats per minute. From this information it was decided to randomly place in Group I, Group II and Group III one subject from the 50 or less resting rate, one subject from the 51 to 55 resting range, and two subjects from the remaining six subjects whose range was between 61 and 75 beats per minute. The random selection was made by placing initialed pieces of paper in a box and drawing for placement into Group I, II or III.

Post 2 weeks resting heart rate. The resting heart rate was again recorded after each subject had completed two weeks of training. The procedure used for the post two weeks resting heart rate was identical to that used for the initial heart rate. These data were used to equate the three groups which had originally been randomly assigned. The groups were found to be similar by statistical evaluation and therefore, there was no change in the three groups of subjects. Group I continued its exercise rate at the 50 per cent level and

Groups II and III increased to the 60 per cent level for the following two weeks.

Post 4 weeks resting heart rate. The resting heart rate was re-evaluated after the completion of four weeks of training. The procedure used to make this evaluation was the same as used for the pre-training resting heart rate measure. The resting heart rate was taken of each subject, but the data collected from members of Group II and Group III were also statistically analyzed to equate two groups before they were allowed to begin the final two weeks of training. The two groups were found to be similar by statistical evaluation. Group II continued to exercise at the 60 per cent intensity level while Group III was increased to the 70 per cent intensity level.

Post 6 weeks resting heart rate. At the conclusion of the six weeks training program, the resting heart rate was once more obtained in an identical manner as described in the pre-training resting heart rate procedure. This collection of data was used for statistical analysis and after adequate collection of the data the subjects were paid $25 for their cooperation in the experimental study.

VI. MAXIMUM HEART RATE

The maximum heart rate data were also needed for the purpose of establishing the various heart rate intensity ranges for each subject. This intensity range was established at points between resting heart rate and the maximum rate values. Each subject was subjected to this "all out" test only once. If any subject had become sick or had fallen from the treadmill or any unusual occurance had taken place that could have appeared to have prevented the subject from performing the maximum heart rate test, this subject would have been given a second maximum heart rate test. All subjects appeared to give "all out" efforts and no one was retested.

Each subject reported to the laboratory at his designated time and was prepared for the testing session. The skin over the manubrium sterni was prepared for the attachment of the electrodes as described in the section on resting heart rate. The hi-gain preamplifier and Physiograph Four units, also used in obtaining the resting heart rate, were on and in the "ready" position. The paper speed was controlled at 0.5 cm/sec by the chart drive assemble in the unit. The hi-gain and Physiograph Four units were switched from "ready" position to "record" position and the amplitude of the heart beat was calibrated to provide an easily readable R spike. The subject was instructed to continue to run on the treadmill as long as he possibly could. The speed of the treadmill was set at 7 mph and the elevation was 0 per cent grade. A stopwatch was used to record the time each subject remained on the treadmill. This time was also recorded by the time and event marker which was set to record each 5 seconds the physiograph paper moved through the recorder at 0.5 cm/sec during the exercise bout. When the subject stepped on the treadmill, the stopwatch was started. Each subject continued to run at 7 mph and 0 per cent grade for one minute. This speed of 7 mph was continued throughout the maximum test. At the end of each minute the grade was increased 2½ per cent until the subject became too exhausted to continue and stepped off the treadmill. The time, speed and per cent of elevation for the maximum heart rate test are given in Table I. The subject remained on the safety platform surrounding the treadmill for an additional 15-second recording immediately upon the cessation of the maximum treadmill run. The hi-gain recorder was then switched from the "record" to the "ready" position and the electrodes were unplugged from the extension cable, and removed from the subject. A lotion was applied to the manubrium sterni area to prevent chafing or contusional effects of day-by-day preparation of the area. The 15-second period on the physiograph paper where the heart rate reached its highest intensity was considered the maximum heart rate. The 15-second period following the exhaustive exercise was also counted and given consideration. These 15-second periods as marked by the physiograph recorder, approximated to the nearest ¼ of a beat and multiplied by four, were considered a minute recording. Figures 6 and 7 in the Appendix illustrate these procedures.

TABLE I

THE CORRESPONDING TIMES, SPEEDS, AND PER CENT OF GRADE FOR THE MAXIMUM TREADMILL TEST

Minute	Speed of Treadmill	Per Cent of Treadmill Elevation
1	7 mph	0
2	7 mph	2½
3	7 mph	5
4	7 mph	7½
5	7 mph	10
6	7 mph	12½
7	7 mph	15
8	7 mph	17½
9	7 mph	20
10	7 mph	22½

VII. FIRST AND SECOND WEEKS OF EXERCISE

The information on resting heart rate and maximum heart rate made it possible to determine the heart rate to be maintained by each subject in order to exercise at a given heart rate intensity level. All subjects, during the first and second weeks of the investigation, exercised at the 50th per cent heart rate intensity. This intensity level was obtained by finding the difference between the maximum heart rate and the resting rate and multiplying this numerical value by the intensity level, 50 per cent. Intensity level = (Maximum heart rate - Resting heart rate) .50. For example, a subject with a resting heart rate of 60 beats per minute and a maximum heart rate of 200 would exercise at 60 + (200 - 60) .50 or 130 beats per minute. Each subject exercised fifteen minutes per day, five days per week on the treadmill at a constant grade of 2½ per cent. The speed of the treadmill was increased or decreased to maintain the desired heart rate intensity of each subject.

The subject reported to the laboratory at his scheduled time and was attached to the recording mechanism as previously described in the section on resting heart rate. The treadmill speed was set at approximately four miles per hour and a constant elevation of 2½ per cent was maintained for each subject. With the Physiograph Four ready to record the subject stepped on the moving treadmill. A stopwatch and the rear drum treadmill revolution counter were started simultaneously as the subject stepped on the treadmill. The front panel of the cardiotachometer indicated the average heart rate per minute. This front panel was intergraded to record in segments of 5 heart beats. These data, as well as the beat-by-beat heart rate and a 5-second event marking, could be recorded at any time at a set paper speed of 0.5 cm/sec by simply lowering the pen lifter attachment. The heart rate was not recorded continuously, but periodically for 5 or 10 second intervals. A chart was used to determine the heart rate per minute from the 5-second count estimated to the nearest ¼ of a beat. Table II gives the 5-second heart rates and their corresponding one minute totals.

The cardiotachometer, intergraded to 5 beat intervals, proved to be inferior to the actual 5-second graphic recording of the beat-by-beat heart rate. Therefore, the beat-by-beat graphic account of the exercise stress for a given 5 seconds was the method used in this study. The speed of the treadmill was decreased or increased after each 5 seconds reading if the physiograph reading indicated the subject was exercising at a lower or higher rate than he should be at the 50 per cent intensity level. The amount of variance of the heart rate was controlled to the nearest ¼ of a beat during the 5-second heart rate counts. This gave a range of deviation of no more than $\pm$ 3 beats per minute from the desired heart rate during the exercise bout. When the 15 minutes

TABLE II

FIVE SECOND AND CORRESPONDING ONE MINUTE HEART RATES

5 Seconds	60 Seconds	5 Seconds	60 Seconds	5 Seconds	60 Seconds
9	108	10 3/4	129	12 1/2	150
9 1/4	111	11	132	12 3/4	153
9 1/2	114	11 1/4	135	13	156
9 3/4	117	11 1/2	138	13 1/4	159
10	120	11 3/4	141	13 1/2	162
10 1/4	123	12	144	13 3/4	165
10 1/2	126	12 1/4	147	14	168

of exercise were completed, the treadmill and revolution counter were stopped simultaneously. From the number of revolutions completed within the 15 minutes, the mean miles per hour rate was determined for each subject after each exercise period. Table III gives the number of rear drum treadmill revolutions which corresponds to the mean miles per hour. An example of a daily exercise session may be found in Figure 8 in the Appendix.

VIII. THIRD AND FOURTH WEEKS OF EXERCISE

The subjects in Group I continued their exercise program during this period following the same procedure as was used by all subjects during the first two weeks. The three groups were given their post two weeks resting heart rates and were statistically equated. The exercise intensity level for Groups II and III was increased from 50 per cent to 60 per cent. The data used to make this calculation were obtained from the pre-exercise resting heart rate and the maximum heart rate test. A subject with a resting heart rate of 60 beats per minute and a maximum heart rate of 200 would exercise at 60 + (200 - 60) .60 or 144 beats per minute.

IX. FIFTH AND SIXTH WEEKS OF EXERCISE

The exercise level for Group I continued in the final two weeks of training at the same exercising level that they had been subjected to during the first four weeks.

TABLE III

CORRESPONDING REAR DRUM TREADMILL REVOLUTIONS AND MEAN MILES PER HOUR

Rear Drum Treadmill Revolutions	Mean Miles Per Hour	Rear Drum Treadmill Revolutions	Mean Miles Per Hour	Rear Drum Treadmill Revolutions	Mean Miles Per Hour
1,764	3.5	2,167	4.3	2,570	5.1
1,815	3.6	2,218	4.4	2,620	5.2
1,865	3.7	2,268	4.5	2,671	5.3
1,915	3.8	2,318	4.6	2,721	5.4
1,966	3.9	2,369	4.7	2,771	5.5
2,016	4.0	2,419	4.8	2,822	5.6
2,066	4.1	2,469	4.9	2,872	5.7
2,117	4.2	2,520	5.0	2,922	5.8

The subjects composing Groups II and III were found to be statistically equal after the completion of the first four weeks of training. The groups remained the same in personnel for the final two weeks of exercise. Group II continued at the 60 per cent heart rate intensity level. Group III was increased to a 70 per cent heart rate intensity level for the final two weeks of training. The calculation of data for this increase was made from the data collected at the pre-exercise resting heart rate sessions and the maximum heart rate test. A subject with a resting heart rate of 60 beats per minute and a maximum heart rate of 200 would exercise at 60 + (200 - 60) .70 or 158 beats per minute. The procedures for all groups were identical to the first two weeks except for the different heart rate intensity levels and the use of surgical tape to secure the electrode wires and shielded extension cable to members of Group III. It was necessary to use the surgical tape to insure good reading and prevent possible disconnections at this higher heart rate intensity level.

X. STATISTICAL ANALYSIS

The statistical evaluation for this study involved four variables: (1) initial maximum heart rate, (2) initial resting heart rate, (3) range between the maximum and resting heart rates, and (4) the training effect on the resting rate. The first three variables were needed to supply the data for the heart rate intensity levels.

The twelve subjects, randomly divided into 3 groups of 4 prior to the beginning of the exercise, were statistically evaluated after the first two week training period. The analysis of variance of the training effect on the resting heart rate was determined and the groups were equated before being allowed to continue the third week of exercise. At the conclusion of the fourth week, a t-test on the training effect of individuals in Groups II and III was calculated using resting heart rate. Groups II and III were found to be statistically equal and were allowed to begin the final two weeks of exercise.

After the completion of the sixth week of exercise, an analysis of variance was used to explore the training effect imposed on each group. The training effect was studied from the initial resting heart rate to (1) the post two weeks resting heart rate, (2) the post four weeks resting heart rate, and (3) the post six weeks resting heart rate. An analysis of variance was also used to investigate the change in exercise tolerance needed to maintain the required heart rate intensity levels.

CHAPTER IV

STATISTICAL AND CASE STUDY EVALUATIONS

The degree of stress placed on the human organism during work and sport has long been readily measured by the heart rate. Research obtained from monitoring the heart rate has elicited valuable information concerning the heart rate and the amount of stress needed to create a workload sufficient to cause a "training effect" is most important to athletic coaches, physical educators and exercise physiologists.

The design of this study was to focus attention on the critical threshold where training is sufficient to cause a physiological change and thus show a "training effect". Karvonen (56, 57, 58) concluded that a critical threshold value must be exceeded during any workout for there to be any improvement in the exercise tolerance of the heart. He believed the critical threshold value was expressed at a point 60 per cent between the resting and the maximum heart rates. By using a motor driven treadmill and direct monitoring of the heart rate, this study investigated cardiac training effect at three heart rate intensities located at 50, 60, and 70 per cent within the range of resting heart rate and maximum heart rate of selected college men.

I. STATISTICAL EVALUATION

The statistical evaluation of the 12 subjects involved in this study was concerned with four variables. These variables were (1) initial maximum heart rate, (2) pre-training resting heart rate, (3) range between the maximum and resting heart rates, and (4) the training effect on the resting rate. The first three variables were needed to supply the data for the heart rate intensity levels.

The subjects. This investigation was conducted with 12 selected college male subjects. The subjects ranged in age from 18 to 24 years of age. The average age of the subjects was 19.9 years. The height of the subjects ranged from 5' 6½" (169.3cm) to 6' 1" (185.5cm) and averaged 5' 11" (180.1cm). The average weight of the subjects was 158¼ pounds (71.78kg), with the lightest subject weighing 124 pounds (56.25kg) and the heaviest 180 pounds (81.65kg). Table IV gives the arithmetical evaluation of the individuals used in the study in relation to age, height and weight. These data verify that the subjects used in this study were similar in age, height and weight to those used by other investigators.

Maximum heart rate. The subjects were given a maximum heart rate test at the beginning of the investigation. Individually the subjects were prepared for monitoring of the heart rate during the maximum heart rate testing session. Each subject was instructed to continue to run on the tread-

TABLE IV

ARITHMETICAL EVALUATION OF THE SUBJECTS IN RELATION TO AGE, HEIGHT AND WEIGHT

Subject	Group	Age	Height Feet	Height Centimeters	Weight Pounds	Weight Kilograms
S. R.	I	20	6' 0"	182.8	150 1/4	68.62
R. E.	I	19	6' 1/2"	184.4	166 1/4	75.41
B. S.	I	19	5' 11"	180.8	128 3/4	58.40
R. A.	I	19	5' 6 1/2"	169.3	139 3/4	63.41
M. T.	II	24	5' 7 1/4"	170.9	124	56.25
R. P.	II	18	5' 9 1/2"	176.7	180	81.65
J. S.	II	19	5' 6 3/4"	169.6	156 3/4	71.10
T. C.	II	23	6' 1"	185.5	161 3/4	73.36
T. W.	III	20	6' 3/4"	185.0	173 3/4	78.81
S. U.	III	19	5' 8 3/4"	174.4	164	74.39
D. S.	III	20	5' 10 3/4"	179.6	152 3/4	69.27
D. R.	III	19	6' 0"	182.6	152 3/4	69.27
Mean	I	19.2	5' 10 1/2"	179.3	146 1/2	66.46
Mean	II	21.0	5' 9 1/4"	175.7	155 1/2	70.59
Mean	III	19.5	5' 11"	180.4	161	73.01
Mean	All	19.9	5' 10 1/4"	178.5	161 1/2	70.33

mill as long as he possibly could. The speed was set at 7 mph and the elevation was 0 per cent grade. Each subject continued to run at 7 mph and 0 per cent grade for one minute. At the end of each minute the grade was increased 2½ per cent until the subject became too exhausted to continue and stepped off the treadmill. A time and event marker, as well as a stopwatch, were used to record the time each subject remained on the treadmill. Table V gives the maximum heart rate and the time each subject was able to continue the maximum heart rate exercise. The mean maximum heart rate of 194.6 beats per minute is almost identical to that observed by Metheny and others (70) in their exhaustion studies. They found a mean maximum heart rate of 194 in male subjects and extremes of 178-210 beats per minute. Eleven of the twelve subjects in this study were within this range. The maximum heart rates exceeded slightly the maximum heart rates of 189 beats per minute, for trained runners, and 190 beats per minute, for untrained subjects, in observations made by Robinson and others (76). The data collected from these subjects were comparable to that secured in similar investigations. Subject M.T., the oldest subject, had a maximum heart rate of 176 beats per minute. This rate was considered close enough to extremes of previous investigations to be used in this study.

Pre-training resting heart rate. The subjects were prepared for the pre-training resting heart rate as described in

TABLE V

MAXIMUM HEART RATE ATTAINED AND TIME OF EXHAUSTIVE EXERCISE

Subject	Group	Maximum Heart Rate	Time of Exhaustive Exercise
S. R.	I	189	7:14
R. E.	I	202	6:04
B. S.	I	204	5:26
R. A.	I	205	5:47
M. T.	II	176	5:21
R. P.	II	205	5:13
J. S.	II	198	4:46
T. C.	II	190	5:29
T. W.	III	185	5:53
S. U.	III	195	4:44
D. S.	III	193	4:58
D. R.	III	193	4:22
Mean	I	200.0	6:08
Mean	II	192.2	5:12
Mean	III	191.5	4:59
Mean	All	194.6	5:26

the procedure chapter of this study. Table VI gives the pre-training resting heart rate of each subject. The pre-training resting heart rate of the subjects ranged from 44 to 75 beats per minute. This falls within the range observed by Dill. Dill stated, "In healthy man the resting heart rate may vary from 40 to 80 [beats per minute]." (40:60) These data also fall within the range of 40 to 100 beats per minute suggested by DeVries (6) as not deviating from the normal.

Range between maximum and resting heart rates. In order to establish the heart rate level at which each subject would train, it was necessary to determine the range between the maximum heart rate level and the pre-training resting heart rate level. From these data, it was then possible to establish the heart rate intensity levels that would be used in monitoring the heart rates at 50, 60, or 70 per cent levels between the maximum and pre-exercise resting heart rates. The formula and an example of procurement of these data were given in the procedure chapter of this study. Table VI gives the maximum heart rate, pre-training heart rate, range between these two sets of data and the heart rate intensity level at which each subject would exercise to maintain a 50, 60, or 70 per cent heart rate intensity level.

