This is to certify that the

thesis entitled

THE EFFECTS OF SEVERAL EXERCISE REGIMENS
ON RAT MYOCARDIUM

presented by

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has been accepted towards fulfillment
of the requirements for

M.A. degree in Physical Education

Wayne D. Van Huss
Major professor

Date May 11, 1979

O-7639

THE EFFECTS OF SEVERAL EXERCISE REGIMENS ON RAT MYOCARDIUM

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Health, Physical Education and Recreation

1979

ABSTRACT

THE EFFECTS OF SEVERAL EXERCISE REGIMENS
ON RAT MYOCARDIUM

By

Bonnie Lee Smoak

This investigation was undertaken to investigate the effects of long-term exhaustive workloads on the myocardium of normal male albino rats. Animals for this study were obtained from two experiments. In the first experiment, the animals were placed in three activity groups, with each group divided into two dietary supplement groups. The second experiment was organized as a two-way design with five activity groups and two dietary supplement groups.

Analysis of variance of the dietary supplements in both experiments indicated no significant differences in body weight gained, absolute heart weight, and relative heart weight.

In experiment one, the absolute heart weight of the control group was significantly larger than the sprint group. No significant differences were observed in relative heart weights.

In experiment two, the absolute heart weights of the control group were significantly larger than the high endurance, regular sprint, and regular endurance groups. Again there were no statistically significant differences observed in relative heart weights.

A chi-square test indicated there was no significant difference in heart damage between trained and control animals.

ACKNOWLEDGEMENTS

Deep appreciation is given to Dr. Wayne Van Huss for his continual guidance during my graduate career and during the writing of this thesis. Gratitude is given to Dr. Herbert Olsen and Dr. Kwok-kai Ho for their participation in the preparation of this manuscript. Finally, I would like to thank all of my friends for their support.

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CHAPTER I

THE PROBLEM

Competition between athletes in any single event has become so intense, that the winner may be determined by one-hundredth of a second. The need for scientific training regimens for athletes has become paramount. It is often not the natural athlete who wins today, but the athlete who has been willing to endure agonizing, painful workouts. It is not enough in this day and age to train hard only during the competitive season. The attainment of high competitive performance levels requires several years of preparation.

With intensified workloads and prolonged training periods, considering the present state of knowledge, it is probable that mistakes in methods and training regimens occur. In addition, with a social milieu demanding improved performance, it is likely that an athlete may be motivated to train at an intense level when ill or under adverse environmental conditions. The athlete also may train so intensively on his regular training regimen that he may surpass his body's ability to adapt to the training load. Physiological changes in metabolism and in neurogenic responses may be impaired, and damage to various tissues could occur.

The phenomenon that this study is designed to explore is of a chronic nature. It is already known that an acute exposure of an individual to extremely heavy workloads, or even to moderate workloads in extreme environmental conditions, can produce damage to the organism and even death (24,34). The problem that needs to be studied is the effects of repetitive workloads on an individual that are so demanding that the body can no longer respond to this chronic stress with beneficial adaptations. A question exists as to whether detrimental effects may result from such excessive training.

Relatively little research appears to have been published in this area. Two studies were completed which have reported damage to the myocardium and myocardial function as a result of intense, prolonged exercise (23,27). The lack of research in this area should not be construed as a lack of a problem. The marked increase in the intensity and duration of training regimens is only of recent origin. Absence of evidence is not evidence of absence.

Several explanations can be given for this dearth of information. Foremost is the difficulty in quantitatively defining the problem. A need exists to identify the sensitive parameters which reflect overtraining. In addition, few researchers would purposely try to damage the tissues of a human subject, even though the result of their experiments may help prevent similar traumas from occurring in other athletes. For such investigations the use of animal models is indicated. In this study, therefore, male albino rats were used as subjects. They were considered overtrained if they were unable to maintain seventy percent (70%) or less of the expected work performance for several weeks.

Previous studies have shown that animals completing 75% of the expected workload had successfully adapted to the training regimen (16,18).

An explanation for the scarcity of animal research in this area is the problem associated with motivation of the animals to perform at such high workloads. The development of the controlled-running wheel for the training of animals provided a system of exercise regimens which could be utilized for "overtraining" experiments (44).

Need for the Study

With increasing numbers of individuals participating in sports and increased pressure to perform at high levels, the effects of prolonged, intense workouts should be examined. This study may help prevent unnecessary physical damage from occurring as a result of an intense training program.

Statement of Problem

The purpose of this study was to determine the effects of six different exercise regimens on the morphologic characteristics of the myocardium in the adult male albino rat. Since there was little prior information regarding the type and the intensity of training that might cause deleterious effects, two activity regimens were selected that required mainly aerobic metabolism (endurance running) and two activity regimens were selected that are thought to require mainly an anaerobic response (sprint running). The final two activity regimens were known

to produce beneficial adaptations to aerobic and anaerobic workloads (16,18).

Research Hypothesis

Animals involved in an intense, exhaustive training program will exhibit morphological damage in the myocardium. Major characteristics of the damaged areas will be: 1) loss of striation and histochemical staining qualities, 2) focal myolysis with or without an inflammatory response, and 3) fibrosis.

Research Design

The animals for this study were obtained from two experiments. Both experiments' primary purpose was to train animals at exhaustive workloads. However, not all animals in the first experiment were available for this study. More data were needed to draw statistical conclusions. This was accomplished by using animals from a later experiment.

In the first experiment, eighty-four male albino rats were used as subjects. The study was organized as a two-way design with three activity groups and two dietary supplement groups. In the second experiment, thirty-eight male albino rats were placed into five activity groups, with each activity group divided into two dietary supplement groups.

Experimental protocol and sacrifice procedures were nearly identical in both experiments. The heart was removed from each animal and the tissues prepared for histological and pathological evaluations.

Rationale

The heart is an extremely important muscle, not only during daily existence but during exercise. It supplies the rest of the body with nutrients and with the removal of waste materials via the blood. Any damage accrued to this muscle will affect the performance of the entire organism. Therefore, the myocardium was examined in this study to observe any microscopic alterations that might result from a prolonged, exhaustive training program.

Previous experiments in this laboratory have shown that training for a period of eight weeks is sufficient to produce physiological changes in male albino rats. For this reason an experimental period of eight weeks was chosen for this study (16,18,36).

Male albino rats were chosen as the experimental model because of their capability for successfully completing a running exercise program.

Limitations

1. The results of this study can only be applied to adult male albino rats.

2. The morphological analyses were limited to two cross sections of the heart, one ventricular and one apical. Small areas of damages may have existed in portions of the heart that were not examined.

3. The shock stimulus used for motivation in the training program may be involved in the production of myocardial changes.

4. There was no quantitative control over diet.

5. While the exercise regimen were designed deliberately to produce an exhaustive overload on the animals, it may not have been difficult enough to produce the phenomenon of overtraining.

Significance of the Study

Determinations of the possible deleterious effects of prolonged, exhaustive exercise in rat myocardium may provide insight into an organism's ability to adapt to such overloads. Injuries to future athletes may be avoided if it is demonstrated that a system of diminished returns operates in heavy training.

CHAPTER II

REVIEW OF RELATED LITERATURE

A small number of studies have reported detrimental effects to the heart as a result of continuous exhaustive exercise. Stevenson et al., in experiments with male albino rats that were swum or run on a treadmill for four weeks, reported that:

> ... the heavier and more frequent the exercise, the poorer was the gain in body weight and the increase in coronary tree size.

Stevenson hypothesized that the tissue catabolism that follows strenuous exercise was detrimental to the vascularization and work hypertrophy of the heart (41).

The supporting data in Stevenson's work are difficult to interpret. The work intensity of the animals running on the treadmill was not given. Only the total distance run is mentioned (1.3 km). Velocity, work time, and rest time were not stated. It is possible that animals in this experiment were still in the process of adapting to a training program. Since the duration of the experimental period was relatively short, the observations may represent the process of adaptation to running rather than effects produced by overtraining.

Interpretation of the swimming data is also difficult. It is currently recognized that while rats can swim with relative ease, it is extremely difficult to quantify the amount of work done. Buoyancy is a

problem in most swimming programs. It was not stated if the animals were shaved, if weights were attached to their bodies, or if a detergent was added to the water to counteract the animals' natural buoyancy. It was also not reported if the animals swam singly or as one group. When rats were swum as a group, the animals try to climb on each others' back, causing frequent submersion of the weaker animals. Unless the training procedures prevented this from occurring, the effects observed on the rat myocardium may have been due to stresses other than exercise.

Further studies are necessary to replicate Stevenson's observations.

Morphological signs of myocardial damage attributed to exhaustive exercise have been reported by Kitamura (23) and Letunov (27). In experiments with young mice trained to swim or to run on a motor-driven treadmill, Kitamura found that after ten weeks of training the myocardial tissue showed small hemorrhages, infiltration of leukocytes, interstitial fibrosis, and myocardial hypertrophy. Six weeks after the completion of fourteen weeks of training, the heart size had decreased and extensive irreversible fibrosis of the myocardium had occurred.

Kitamura also studied the effects of eight weeks of intensive exercise on the ultrastructure of cardiac muscle fibers. When compared to the control animals the structure of the muscle fibers appeared disarranged. In some cases, vacuolization of the muscle fiber and osmiophilic degeneration within the myocardium nuclei were seen.

The ratio between the number of myocardial fibers and capillaries within 100 square microns was also studied. The exercise group showed a marked decrease in fiber to capillary ratios for the first forty days of

the training program when compared to the ratio of the control animals. After forty days, the ratios of the exercise group jumped markedly surpassing the ratios of the control groups. These data may support the view that the detrimental effects of exhaustive exercise as mentioned in the Stevenson's study are part of an adaptive process. Unfortunately, as in the Stevenson's paper, the training regimen of Kitamura was not described.

Letunov has summarized the works of several authors on the effects of exhaustive training in a paper presented at the International Congress of Sport Sciences, 1964. Unfortunately, due to the format of publication, no bibliography was given and the original articles could not be located. Therefore, the results of these studies will be presented as described by Letunov.

Morphological data on the myocardium from overtraining studies performed by Gudz were discussed by Letunov. Perivascular bleeding in the right and left ventricle as well as microinfractions and micronecroses in the anterior and posterior wall of the left ventricle were noted. Fatty degeneration and myolysis of the cardiac muscle fibers also were reported. Although the experimental model and training regime were not reported, it is interesting to note the similarities in morphological findings between Kitamura and Gudz.

Clinical symptoms of chronic overtraining described by Letunov in humans are hypertension, heart pain, and abnormal EKG patterns. Two percent of athletes tested had abnormal EKG patterns of the left ventricles attributed solely to overtraining (27).

Cases of sudden death in supposedly fit athletes occurring during or after extremely heavy physical activity have been reported. Many of these deaths were attributed to organic defects of the heart structure (21,22). Other deaths were associated with extreme environmental conditions concommitant with exercise (33,38). In addition, a few case studies have reported that small cardiac lesions of the conduction system will cause death (19). This mechanism could explain those cases of sudden death not involving the myocardium, valves, or coronary vessels. Small hemorrhages, like those observed by Gudz and Kitamura, would cause death if they affected the conduction system of the heart.

In the data reviewed, exercise was not determined to be the sole causal factor in producing sudden death in any athlete. This is not surprising. Currently there is no syndrome to delineate exercise as the cause of death during an autopsy.

The mechanism that causes an apparently healthy heart to develop pathological symptoms from overtraining have not been elucidated. One possible mechanism, suggested by Raab (34), is the intensive absorption of catecholamines by the myocardium during exercise. In the following sections, the effects of catecholamines on the myocardium and the effects of exercise on catecholamine secretion are briefly reviewed.