The training effect as determined by resting heart rates. In this study "training effect" was concerned with any

TABLE VI

HEART RATE INTENSITY LEVELS AS DERIVED FROM THE RANGE BETWEEN MAXIMUM AND RESTING HEART RATES

Subject	Group	Maximum Heart Rate	Pre-Tr. Resting H. R.	Range Between Maximum and Resting	Heart Rate Intensity Levels 50%	60%	70%
S. R.	I	189	44	145	117		
R. E.	I	202	51	151	127		
B. S.	I	204	63	141	134		
R. A.	I	205	75	130	140		
M. T.	II	176	49	127	113	125	
R. P.	II	205	54	151	130	145	
J. S.	II	198	64	134	131	144	
T. C.	II	190	66	124	128	140	
T. W.	III	185	46	139	116	129	143
S. U.	III	195	55	140	125	139	153
D. S.	III	193	61	132	127	140	153
D. R.	III	193	64	129	129	141	154
Mean	I	200.0	58.2	141.7	129.5		
Mean	II	192.2	58.2	134.0	125.2	138.5	
Mean	III	191.5	56.5	135.0	124.2	137.2	150.7
Mean	All	194.6	57.7	136.9	126.4	137.9	150.7

physiological changes made by the subject's heart rate. This change was noted by (1) decrease in resting heart rate at the conclusion of the investigation, and/or (2) increase in exercise tolerance to maintain the required heart rate intensity level. Table VII gives the resting heart rates as determined in pre-training, post two weeks, post four weeks and post six weeks training. The 12 subjects were placed in three groups of four subjects each as stated in the procedure chapter of this study. Upon completion of this grouping procedure an analysis of variance between groups based on resting heart rate prior to the beginning of the first week of exercise was determined. Table VII supplies the data showing that Groups I, II and III had mean resting rates of 58.2, 58.2 and 56.5 beats per minute respectively. It was determined that no significant difference (F = 0.157) was found between the three groups. These data are recorded in Table VIII. After all 12 subjects had exercised for two weeks at the 50 per cent heart rate intensity level an additional analysis of variance was determined between the three groups. Table VII supplies the data for each individual and also gives the mean post two weeks training resting rate as 58.2, 55.2 and 53.0 in Groups I, II and III respectively. Additional data, recorded in Table VIII, showed no significant difference between the groups (F = 0.372). Group I was selected to continue training at the 50 per cent level and Groups II and III were elevated to the 60 per cent

TABLE VII

RESTING HEART RATES AS DETERMINED IN PRE-TRAINING, POST TWO WEEKS, POST FOUR WEEKS AND POST SIX WEEKS TRAINING

Subject	Group	Pre-Training Resting Heart Rate	Post 2 Weeks Resting Heart Rate	Post 4 Weeks Resting Heart Rate	Post 6 Weeks Resting Heart Rate
S. R.	I	44	45	49	45
R. E.	I	51	58	60	54
B. S.	I	63	66	69	59
R. A.	I	75	64	60	58
M. T.	II	49	52	47	45
R. P.	II	54	48	46	48
J. S.	II	64	52	59	48
T. C.	II	66	69	56	57
T. W.	III	46	46	43	42
S. U.	III	55	50	50	48
D. S.	III	61	62	57	57
D. R.	III	64	54	53	49
Mean	I	58.2	58.2	59.5	54.0
Mean	II	58.2	55.2	52.0	49.5
Mean	III	56.5	53.0	50.7	49.0
Mean	All	57.7	55.5	54.1	50.9
Mean	II & III	57.4	54.1	51.4	49.3

TABLE VIII

ANALYSIS OF VARIANCE BETWEEN GROUPS BASED ON RESTING HEART RATES

Groups	Resting Heart Rates Pre-Training	Resting Heart Rates Post Two Weeks	Resting Heart Rates Post Four Weeks	F	t	Significant Difference
I, II & III	X			0.157		No
I, II & III		X		0.372		No
II & III			X		0.291	No

TABLE IX

ANALYSIS OF VARIANCE ON RESTING HEART RATE

Group	Weeks At Work Rate 50%	Weeks At Work Rate 60%	Weeks At Work Rate 70%	F	t	Significant Difference
I	6	0	0	0.655		No
II	2	4		7.705		.01
III	2	2	2	7.179		.01
II & III	2	2			6.401	.01
I, II & III	2				1.939	No

heart rate intensity level for the following two weeks of training. At the conclusion of four weeks of exercise, and the second week at the 60 per cent heart rate intensity level, a *t* test was made between Groups II and III. The mean resting heart rate for Group II subjects was 52.0 beats per minute while Group III subjects had a 50.7 mean resting heart rate. These data showed no significant difference between these two groups (t = 0.291). These data are recorded in Table VIII.

At the conclusion of the six weeks of exercise an analysis of variance on resting heart rate was calculated. Group I, which exercised for the entire six weeks at the 50 per cent heart rate intensity level, showed no significant difference in the resting heart rate due to the exercise (F = 0.655). The mean resting heart rates for this group were 58.2 pre-training, 58.2 post two weeks training, 59.5 post four weeks training and 54.0 post six weeks training. It was evident from these data, found in Table VII, that significant training did not occur from six weeks training at 50 per cent heart rate intensity level. These data showed that a heart rate intensity of 50 per cent between resting and maximum heart rates was not adequate to cause a "training effect" in Group I subjects.

Group II trained for two weeks at the 50 per cent heart rate intensity level and for four weeks at the 60 per cent heart rate intensity level. The analysis of variance data showed a significant difference in the resting heart rate of the subjects at the .01 level (F = 7.705) at the conclusion of the six weeks training period. The mean resting heart rate for Group II subjects decreased from a pre-training level of 58.2 to 55.2 beats per minute at the conclusion of two weeks of training. The mean continued to decrease to a post four weeks resting rate of 52.0 beats per minute and concluded the post six weeks training period with 49.5 beats per minute. This mean decrease of 8.7 beats per minute per subject was sufficient to reflect a "training effect". This four weeks training period at the 60 per cent heart rate intensity level was adequate to show a significant "training effect". The resting heart rate data of Group II subjects, individually and collectively, are found in Table VII.

Group III exercised for the first two weeks at the 50 per cent heart rate intensity level, the second two weeks at the 60 per cent heart rate intensity level and at the 70 per cent heart rate intensity level for the final two weeks. The six weeks of exercise at these three intensities produced a significant difference in the resting heart rate of these subjects at the .01 level (F = 7.179). The resting heart rates of these subjects decreased from a pre-training mean of 56.5 beats per minute to a post six weeks mean rate of 49.0 beats per minute. This decrease in mean heart rate of 7.5 beats per minute produced a difference significant to justify that "training effect" also occurred in Group III. The data of Group III subjects are also supplied in Table VII.

A *t* test between pre-training resting heart rate (57.7 beats per minute) and post two weeks resting heart rate (55.5 beats per minute) was determined on all subjects. No significant difference was found after a two-week exercise period at the 50 per cent heart rate intensity level ($t = 1.939$). A pre-training (57.4 beats per minute) and post four weeks (51.4 beats per minute) resting heart rate *t* test was made of Group II and III subjects after they had completed four weeks of training. There was significant evidence of training effect based on pre-exercise and post four weeks resting heart rate at the .01 level ($t = 6.401$).

These data support the beliefs of Karvonen (56, 57, 58) who concluded that a critical threshold value of 60 per cent between resting and maximum heart rates was needed to produce a physiological change and thus show a "training effect". Group I showed no significant change ($F = 0.655$) during the six week training period. Groups II and III both showed significant change in the resting heart rate at the .01 level. Group II's resting heart rate decreased from 58.2 to 49.5 beats per minute and produced a significant difference at the .01 level ($F = 7.705$). The subjects in Group III produced a decrease in the resting rate from 56.5 to 49.0 beats per minute and also a significant difference at the .01 level

(F = 7.179). From the resting rate data of the three groups exercised in this study, the critical threshold where training effect occurred was located between the 50 and 60 per cent heart rate intensity levels. Table IX depicts the above data concerning analyses of variance and t tests.

An analysis of matched pair data was conducted on each group concerning resting heart rate differences. These resting heart rate data are produced in Table VII and the statistical analysis is recorded in Table X. From this information, it was determined that subjects in Group I showed no significant difference in pre-training (58.2 beats per minute) resting rate when compared to the post two weeks (58.2 beats per minute) resting heart rate (t = 0.000), post four weeks (59.5 beats per minute) resting heart rate (t = 0.189) or post six weeks (54.0 beats per minute) resting heart rate (t = 0.944). When Group II subjects' pre-training (58.2 beats per minute) and post two weeks (55.2 beats per minute) resting heart rates were compared there was no significant difference in resting heart rates (t = 0.354). A significant difference (t = 3.571) was noted, however, at the .05 level when the post four weeks (52.0 beats per minute) resting heart rate was compared with the pre-training (58.2 beats per minute) resting heart rate. When the comparison was extended to the post six weeks training (49.5 beats per minute) resting heart rate, a significant difference (t = 3.327) was noted at the .05 level. Group III was examined in the same

TABLE X

ANALYSIS OF MATCHED PAIR DATA ON RESTING HEART RATE

Group	Resting Heart Rates Pre-Training	Two Weeks	Four Weeks	Six Weeks	t	Significant Difference
I	X	X			0.000	No
I	X		X		0.189	No
I	X			X	0.944	No
II	X	X			0.354	No
II	X		X		3.571	.05
II	X			X	3.327	.05
III	X	X			1.077	No
III	X		X		3.212	.05
III	X			X	4.355	.05

manner and no significant difference (t = 1.077) was found between the pre-training (56.5 beats per minute) and post two weeks (53.0 beats per minute) resting heart rates. A significant difference at the .05 level (t = 3.212) was found, however, between the pre-training resting heart rates and the post four weeks (50.7 beats per minute) training resting heart rates. The pre-training and post six weeks (49.0 beats per minute) resting heart rates, likewise, resulted in a significant difference (t = 4.355) at the .05 level.

These matched pair data further substantiate that no "training effect" occurred at the 50 per cent heart rate intensity level and that training effect did occur in the two groups which exercised at 60 per cent or higher during the final four weeks of the study. This gives greater indication that Karvonen (56,57,58) was correct in assuming that training effect occurs at approximately 60 per cent between resting heart rate and maximum heart rate.

<u>The training effect as determined by exercise tolerance level</u>. The second criterion used to determine if training effect occurred was the change in the exercise tolerance level while the heart rate intensity level remained the same. Table XI gives the mean weekly exercise tolerance for each group and also each subject within the group. Table XII gives the *t* for each possible two weeks, four weeks, or six weeks period in which the subjects worked at the same heart rate

TABLE XI

THE MEAN WEEKLY EXERCISE TOLERANCE FOR EACH GROUP AND SUBJECTS WITHIN THE GROUP AS MEASURED IN MILES PER HOUR

Group or Subject	1st Week MPH	2nd Week MPH	3rd Week MPH	4th Week MPH	5th Week MPH	6th Week MPH
S. R.	3.93	4.12	4.29	4.54	4.44	4.49
R. E.	4.03	4.21	4.26	4.29	4.22	4.27
B. S.	4.00	4.23	4.32	4.45	4.33	4.43
R. A.	3.93	3.96	4.16	4.31	4.33	4.27
M. T.	3.63	3.69	4.33	4.49	4.52	4.68
R. P.	3.70	4.02	4.38	4.44	4.51	4.56
J. S.	3.85	3.92	4.30	4.32	4.39	4.42
T. C.	4.10	4.25	4.69	4.77	4.86	4.93
T. W.	4.13	4.17	4.62	4.66	5.36	5.44
S. U.	3.78	3.98	4.37	4.34	5.10	4.96
D. S.	3.95	4.12	4.41	4.32	4.78	4.90
D. R.	3.65	3.86	4.26	4.43	4.94	5.27
Group I	3.97	4.13	4.26	4.40	4.33	4.37
Group II	3.82	3.97	4.43	4.51	4.57	4.65
Group III	3.88	4.03	4.42	4.44	5.05	5.14
Group All	3.89	4.04				
Group II & III			4.42	4.48		

TABLE XII

WORK TOLERANCE IN RELATION TO WEEKS TRAINING
AT VARIOUS WORK INTENSITIES

Group	Work Intensity 50%	60%	70%	Week 1	2	3	4	5	6	t	Significant Difference
I	X			X	X					3.268	.05
I	X					X	X			3.354	.05
I	X							X	X	0.267	No
I	X			X			X			5.757	.05
I	X			X					X	5.476	.05
II	X			X	X					2.496	No
II		X				X	X			2.721	No
II		X						X	X	2.700	No
II		X				X			X	4.532	.05
III	X			X	X					3.944	.05
III		X				X	X			0.402	No
III			X					X	X	1.012	No
I, II & III	X			X	X					5.908	.01
II & III		X				X	X			1.626	No

intensity level.

Group I trained at only one heart rate intensity level during the six weeks of exercise. All exercise was at the 50 per cent heart rate intensity level. When the first week (3.97 mph) of training was compared with the second week (4.13 mph) of training a significant increase (t = 3.268) in work was observed at the .05 level. Comparing the data from the third week (4.26 mph) of training to the fourth week (4.40 mph) of training showed an increase in work tolerance at the .05 level (t = 3.354). When the subjects in Group I were examined for the fifth (4.33 mph) and the sixth (4.37 mph) weeks of work there was no sifnificant difference (t = 0.267) made during this period. Group I's first week (3.97 mph) data were compared with the data from the fourth week (4.40 mph) and the sixth week (4.37 mph). The first and fourth weeks' data resulted in a significant increase in the workload at the .05 level (t = 5.757). The first and six weeks' work also showed an increase at the .05 level (t = 5.476).

The subjects comprising Group II exercised at the 50 per cent heart rate level for the initial two weeks. There was no significant change in workload at the .05 level (t = 2.496). This group exercised during the last four weeks at the 60 per cent heart rate intensity level. The increased exercise tolerance was not significant from the third (4.43 mph) week to the fourth (4.51 mph) week (t = 2.721) nor between the fifth (4.57 mph) and sixth (4.64 mph) weeks (t = 2.700). When the comparison was made between the third (4.43 mph) week and the sixth (4.65 mph) week there was a significant increase in exercise workload at the .05 level (t = 4.532).

Group III subjects trained at the 50 per cent heart rate level for the first two weeks. The comparison of the data from these two periods (3.88 and 4.03 mph) showed a significant increase at the .05 per cent level (t = 3.944). The relationship between the third (4.42 mph) and fourth (4.44 mph) weeks of exercise at the 60 per cent heart rate intensity level showed no significant change in exercise tolerance (t = 0.402). The final two weeks of training were at the 70 per cent level and did not substantiate any significant change during this two week (5.05 and 5.14 mph) period (t = 1.012).

All three groups exercised during the first two weeks at the 50 per cent heart rate intensity level. When the results of the first (3.89 mph) and second (4.04 mph) weeks of training for all 12 subjects were compared, a significant change was noted at the .01 level (t = 5.908). Members of Groups II and III engaged in identical 60 per cent heart rate intensity level workloads during the third and fourth weeks of training. The comparison of workloads of these eight subjects during the third (4.42 mph) and fourth (4.48 mph) weeks produced no significant change (t = 1.626) for the two-week period. All twelve subjects showed a significant change from the first to the second week of exercising. This change could reflect the training effect of the subjects or it could show the results of the subjects becoming more accustomed to the exercise. The subjects exercised only one time per subject on the treadmill prior to the beginning of this study, and they were not accustomed to exercising on a motor driven treadmill.

Group I trained for the entire six weeks at the 50 per cent heart rate intensity level. The mean weekly exercise tolerance increased significantly through the first four weeks before leveling off and showed no significant change in work for the final two weeks.

Group II exercised at 60 per cent heart rate intensity level after the initial two weeks at the 50 per cent level. When a comparison was made of the four weeks in which these subjects exercised at the 60 per cent heart rate intensity level, a significant change did occur. Group III did not show a significant difference in any two-week period at a given intensity beyond the initial two weeks. The changes that occurred did not suggest training because the two groups which exercised at the higher rates had less significant changes than Group I which exercised at the lesser heart rate intensity level. The work tolerance evidently reflected the time needed for members of a group to accustom themselves to the exercise on the motor driven treadmill.

II. CASE STUDY EVALUATIONS

The purpose of the case study evaluation was to examine each subject and to observe the effects of the training at various heart rate intensity levels in relation to "training effect". The subjects within each of the three groups varied in their pre-exercise heart rates as evidenced by the analysis of variance between subjects. There was a significant difference in Groups I, II, and III at the .01 level. The variance within these groups showed an F of 11.294, 26.468 and 19.443 respectively. In using the case study evaluation of each of the subjects, it is possible to study more closely the data produced by each subject within the study.

Group I, subject S.R. This subject was 20 years old, stood 6' 0" (182.8cm) and weighed 150½ pounds (68.62kg). He, along with all other members of Group I, trained at only the 50 per cent heart rate intensity level which was located 50 per cent between his resting rate of 44 heart beats per minute and his maximum of 189 beats per minute. This subject appeared to be one of the better cardio-respiratory conditioned subjects as indicated by the 7 minutes and 14 seconds needed to complete his maximum heart rate test. Based on the data obtained in the pre-training resting heart rate sessions and the maximum heart rate, it was calculated that he should train at the 117 beats per minute level for the entire six weeks period.

This subject had been very active during the winter months as a member of the varsity basketball team. This study was not begun until eight weeks had elapsed after the conclusion of the basketball season to prevent "training effect" resulting from the daily basketball practice. The resting rate of this subject increased from a pre-training rate of 44 beats per minute to 45 beats per minute after two weeks of training. His resting rate increased to 49 beats after the conclusion of the fourth week of exercise and returned to 45 beats per minute at the conclusion of the six weeks of training. The six-weeks training session resulted in an increase of one beat per minute over the pre-training resting heart rate.

The mean workload increased weekly from a mean of 3.93 mph during the first week of exercise to a mean of 4.54 mph for the fourth week of exercise before declining to a mean of 4.49 mph during the final week of exercise. These data are illustrated graphically in Figure 9 in the Appendix.

<u>Group I, subject R.E.</u> A 19 year-old, 6' ½" (184.4cm), 166¼ pounds (75.41kg) subject was the second subject in Group I. His pre-training resting heart rate was 51 beats per minute, and he obtained a maximum heart rate of 202 beats per minute during the maximum run test of 6 minutes and 4 seconds. These data indicated subject R.E. was to exercise at 134 beats per minute during the six weeks of training. His post two weeks training resting heart rate increased to 58 beats

and continued to rise to 60 beats per minute when examined for a post four weeks training resting heart rate. His resting rate was 54 beats per minute or 3 beats greater at the conclusion of the sixth week than at the onset of the training. This subject had also been a member of the basketball squad which ended its season eight weeks prior to the initiation of this study.

This individual showed a very constant mean work tolerance during the six weeks program. His mean work rate was 4.03, 4.21, 4.26, 4.29, 4.22 and 4.27 mph during weeks one through six respectively. These data are graphically illustrated in Figure 10 in the Appendix.

Group I, subject B.S. This subject had been very inactive during the school year prior to this study. He desired to take part in the study primarily for the purpose of having some form of daily activity. His pre-training resting heart rate was 63 beats per minute and after a maximum heart rate test of 5 minutes and 26 seconds duration he had obtained a maximum heart rate of 204 beats per minute. These data indicated he should exercise at 134 beats per minute to maintain the heart rate intensity level of 50 per cent. This slender 19 year-old stood 5' 11" 9180.8cm) and weighed 128 3/4 pounds (58.40kg). His resting heart rate was monitored at 66 beats per minute upon completion of the first two weeks of exercise. This decreased to 60 beats per minute when the post four weeks training resting rate was recorded.

After the conclusion of the sixth or final week of training, he graphically recorded a resting heart rate of 59 beats per minute. The six weeks of training resulted in a decrease in resting heart rate of 4 beats per minute.

The mean work produced during the daily 15 minute exercise began at 4.00 mph for the first week and increased to 4.23, 4.32 and a high of 4.55 mph during the weeks two through four. This work decreased to 4.33 mph for the fifth week and increased to 4.43 mph for the final week of training. The daily work as measured in miles per hour and other data on this subject are located in Figure 11 in the Appendix.

Group I, subject R.A. This 19 year-old subject had been very active as a cross country and track athlete in high school but after graduation he had become very inactive. His height was 5' 6½" (169.3cm) and weighed 139 3/4 pounds (63.41kg). When given the pre-training resting heart rate, the lowest heart rate monitored was 75 beats per minute. This appeared to be too high and he was retested but no lower rate could be produced. He was then asked to count his own resting heart rate each morning before getting out of bed. The lowest available heart rate under these conditions was 72 beats per minute. The resting heart rate of 75 beats per minute secured in the quiet surroundings of the laboratory was the data used in the study. The maximum heart rate of this individual was 205 beats per minute and his running time was

5 minutes and 47 seconds during the maximum heart rate test. This subject exercised at the 50 per cent heart rate intensity level during the six weeks exercise period. His exercise rate for this period was 140 beats per minute based on his resting and maximum heart rate data. After training at this rate for two weeks, his resting heart rate declined to 64 beats per minute. The following two weeks of exercise lowered the resting rate to 60 beats per minute. The post six weeks training resting heart rate showed a rate of 58 beats per minute. In the six weeks training period at the 50 per cent heart rate intensity level, the heart rate of this subject had been reduced 17 beats per minute when at rest.

The workload for R.A. began at 3.93 mph and increased to 4.33 mph by the fifth week. A decline to 4.27 mph was noted for the final week of work. These data on this subject are graphically illustrated in Figure 12 in the Appendix.

Group II, subject M.T. The eldest subject at 24 years and one of the smallest at 5' 7¼' (170.9cm) and 124 pounds (56.25kg), M.T. was a moderately active graduate student. His pre-training resting heart rate was 49 beats per minute. The maximum heart rate test lasted for 5 minutes and 21 seconds and produced a maximum 176 beats per minute heart rate. During the first two weeks he trained at a heart rate intensity level of 50 per cent or 113 beats per minute. The post two weeks resting heart rate results were 52 beats per minute. The mean workload for the first week was 3.63 mph and 3.69 mph for the second week.

Beginning with the third week all members of Group II were increased to 60 per cent heart rate intensity level determined from the data of maximum heart rate and pre-training resting rate. The post four weeks resting rate for this subject was 42 beats per minute. At the conclusion of the fourth week of exercising at the 60 per cent level and the sixth week of training M.T. produced a resting heart rate of 45 beats per minute.

During the first week of training at the 60 per cent level the workload increased to 4.33 mph, this continued to increase throughout the 60 per cent training period with values of 4.49, 4.52, and 4.68 mph for the final three weeks of training. Figure 13 in the Appendix gives the graphic details of this member of Group II.

Group II, subject R.P. This subject had played football in high school but his only activity during college was a beginning swimming class. He stood 5' 9½" (176.7cm) and was the heaviest subject at 180 pounds (81.65kg). He also had the distinction of being the youngest member of the study at 18 years of age. His pre-training resting heart rate was 54 beats per minute and the maximum heart rate of 205 beats was obtained during an exhausting period of 5 minutes and 13 seconds. R.P. exercised at the 50 per cent heart rate intensity level or 130 beats per minute for the first two weeks. His post two weeks resting heart rate was 48 beats per minute. The mean work tolerance of 3.70 mph for the initial week of training was increased to 4.02 during the second week of treadmill training.

The heart rate needed to obtain the 60 per cent intensity level for weeks three through six was 145 beats per minute. Post four weeks training resting heart rate was 46 beats per minute and this increased to 48 at the conclusion of the study. The mean work produced during the third week was 4.38 mph and increased to 4.44 mph for the fourth week of training. The final two weeks of work tolerance were 4.51 and 4.56 mph respectively. Figure 14 in the Appendix elaborates on the daily exercise data of this subject.

Group II, subject J.S. This subject did not have any history of athletic participation other than required physical education in high school or college. In 19 years he had developed into a young man who stood 5' 6 3/4" (169.6cm), and weighed 156 3/4 pounds (71.10kg). He remained on the treadmill for 4 minutes and 46 seconds during the maximum heart rate session. The maximum heart rate recorded was 198 beats per minute. The pre-training resting rate recorded was 64 beats per minute. When the 50 per cent heart rate intensity level was computed, he trained at 131 beats per minute during the first two weeks. He worked at the mean rate of 3.85 mph the first week and increased this to 3.92 mph for the second week. The post two weeks resting heart rate for this subject was 52 beats per minute.

J.S. trained at 144 beats per minute, beginning with the third week of exercise, which was his 60 per cent heart rate intensity level. The post four weeks training resting heart rate was 59 beats per minute while the final resting heart rate taken at the conclusion of six weeks training resulted in a 48 beats per minute reading. There was a very slight increase in mean work tolerance during weeks three through six. The mean mph for these four weeks was 4.30, 4.32, 4.39 and 4.42 mph as recorded in order of occurance. Additional data are available in Figure 15 in the Appendix.

Group II, subject T.C. This 23 year-old subject was a senior who completed his basketball eligibility eight weeks prior to the beginning of this study. He weighed 161 3/4 pounds (73.36kg) and stood 6' 1" (185.5cm) tall. The pre-training resting rate was 66 beats per minute and he produced a maximum heart rate of 190 beats during an exercise period which lasted for 5 minutes and 29 seconds before exhaustion forced discontinuation. His exercise heart rate intensity level for the first two weeks was 128 beats per minute. The post two weeks training resting heart rate was monitored at 69 beats per minute. The mean work tolerance produced during the first week was 4.10 mph. This increase to 4.25 mph for the second week. The exercise mean rate of 4.25 mph was the greatest workload of any of the 12 subjects who worked at the 50 per cent heart rate intensity level during the initial two weeks.

T.C. trained at the 60 per cent heart rate intensity level during the final four weeks of the study. This required a heart rate of 140 beats per minute for this subject. Two weeks of exercise at this heart rate intensity reduced the post four weeks resting heart rate to 56 beats per minute. An additional two weeks work produced a post six weeks resting rate of 57 beats per minute. The mean workload measured each week increased steadily from 4.69 to 4.93 mph. The Appendix has additional information concerning this subject in Figure 16.

Group III, subject T.W. T.W. was a 20 year-old subject with very limited high school athletic background. This 6' 3/4" (185.0cm) 173 3/4 pound (78.81kg) male participated in varsity basketball on the college level eight weeks prior to this study. His pre-training resting heart rate was 46 beats per minute. The maximum heart rate test produced a maximum heart rate of 185 beats per minute after 5 minutes and 53 seconds. A resting heart rate of 46 beats per minute was again produced after completion of two weeks training at his 50 per cent heart rate intensity level of 116 beats per minute. The workload for the first two weeks averaged 4.13 and 4.17 mph respectively.

The training intensity was increased to 60 per cent for the third and fourth weeks. The mean work tolerance was 4.62

mph for the third week and 4.66 mph for the fourth week. The resting heart rate at the conclusion of the fourth week was 43 beats per minute. The heart rate was maintained at 129 beats per minute during this period of exercise.

Being a member of Group III required a workload of 70 per cent or 143 heart beats per minute during the final two weeks of exercise. The work tolerance increased to 5.36 mph for the fifth week and increased to a high among all subjects of 5.44 mph during the final week. The post six weeks resting heart rate was monitored at 42 beats per minute. A complete graphic discription of this subject is found in Figure 17 within the Appendix.

Group III, subject S.U. This 19 year-old college sophomore was a member of the varsity basketball team at the conclusion of the season eight weeks prior to the beginning of this study. This young man weighed 164 pounds (74.39kg) and had attained a height of 5' 8 3/4" (174.4cm). He produced a maximum heart rate of 195 beats per minute on the treadmill during a 4 minute and 44 second exhaustive run. The pre-training resting heart rate was 55 beats per minute and his heart rate for the 50 per cent intensity level was 125 beats per minute. A resting heart rate of 50 was monitored on the physiograph equipment after exercising for two weeks at this intensity level. The mean work tolerance for the first week was 3.78 mph and this increased to 3.98 mph during the second week.

The subject trained at 139 beats per minute during the third and fourth weeks and again the resting heart rate of 50 beats per minute was monitored at the conclusion of the two-week session. The mean work produced for the third and fourth weeks was 4.37 and 4.34 mph respectively.

The training heart rate for the 70 per cent heart rate intensity level was 153 beats per minute. The post six weeks resting heart rate was recorded at 48 beats per minute. The mean workload for the fifth week was 5.10 mph. It should be noted by observing the daily work tolerance in Figure 18 in the Appendix that, on Thursday of the fifth week, this subject exercised at an average of 5.54 mph. This datum was .40 mph greater than any other daily exercise for this subject. After evaluating these data and those taken in the six training sessions following this session, it was believed that data were inaccurate. The data collected during the latter part of this session were not that of the subject's heart but a monitoring of the pace of the subject. This could not be proven to be inaccurate data, and for this reason it was not deleted from the subject's data sheet. Due to the possibility of this erroneous datum produced during the Thursday training period of the fifth week, the weekly work tolerance for this week was a high of 5.10 mph. The sixth week mean work product was 4.96 mph.

Group III, subject D.S. This individual had been active in track during his high school days three years prior to this study. He volunteered for the study for the purpose of trying to develop the habit of daily exercising. As a 20 year-old he weighed 152¼ pounds (69.27kg) and stood 5' 10¾" (179.6cm). A maximum of 193 heart beats per minute was obtained during an exhaustive test of 4 minutes and 58 seconds. Based on these data, the subject trained for two weeks at his 50 per cent heart rate intensity level or 127 beats per minute. The post two weeks resting heart rate was 62 beats per minute. The mean workload of 3.95 mph for the first week increased to 4.12 mph during the second week.

When the heart rate intensity level increased to 60 per cent for the third and fourth weeks, the subject had to train at 140 beats per minute. This produced a mean work product of 4.41 mph for the third week and 4.32 mph for the fourth week. The post four weeks resting heart rate was 57 beats per minute.

The final two weeks of the study was conducted at the 70 per cent heart rate intensity level. For D.S., the training rate, for the 15 minutes per day, five days per week sessions, was 153 heart beats per minute. The post six weeks resting heart rate was 56 beats per minute. The mean work performed during the fifth week was 4.78 mph and increased to 4.90 mph for the sixth and final week. Additional data are presented in Figure 19 in the Appendix.

Group III, subject D.R. This 6' 0" (182.6cm), 152¼ pounds (69.27kg) 19 year-old sophomore did not have any background in athletic activities. He ran for 4 minutes and 22 seconds before becoming exhausted. His maximum heart rate for this exhaustive exercise was 193 beats per minute. For two weeks he trained at his 50 per cent heart rate intensity level or 129 beats per minute. This necessitated exercising at a mean workload of 3.65 mph for the first week and 3.86 mph for the second week. The post two weeks training resting heart rate was 54 beats per minute.

The subject's 60 per cent heart rate intensity level was 141 heart beats per minute. After training two additional weeks at this level, the post four weeks resting heart rate was 53 beats per minute. The average work produced was 4.26 mph for the third week of training and increased to 4.43 mph for the fourth week.

The final two weeks for all subjects in Group III required a training period of 70 per cent heart rate intensity level. For D.R. the training level demanded 154 beats per minute from his heart. His post six weeks training resting heart rate was 49 beats per minute. He worked at a mean rate of 4.94 mph during the fifth week and concluded with a 5.27 mph average workload produced during the final week of training. Additional data on this subject are found in Figure 20 of the Appendix.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was designed to further investigate a pilot study conducted by Martti J. Karvonen (56, 57, 58). He theorized from his investigation of seven male medical students that "training effect" occurred at 60 per cent between the resting heart rate and the maximum heart rate.

This study increased the number of subjects from 7 to 12. The duration of the investigation was increased from 4 to 6 weeks. A cardiotachometer and graphic EKG readout on physiograph paper were used to obtain the heart rate. This method was superior to Karvonen's using a stethoscope to count the subject's exercising heart rate for a period of 10 seconds after stepping off the treadmill for a time not to exceed 15 seconds. He used this method at 10-minute intervals during his daily investigations. Studies conducted by McArdle and others (69) showed moderate exercise rate of approximately 140 beats per minute require approximately 4 seconds to locate the pulse and may deviate up to 13.5 per cent due to unsimilar rates of recovery during moderate training sessions. The direct monitoring of heart rates in this study eliminated stopping of the exercise sessions and thus eliminated the possibility of the 13.5 per cent of error during the daily exercise sessions.

I. SUMMARY

The 12 subjects used in this study had a mean height, weight and age of 5' 11" (180.1cm), 158¼ pounds (71.78kg) and 19.9 years respectively. The subjects were promised and paid, upon completion of the study, the sum of $25.

A Physiograph Four was used to directly monitor the resting heart rates of the subjects prior to the beginning of the exercise sessions. This pre-training resting rate was obtained after the subject had maintained a supine position for a minimum period of 30 minutes. The subjects' resting rates varied from 44 to 75 beats per minute. A maximum heart rate was then determined of each subject. They were instructed to continue to run on the treadmill until exhaustion. The speed of the treadmill was 7 mph and the elevation was 0 per cent grade. This speed of 7 mph was continued throughout the maximum test. At the end of each minute the grade was increased 2½ per cent until the subject stepped off the treadmill due to exhaustion.

The exercise period for each subject was 15 minutes per day, 5 days per week and for a duration of 6 weeks. The pre-training resting heart rate and maximum heart rate data made it possible to determine the 50 per cent heart rate intensity level. This level was located at 50 per cent between the pre-training resting heart rate and the maximum heart rate. All 12 subjects exercised for the first two weeks at the 50 per cent heart rate intensity level. A post two weeks resting heart rate was taken at the conclusion of the initial two weeks of exercise. The subjects who were arbitrarily assigned to one of three groups were equated and found to be similar and allowed to continue in their groups for the second two weeks of training.

The heart rate intensity level for Group I was 50 per cent while Groups II and III exercised at the 60 per cent level during the third and fourth weeks of training. A post four weeks resting heart rate was obtained after the subjects concluded their fourth week of exercise.

Group I subjects continued to exercise at the 50 per cent heart rate intensity level during the final two weeks of the six week training program. Group II subjects continued their exercise at the 60 per cent heart rate intensity level to 70 per cent for the final two weeks of training. A post six weeks resting heart rate of all subjects was monitored at the conclusion of the exercise.

An analysis of variance on resting heart rates was calculated at the conclusion of the six weeks of exercise. Group I subjects, having exercised only at the 50 per cent heart rate intensity level, showed no significant difference in the resting heart rate due to exercise ($F = 0.655$). Group II subjects showed a significant difference in the resting heart rate at the .01 level ($F = 7.705$) upon completion of six weeks of training. The training consisted of two weeks of training at the 50 per cent heart rate intensity level and four weeks at the 60 per cent heart rate intensity level. Group III subjects also showed a significant difference (F = 7.179) after exercising at 50 per cent, 60 per cent and 70 per cent heart rate intensity for a period of two weeks at each intensity level.

A _t_ test produced no significant difference (t = 1.939) in the resting heart rate of pre-training and post two weeks resting heart rate of all subjects. A _t_ test of Group II and III subjects after four weeks of exercise showed a significant difference between pre-exercise and post four weeks resting heart rate at the .01 level (t = 6.401).

Analysis of matched pair data was also conducted at two-week intervals on each group. Group I subjects produced no significant difference when the pre-training resting heart rate was compared with the post two weeks (t = 0.000), post four weeks (t = 0.189) and post six weeks (t = 0.944) resting heart rates. Group II subjects showed no significant difference between the pre-training resting heart rate and the post two weeks (t = 0.354) training. A significant difference was noted upon the completion of the four weeks (t = 3.571) and six weeks (t = 3.327) resting heart rates. Group III subjects did not show a significant difference when pre-training resting heart rates were compared with post two week resting heart rates (t = 1.077). When the comparison was made with post four and post six weeks training resting heart rates, significant differences of (t = 3.212) and (t = 4.355) were noted respectively at the .05 level.

The second criterion used to determine if training effect occurred was the change in the exercise tolerance level while the heart rate intensity remained the same. Group I trained at only one heart rate intensity level during the six weeks of exercise. There was significant increase in the work tolerance at the .05 level of this group between the first and second weeks (t = 3.268), the third and fourth weeks (t = 3.354), the first and fourth weeks (t = 5.757) and the first and sixth weeks (t = 5.476). Group II produced only one significant increase in work tolerance. This occurred between the third and sixth weeks of training (t = 4.532). Group III showed a significant difference only during the work comparisons of weeks one and two (t = 3.944). A comparison of all 12 subjects, made between first and second weeks, produced a significant difference at the .01 level (t = 5.908).

All 12 subjects showed a significant change from the first to second week of training. This change either could reflect the training effect of the subjects during the initial two weeks of work or it could show the results of the subjects becoming more accustomed to the daily treadmill exercise sessions. Eleven of the twelve subjects had exercised only one time on the treadmill prior to the beginning of this study, and they were not accustomed to exercising in this manner.

The case study evaluations examined each subject within the three groups. Each group included a subject who registered one of the three lowest pre-training resting heart rates. Each group also included a subject with the fourth, fifth or sixth lowest pre-training resting heart rate and two subjects from the group of six with the highest pre-training resting heart rates.

The case study evaluation showed subject R.A., in Group I, decreased his resting heart rate 17 beats during the six weeks training at the 50 per cent heart rate intensity level. A decrease of 11 beats was noted during the first two weeks of training. Subject J.S., in Group II, had a decrease of 12 beats between the pre-training resting heart rate and the post two weeks resting heart rate. Subject D.R., in Group III, produced a decrease in resting rate from 64 to 54 beats between the pre-training and post two weeks training resting heart rates. These three subjects continued to decrease their resting heart rate six, four and five beats respectively. These three subjects, one from each group, made the greatest decreases in resting heart rate during the six weeks training period.

II. CONCLUSIONS

1. Exercise at the 50 per cent heart rate intensity level was not strenuous enough to cause a "training effect" to occur.

2. Exercise at the 60 per cent heart rate intensity level was strenuous enough to cause a "training effect" to occur.

3. Exercise at the 70 per cent heart rate intensity level was strenuous enough to cause a "training effect" to occur.

4. Data from this study indicated the critical threshold for "training effect" occurred after the 50 per cent heart rate intensity level and before the 60 per cent heart rate intensity level.

5. Case studies indicated that subjects with high resting heart rates may benefit from exercise at a lesser heart rate intensity than 60 per cent.