Catecholamines and Heart Damage

Various studies have demonstrated that exogenously administered catecholamines can elicit heart damage. Morphological alterations in the myocardium following the injection of epinephrine are essentially of

two types: 1) hypertrophy and dilation, and 2) myocardial degenerative changes varying from slight edema, hyaline degeneration, leukocytes infiltration to necroses and scar formation (34).

Alterations in the ultrastructure of myocardial cells occur after the injection of minute doses of epinephrine (39). These changes are reversible. Larger doses cause an abnormal distribution of potassium, a depletion of glycogen reserves, and a decline in phosphorylase activity in the subendocardium and apex (1). The spotty distribution of potassium is similar to that produced by experimental myocardial hypoxia. This led Bajusz and Raab (1) to hypothesize that the necrotizing properties of catecholamines is related to their influence on myocardial electrolyte metabolism. Raab had suggested earlier the epinephrine mimics the effects of coronary insufficiency by increasing local oxygen consumption (34). Damage occurs because the increased oxygen consumption is only partially compensated for by an increased coronary flow.

Catecholamine Secretion During Exercise

The release of epinephrine during exercise was observed as early as 1922 by Hartman (15). These early studies measured the secretion of the adrenomedullary hormones in venous plasma from an exteriorized gland. Current methods for the estimation of catecholamines allow measurement of the actual level of catecholamines in the circulating blood.

Epinephrine values in venous plasma of cats (5,15), dogs (4), and humans (2,11,13,14,20,25,43) have been shown to increase progressively with heavy exercise. The rise in epinephrine level in venous plasma

during heavy exercise is also manifested by an increased epinephrine value in arterial plasma (6,11).

There is general agreement that norepinephrine increases during heavy exercise both in venous and arterial plasma. However, the increase is not proportional to workload. There are small increases in norepinephrine levels up to 60-70% of an individual's max V_{O_2}, whereafter it rises relatively quickly. Haggendal has proposed that the norepinephrine level rises exponentially to the workload (12).

The levels of catecholamines in venous plasma for untrained subjects during a given workload is higher than for trained subjects, even though both groups have similar values at rest (13,14).

Training of an individual decreases the catecholamine levels in venous plasma for a given workload (11,13,14,20). Decreased, increased, and unchanged myocardial norepinephrine levels in heart tissues of trained animals have been reported. However, these levels have not been closely correlated with resting heart rate (8,26,31,32).

Epinephrine and norepinephrine uptake and turnover were found to be decreased in the hearts of trained animals. The results indicated that physical conditioning causes an adaptation of the sympatho-adrenal system to exercise stress. The functional changes that accompany training lead to a better transmitter economy during exercise.

It appears that training provides protection to the heart from the necrotizing effects of catecholamines. Both epinephrine and norepinephrine secretion and myocardial uptake and turnover are lower for the trained animal during exercise. It is not likely that myocardial damage from exercise can be attributed solely to catecholamines.

CHAPTER III

METHODS AND MATERIALS

Exercise can be viewed as a continuum of various activities. Each level within the continuum requires specific adaptation of the body in order to meet the metabolic requirements of that activity. For example, distance running is dependent on oxidative metabolism and a high oxygen uptake, while sprint running is dependent on anaerobic metabolism and a high oxygen debt. Each of these events requires different cellular and cardiovascular adjustments of the body.

It would seem likely then, that repetitive exhaustive workloads of differing exercise regimens would lead to different pathological states. This study was designed to investigate different exhaustive training regimens and their effects on the morphological condition of the heart. In order to sample from a variety of training programs, animals for this study were selected from two experiments.

Animals In Experiment One

Eighty-four normal male albino rats of the Sprague-Dawley strain were obtained from Hormone Assay Inc., Chicago, Illinois.[1] They were

[1] Hormone Assay Laboratory, 8159 S. Spalding, Chicago, Illinois.

received at weekly intervals in three shipments of 30, 24, and 30 animals respectively. Each shipment was designated as a separate activity group. A standard period of 12 days was allowed for adjustment to the laboratory conditions. Activity was initiated when the animals were 84 days old.

Research Design In Experiment One

This study was organized as a two-way design with three activity groups and two dietary supplement groups. The duration of the experiment was eight weeks. The treatment conditions were as follows.

Control Group

The 24 animals in the second shipment constituted the sedentary control (CON) group. These animals received no exercise and were forced to remain relatively inactive throughout the experiment. The animals were housed in individual sedentary cages (24 x 18 x 18 cm) during both the adjustment and treatment periods.

Sprint Group

The sprint running (SPT) group was comprised of the 30 animals in the first shipment. Each of these animals were housed in individual voluntary activity cages (sedentary cages with access to a freely revolving wheel) during the adjustment period and in individual sedentary cages during the experimental period. The SPT animals were subjected to an interval training program of very high-intensity sprint running. The workload of the SPT group was gradually increased until on the 27th

day of training and thereafter, the animals were expected to complete six bouts of exercise with 2.5 minutes of inactivity between bouts. Each bout included five 15-second work periods with four 30-second rest periods. During the work periods, the animals were expected to run at a velocity of 108 m/min.

Endurance Group

The endurance running (END) group was composed of the 30 animals of the third shipment. These animals were housed the same as the SPT animals. The END animals were subjected to a demanding program of distance running. The workload was gradually increased so that on the 30th day of training and thereafter, the animals were expected to complete 60 minutes of continuous running at 36 m/min.

Vitamin C Group

One-half of the animals in each activity group received Vitamin C supplementation (C group). Vitamin C supplementation was administered orally by syringe with a dosage of 2.4 mg vitamin (Merck)[2] in a .1 ml 5% sugar solution per 100 g body weight between 1900 and 2100 hrs daily. The administration of the supplement was begun the day prior to the initiation of activity and terminated the day prior to sacrifice. The dosage used was equivalent to 1680 mg daily for a 70 kg man.

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[2]Merck and Co., Inc., Rathway, N. J.

Placebo Group

The remaining animals in each of the activity groups (no C group) received an identical quantity of the sugar solution per unit of body weight.

Animals In Experiment Two

Thirty-eight normal male albino rats of the Sprague-Dawley strain were obtained from Hormone Assay, Inc., Chicago, Illinois. The animals were randomly assigned to treatment groups. A standard period of twelve days was allowed for adjustment to laboratory conditions. Training was initiated when the animals were eighty-four days old.

Research Design In Experiment Two

This study was organized as a two-way design with five activity groups and two dietary supplement groups. The duration of the treatment period was eight weeks. The treatment conditions were as follows.

Control Group

Six animals were randomly assigned to the control group. These animals were placed in individual sedentary cages (24 x 18 x 18) throughout the adjustment and treatment period. The animals remained sedentary the entire period.

Regular Sprint Group

Eight animals were subjected to a high-intensity, short duration exercise program. Gradual increases in the intensity of the program

were made so that by the 37th day of training the animals were required to run eight bouts at a velocity of 99 m/min. Each bout consisted of six 10-second work intervals alternated with 40-second rest intervals. The animals were allowed to rest 2.5 min between bouts. A description of the complete training program is given in Appendix A.

The regular sprint (REG SPT) group animals were housed in individual voluntary activity cages during the adjustment period and in individual sedentary cages during the experimental period.

High Sprint Group

Eight animals were subjected to a very high-intensity, short duration running program. The training progression was identical to the regimen used by the sprint group. A description of the complete training program is given in Appendix A.

Animals in the high sprint (HI SPT) group were housed in a similar manner as the REG SPT.

Regular Endurance Group

The regular endurance (REG END) group was composed of eight animals which were subjected to a low-intensity, long duration running program. By the 37th day and thereafter, the animals were expected to complete four bouts of exercise with 2.5 minutes of inactivity between bouts. Each bout consisted of one 12.5 minute continuous run at a speed of 36 m/min (see Appendix A).

These animals were housed similarly to the REG SPT.

High Endurance Group

Eight animals were subjected to a moderate intensity, long duration running program. The workload was rapidly increased so that by the 32nd day, the animals were expected to run 60 minutes at a velocity of 45 m/min (see Appendix A).

The high endurance (HI END) group were housed like the REG SPT group.

Sugar Group

One-half of the animals in each activity group received daily sugar supplements. The sugar was administered orally by syringe after completion of the exercise regimen, or for the controls, between 1100 and 1200 daily. Each dose consisted of .1 ml 5% solution per 100 g body weight. The administration of the sugar supplement was initiated on the first day of the treatment period and terminated the day prior to sacrifice.

Placebo Group

The remaining animals in each activity group received an identical quantity of water per unit of body weight under identical circumstances.

Training Procedures

All exercise groups in both experiments were trained in a battery of individual controlled running wheels (CRM). The apparatus has been described as:

> ... a unique animal-powered wheel which is capable of inducing small laboratory animals to participate in highly specific programs of controlled, reproducible exercise. (44)

Animals learn to run in the CRW by avoidance-response operant conditioning. A low intensity controlled shock current (1.2 ma), applied through alternating grids comprising the running surface, provides the motivation for the animals to run. A light above the wheel signals the start of each work period. The animal is given a predetermined amount of time (acceleration time) to attain a prescribed running speed. If the animal does not reach the prescribed speed by the end of the acceleration period, the light remains on and shock is administered. As soon as the animal reaches the desired speed, the light is immediately extinguished and shock is avoided. If the animal fails to maintain the prescribed speed throughout the work period, the light-shock sequence is repeated. Most animals learn to react to the light stimulus after only a few days of training.

A typical training session consists of alternated work and rest periods. The wheel is braked automatically during all rest periods to prevent spontaneous activity. The brake is released and the wheel is free to turn during the work periods.

Performance data are displayed for each animal in terms of the total meters run (TMR) and the cumulative duration of shock (CDS). The TMR and the total expected meters (TEM) are used to calculate the percentage of expected meters (PEM):

$$PEM = 100(TMR/TEM)$$

PEM values are the chief criteria used to evaluate and compare training

performance. A secondary criteria is provided by the percentage of shock-free time (PSF) which is calculated from the CDS and the total work time (TWT):

$$PSF = 100 - 100(CDS/TWT)$$

In experiment one, all exercise treatments were administered once a day, Monday through Friday, between 1230 and 1730. In experiment two, all exercise treatments were administered once a day, Monday through Friday, between 0800 and 1230.

Animal Care

Animal care procedures were identical in both experiments. All housing cages were steam-cleaned every two weeks. Standard procedures for CRW cleaning and maintenance were observed.

The animals received food (Wayne Lab Blox)[3] and water ad libitum. A relatively constant environment was maintained for the animal by daily handling as well as by temperature control.

The animals were exposed to an automatically regulated daily sequence of 12 hours of light followed by 12 hours without light. Since the rat is normally a nocturnal animal, the light sequence was established so that the lights were off between 1300 and 0100 and on between 0100 and 1300. This lighting pattern altered the normal day-night schedule for the animals so that they were trained during the active phase of their diurnal cycle.

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[3]Allied Mills, Chicago, Illinois.

Body weights of all exercised animals were recorded before and after each training session. The control animals in each experiment were weighed weekly.

Sacrifice Procedures

Experiment One

Anticipated limitations of time and personnel restricted the number of animals that could be handled at sacrifice to 12 in each treatment group. Since one of the inherent purposes of the study was to compare various parameters in two groups of highly trained animals and a group of untrained animals, three extra rats originally were included in the SPT and END groups. Twelve animals were selected for sacrifice from each of these two groups on the basis of their health and their training performance throughout the treatment period. Only animals subjectively determined to be in good health were chosen. Because the training requirements were extremely vigorous, no absolute minimal performance criteria were established. However, individual daily records of PEM and PSF values were examined, and those animals making the best adaptations to the training regimens were selected for sacrifice. All 12 CON animals were judged to be healthy and were sacrificed.