6. There is a need for additional study in the area of heart rate intensity level and degrees of fitness as measured by resting heart rate.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

1. Astrand, Per-Olof, and Kaare Rodahl. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1970.

2. Boas, E. P., and E. F. Goldschmidt. The Heart Rate. Springfield, Ill.: Charles C. Thomas Publishers, 1932.

3. Burch, George E., and Travis Winsor. A Primer of Electrocardiography. Fourth edition. Philadelphia: Lea & Febiger, 1960.

4. Cohen, Hyman L., and Joel Brumlik. A Manual of Electroneuromyography. New York: Hoeber Medical Division, Harper and Row, Inc., 1968.

5. Consolazio, C. Frank, Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Functions in Man. New York: McGraw-Hill Book Company, Inc., 1963.

6. DeVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: William C. Brown Company Publishers, 1966.

7. Falls, Harold B. (ed.). Exercise Physiology. New York: Academic Press, 1968.

8. Ganong, William F. Review of Medical Physiology. Fourth edition. Los Altos, California: Lange Medical Publications, 1969.

9. Heymans, Corneille. Introduction to the Regulation of Blood Pressure and Heart Rate. First edition. Springfield, Ill.: Charles C. Thomas Publisher, 1950.

10. Johnson, Warren R. (ed.). Science and Medicine of Exercise and Sports. New York: Harper and Brothers Publishers, 1960.

11. Karpovich, Peter V., and Wayne E. Sinning. Physiology of Muscular Activity. Seventh Edition. Philadelphia: W. B. Saunders Company, 1971.

12. Karvonen, Martti J., and Alan J. Barry (eds.). Symposium on Physical Activity and the Heart. Springfield, Ill.: Charles C. Thomas Publisher, 1967.

13. Lewis, Sir Thomas. The Mechanism and Graphic Registration of the Heart Rate. Third edition. Chicago: Chicago Medical Book Company, 1924.

14. Licht, Sidney Herman. Electrodiagnosis and Electromyography. Second edition. New Haven: E. Licht, 1961.

15. Mathews, Donald K., and Edward L. Fox. The Physiological Bases of Physical Education and Athletics. Philadelphia: W. B. Saunders Company, 1971.

16. Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. Fifth edition. Saint Louis: The C. V. Mosby Company, 1967.

B. PERIODICALS

17. Alderman, Richard B. "Interindividual Differences in Heart Rate Response to Bicycle Ergometer Work," The Research Quarterly, 38:323-29, October, 1967.

18. Alderman, Richard B. "Reliability of Individual Differences in the 180 Heart Rate Response Test in Bicycle Ergometer Work," The Research Quarterly, 37:429-31, October, 1966.

19. Antel, Jack, and Gordon R. Comming. "Effect of Emotional Stimulation on Exercise Heart Rate," The Research Quarterly, 40:6-10, March, 1969.

20. Asmussen, Erling, and Marius Nielsen. "Cardiac Output During Muscular Work and Its Regulation," Physiological Reviews, 35:778-800, October, 1955.

21. Astrand, Irma. "Physical Work Capacity of Workers 50-64 Years Old," ACTA Physiologica Scandinavica, 42:73-86, February 10, 1958.

22. Astrand, Per-Olof. "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, 36:307-35, July, 1956.

23. Astrand, P.-O., and Irma Ryhming. "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) From Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7:218-221, September, 1954.

24. Astrand, Per-Olof, and Bengt Saltin. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16:977-81, November, 1961.

25. Balke, Bruno. "Correlation of Static and Physical Endurance. 1. A Test of Physical Performance Based on Cardiovascular and Respiratory Response to Gradually Increased Work," Project 21-32-004 Report No. 1, USAF School of Aviation Medicine, Randolph Field, Texas, April, 1952.

26. Balke, Bruno, and Ray W. Ware. "An Experimental Study of 'Physical Fitness' of Air Force Personnel," U.S. Armed Force Medical Journal, 10:675-88, June, 1959.

27. Balke, Bruno., and others. "Work Capacity After Blood Donation," Journal of Applied Physiology," 7:231-38, November, 1954.

28. Brooker, Charles. "Use of Efficiency as a Measure of Endurance Training Intensity," The Research Quarterly, 39:865-71, December, 1968.

29. Brouha, Lucien. "Effect of Work on the Heart," in Francis F. Rosenbaum and Elston L. Belknap (eds.). Work and the Heart. New York: Paul B. Hoeber, Inc., 1959.

30. Brouha, Lucien. "Training," in Warren R. Johnson (ed.). Science and Medicine of Exercise and Sport. New York: Harper and Brothers Publishers, 1960.

31. Brouha, Lucien, and Clark W. Heath. "Resting-Pulse and Blood-Pressure Values in Relation to Physical Fitness in Young Men," New England Journal of Medicine, 228:473-7, April 15, 1943.

32. Brouha, Lucien, and Edward P. Radford, Jr. "The Cardiovascular System in Muscular Activity," in Warren R. Johnson (ed.). Science and Medicine

of Exercise and Sports. New York: Harper and Brothers, 1960.

33. Brouha, Lucien, and others. "Discrepancy Between Heart Rate and Oxygen Consumption During Work in the Warmth," Journal of Applied Physiology, 18:1095-1098, November, 1963.

34. Bruce, R. A., and others. "Exercise Testing in Adult Normal Subjects and Cardiac Patients," Pediatrics, 32:742-56, October, 1963.

35. Campbell, Donald E. "Heart Rates of Selected Male College Freshmen During a Season of Basketball," The Research Quarterly, 39:880-87, December, 1968.

36. Cotton, F. S., and D. B. Dill. "On the Relation Between the Heart Rate During Exercise and That Immediate Post-Exercise Period," American Journal of Physiology, 111:554-6, April, 1935.

37. Cureton, Thomas K. "Comparison of Various Factor Analyses of Cardiovascular-Respiratory Test Variables," The Research Quarterly, 37:317-25, October, 1966.

38. Davis, C. T. M., and E. A. Harris. "Heart Rate During Transition from Rest to Exercise," Journal of Applied Physiology, 19:857-862, June, 1964.

39. Dexter, L., and others. "Effect of Exercise on Circulatory Dynamics of Normal Individuals," Journal of Applied Physiology, 3:439-53, February, 1951.

40. Dill, D. B. "Regulation of the Heart Rate," in Francis F. Rosenbaum and Elston L. Belknap (eds.). Work and the Heart. New York: Paul B. Hoeber, Inc., 1959.

41. Dill, D. B. "The Economy of Muscular Exercise," Physiological Reviews, 16:263-91, April, 1936.

42. Dill, D. B. "The Influence of Age on Performance as Shown by Exercise Test," Pediatrics, 32:737-41, October, 1963.

43. Dill, D. B. "The Nature of Fatigue," Personnel, 9:113

44. Dill, D. B., H. T. Edwards, and J. H. Talbott. "Studies in Muscular Activity: Factors Limiting Capacity for Work," Journal of Physiology, 77:49-62, December 19, 1932.

45. Dill, D. B., S. M. Horvath, and F. N. Craig. "Response to Exercise as Related to Age," Journal of Applied Physiology, 12:195-6, March, 1958.

46. Durnin, J. V. G. A., J. M. Brockway, and H. W. Whitcher. "Effects of a Short Period of Training of Varying Severity on Some Measure-Ments of Physical Fitness," Journal of Applied Physiology, 15:161-65, January, 1960.

47. Erickson, Lester, and others. "The Energy Cost of Horizontal and Grade Walking on the Treadmill," American Journal of Physiology, 145:391-401, January, 1946.

48. Freedman, M. E., and others. "Effects of Training on Response of Cardiac Output to Muscular Exercise in Athletes," Journal of Applied Physiology, 8:37-47, July, 1955.

49. Frick, M. Heikki, Aarne Konttinen, and H. S. Samuli Sarajas. "Effects of Physical Training on Circulation at Rest and During Exercise," The American Journal of Cardiology, 12:142-6, August, 1963.

50. Hall, Victor E. "The Relationship of Heart Rate to Exercise Fitness: An Attempt at Physiological Interpretation of the Bradycardia of Training," Pediatrics, 32:723-9, October, 1963.

51. Harris, E. A. "Exercise Tolerance Test," The Lancet, 78:409-11, August 23, 1958.

52. Henry, Franklin M. "Influence of Athletic Training on the Resting Cardiovascular System," The Research Quarterly, 25:28-41, March, 1954.

53. Herxheimer, H. "Heart Rate in Recovery from Severe Exercise," Journal of Applied Physiology, 1:279-84, October, 1948.

54. Holmgren, A., and others. "Effect of Training on Work Capacity, Total Hemoglobin, Blood Volume, Heart Volume and Pulse Rate in Recumbent and

Upright Positions," ACTA Physiologica Scandinavica, 50:72-83, January, 1960.

55. Hyman, Albert Salisbury. "The Q-First Heart Sound Interval in Athletes at Rest and After Exercise," Journal of Sports Medicine and Physical Fitness, 4:199-203, December, 1964.

56. Karvonen, Martti J. "Effects of Vigorous Exercise on the Heart," in Francis F. Rosenbaum and Elston L. Belknap (eds.). Work and the Heart. New York: Paul B. Hoeber, Inc., 1959.

57. Karvonen, Martti J. "Problems of Training of the Cardiovascular System," Ergonomics, 2:207-15, February, 1959.

58. Karvonen, M. J., E. Kentala, and O. Mustala. "The Effects of Training on Heart Rate: A Longitudinal Study," Annales Medicinae Experientalis Et Biologea Fenniae, (Helsinki), 35:307-15, 1957.

59. Knehr, C. A., D. B. Dill, and William Neufeld. "Training and its Effects on Man at Rest and at Work," American Journal of Physiology, 136:148-156, March, 1942.

60. Kozar, Andrew J., and Paul Hunsicker. "A study of Telemetered Heart Rate During Sports Participation of Young Adult Men," Journal of Sports Medicine and Physical Fitness, 3:1-5, March, 1963.

61. Kurucz, Robert L., Edward L. Fox, and David K. Mathews. "Construction of a Submaximal Cardiovascular Step Test," The Research Quarterly, 40:115-22, March, 1969.

62. LeBlanc, J. A. "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, 10:275-80, March, 1957.

63. Linde, Leonard M. "An Appraisal of Exercise Fitness Tests," Pediatrics, 32:656-9, October, 1963.

64. Lundgen, Nils P. V. "The Physiological Effects of Time Schedule Work on Lumber-Workers," ACTA Physiologica Scandinavica, 13 (Supp. 41):5-137.

65. Malhotra, M. S., J. Sen Gupta, and R. M. Rai. "Pulse Count as a Measure of Energy Expenditure," Journal of Applied Physiology, 18:994-96, September, 1963.

66. Masters, Arthur M., and Isadore Rosenfield. "Clinical Application of the Two-Step Exercise Test," Journal of American Medical Association, 178: 283-285.

67. Maxfield, Mary E., and Lucien Brouha. "Validity of Heart Rate as an Indication of Cardiac Stress," Journal of Applied Physiology," 18:1099-1104, November, 1963.

68. McArdle, William D., Guido Foglin, and Anthony V. Patti. "Telemetered Cardiac Response to Selected Running Events," Journal of Applied Physiology, 23:566-70, October, 1967.

69. McArdle, William, Linda Zwiren, and John R. Magel. "Validity of the Post-exercise Heart Rate as a Means of Estimating Heart Rate During Work of Varying Intensities," The Research Quarterly, 40:523-28, October, 1969.

70. Metheny, E., and others. "Some Physiologic Responses of Women and Men to Moderate and Strenuous Exercise: A Comparative Study," American Journal of Physiology, 137:318-323, September, 1942.

71. Michael, Ernest D., Jr., and Steven M. Horvath. "Physical Work Capacity of College Women," Journal of Applied Physiology, 20:263-66, March, 1965.

72. Montoye, Henry J. "Inter-relation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse Rate and Post-Exercise Blood Lactate," The Research Quarterly, 24:453-58, December, 1953.

73. Nagle, Francis J., and Thomas G. Bedecki. "Use of the 180 Heart Rate Response as a Measure of Circulorespirator Capacity," The Research Quarterly, 34:361-69, October, 1963.

74. Olds, L. W. "The Study of the Effects of Competitive Basketball Upon the Physical Fitness of High School Boys as Determined by McCurdy-Larsen Organic Efficiency Tests," The Research Quarterly, 12:254-65, May, 1941.

75. Reeves, John T., and others. "Cardiac Output Response to Standing and Treadmill Walking," Journal of Applied Physiology, 16:283-88, March, 1961.

76. Robinson, S., H. T. Edwards, and D. B. Dill. "New Records in Human Power," Science, 85:409-10, April 23, 1937.

77. Robinson, S., and others. "Fatigue and Efficiency of Men During Exhausting Runs," Journal of Applied Physiology, 12:197-201, March, 1958.

78. Sharkey, Brian J., and John P. Holleman. "Cardio-respiratory Adaptations to Training at Specific Intensities," The Research Quarterly, 38:698-704, December, 1967.

79. Steinhaus, Arthur H. "Chronic Effects of Exercise," Physiological Reviews, 13:103-47, January, 1933.

80. Taylor, Craig. "A Maximal Pack Test of Exercise Tolerance," The Research Quarterly, 15:291-302, December, 1944.

81. Taylor, Craig. "Some Properties of Maximal and Sub-maximal Exercise With Reference to Physiological Variation and the Measurement of Exercise Tolerance," American Journal of Physiology, 142:200-212, September, 1944.

82. Taylor, Craig. "Studies in Exercise Physiology," American Journal of Physiology, 135:27-42, December, 1941.

83. Taylor, Henry Longstreet, Elsworth Buskirk, and Austin Henschel. "Maximal Oxygen Intake as an Objective Measure of Cardio-Respiratory Performance," Journal of Applied Physiology, 8:73-80, July, 1955.

84. Taylor, Henry L., and others. "The Standardization and Interpretation of Submaximal and Maximal Tests of Working Capacity," Pediatrics, 32:703-22, October, 1963.

85. Tharp, Gerald D. "Cardiac Function Tests as Indexes of Fitness," The Research Quarterly, 40:818-22, December, 1969.

86. Tuttle, W. W., and Frank H. Walker. "The Effect of a

Season of Training and Competition on the Response of the Hearts of High School Boys," The Research Quarterly, 11:78-81, December, 1940.

87. Wahlund, Holger. "Determination of the Physical Working Capacity," ACTA Medicinae Scandinavica, 215 (Suppl.):9-78, 1948.

88. Wyndham, C.H., and others. "Maximum Oxygen Intake and Maximum Heart Rate During Strenuous Work," Journal of Applied Physiology, 14:927-36, November, 1959.

C. UNPUBLISHED MATERIALS

89. Edwards, Marigold A. "A Study to Determine the Effects of Training at Pre-determined Heart Rate Levels in College Women," Abstracts of Research Papers, 1971 AAHPER Convention, Detroit, April 3-6, 1971.

90. Forker, B. E. "Effects of a Season of Basketball Practice on Male College Freshmen as Indicated by Selected Tests of Fatigue," Unpublished Doctoral dissertation, The University of Michigan, Ann Arbor, 1958.

91. Hartung, G. Harley. "Specificity of Training as Indicated by Heart Rate Response to Treadmill Exercise," Abstracts of Research Papers, 1971 AAHPER Convention, Detroit, April 3-6, 1971.

92. Hunsicker, Paul A. "A Validation of Cardiovascular Tests by Cardiac Output Measurements," Unpublished Doctoral dissertation, Physical Education, University of Illinois, Urbana, 1949.

93. Humphrey, L. Dennis, and Harold B. Falls. "Validity of the 180 Heart Rate Termination in Assessment of Aerobic Capacity in Young Women by Progressive Treadmill Exercise," Abstracts of Research Papers, 1971 AAHPER Convention, Detroit, April 3-6, 1971.

94. Knowlton, R.G. "A Ballistocardiographic Investigation of the Cardiac Response to Physical Training," Unpublished Doctoral dissertation, Physical Education, University of Illinois, Urbana, 1961.

95. Strydom, N. B. "Changes in Cardiac Output with Progressive Work," Unpublished Doctoral dissertation, Physical Education, University of Illinois, Urbana, 1950.

96. Philips, E. E. "Physical Fitness Changes in Adults Attributed to Equal Periods of Training, Non-training, and Re-training," Unpublished Doctoral dissertation, Physical Education, University of Illinois, Urbana, 1960.

APPENDIX

TABLE XIII

THE EQUIPMENT USED IN THE INVESTIGATION OF THE THREE HEART RATE INTENSITIES OF COLLEGE AGE MEN

Item	Part Number or Model	Company
Physiograph Four Recorder		
Hi-Gain Preamplifier	93-300-71	1
Recording Channel, Rectilinear	90-200-71	1
Cardiotach	95-400-70	1
Physiograph Four Recording Paper Rectilinear Coordinates	90-101-00	1
General Purpose Ink, Red	90-101-02	1
Surface Electrodes	96-600-83	1
Adhesive Washers	96-600-84	1
Electrode Paste	96-600-85	1
Cardiotach Trig Cable	95-401-70	1
Shielded Input Extension Cable	96-600-93	1
Electrode Paste		2
Volt Ohm Meter	630, Type 2	3
Clinical Treadmill	18-49C	4
Stopwatch	212	5
Two-Sided Adhesive Tape	942	6
Blenderm Surgical Tape	1525	7

Companies: 1. Narco Bio-Systems Incorporated, 2. The Burdick Corporation, 3. Triplett Electrical Instrument Company, 4. Quinton Instruments, 5. Meylan Stopwatch Corporation, 6. Norton Company, 7. 3-M Company.

EXERCISE PERMIT

I, ______________________________
am not, nor have I ever been restricted from participating in any physical education activity at the University of North Carolina at Greensboro. Physical activities in which I have engaged in during the present school year include:

______________ Date

______________________ Signature

FIGURE 2

"EXERCISE PERMIT" CARD SIGNED BY EACH STUDENT PRIOR TO PARTICIPATING IN THE STUDY

FIGURE 3

SURFACE ELECTRODES AS ATTACHED TO THE MANUBRIUM STERNI ON EACH SUBJECT

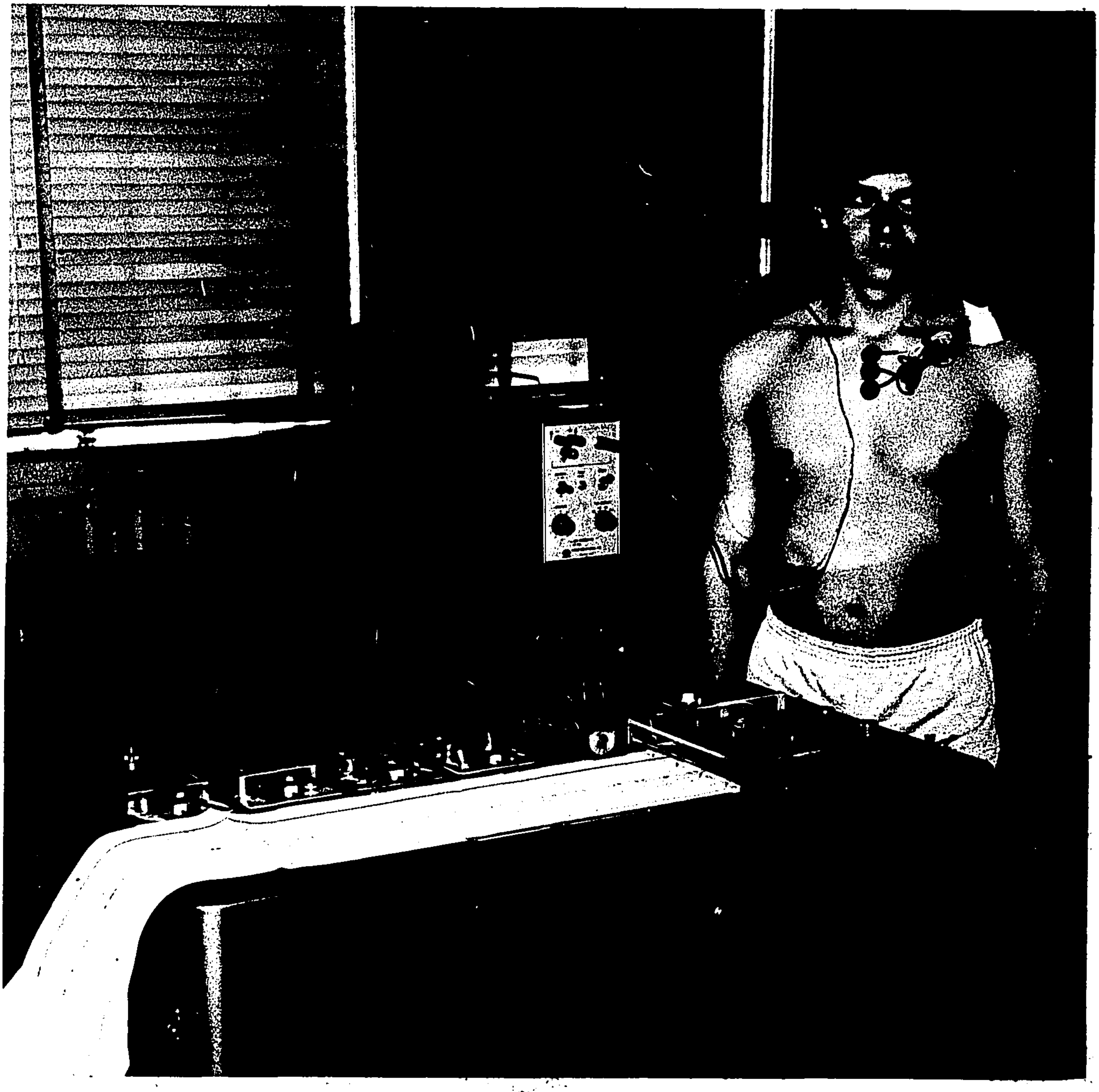


FIGURE 4

SUBJECT AND EQUIPMENT USED IN THE STUDY

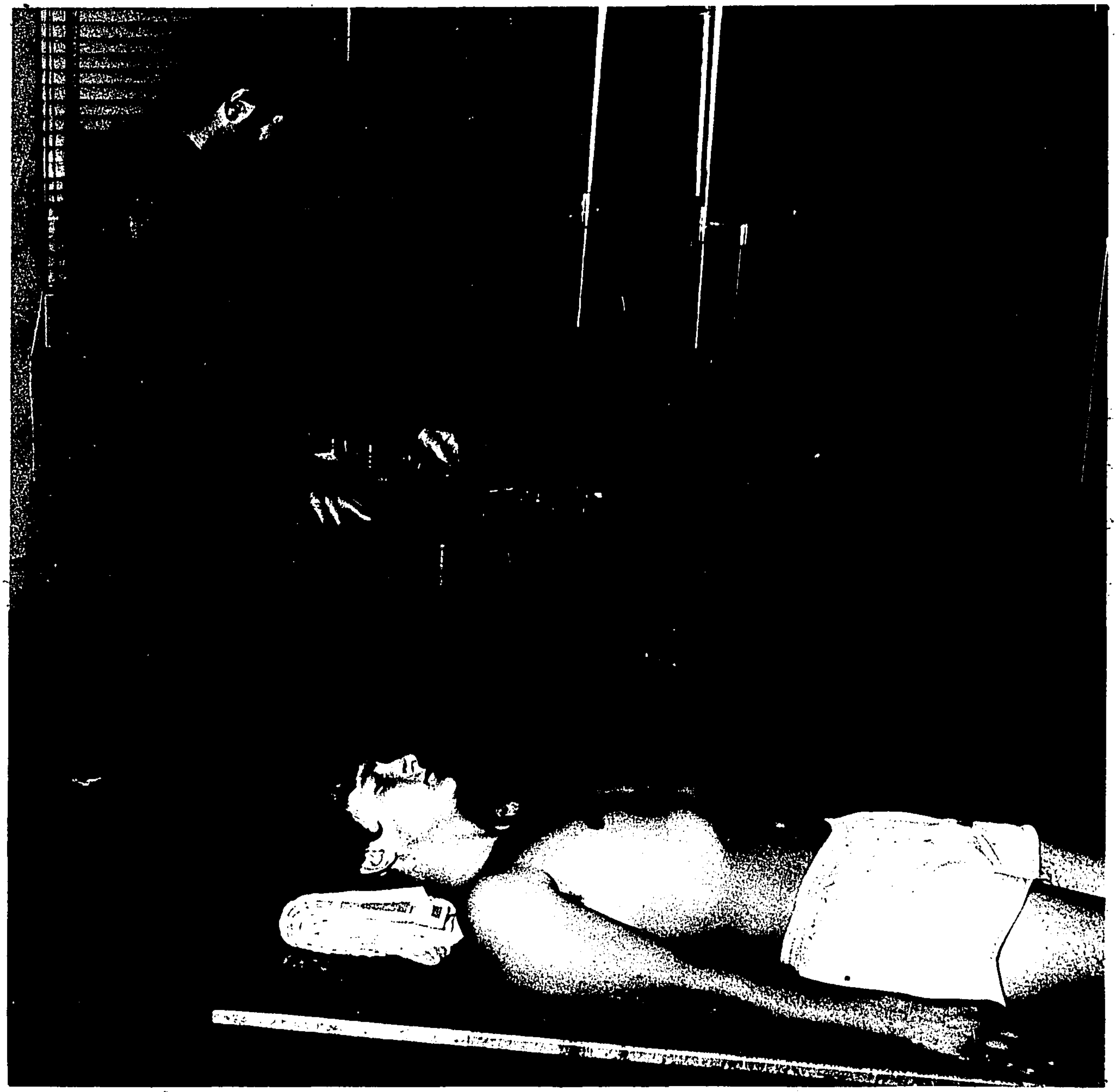


FIGURE 5

SUBJECT IN SUPINE POSITION FOR THE MONITORING OF RESTING HEART RATE DATA

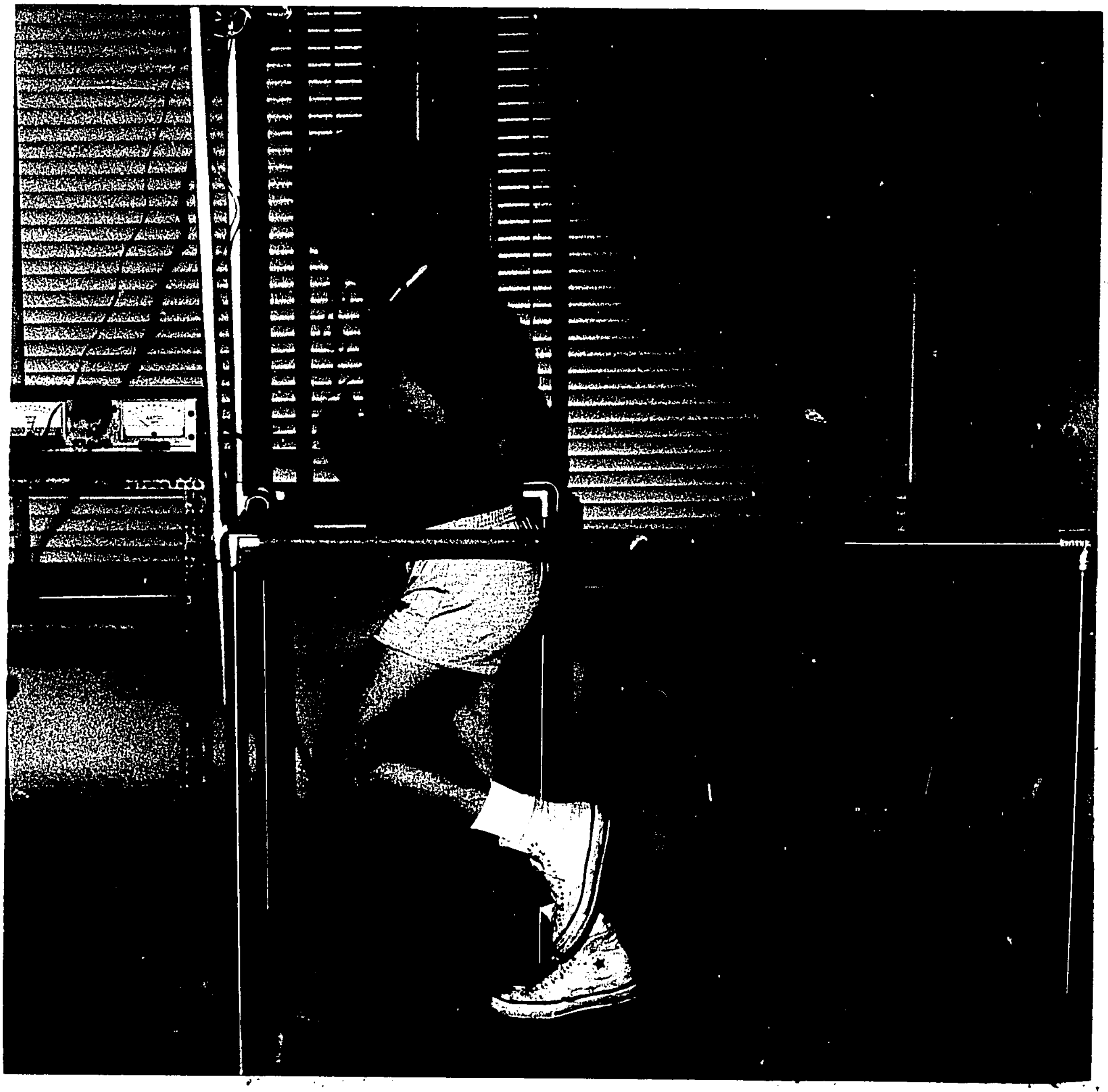


FIGURE 6

SUBJECT BEING MONITORED DURING MAXIMUM HEART RATE TEST.
TREADMILL SPEED IS 7 MPH WITH 0
PER CENT GRADE

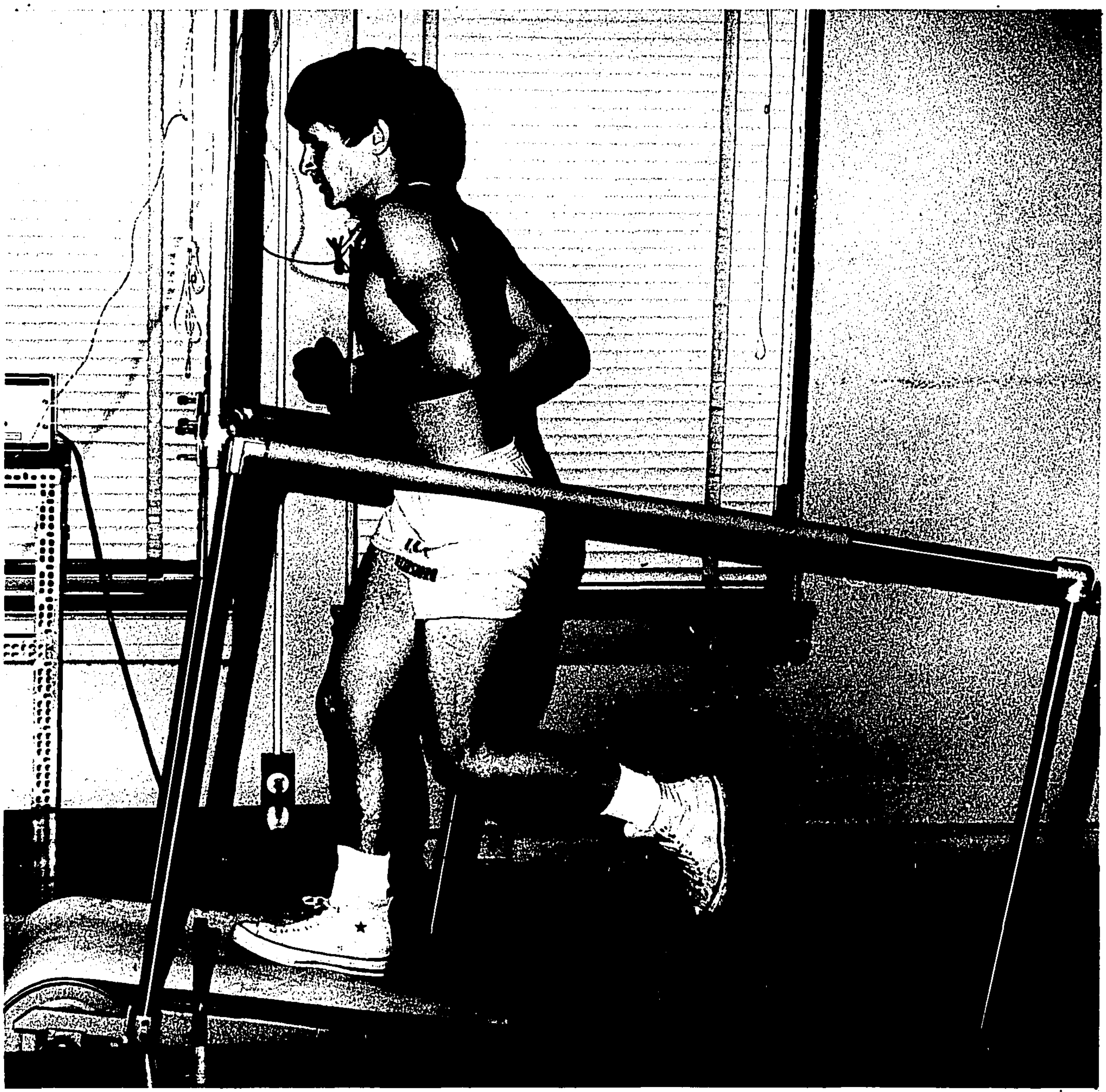


FIGURE 7

SUBJECT BEING MONITORED DURING MAXIMUM HEART RATE TEST.
TREADMILL SPEED IS 7 MPH WITH 15
PER CENT GRADE

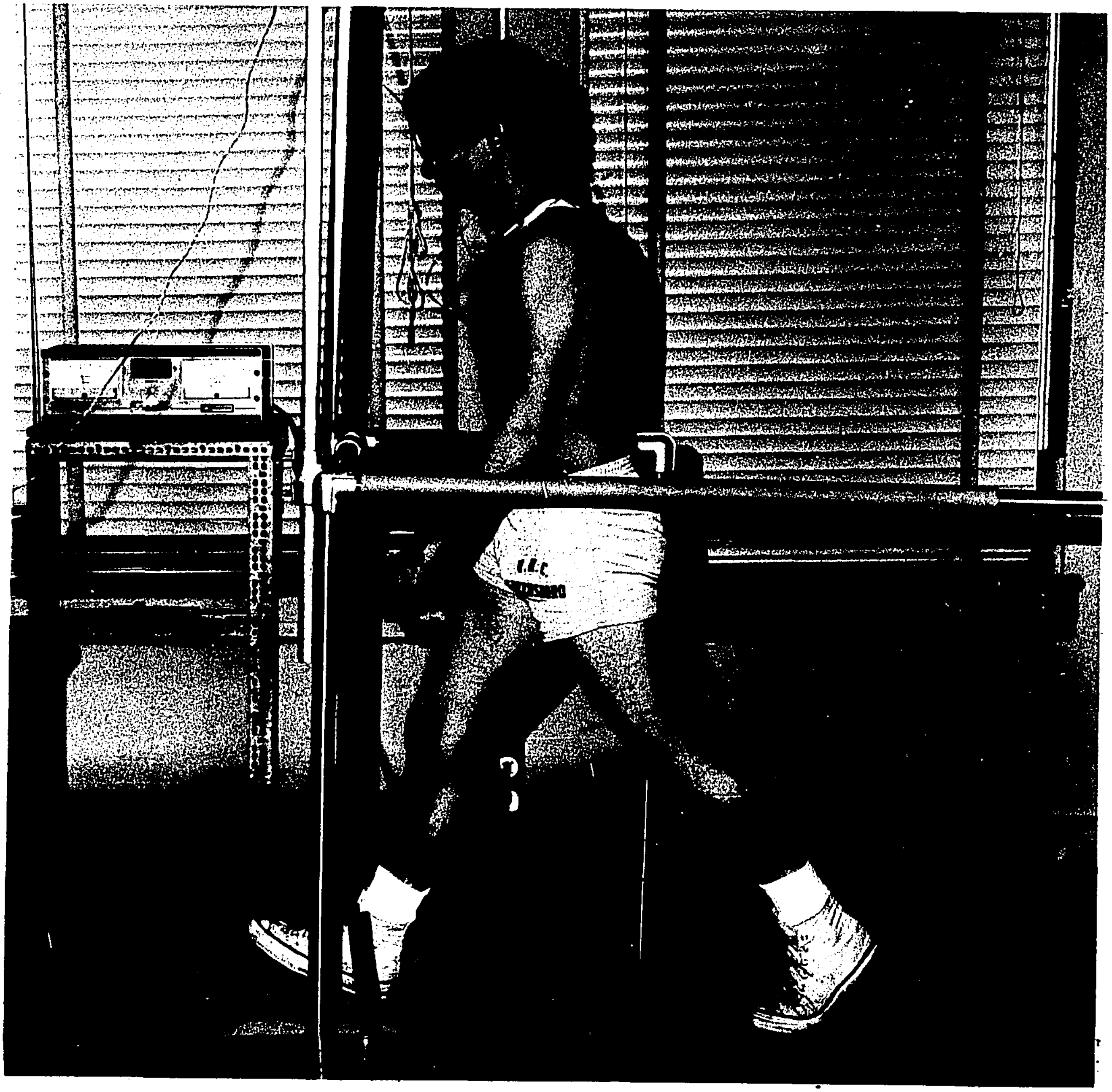
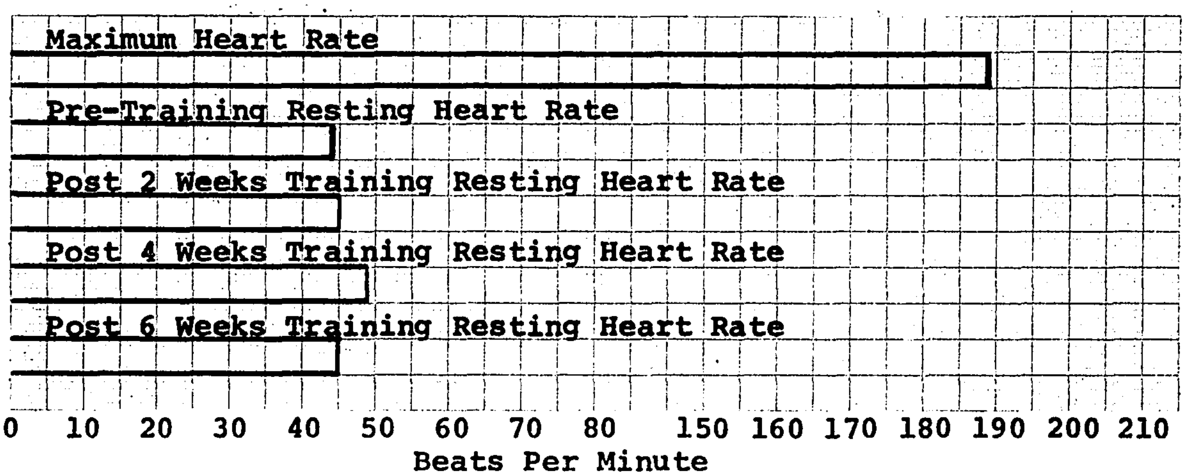