Three sacrifice periods of two-days duration (Monday and Tuesday) were established. All animals within a treatment group were killed during a single sacrifice period (i.e., six animals each day). The trained animals were killed either 72 or 96 hrs after their last exercise bouts

were completed. This procedure was followed to eliminate any transient effects of acute exercise. The animals were either 140 or 141 days old at sacrifice.

Final body weights were recorded immediately prior to sacrifice. Each animal was anesthetized by an interperitoneal injection (4 mg/100 gm body weight) of a 6.48% sodium pentobarbital (Halatal) solution.[4] After selected leg muscles were removed for analysis by other investigators, the heart was removed and washed free of blood with Ringer's solution. The great vessels of the heart were trimmed. A dissection along the atrioventricular groove was performed to separate the atria from the ventricles which then were tranversely sectioned approximately one-third of the ventricular length from the apex. The apical portion, mounted apex up, and the ventricles were mounted on cork strips using 5% gum tragacanth. The preparation was held with forceps and lowered, for approximately 20 seconds, into 2-methylbutane (isopentane) pre-cooled to a viscous fluid (-140° to -185° C) by liquid nitrogen. The apical portion of the heart was sectioned approximately 300μ from the apex. Sections, 10μ thick, for both portions were cut on a microtome in a cryostat at a temperature of -20°C.

Experiment Two

One sacrifice period of two-day duration (Saturday and Sunday) was established. Animals were randomly assigned to sacrifice order. The trained animals were killed 72 hrs after their last exercise bout was completed. The animals were 140 or 141 days old at sacrifice.

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[4]Haver-Lockhart Laboratories, Shawnee, Kansas.

Eighteen animals were killed on Saturday and seventeen animals were killed on Sunday.

Final body weights were recorded immediately prior to sacrifice. Each animal was decapitated and quartered. The heart was removed and the great vessels trimmed. The heart was sectioned approximately one-third of the ventricular length from the apex.

At this time, sacrifice procedures parallel those described in experiment one.

Histological Methods

The fresh frozen sections from the apical and ventricular portions of the heart were stained with a hematoxylin-eosin (H&E) technique for the evaluation of general cellular structure (28). A modified Gomori's trichrome and Van Kossa's stain were used to identify collagen deposition and calcification, respectively (28). Absence of succinic dehydrogenase (SDH) activity was used as an indication of early necrosis (29).

Pathological Evaluations

The heart sections stained with H&E, SDH, modified Gomori's trichrome, and Van Kossa's stain were evaluated subjectively under a light microscope. They were rated on a 0 to 4 scale (29,35) according to the lesions exhibited. Both the severity and the number of lesions were considered. A low rating (0 to 1) was assigned to those sections with no damage or only a few small foci of damage. A higher rating was used to indicate more extensive pathological involvement.

Statistical Procedures

The body weights and the absolute and relative heart weights were analyzed using a two-way (3 x 2 design in experiment one; a 5 x 2 design in experiment two) fixed effects analysis of variance. Student-Newman-Kuels tests were used to evaluate differences between pairs of means whenever a significant F-ratio is obtained. Chi-square contingency tests were used for the pathological data. Levels were combined to meet the assumptions of chi-square tests.

CHAPTER IV

RESULTS AND DISCUSSION

The material in this chapter is organized into six main sections. The first part deals with training results from the Controlled-Running Wheel (CRW) programs of experiment one. The second section covers the training results of experiment two. Body and heart weight results at sacrifice are discussed in the third and fourth sections for experiment one and two respectively. Histopathological results are presented next. Finally, a discussion of the more important findings is given at the end of this chapter.

Training Results of Experiment One[1]

The sprint (SPT) and endurance (END) Controlled-Running Wheel (CRW) training programs are presented in Appendix A. These programs are modified versions of standard regimens routinely used in the Human Energy Research Laboratory, Michigan State University, East Lansing, Michigan. The modifications were incorporated in an attempt to design strenuous exercise programs which would primarily stimulate anaerobic or aerobic

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[1]Part of the material in this section has been adapted from the unpublished Ph.D. dissertation of Roland R. Roy (36).

metabolic processes in the animals. The performances of the animals were evaluated using the percentage of expected meters (PEM) and the percentage of shock-free time (PSF) as criterion measures (44).

The performance data for the SPT-C and the SPT-No C groups are presented in Figure 1. A runs test indicated that there were no significant differences in performance between the SPT-C and SPT-No C animals. Progressive increases in the required running velocity were made rapidly. From the beginning of the fourth week of training to the end of the program, the animals were expected to run at velocities ranging from 90 to 108 m/min (see Figure 1 and Appendix A). No comparable exercise programs for small animals have been found in the literature. The results indicate that the animals could not maintain the program requirements. PEM values fell to approximately 45% during the last three weeks of training as contrasted with the usual criteria of 75% for satisfactory completion of an exercise regimen.

The training data for the END-C and END-No C groups are shown in Figure 2. PEM values were 70% or higher each day of training in both the C and the No C animals. These results indicate that the animals were able to maintain the daily requirements of the END program relatively well.

The END animals ran at the relatively slow speed of 36 m/min. Periods of continuous running were progressively increased to 60 min at the end of five weeks of training and were maintained at this level for the remainder of the eight week program (see Figure 2 and Appendix A). The single bout of exercise was determined subjectively to result in daily physical exhaustion of the animals. On the average, the rats lost

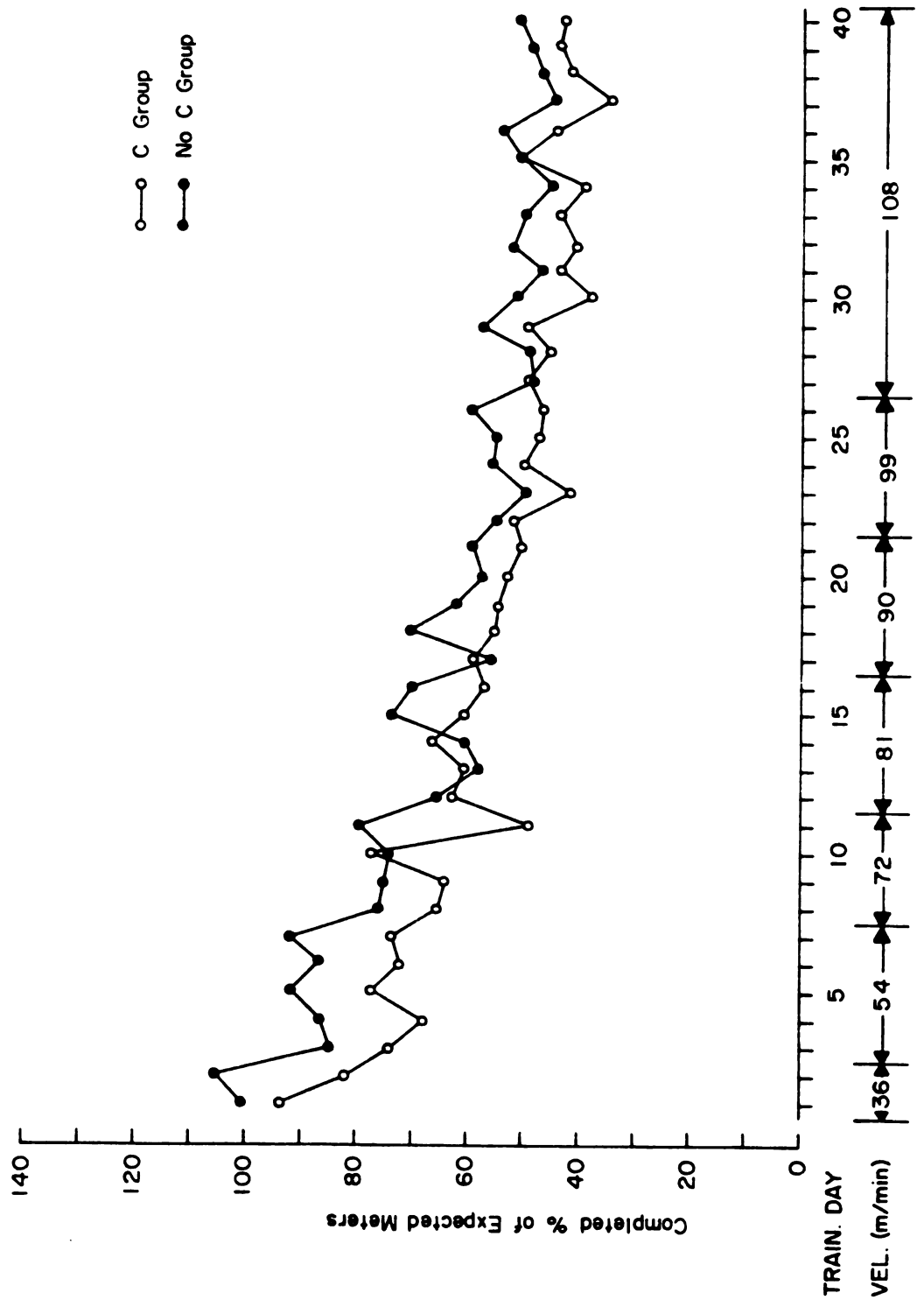

Figure 1. Mean Daily Percent Expected Meters Run for SPRINT Animals.