FIGURE 8

SUBJECT EXERCISING DURING A DAILY EXERCISE SESSION AT 2½ PER CENT GRADE AND SPEED AS INDICATED BY HEART RATE

S. R. Height 182.8cm Group I 50% = 117
Weight 68.62kg Heart Rate
Age 20 Intensity Level



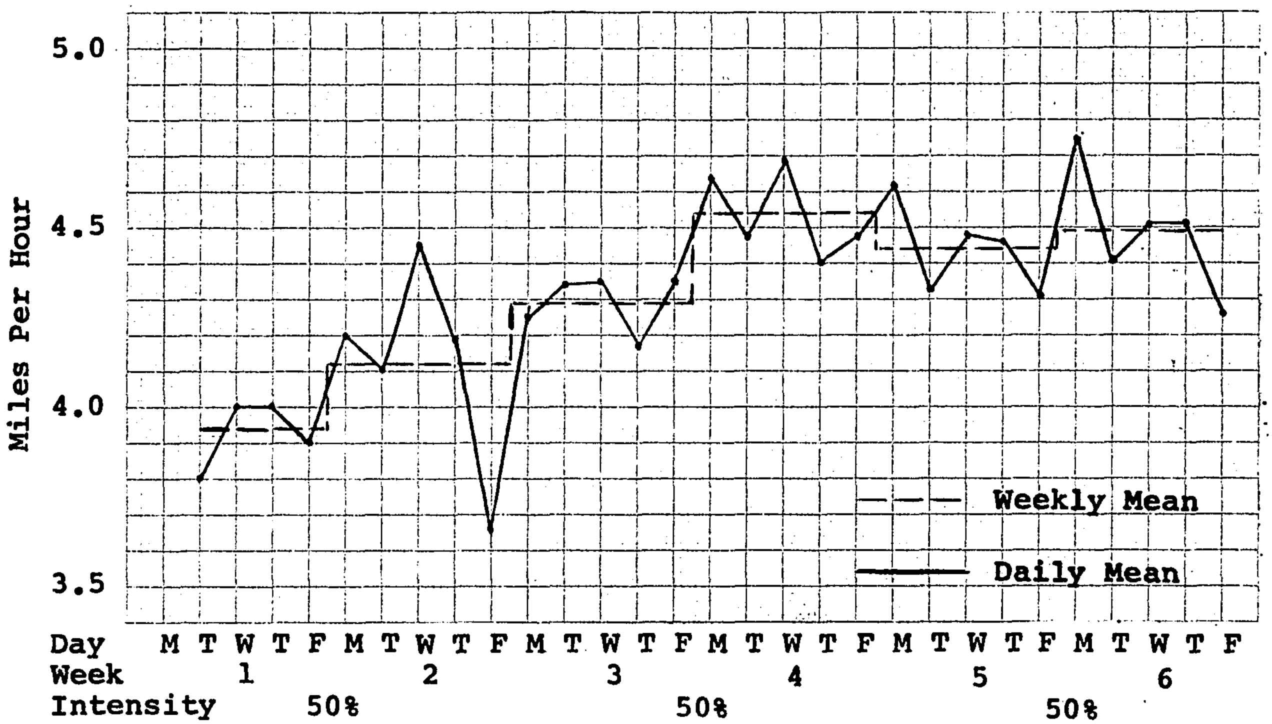


FIGURE 9

DATA SHEET ON SUBJECT S. R.

R. E.	Height 184.4cm	Group I	50% = 127
	Weight 75.41kg	Heart Rate	
	Age 19	Intensity Level	

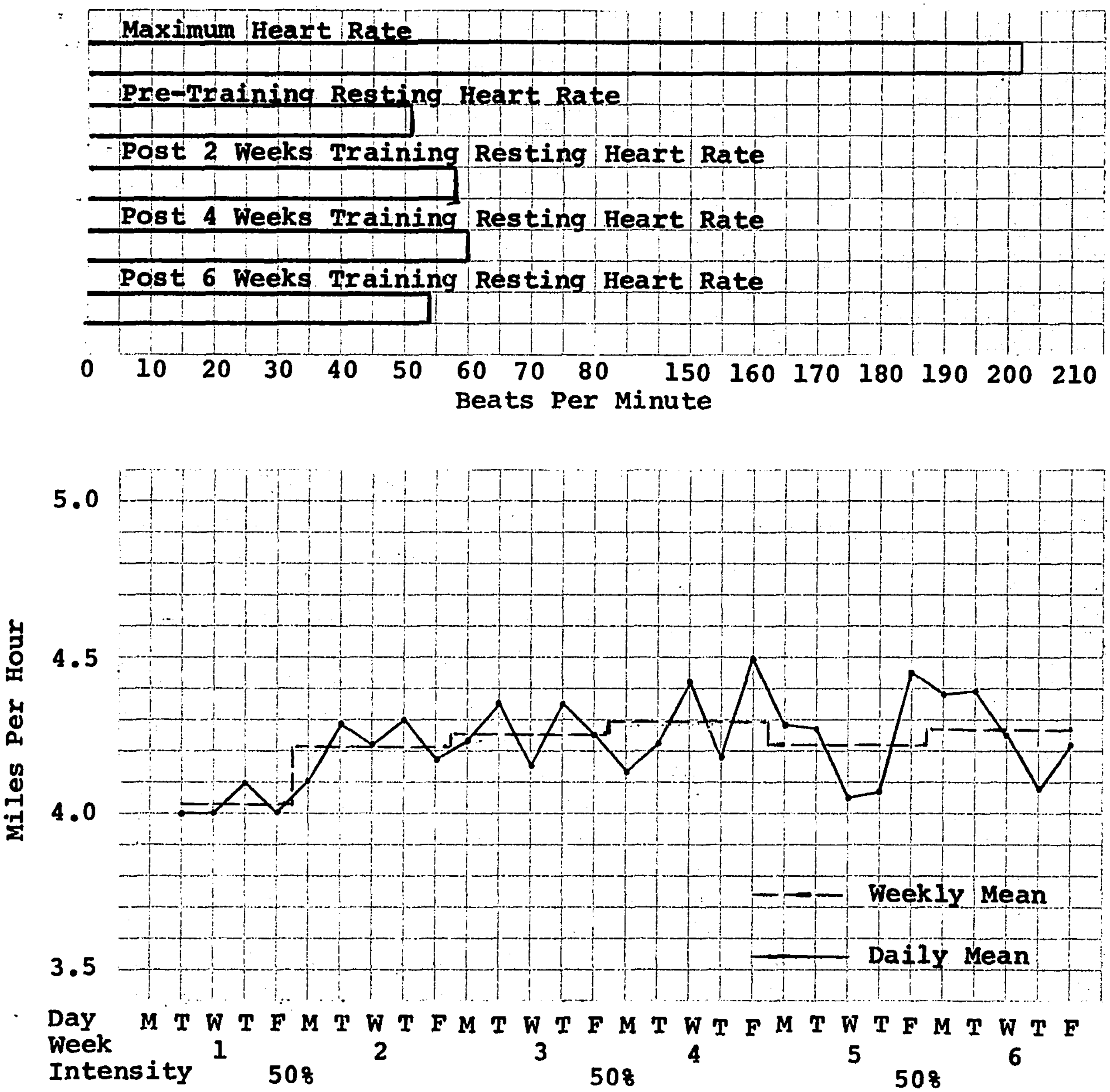
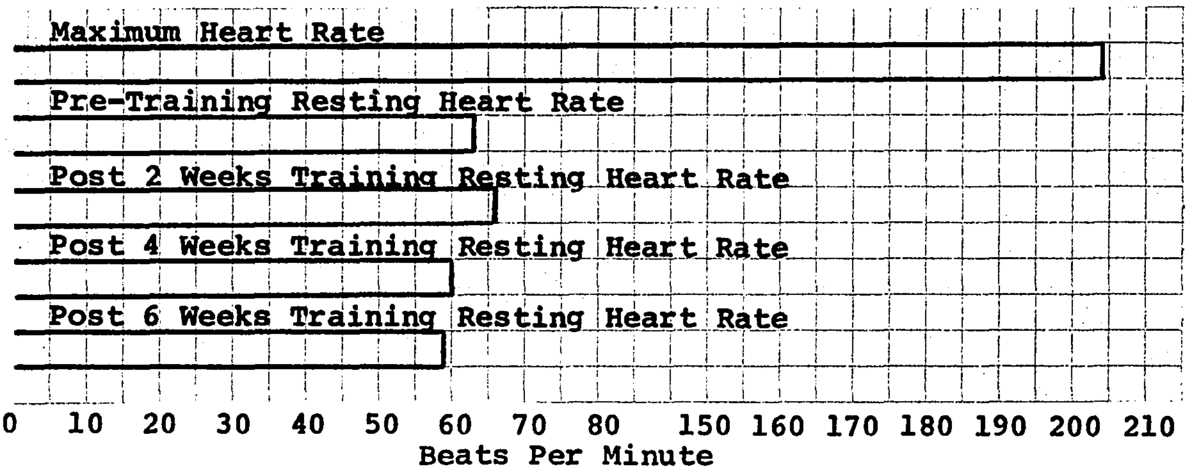


FIGURE 10

DATA SHEET ON SUBJECT R. E.

B. S.   Height 180.8cm   Group I   50% = 134
Weight 58.40kg   Heart Rate
Age 19   Intensity Level



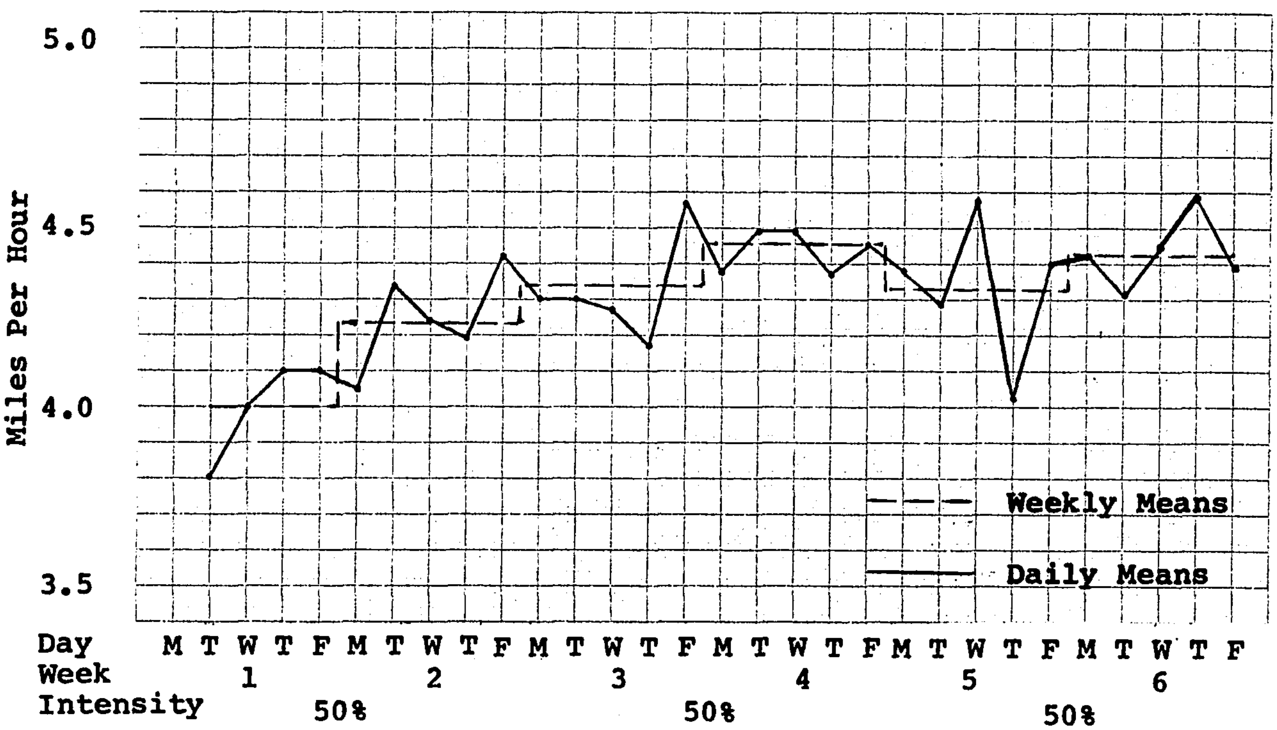
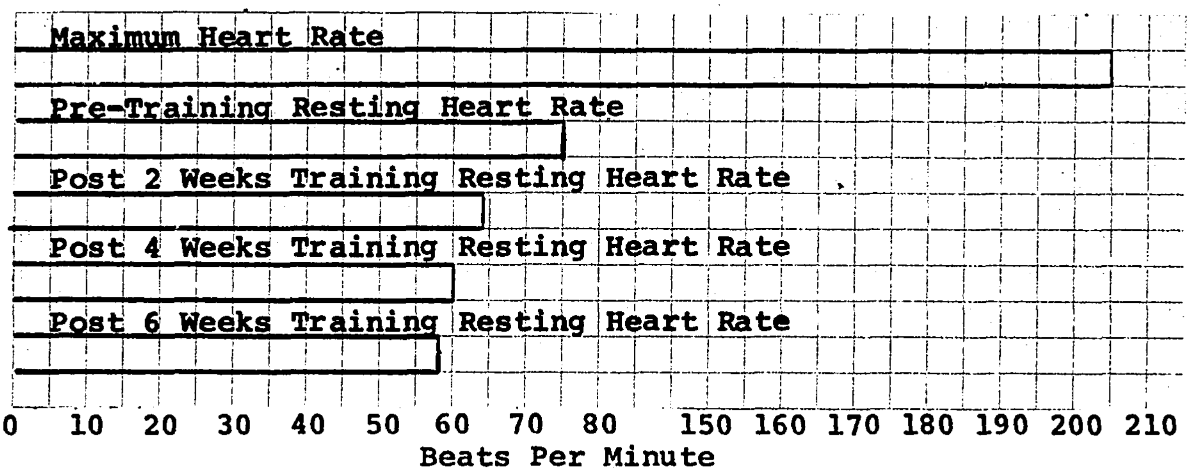


FIGURE 11

DATA SHEET ON SUBJECT B. S.

R. A.	Height	169.3cm	Group I	50% = 140
	Weight	63.41kg	Heart Rate	
	Age	19	Intensity Level	



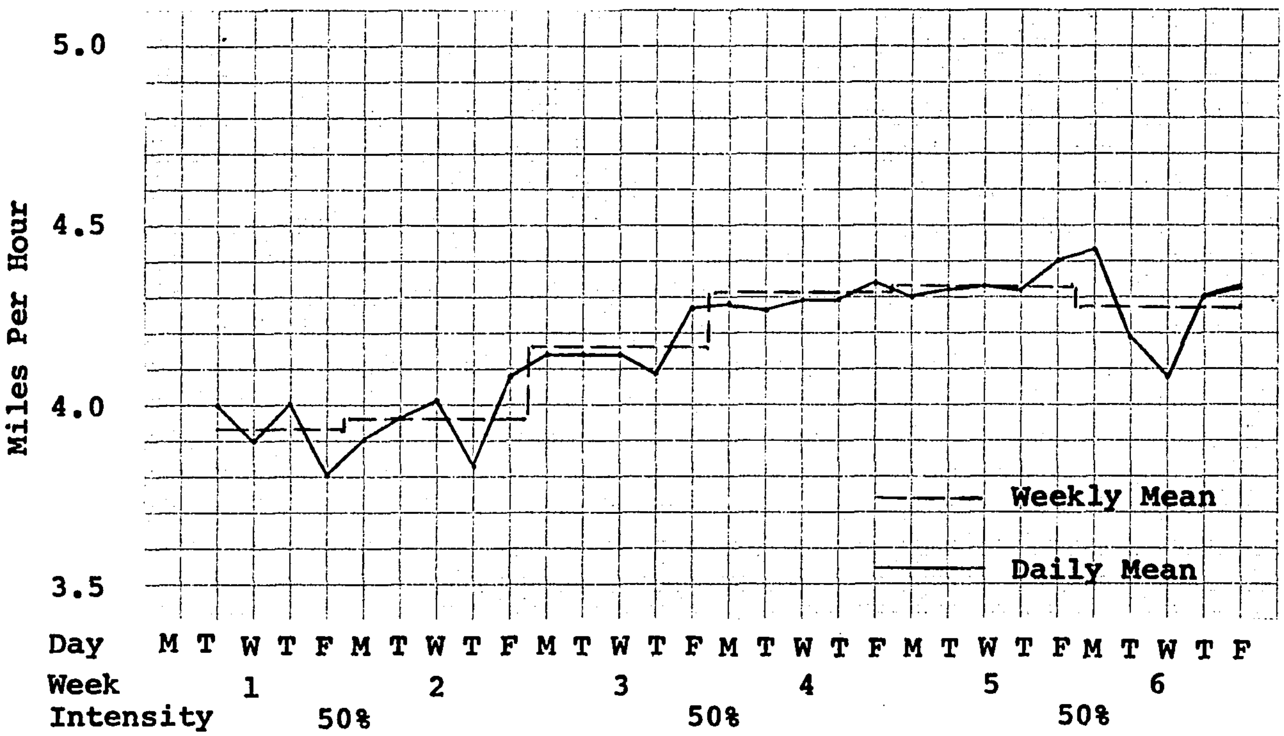
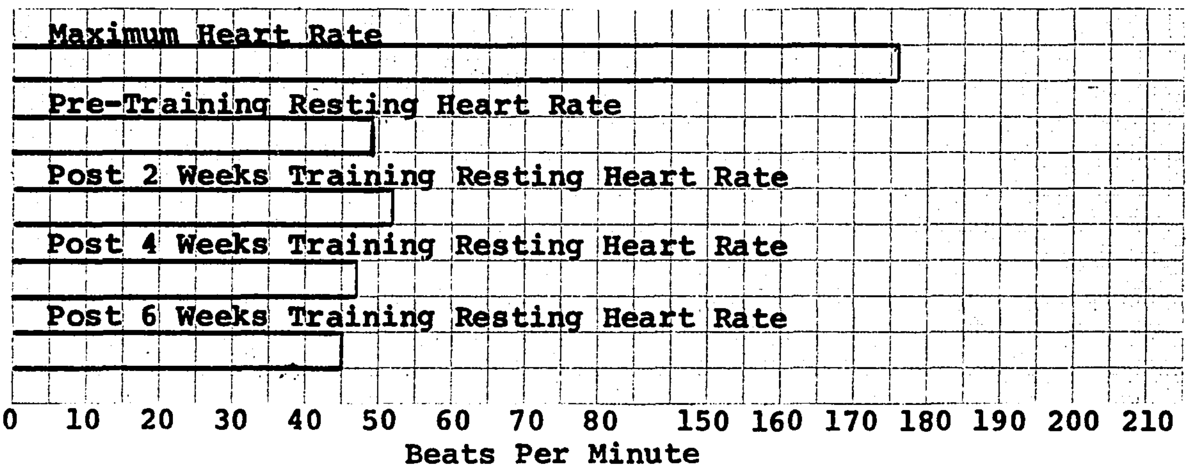


FIGURE 12

DATA SHEET ON SUBJECT R. A.