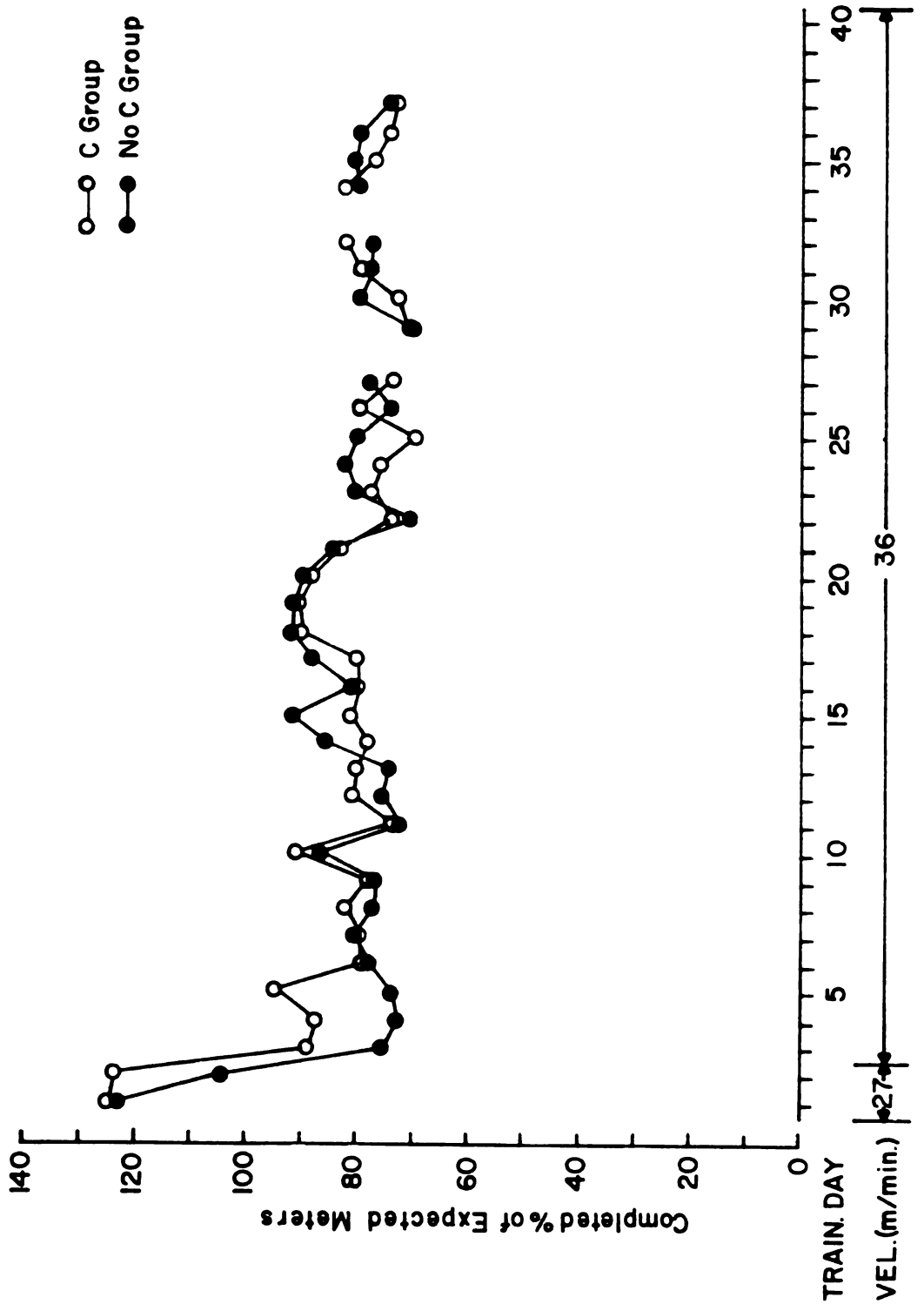

Figure 2. Mean Daily Percent Expected Meters Run for ENDURANCE Animals.

2.55% of their body weight during each training session (see Appendix B). Body weight data were used to award an unplanned recovery day on Wednesday of each of the last three weeks of training. The animals were run on the 39th and 40th day of the program, but the results were not recorded due to a technician error.

Training Results of Experiment Two

The regular sprint (REG SPT), the regular endurance (REG END), the high sprint (HI SPT), and the high endurance (HI END) Controlled-Running Wheel training programs are presented in Appendix A. The REG SPT and REG END programs are the standard regimens routinely used at the Human Energy Research Laboratory at Michigan State University to stimulate anaerobic and aerobic metabolic processes in small animals. The HI SPT and HI END programs are modified versions of the SPT and END programs used in experiment one. The modifications were incorporated to further refine strenuous exercise programs. The performances of the animals were evaluated using the percentage of expected meters (PEM) and the percentage of shock-free time (PSF) as criterion measures.

The performance data for the REG SPT-Sugar and the REG SPT-Placebo are presented in Figure 3. Animals in both groups demonstrated similar training patterns throughout the experimental period. A runs test was significant ($p < .05$). An unknown factor may have influenced the performance of the SPT group. The sugar treatment is most likely the unknown factor. PEM values for the REG SPT groups were 56% or higher each day of training. These values are lower than values from animals previously

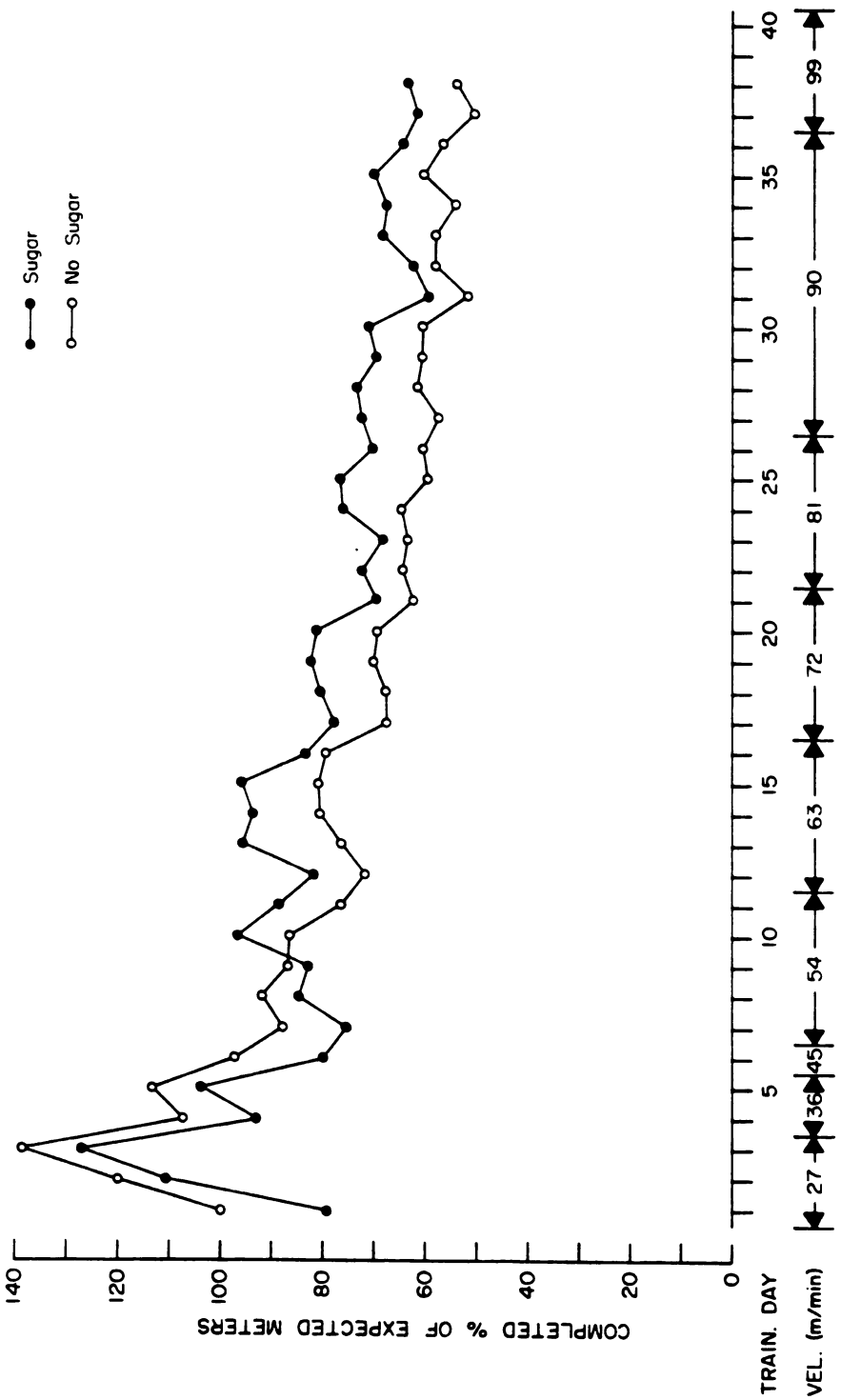

Figure 3. Mean Daily Percent Expected Meters Run for REGULAR SPRINT Animals.

trained using the identical protocol (16,18). A PEM value of 75% is the usual criteria for satisfactory completion of an exercise regimen. The small sample size of this experiment required that every animal trained be considered in the data analysis.

The correlation between PEM and PSF (.45) for the REG SPT animals was also lower than earlier studies (see Appendix B). This may indicate that the current animals did not respond satisfactorily to the training regimen. A small sample size (N=7) may have depressed the correlation.

The training data for the REG END-Sugar and REG END-Placebo groups are shown in Figure 4. Animals in these groups were subjected to a low intensity, long duration exercise program designed to stimulate aerobic metabolic processes. Both the Sugar and Placebo groups demonstrated similar training patterns. The data indicates that these animals maintained a PEM of approximately 70% during the later stages of training. While this value is lower than previous studies, it is sufficiently high to assume that the majority of animals had successfully completed the requirements of the training program.

The training data for the HI SPT-Sugar and HI SPT-Placebo are shown in Figure 5. Animals in both groups had similar training patterns.

The HI SPT program in experiment two is very similar to the SPT program in experiment two. The main differences exist in the first seven days of training. In experiment two, the intensity and total work time was increased in the early phase of training to stimulate anaerobic processes (see Appendix A). Progressive increases in the required

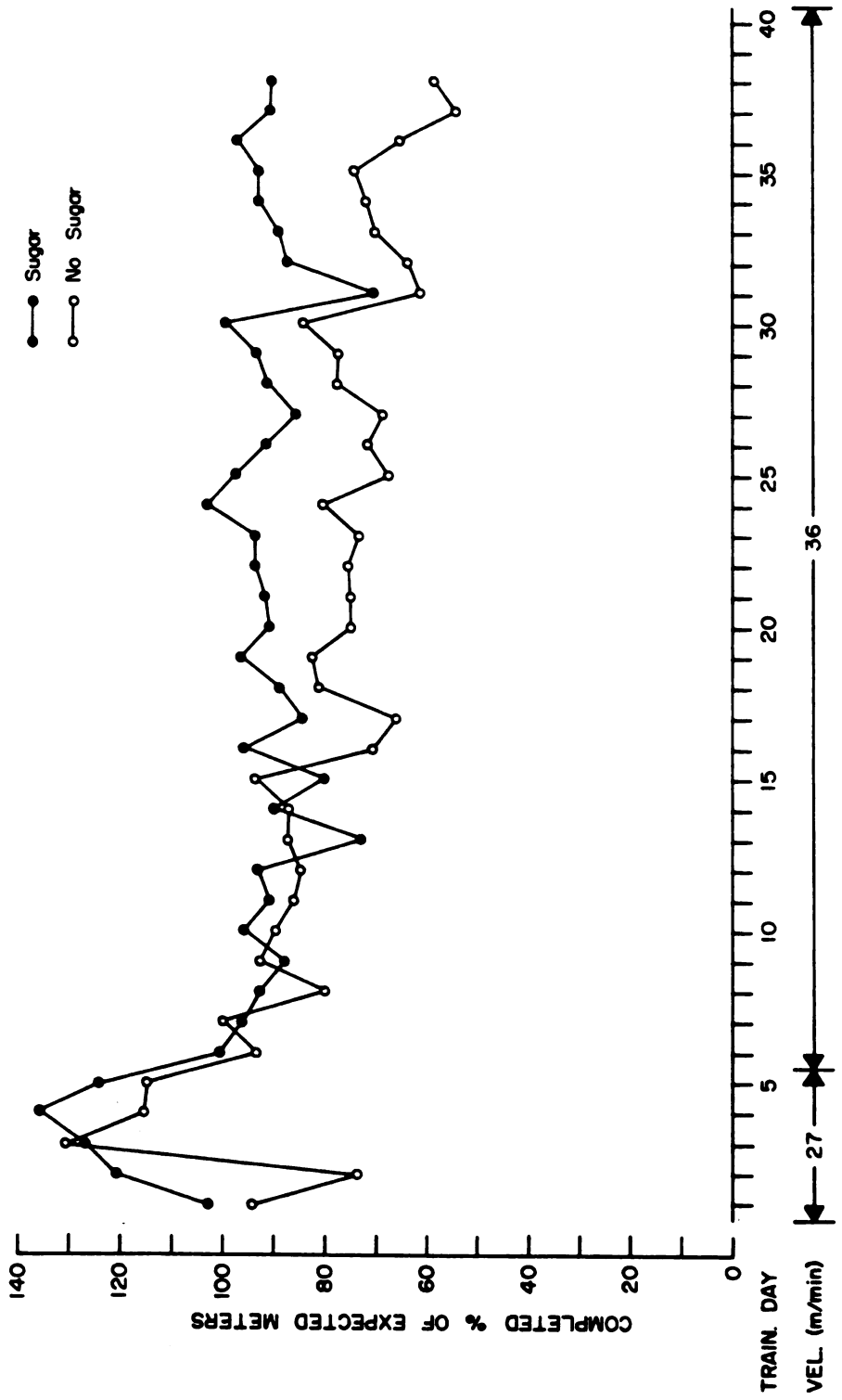

Figure 4. Mean Daily Percent Expected Meters Run for REGULAR ENDURANCE Animals.

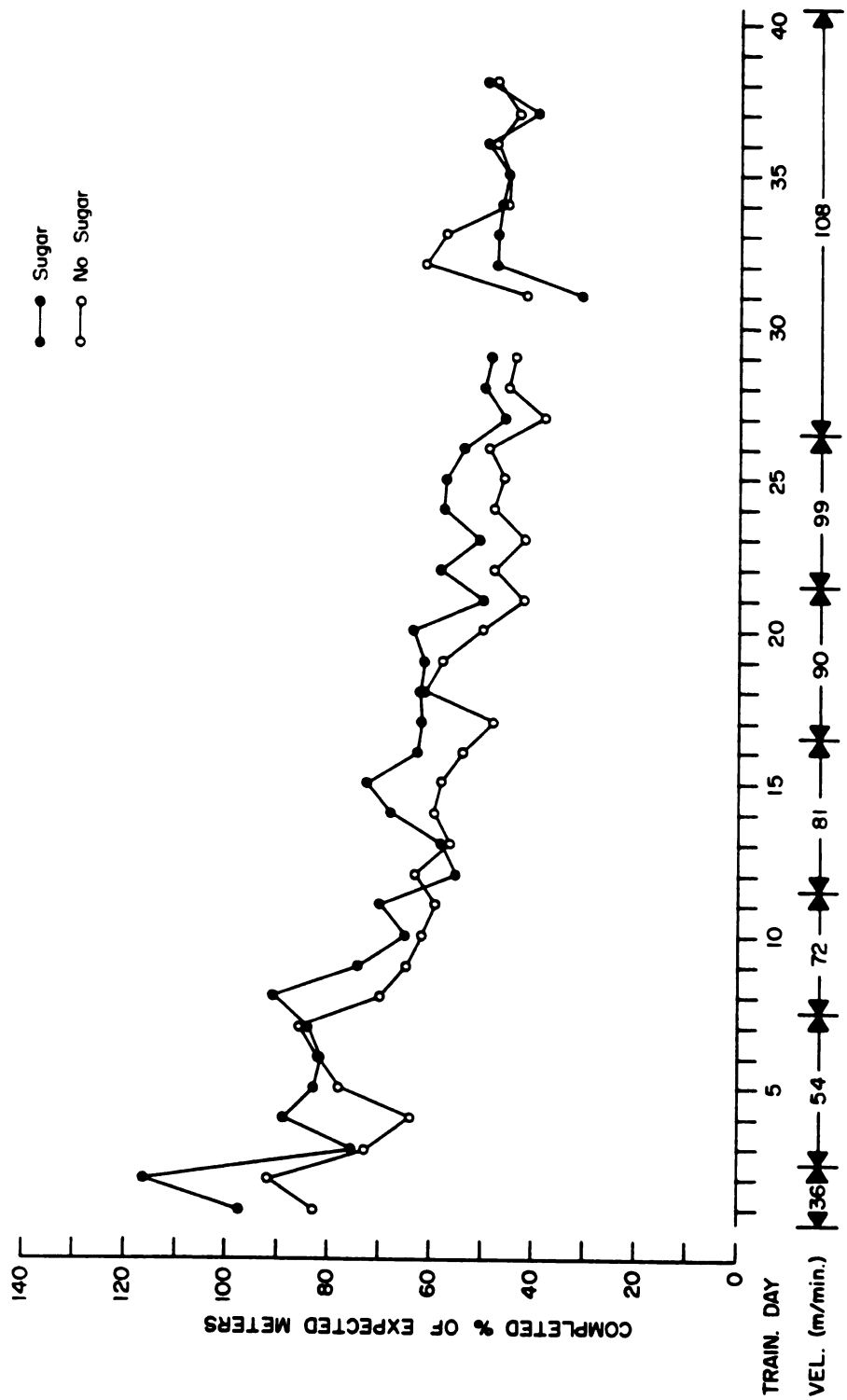

Figure 5. Mean Daily Percent Expected Meters Run for HIGH SPRINT Animals.

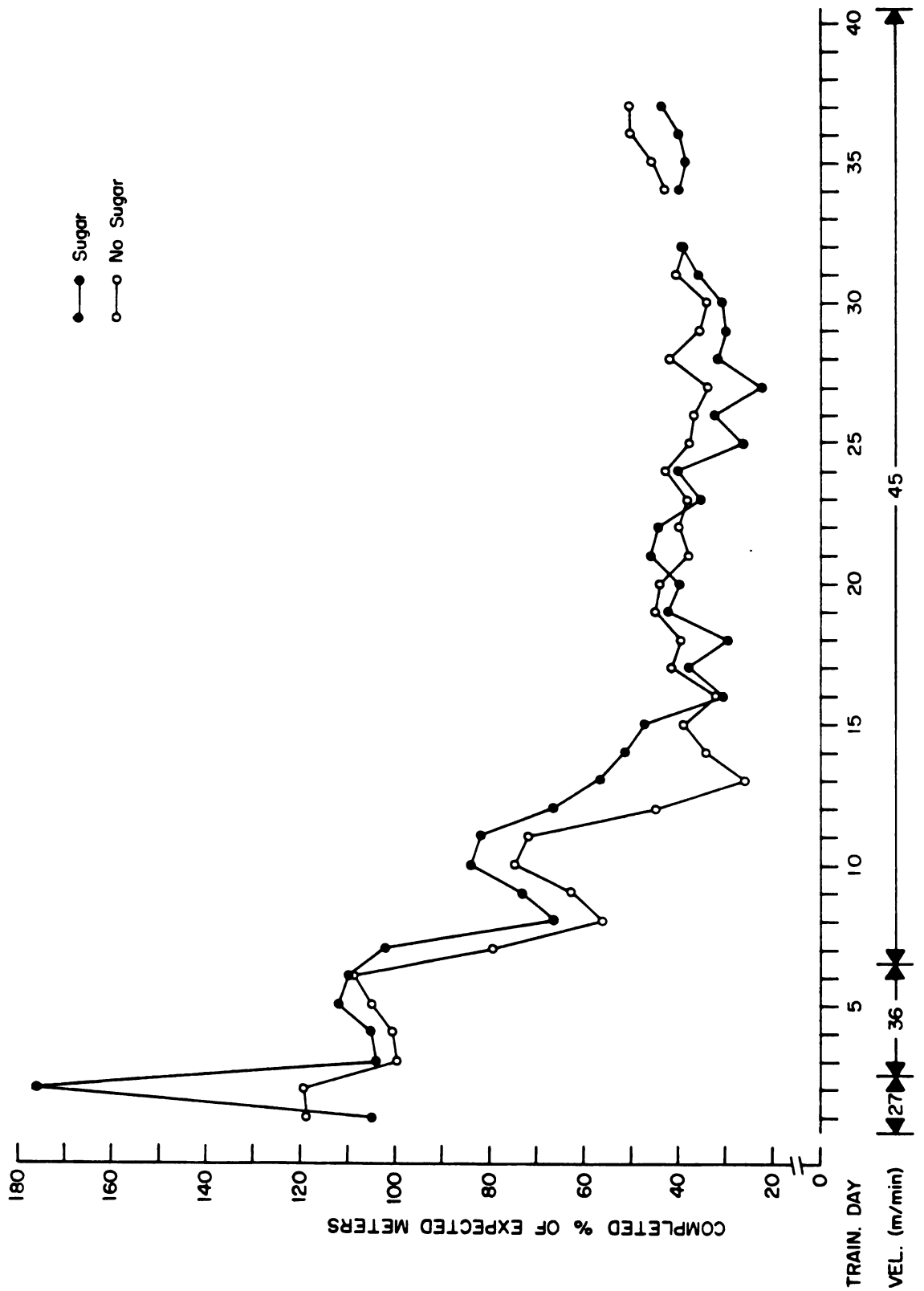

Figure 6. Mean Daily Percent Expected Meters Run for HIGH ENDURANCE Animals.

running velocity were made rapidly. From the beginning of the fourth week of training to the end of the program, the animals were expected to run at velocities ranging from 90 to 108 m/min. As in experiment one, PEM values fell to approximately 45% during the last three weeks of training.

The response of the HI END-Sugar and HI END-Placebo animals to the training regimen is presented in Figure 6. The HI END program was a modification of the END program from experiment one. Changes in the regimen were made to produce a more exhaustive, long duration exercise program. At the completion of six weeks of training and thereafter, the HI END animals maintained a running velocity of 45 m/min for one hour. During the same period of training the animals in experiment one only maintained a running velocity of 36 m/min for one hour. PEM values indicate that the HI END animals could not maintain the program's requirements. PEM values in experiment two fell to approximately 39% during the last three weeks of training. In experiment one, PEM values were approximately 70% during this time.

Body and Heart Weight Results at Sacrifice for Experiment One

At the end of eight weeks of exercise, the trained animals were significantly lighter than the sedendary control animals (Table 1). The differences in body weight between the SPT and END groups of animals were not statistically significant (Table 1). Both trained groups were approximately 20% lighter than the CON group. These results are in agreement with those of previous studies using the CRW (16,18,42) and

Table 1. Analysis of variance for overall training effects and Newman-Keul's tests of paired comparisons for body weight at sacrifice and absolute and relative heart weights, for experiment one.

Dependent Variable	Treatment Means CON	SPT	END	F Value	P Value	SNK
Body weight at sacrifice (g)	515.1	397.3	408.3	96.731	<.0005*	SPT < CON END < CON
Absolute Heart Weight (g)	1.848	1.483	1.659	3.577	.035	CON > SHT
Relative Heart Weight (10^{-3})	3.59	3.70	4.12	1.546	.222	

* Significant overall treatment effect at the 0.05 level.

and support the general observation that strenuous exercise slows the usual gain in body weight seen in the male rat over time (7). The slower rate of weight gain usually is attributed to an increase in caloric expenditure associated with exercise. In some instances the growth impairment has been ascribed to a significant reduction in food intake (7,30). However, these parameters were not monitored in the present study.

Animals in the control group had a statistically significant larger absolute heart weight than the animals in the sprint group. The absolute heart weights of the control animals were not different from the endurance animals. The exercised animals had larger relative heart weights than the control animals and the END animals had larger relative weights than the SPT animals. None of the differences in relative heart weight were statistically significant.

Vitamin C supplementation did not appear to affect body weight, absolute heart weight, or relative heart weight. Mean values and the two-way ANOVA results are shown in Table 2.

Body and Heart Weight Results at Sacrifice for Experiment Two

Training and diet had an interaction effect on body weight at sacrifice (see Table 3). This interaction may have been caused by a significant diet effect on body weight at the start of the exercise program. An analysis of the weight gained data indicated that there was no true diet effect. Animals in the control group gained significantly more weight during the experimental period than did animals in

Table 2. Analysis of variance for overall vitamin C effects for body weight at sacrifice and absolute and relative heart weights for experiment one.