M. T.	Height	170.9cm	Group II	50% = 113
	Weight	56.25kg	Heart Rate	60% = 125
	Age	24	Intensity Levels	



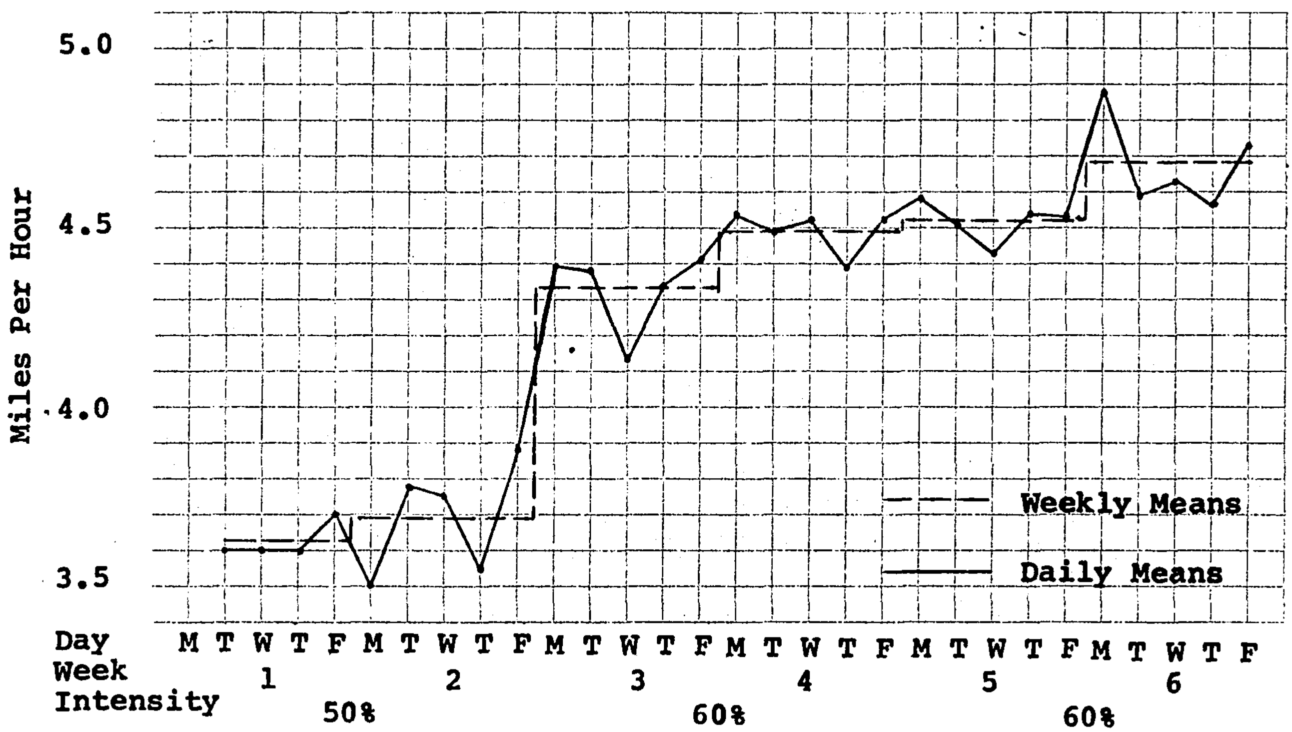


FIGURE 13

DATA SHEET ON SUBJECT M. T.

R. P.

Height 176.7cm
Weight 81.65kg
Age 18

Group II
Heart Rate
Intensity Levels

50% = 130
60% = 145

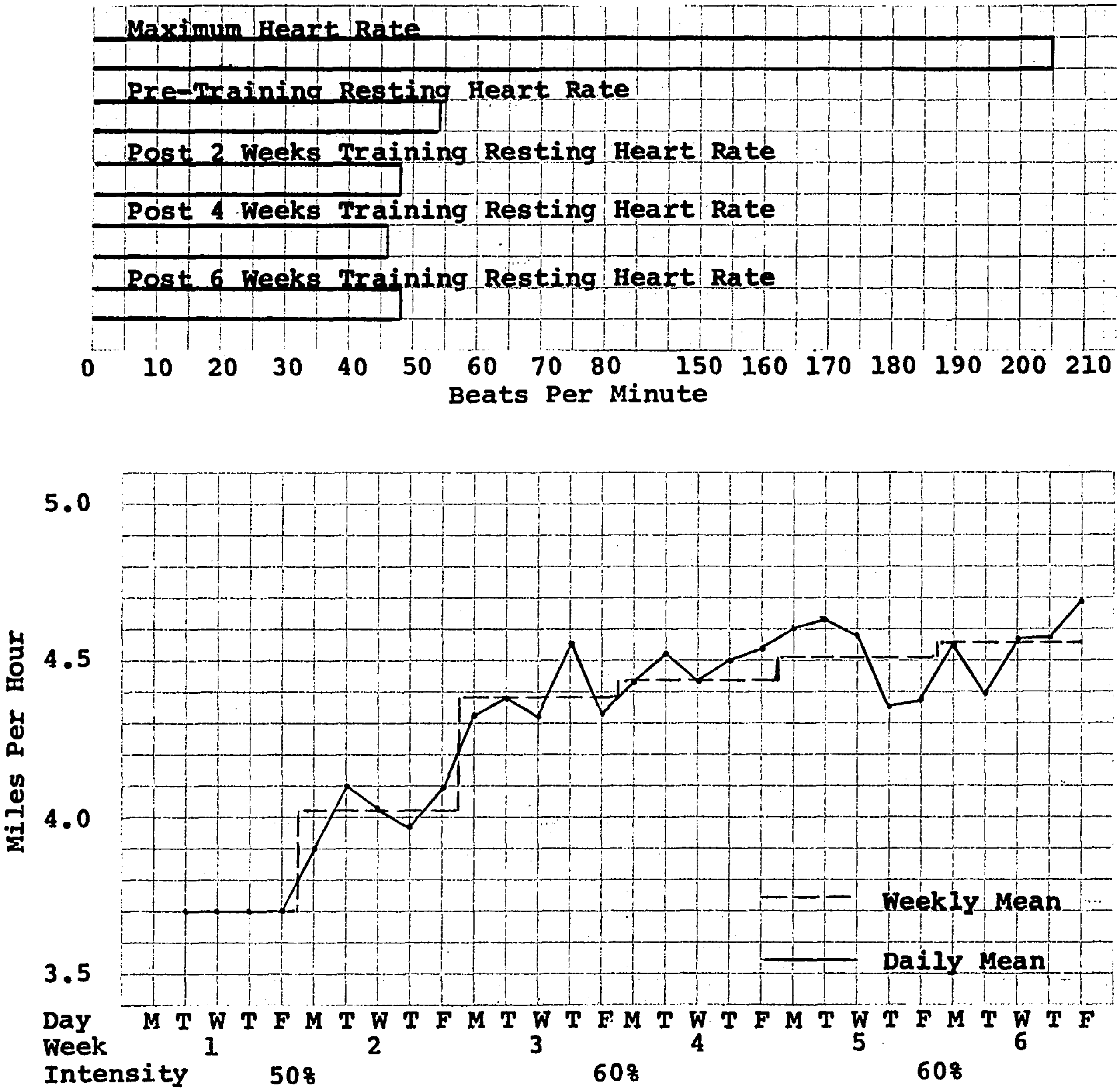


FIGURE 14

DATA SHEET ON SUBJECT R. P.

J. S.

Height 169.6cm
Weight 71.10kg
Age 19

Group II
Heart Rate
Intensity Levels

50% = 131
60% = 144

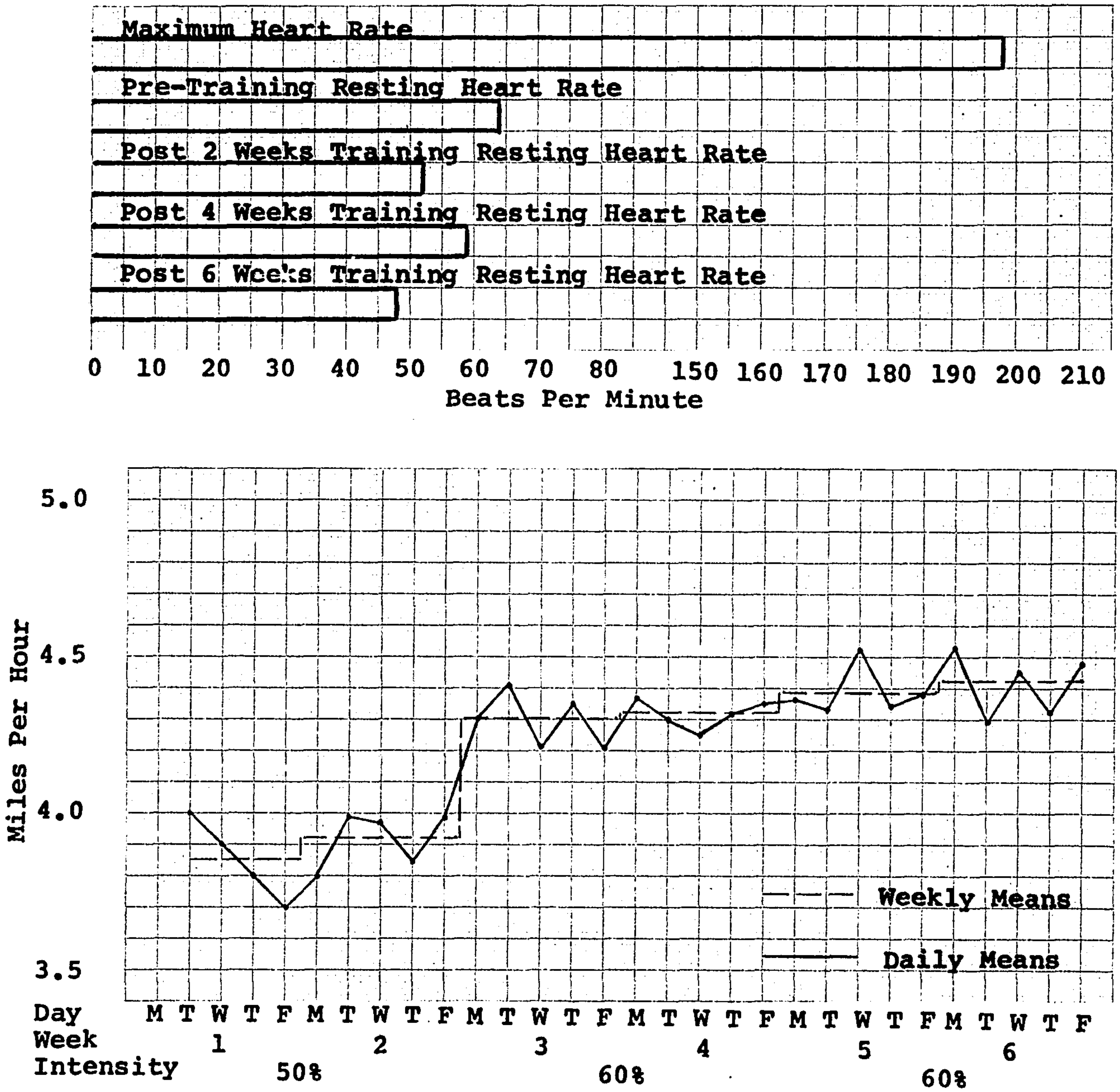


FIGURE 15

DATA SHEET ON SUBJECT J. S.

T. C.	Height 185.5cm	Group II	50% = 128

T. C.	Height 185.5cm	Group II	50% = 128
	Weight 73.36kg	Heart Rate	60% = 140
	Age 23	Intensity Levels	

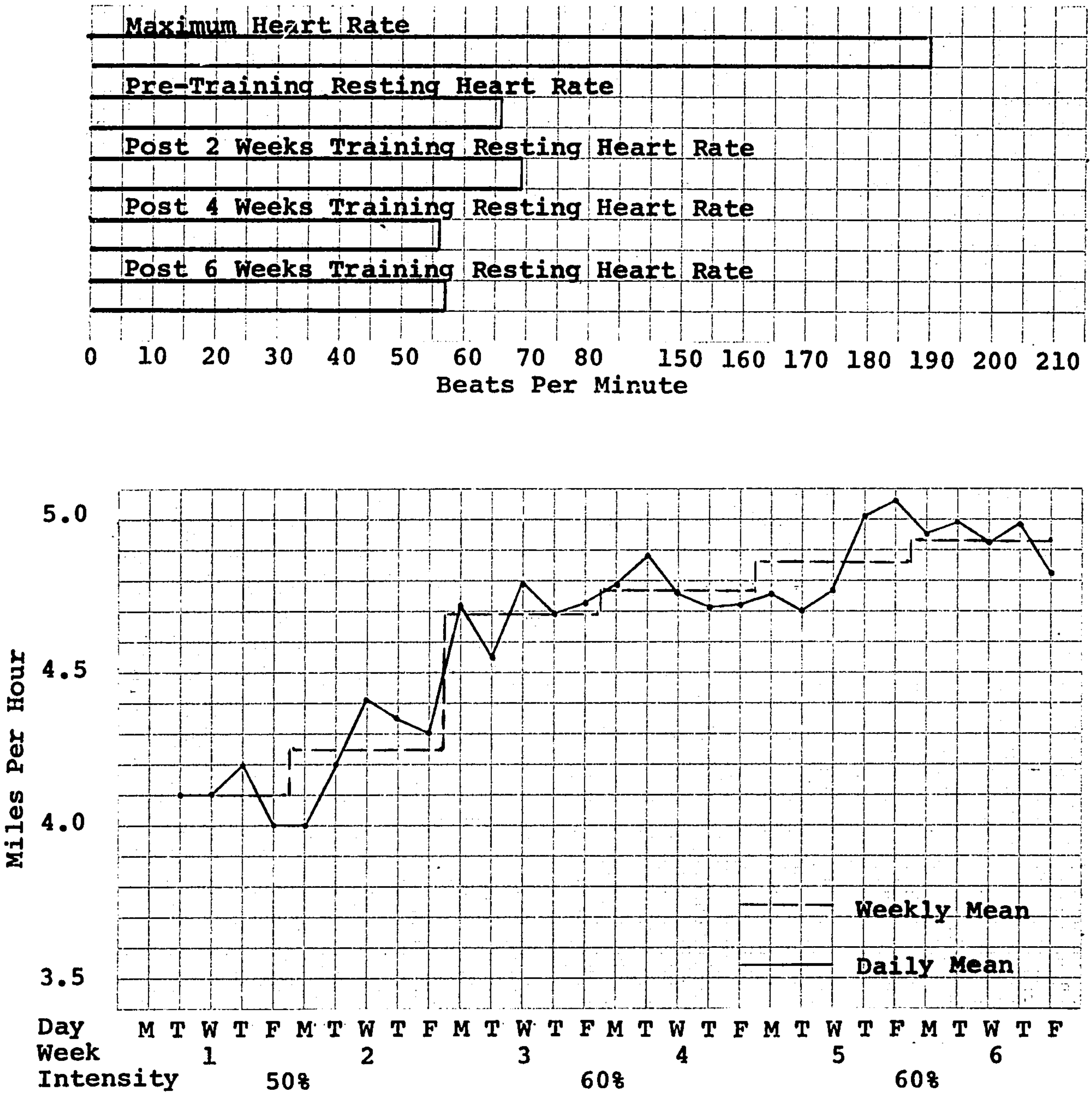
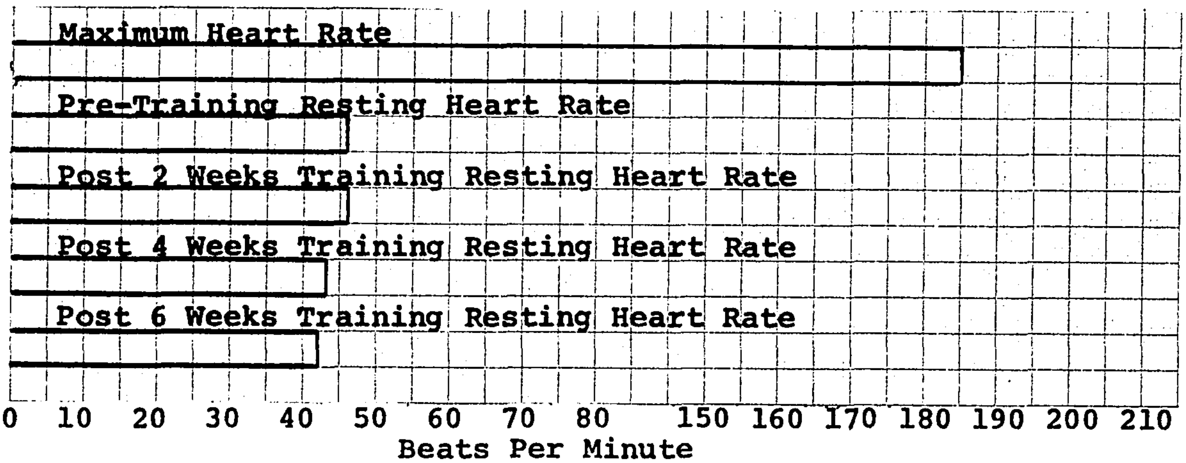


FIGURE 16

DATA SHEET ON SUBJECT T. C.