Dependent Variable	Treatment Means		F Values	P Value
	C	No C		
Body Weight at sacrifice (g)	433.367	447.033	3.202	.079
Absolute Heart Weight (g)	1.641	1.685	.157	.694
Relative Heart Weight (10^{-3})	3.83	3.78	.036	.851

Table 3. Analysis of variance for overall sugar effects for experiment one.

Dependent Variable	Treatment Means		F Value	P Value
	Sugar	Placebo		
Body Weight* at sacrifice (g)	423.824	440.778	4.870	.035
Beginning Body Weight (g)	321.471	339.333	17.530	.001
Weight Gained (g)	101.444	102.353	.070	.999
Absolute Heart Weight (g)	1.434	1.411	.029	.999
Relative Heart Weight (10^{-3})	3.261	3.329	.921	.999

*A two-way interaction effect between Diet and Training was observed with body weight at sacrifice (F value = 3.14, P value = .032). There were no other significant two-way interactions among the dependent variables.

the running programs (see Table 4). The trained animals were 35% lighter than the control animals. There was no difference in the amount of weight gained between any of the exercised animals.

Animals in the control group also had significantly larger absolute heart weights than animals in the HI END, REG SHT, and REG END groups. These differences were not significant when relative heart weights were considered. However, the means of relative heart weights for all exercise animals were higher than the control animals.

Histopathological Results

Microscopic evaluations of the hearts as previously described revealed a small number of animals who developed heart damage. In order to meet the criteria of Chi-square test, it was necessary to pool the heart damage ratings and the training treatment. Animals with the rating of 0 formed the no myocardial damage group. Animals with a rating of 1 or higher formed the myocardial damage group. As these groups indicate at least some degree of myocardial damage, the high number of animals classified as having myocardial damage may be misleading. The majority of animals in this group showed very slight damage. The heart damage in most animals consisted of small focal areas of inflammatory reaction. Moderate heart damage was observed in four of the thirty-six trained animals, while only one of fifteen control animals showed such damage (see Tables 5 and 6, on the following page).

A Chi-square contingency test showed that there was no statistically significant difference in heart damage between the exercised and control animals (see Table 7).

Table 4. Analysis of variance for overall training effects and student Newman-Keul's tests of paired comparisons for experiment two.

Dependent Variable	Treatment Means					F Value	P Value	SNK Test
	CON	REG SHT	HI SHT	REG END	HI END			
Body Weight at sacrifice (g)	479.000	422.429	429.375	418.625	420.667	8.662	.001	
Weight gained (g)	144.167	96.429	96.375	87.875	92.0	7.749	.001	SED>HI END SED>HI SPT SED>NEG END SED>NEG SPT
Absolute Heart Weight (g)	1.539	1.373	1.459	1.392	1.358	4.031	.015	SED>HI END SED>REG SHT SED>REG END
Relative Heart Weight (10^{-3})	3.215	3.254	3.407	3.323	3.232	.778	.999	--
Beginning Body Weight (g)	334.833	326.000	333.000	330.750	328.667	.678	.999	--

Table 5. Frequency distribution of ratings of myocardial damage in experiment one.

Rating	Training Group		
	CON	SPT	END
0	8	6	7
1	2	2	1
2	0	2	1
3	0	0	1
4	0	0	0

Table 6. Frequency distribution of ratings of myocardial damage in experiment two.

Rating	Training Group				
	CON	REG SPT	HI SPT	REG END	HI END
0	5	5	7	5	5
1	1	2	1	3	0
2	0	0	0	0	1
3	0	0	0	0	0
4	0	0	0	0	0

Table 7. Chi-square test for treatment effects on the degree of myocardial damage.

	CON	TRAINED	N
No Damage	13	35	48
Damage	3	14	17
	16	49	65

$x^2 = .60$ $p > .05$

Discussion

Several possible explanations could account for the relatively poor performance data of the SPT, HI SPT, and HI END groups. The required running velocities may have been too fast. Observations during the training sessions, however, showed that the animals were capable of running at the desired speeds. Low PEM and PSF values might suggest that the animals responded to the unconditioned shock stimulus rather than to the conditioned light stimulus. Improper initial training and defects in the CRW equipment could lead to such a learning problem, but the END, REG SPT, and REG END groups learned to run under the same conditions and had no such difficulties. A lack of control of environmental factors affecting training performance might have accounted for the poor results of the SPT group. This is particularly true for air temperature and percent humidity, but again the END data make this explanation improbable (see Appendix B). The environmental factors during experiment two did not vary as drastically as in experiment one. The most likely cause of the low PEM and PSF values is that the SPT, HI SPT, and HI END regimens may have produced a state of overtraining. The data in Figures 1, 5 and 6 support this hypothesis. Repeated increases in the required velocity may have been expected from the animals before they were fully adapted to the previous velocity. The constant additional stress could have resulted in overtraining.

Bone data from the animals in experiment one strongly reinforce the hypothesis that overtraining was produced by these exercise regimens (40). A retardation of long bone growth occurred with the trained

animals. In addition the SPT group had significantly lighter tibia weights when compared to the bones of the CON group. These results were not anticipated in light of Wolff's Law.

The body weight data from experiment one and experiment two are consistent among themselves and with previous studies (16,17). The control animals gained significantly more weight than the trained animals. Larger animals may have larger hearts. From the body weight data, it was not surprising that the CON animals had larger absolute heart weight than did the exercised animals. Although not statistically significant, when body weight was controlled for mathematically by a heart weight/ body weight ratio, the trained animals had relatively larger hearts to support relatively less body mass.

There was not a statistically significant degree of myocardial damage associated with strenuous training. Indeed, four of the CON animals showed some degree of myocardial damage. The heart damage seen in control and trained animals may have been caused by unknown stress factors or by an advanced degree of atherosclerosis in the coronary arteries. Since the degree of atherosclerosis was not measured in this experiment, there is no way of determining if either of the above factors were instrumental in the production of myocardial damage.

From the training data, it appeared that the trained animals were subjected to exhaustive workloads. It may be that these exercise regimens were not sufficiently intense or of a long enough duration to produce myocardial damage. A more likely explanation is that exercise. as a sole factor in a healthy animal, will not produce myocardial damage.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was undertaken to investigate the effects of long-term, exhaustive workloads on the myocardium of normal male adult rats (Sprague-Dawley strain). Six different exercise regimens were selected. The programs included two regimens that required mainly aerobic metabolism (endurance running), two regimens that are thought to require mainly anaerobic metabolism (sprint running), and two activity regimens that were known to produce beneficial adaptations to aerobic and anaerobic workloads (16,18). Animals for this study were obtained from two experiments. In the first experiment, eighty-four male albino rats were placed into three activity groups, with each activity group divided into two dietary supplement groups. The second experiment was organized as a two-way design with five activity groups and two dietary supplement groups. Experimental protocol and sacrifice procedures were nearly identical in both experiments. The heart was removed from each animal and the tissues prepared for histological and pathological evaluations.

Analysis of variance of the dietary supplements in both experiments indicated no significant differences in body weight gained, absolute heart weight, and relative heart weight.

In experiment one, the absolute heart weight of the CON group was significantly larger than the SPT group. No significant differences were observed in relative heart weights.

In experiment two, the absolute heart weights of the CON group were significantly larger than the HI END, REG SPT, and REG END groups. Again there were no statistically significant differences observed in relative heart weights.

A chi-square test indicated there were no significant differences in heart damage between trained and control animals.

Conclusions

The results of this study have led to the following conclusions:

1) Sedentary animals had significantly larger absolute heart weights than the SPT, REG SPT, REG END, and HI END animals.

2) The inclusion of vitamin C in experiment one and of sugar in experiment two did not affect body weight or heart weight of the animals.

3) The exercise imposed in this study did not affect the amount of heart damage observed.

Recommendations

1) Studies are needed to further refine exercise regimens involving repetitive, exhaustive workloads.

2) Exercise regimens that involve power events such as weightlifting and high jumping should be developed. The effects of these

training programs on the myocardium should be investigated.

3) Further studies are needed to delineate the phenomenon of overtraining. These studies should consider serum catecholamine levels, heart catecholamine levels, and adrenal and thyroid responses to chronic exhaustive exercise.

4) Histochemical analysis of the extent of atherosclerosis in coronary arteries of animals with heart damage should be investigated.

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APPENDICES

APPENDIX A

TRAINING PROGRAMS

Table A-1. Modified Eight Week Sprint Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels for Experiment One

Wk.	Day of Wk.	Day of Tr.	Acceleration Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repetitions per Bout	No. of Bouts	Time Between Bouts (min)	Shock (ma)	Run Speed (m/min)	Total Time of Prog. (min: sec)	Total Exp. Meters TEM	Total Work Time (sec) TWT
0	4=T	-2	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
	5=F	-1	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
1	1=M	1	2.0	00:10	10	10	8	2.5	1.2	36	42:50	480	800
	2=T	2	2.0	00:10	10	10	8	2.5	1.2	36	42:50	480	800
	3=W	3	1.5	00:10	15	10	8	2.5	1.2	54	49:50	720	800
	4=T	4	1.5	00:10	15	10	8	2.5	1.2	54	49:50	720	800
	5=F	5	1.5	00:10	15	10	8	2.5	1.2	54	49:50	720	800
2	1=M	6	1.5	00:10	15	10	8	2.5	1.2	54	49:50	720	800
	2=T	7	1.5	00:10	15	10	8	2.5	1.2	54	49:50	720	800
	3=W	8	1.5	00:15	30	6	7	2.5	1.2	72	43:00	756	630
	4=T	9	1.5	00:15	30	6	7	2.5	1.2	72	43:00	756	630
	5=F	10	1.5	00:15	30	6	7	2.5	1.2	72	43:00	756	630
3	1=M	11	1.5	00:15	30	6	7	2.5	1.2	72	43:00	756	630
	2=T	12	1.5	00:15	30	6	6	2.5	1.2	81	36:30	729	540
	3=W	13	1.5	00:15	30	6	6	2.5	1.2	81	36:30	729	540
	4=T	14	1.5	00:15	30	6	6	2.5	1.2	81	36:30	729	540
	5=F	15	1.5	00:15	30	6	6	2.5	1.2	81	36:30	729	540
4	1=M	16	1.5	00:15	30	6	6	2.5	1.2	81	36:30	729	540
	2=T	17	2.0	00:15	30	5	6	2.5	1.2	90	32:00	675	450
	3=W	18	2.0	00:15	30	5	6	2.5	1.2	90	32:00	675	450
	4=T	19	2.0	00:15	30	5	6	2.5	1.2	90	32:00	675	450
	5=F	20	2.0	00:15	30	5	6	2.5	1.2	90	32:00	675	450
5	1=M	21	2.0	00:15	30	5	6	2.5	1.2	90	32:00	675	450
	2=T	22	2.0	00:15	30	5	6	2.5	1.2	99	32:00	743	450
	3=W	23	2.0	00:15	30	5	6	2.5	1.2	99	32:00	743	450
	4=T	24	2.0	00:15	30	5	6	2.5	1.2	99	32:00	743	450
	5=F	25	2.0	00:15	30	5	6	2.5	1.2	99	32:00	743	450
6	1=M	26	2.0	00:15	30	5	6	2.5	1.2	99	32:00	743	450
	2=T	27	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	3=W	28	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	4=T	29	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	5=F	30	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
7	1=M	31	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	2=T	32	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	3=W	33	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	4=T	34	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	5=F	35	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
8	1=M	36	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	2=T	37	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	3=W	38	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	4=T	39	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450
	5=F	40	2.0	00:15	30	5	6	2.5	1.2	108	32:00	810	450

This training program is a modified version of a standard program designed using male rats of the Sprague-Dawley strain (16,42).

All animals should be exposed to a minimum of one week of voluntary running in a wheel prior to the start of the program. Failure to provide this adjustment period will impose a double learning situation on the animals and will seriously impair the effectiveness of the training program.

APPENDIX A--continued

Table A-2. Modified Eight Week Sprint Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels for Experiment One

Wk.	Day of Wk.	Day of Tr.	Acceleration Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repetitions per Bout	No. of Complete Bouts	Partial Bouts (min: sec)	Time Between Bouts (min)	Shock (ma)	Run Speed (m/min)	Total Time of Prog. (min: sec)	Total Exp. Meters TEM	Total Work Time (sec) TWT
0	4=T	-2	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
	5=F	-1	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
1	1=M	1	2.0	02:30	0	1	6		2.5	1.2	27	27:30	405	900
	2=T	2	2.0	02:30	0	1	6		2.5	1.2	27	27:30	405	900
	3=W	3	1.5	05:00	0	1	3		5.0	1.2	36	25:00	540	900
	4=T	4	1.5	05:00	0	1	3		5.0	1.2	36	25:00	540	900
	5=F	5	1.5	05:00	0	1	3		5.0	1.2	36	25:00	540	900
2	1=M	6	1.5	05:00	0	1	3		5.0	1.2	36	25:00	540	900
	2=T	7	1.0	07:30	0	1	2		5.0	1.2	36	20:00	540	900
	3=W	8	1.0	07:30	0	1	2		2.5	1.2	36	17:30	540	900
	4=T	9	1.0	07:30	0	1	2		1.0	1.2	36	16:00	540	900
	5=F	10	1.0	15:00	0	1	1		0.0	1.2	36	15:00	540	900
3	1=M	11	1.0	15:00	0	1	1	05:00	1.0	1.2	36	21:00	720	1200
	2=T	12	1.0	15:00	0	1	1	07:30	1.0	1.0	36	23:30	810	1350
	3=W	13	1.0	15:00	0	1	1	10:00	1.0	1.0	36	26:00	900	1500
	4=T	14	1.0	15:00	0	1	1	12:30	1.0	1.0	36	28:30	990	1650
	5=F	15	1.0	15:00	0	1	2		1.0	1.0	36	31:00	1080	1800
4	1=M	16	1.0	15:00	0	1	2	05:00	1.0	1.0	36	37:00	1260	2100
	2=T	17	1.0	15:00	0	1	2	07:30	1.0	1.0	36	39:30	1350	2250
	3=W	18	1.0	15:00	0	1	2	10:00	1.0	1.0	36	42:00	1440	2400
	4=T	19	1.0	15:00	0	1	2	12:30	1.0	1.0	36	44:30	1530	2550
	5=F	20	1.0	15:00	0	1	3		1.0	1.0	36	47:00	1620	2700
5	1=M	21	1.0	15:00	0	1	3	05:00	1.0	1.0	36	52:00	1800	3000
	2=T	22	1.0	15:00	0	1	3	07:30	1.0	1.0	36	54:30	1890	3150
	3=W	23	1.0	15:00	0	1	3	10:00	1.0	1.0	36	57:00	1980	3300
	4=T	24	1.0	15:00	0	1	3	12:30	1.0	1.0	36	59:30	2070	3450
	5=F	25	1.0	15:00	0	1	4		1.0	1.0	36	63:00	2160	3600
6	1=M	26	1.0	15:00	0	1	4		1.0	1.0	36	64:00	2160	3600
	2=T	27	1.0	30:00	0	1	2		5.0	1.0	36	65:00	2160	3600
	3=W	28	1.0	30:00	0	1	2		2.5	1.0	36	62:30	2160	3600
	4=T	29	1.0	30:00	0	1	2		1.0	1.0	36	61:00	2160	3600
	5=F	30	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
7	1=M	31	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	2=T	32	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	3=W	33	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	4=T	34	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	5=F	35	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
8	1=M	36	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	2=T	37	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	3=W	38	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	4=T	39	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600
	5=F	40	1.0	60:00	0	1	1		0.0	1.0	36	60:00	2160	3600

This training program is a modified version of a standard program designed using male rats of the Sprague-Dawley strain (16,42).

APPENDIX A--continued

Table A-3. Modified Eight Week Regular Sprint Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels

Wk.	Day of Wk.	Day of Tr.	Acc-eler-ation Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repe-ti-tions per Bout	No. of Bouts	Time Be-tween Bouts (min)	Shock (ma)	Run Speed (m/ min)	Total Time of Prog. (min: sec)	Total Exp. Meters TEM	Total Work Time (sec) TRT
0	4=T	-2	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
	5=T	-1	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
1	1=M	1	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	2=T	2	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	3=W	3	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	4=T	4	2.5	00:10	10	40	3	5.0	1.2	36	49:30	720	1200
	5=F	5	2.0	00:10	10	40	3	5.0	1.2	36	49:30	720	1200
2	1=M	6	1.5	00:10	10	28	4	5.0	1.2	45	51:40	840	1120
	2=T	7	1.5	00:10	15	27	4	5.0	1.2	54	59:00	972	1080
	3=W	8	1.5	00:10	15	27	4	5.0	1.2	54	59:00	972	1080
	4=T	9	1.5	00:10	15	27	4	5.0	1.2	54	59:00	972	1080
	5=F	10	1.5	00:10	15	27	4	5.0	1.2	54	59:00	972	1080
3	1=M	11	1.5	00:10	15	27	4	5.0	1.2	54	59:00	972	1080
	2=T	12	1.5	00:10	20	23	4	5.0	1.2	63	59:40	966	920
	3=W	13	1.5	00:10	20	23	4	5.0	1.2	63	59:40	966	920
	4=T	14	1.5	00:10	20	23	4	5.0	1.2	63	59:40	966	920
	5=F	15	1.5	00:10	20	23	4	5.0	1.2	63	59:40	966	920
4	1=M	16	1.5	00:10	20	23	4	5.0	1.2	63	59:40	966	920
	2=T	17	1.5	00:10	25	20	4	5.0	1.0	72	60:00	960	800
	3=W	18	1.5	00:10	25	20	4	5.0	1.0	72	60:00	960	800
	4=T	19	1.5	00:10	25	20	4	5.0	1.0	72	60:00	960	800
	5=F	20	1.5	00:10	25	20	4	5.0	1.0	72	60:00	960	800
5	1=M	21	1.5	00:10	25	20	4	5.0	1.0	72	60:00	960	800
	2=T	22	1.5	00:10	30	16	4	5.0	1.0	81	55:40	864	640
	3=W	23	1.5	00:10	30	16	4	5.0	1.0	81	55:40	864	640
	4=T	24	1.5	00:10	30	16	4	5.0	1.0	81	55:40	864	640
	5=F	25	1.5	00:10	30	16	4	5.0	1.0	81	55:40	864	640
6	1=M	26	1.5	00:10	30	16	4	5.0	1.0	81	55:40	864	640
	2=T	27	2.0	00:10	35	10	5	5.0	1.0	90	54:35	750	500
	3=W	28	2.0	00:10	35	10	5	5.0	1.0	90	54:35	750	500
	4=T	29	2.0	00:10	35	10	5	5.0	1.0	90	54:35	750	500
	5=F	30	2.0	00:10	35	10	5	5.0	1.0	90	54:35	750	500
7	1=M	31	2.0	00:10	35	10	5	5.0	1.0	90	54:35	750	500
	2=T	32	2.0	00:10	35	7	8	2.5	1.0	90	54:50	840	560
	3=W	33	2.0	00:10	35	7	8	2.5	1.0	90	54:50	840	560
	4=T	34	2.0	00:10	35	7	8	2.5	1.0	90	54:50	840	560
	5=F	35	2.0	00:10	35	7	8	2.5	1.0	90	54:50	840	560
8	1=M	36	2.0	00:10	35	7	8	2.5	1.0	90	54:50	840	560
	2=T	37	2.0	00:10	40	6	8	2.5	1.0	99	52:10	792	480
	3=W	38	2.0	00:10	40	6	8	2.5	1.0	99	52:10	792	480
	4=T	39	2.0	00:10	40	6	8	2.5	1.0	99	52:10	792	480
	5=F	40	2.0	00:10	40	6	8	2.5	1.0	99	52:10	792	480

APPENDIX A--continued

Table A-4. Modified Eight Week Regular Endurance Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels

Wk.	Day of Wk.	Day of Tr.	Acc-eler-ation Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repe-ti-tions per Bout	No. of Bouts	Time Be-tween Bouts (min)	Shock (ma)	Run Speed (m/ min)	Time of Prog. (min: sec)	Exp. Meters TEM	Total Work Time (sec) TRT
0	4=T	-2	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
	5=F	-1	3.0	40:00	10	1	1	5.0	0.0	27	40:00	---	---
1	1=M	1	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	2=T	2	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	3=W	3	3.0	00:15	15	25	3	5.0	1.2	27	46:45	506	1125
	4=T	4	2.5	00:30	15	20	2	5.0	1.2	27	34:30	540	1200
	5=F	5	2.5	00:30	15	20	2	5.0	1.2	27	34:30	540	1200
2	1=M	6	2.0	00:40	20	15	2	5.0	1.2	36	34:20	720	1200
	2=T	7	2.0	00:50	25	12	2	5.0	1.2	36	34:10	720	1200
	3=W	8	1.5	01:00	30	10	2	5.0	1.2	36	34:00	720	1200
	4=T	9	1.5	02:30	60	4	2	5.0	1.2	36	31:00	720	1200
	5=F	10	1.0	02:30	60	4	2	5.0	1.2	36	31:00	720	1200
3	1=M	11	1.0	02:30	60	4	2	5.0	1.2	36	31:00	720	1200
	2=T	12	1.0	05:00	10	1	5	2.5	1.2	36	35:00	900	1500
	3=W	13	1.0	05:00	10	1	5	2.5	1.2	36	35:00	900	1500
	4=T	14	1.0	05:00	10	1	5	2.5	1.2	36	35:00	900	1500
	5=F	15	1.0	05:00	10	1	5	2.5	1.2	36	35:00	900	1500
4	1=M	16	1.0	05:00	10	1	5	2.5	1.2	36	35:00	900	1500
	2=T	17	1.0	07:30	10	1	4	2.5	1.0	36	37:30	1080	1800
	3=W	18	1.0	07:30	10	1	4	2.5	1.0	36	37:30	1080	1800
	4=T	19	1.0	07:30	10	1	4	2.5	1.0	36	37:30	1080	1800
	5=F	20	1.0	07:30	10	1	4	2.5	1.0	36	37:30	1080	1800
5	1=M	21	1.0	07:30	10	1	4	2.5	1.0	36	37:30	1080	1800
	2=T	22	1.0	07:30	10	1	5	2.5	1.0	36	47:30	1350	2250
	3=W	23	1.0	07:30	10	1	5	2.5	1.0	36	47:30	1350	2250
	4=T	24	1.0	07:30	10	1	5	2.5	1.0	36	47:30	1350	2250
	5=F	25	1.0	07:30	10	1	5	2.5	1.0	36	47:30	1350	2250
6	1=M	26	1.0	07:30	10	1	5	2.5	1.0	36	47:30	1350	2250
	2=T	27	1.0	10:00	10	1	4	2.5	1.0	36	47:30	1440	2400
	3=W	28	1.0	10:00	10	1	4	2.5	1.0	36	47:30	1440	2400
	4=T	29	1.0	10:00	10	1	4	2.5	1.0	36	47:30	1440	2400
	5=F	30	1.0	10:00	10	1	4	2.5	1.0	36	47:30	1440	2400
7	1=M	31	1.0	10:00	10	1	4	2.5	1.0	36	47:30	1440	2400
	2=T	32	1.0	10:00	10	1	5	2.5	1.0	36	60:00	1800	3000
	3=W	33	1.0	10:00	10	1	5	2.5	1.0	36	60:00	1800	3000
	4=T	34	1.0	10:00	10	1	5	2.5	1.0	36	60:00	1800	3000
	5=F	35	1.0	10:00	10	1	5	2.5	1.0	36	60:00	1800	3000
8	1=M	36	1.0	10:00	10	1	5	2.5	1.0	36	60:00	1800	3000
	2=T	37	1.0	12:30	10	1	4	2.5	1.0	36	57:30	1800	3000
	3=W	38	1.0	12:30	10	1	4	2.5	1.0	36	57:30	1800	3000
	4=T	39	1.0	12:30	10	1	4	2.5	1.0	36	57:30	1800	3000
	t=F	40	1.0	12:30	10	1	4	2.5	1.0	36	57:30	1800	3000