T. W.	Height	185.0cm	Group III	50% = 116
	Weight	78.81kg	Heart Rate	60% = 129
	Age	20	Intensity Levels	70% = 143



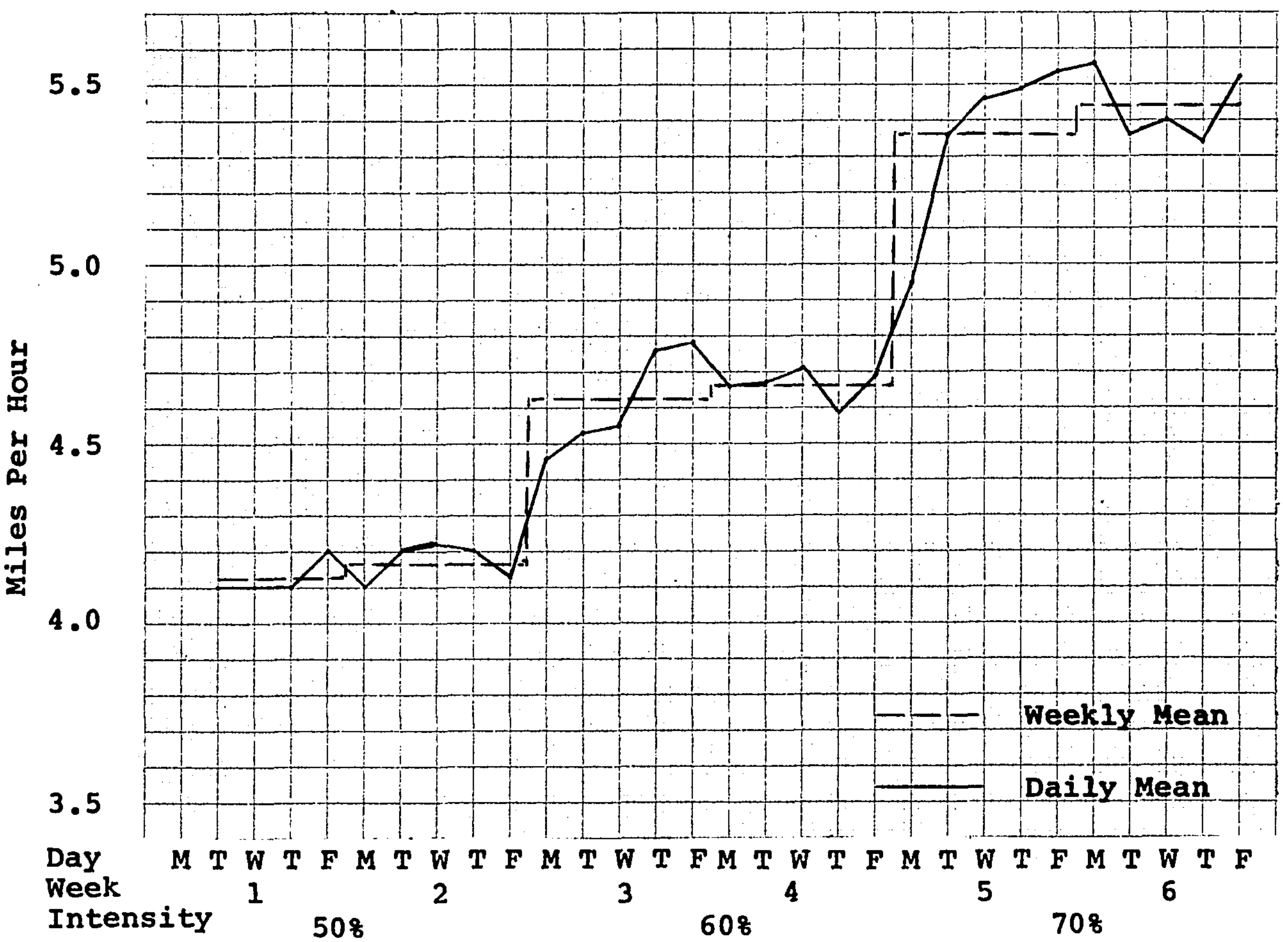


FIGURE 17

DATA SHEET ON SUBJECT T. W.

S. U.

Height 174.4cm
Weight 74.39kg
Age 19

Group III
Heart Rate
Intensity Levels

50% = 125
60% = 139
70% = 153

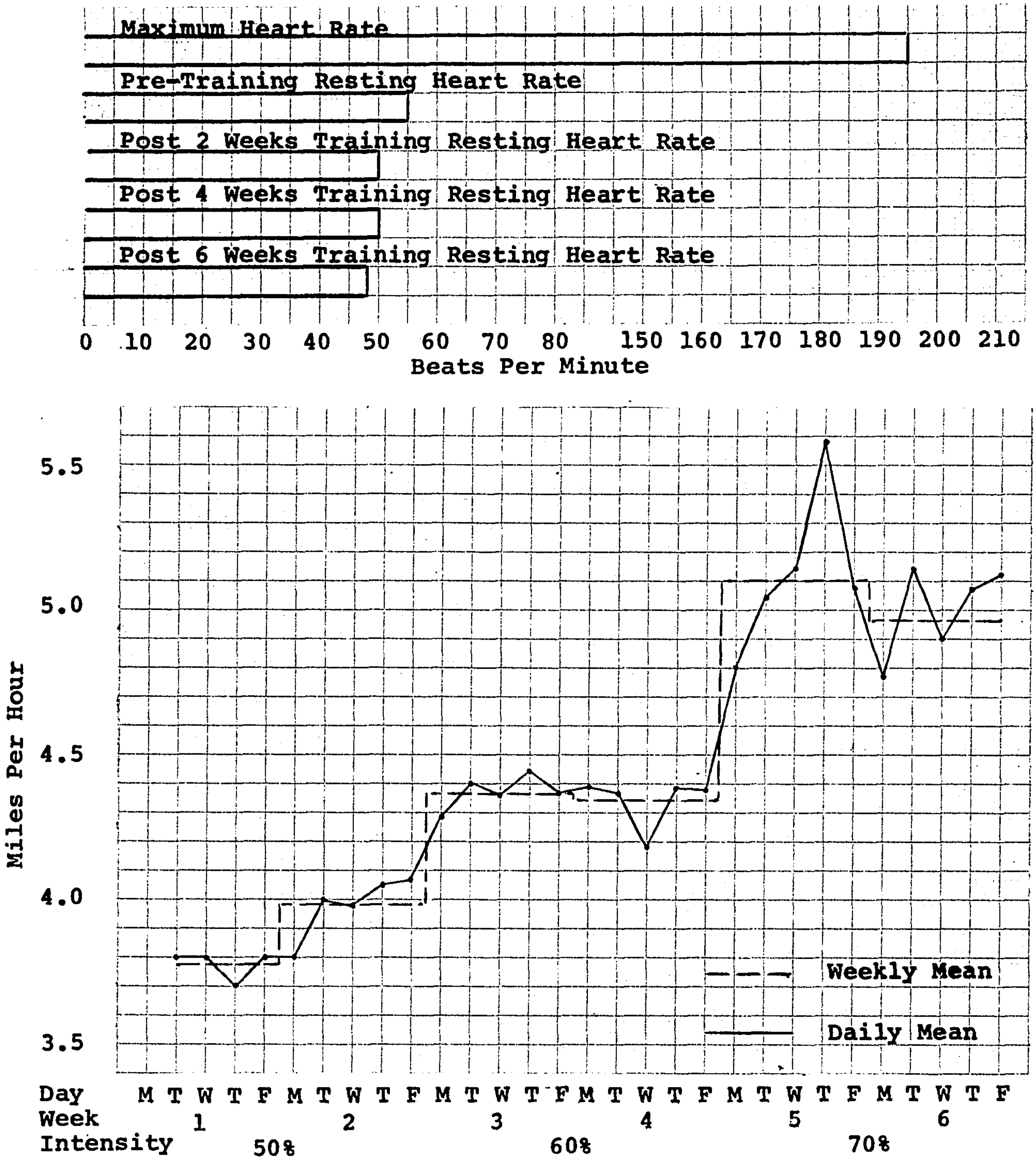


FIGURE 18

DATA SHEET ON SUBJECT S. U.

D. S.	Height	179.6cm	Group III	50% = 127
	Weight	69.27kg	Heart Rate	60% = 140
	Age	20	Intensity Levels	70% = 153

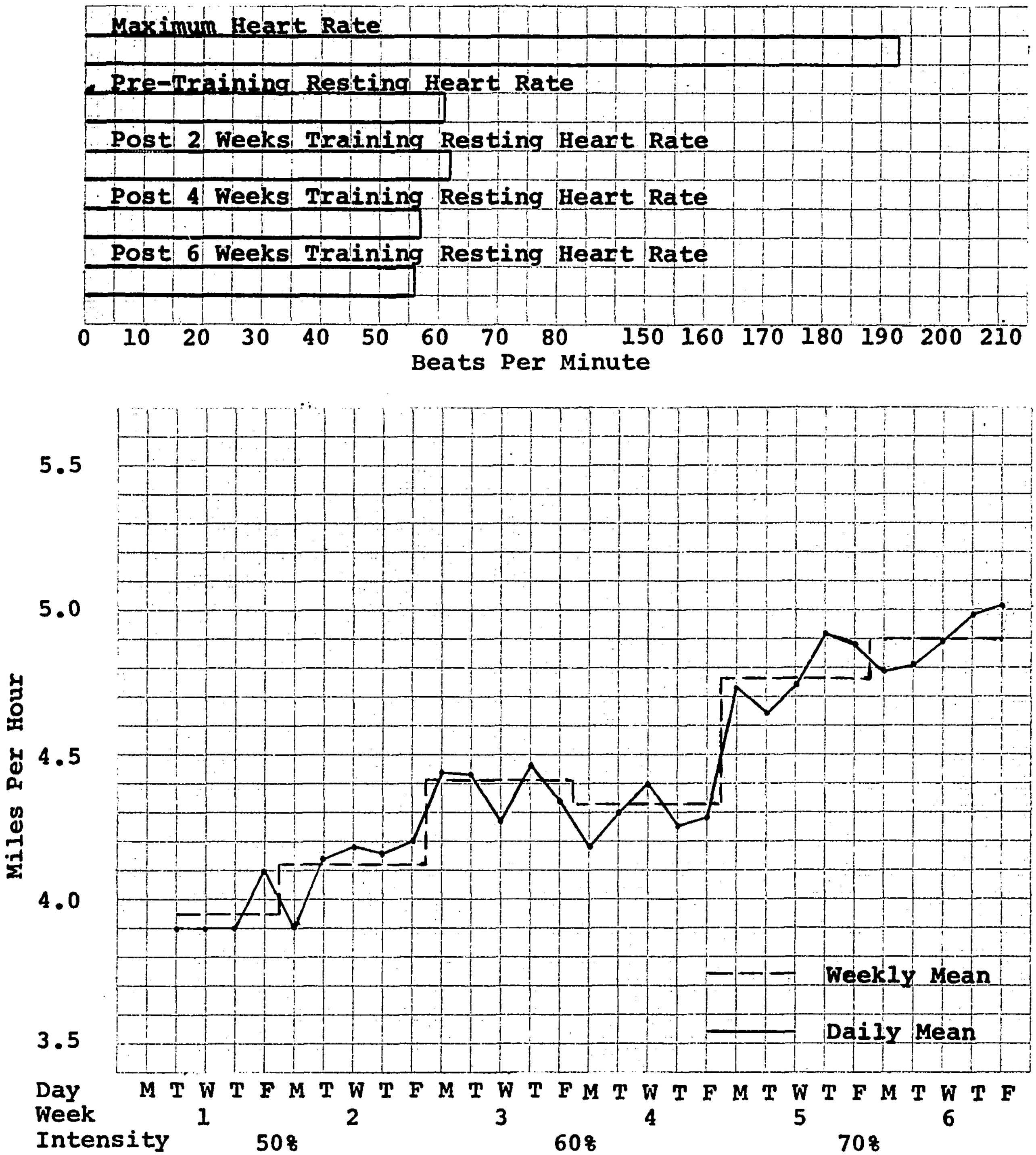
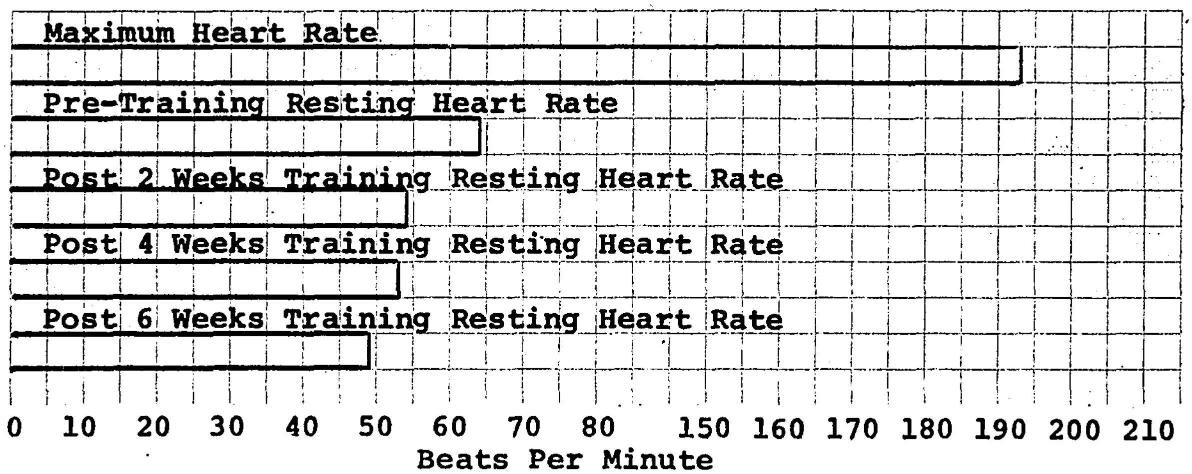


FIGURE 19

DATA SHEET ON SUBJECT D. S

D. R.	Height	182.6cm	Group III	50% = 129
	Weight	69.27kg	Heart Rate	60% = 141
	Age	19	Intensity Levels	70% = 154



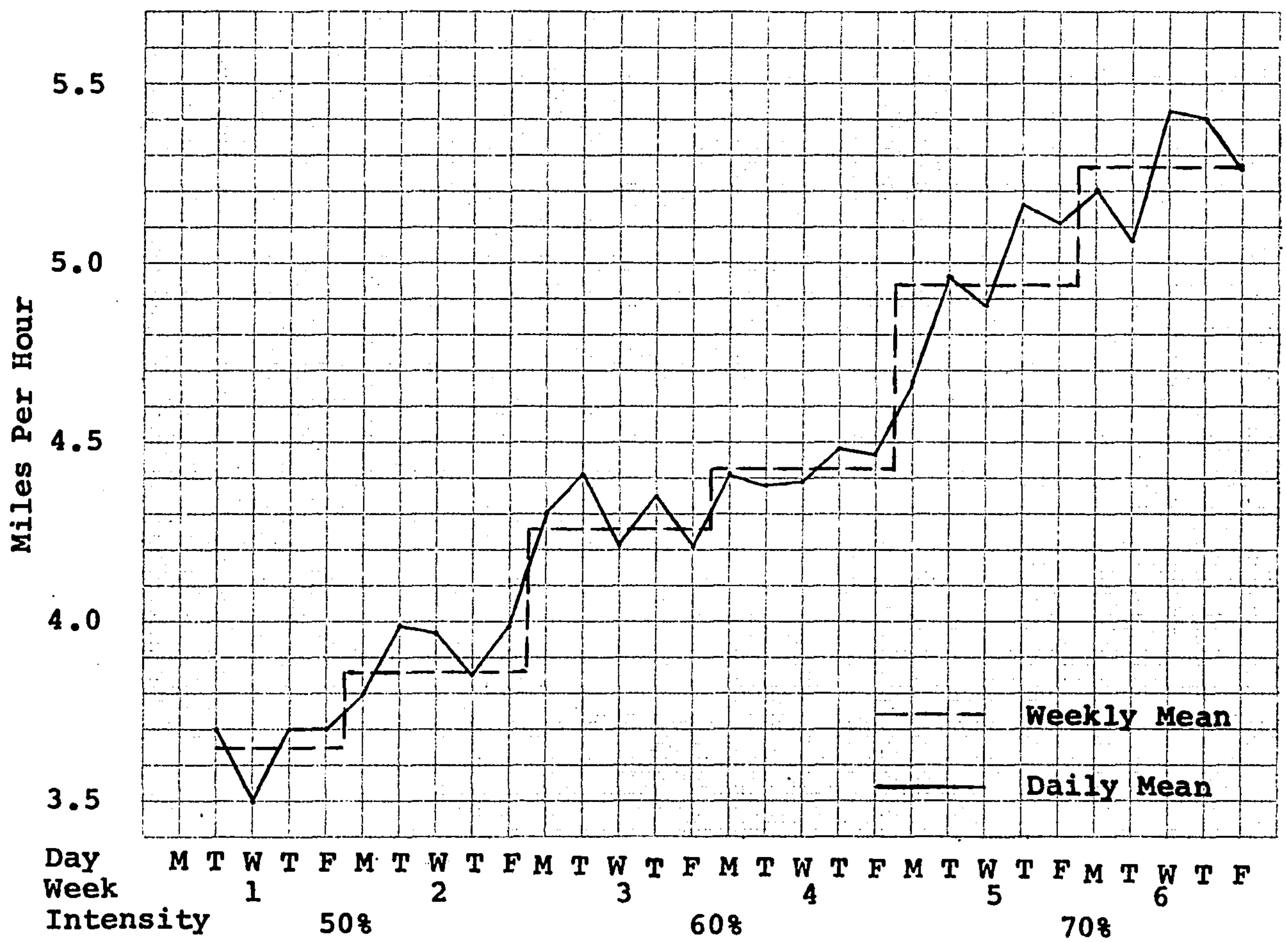


FIGURE 20

DATA SHEET ON SUBJECT D. R.