APPENDIX A--continued

Table A-5. Modified Eight Week High Sprint Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels

Wk.	Day of Wk.	Day of Tr.	Acc-eler-ation Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repe-ti-tions per Bout	No. of Com-plete Bouts	Par-tial Bouts (min: sec)	Time be-tween Bouts (min)	Shock (ma)	Run Speed (m/ min)	Total Time of Prog. (min: sec)	Total Exp. Meters TEM	Total Work Time (sec) TWT
0	4=T	-2	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
	5=F	-1	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
1	1=M	1	2.0	00:15	15	8	7		2.5	1.2	36	41:15	504	840
	2=T	2	2.0	00:15	15	8	7		2.5	1.2	36	41:15	504	840
	3=W	3	1.5	00:15	25	8	7		2.5	1.2	54	49:25	756	840
	4=T	4	1.5	00:15	25	8	7		2.5	1.2	54	49:25	756	840
	5=F	5	1.5	00:15	25	8	7		2.5	1.2	54	49:25	756	840
2	1=M	6	1.5	00:15	25	8	7		2.5	1.2	54	49:25	756	840
	2=T	7	1.5	00:15	25	8	7		2.5	1.2	54	49:25	756	840
	3=W	8	1.5	00:15	30	6	7		2.5	1.2	72	43:00	756	630
	4=T	9	1.5	00:15	30	6	7		2.5	1.2	72	43:00	756	630
	5=F	10	1.5	00:15	30	6	7		2.5	1.2	72	43:00	756	630
3	1=M	11	1.5	00:15	30	6	7		2.5	1.2	72	43:00	756	630
	2=T	12	1.5	00:15	30	6	6		2.5	1.2	81	36:30	729	540
	3=W	13	1.5	00:15	30	6	6		2.5	1.2	81	36:30	729	540
	4=T	14	1.5	00:15	30	6	6		2.5	1.2	81	36:30	729	540
	5=F	15	1.5	00:15	30	6	6		2.5	1.2	81	36:30	729	540
4	1=M	16	1.5	00:15	30	6	6		2.5	1.2	81	36:30	729	540
	2=T	17	2.0	00:15	30	5	6		2.5	1.2	90	32:00	675	450
	3=W	18	2.0	00:15	30	5	6		2.5	1.2	90	32:00	675	450
	4=T	19	2.0	00:15	30	5	6		2.5	1.2	90	32:00	675	450
	5=F	20	2.0	00:15	30	5	6		2.5	1.2	90	32:00	675	450
5	1=M	21	2.0	00:15	30	5	6		2.5	1.2	90	32:00	675	450
	2=T	22	2.0	00:15	30	5	6		2.5	1.2	99	32:00	743	450
	3=W	23	2.0	00:15	30	5	6		2.5	1.2	99	32:00	743	450
	4=T	24	2.0	00:15	30	5	6		2.5	1.2	99	32:00	743	450
	5=F	25	2.0	00:15	30	5	6		2.5	1.2	99	32:00	743	450
6	1=M	26	2.0	00:15	30	5	6		2.5	1.2	99	32:00	743	450
	2=T	27	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	3=W	28	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	4=T	29	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	5=F	30	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
7	1=M	31	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	2=T	32	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	3=W	33	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	4=T	34	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	5=F	35	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
8	1=M	36	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	2=T	37	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	3=W	38	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	4=T	39	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450
	5=F	40	2.0	00:15	30	5	6		2.5	1.2	108	32:00	810	450

This training program is a modified version of a standard program designed using male rats of the Sprague-Dawley strain (16,42).

All animals should be exposed to a minimum of one week of voluntary running in a wheel prior to the start of the program. Failure to provide this adjustment period will impose a double learning situation on the animals and will seriously impair the effectiveness of the training program.

APPENDIX A--continued

Table A-6. Modified Eight Week High Endurance Training Program for Postpubertal and Adult Male Rats in Controlled-Running Wheels

Wk.	Day of Wk.	Day of Tr.	Acc-eler-ation Time (sec)	Work Time (min: sec)	Rest Time (sec)	Repe-ti-tions per Bout	No. of Com-plete Bouts	Par-tial Bouts (min: sec)	Time Be-tween Bouts (min)	Shock (ma)	Run Speed (m/min)	Total Time of Prog. (min: sec)	Total Exp. Meters TEM	Total Work Time (sec) TWT
0	4=T	-2	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
	5=F	-1	3.0	40:00	10	1	1		5.0	0.0	27	40:00	---	---
1	1=M	1	2.0	1:00	0	1	15		2.5	1.2	27	50:00	405	900
	2=T	2	2.0	1:00	0	1	15		2.5	1.2	27	50:00	405	900
	3=W	3	1.5	1:00	0	1	15		2.5	1.2	36	50:00	540	900
	4=T	4	1.5	1:00	0	1	15		2.5	1.2	36	50:00	540	900
	5=F	5	1.5	1:00	0	1	15		2.5	1.2	36	50:00	540	900
2	1=M	6	1.5	1:00	0	1	15		2.5	1.2	36	50:00	540	900
	2=T	7	1.0	1:00	0	1	15		2.5	1.2	45	50:00	675	900
	3=W	8	1.0	1:00	0	1	15		2.5	1.2	45	50:00	675	900
	4=T	9	1.0	1:00	0	1	15		2.5	1.2	45	50:00	675	900
	5=F	10	1.0	1:00	0	1	15		2.5	1.0	45	50:00	675	900
3	1=M	11	1.0	1:00	0	1	15		2.5	1.0	45	50:00	675	900
	2=T	12	1.0	2:30	0	1	9		2.5	1.0	45	43:30	1012	1350
	3=W	13	1.0	2:30	0	1	9		1.0	1.0	45	30:30	1012	1350
	4=T	14	1.0	5:00	0	1	7		2.5	1.0	45	50:00	1575	2100
	5=F	15	1.0	5:00	0	1	7		1.0	1.0	45	41:00	1575	2100
4	1=M	16	1.0	5:00	0	1	7		2.5	1.0	45	50:00	1575	2100
	2=T	17	1.0	7:30	0	1	6		2.5	1.0	45	57:30	2025	2700
	3=W	18	1.0	7:30	0	1	6		1.0	1.0	45	50:00	2025	2700
	4=T	19	1.0	10:00	0	1	5		2.5	1.0	45	60:00	2250	3000
	5=F	20	1.0	10:00	0	1	5		1.0	1.0	45	54:00	2250	3000
5	1=M	21	1.0	10:00	0	1	5		2.5	1.0	45	60:00	2250	3000
	2=T	22	1.0	12:30	0	1	4		2.5	1.0	45	57:30	2250	3000
	3=W	23	1.0	12:30	0	1	4		1.0	1.0	45	53:00	2250	3000
	4=T	24	1.0	15:00	0	1	4		2.5	1.0	45	67:30	2700	3600
	5=F	25	1.0	15:00	0	1	4		1.0	1.0	45	63:00	2700	3600
6	1=M	26	1.0	15:00	0	1	4		2.5	1.0	45	67:30	2700	3600
	2=T	27	1.0	20:00	0	1	3		2.5	1.0	45	65:00	2700	3600
	3=W	28	1.0	20:00	0	1	3		1.0	1.0	45	62:00	2700	3600
	4=T	29	1.0	30:00	0	1	2		2.5	1.0	45	62:30	2700	3600
	5=F	30	1.0	30:00	0	1	2		1.0	1.0	45	61:00	2700	3600
7	1=M	31	1.0	30:00	0	1	2		2.5	1.0	45	62:30	2700	3600
	2=T	32	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	3=W	33	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	4=T	34	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	5=F	35	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
8	1=M	36	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	2=T	37	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	3=W	38	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	4=T	39	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600
	5=F	40	1.0	60:00	0	1	1		0.0	1.0	45	60:00	2700	3600

APPENDIX B

BASIC STATISTICS FOR TRAINING DATA

Table B-1. **Basic Statistics for Percentage of Body Weight Loss, Environmental Factors and Performance Criteria for Experiment One**

Variable	N[a]	Mean	Standard Deviation	Simple Correlations				
				Air Temp	Per Humid	Bar Press	Per Body Wt Loss	PEM
SPT C								
Air Temp (F)	367	72.9	4.8					
Per Humid	367	39.0	12.1	.110				
Bar Press (mmHg)	367	740.7	4.3	-.276	-.713			
Per Body wt loss	367	1.7	.5	-.066	-.206	.044		
PEM	367	55.4	20.2	-.199	-.359	.121	.258	
PSF	367	56.8	19.5	-.398	-.312	.164	.196	.872
SPT No C								
Air Temp (F)	376	73.1	4.6					
Per Humid	376	38.5	12.3	.125				
Bar Press (mmHg)	376	740.8	4.2	-.263	-.715			
Per Body wt loss	376	1.7	.6	.000	-.200	.046		
PEM	376	61.6	25.9	-.165	-.383	.210	.115	
PSF	376	62.6	23.4	-.260	-.271	.129	.032	.868
END C								
Air temp (F)	340	73.9	4.0					
Per Humid	340	47.1	10.7	.134				
Bar Press (mmHg)	340	739.5	3.8	-.288	-.675			
Per Body wt loss	340	2.5	1.0	.374	.139	-.240		
PEM	340	82.8	24.7	-.279	-.173	.232	-.069	
PSF	340	70.7	18.6	-.403	-.083	.159	-.118	.685
END No C								
Air Temp (F)	348	73.9	4.0					
Per Humid	348	47.0	10.6	.151				
Bar Press (mmHg)	348	739.5	3.8	-.294	-.677			
Per Body wt loss	348	2.6	1.0	.439	.114	-.159		
PEM	348	82.2	18.7	-.231	-.253	.286	-.003	
PSF	348	69.6	19.2	-.254	-.102	.153	.021	.748

N[a] = total days training, all animals

APPENDIX B--continued

Table B-2. Basic Statistics for Percentage of Body Weight Loss, Environmental Factors, and Performance Criteria for Experiment Two

Variable	N[a]	Mean	Standard Deviations	Simple Correlations: Air Temp.	Per Humid	Bar Press	Per Body Wt Loss	PEM
REG SPT - Sugar								
Air Temp (F)	105	75.32	2.99					
Per Humid	105	45.70	6.20	.638				
Bar Press (mmHg)	105	742.78	2.56	-.414	-.711			
Per Body Wt. Loss	105	2.42	.59	.044	.086	-.176		
PEM	105	79.57	14.85	.293	.309	-.362	.173	
PSF	105	89.31	7.40	.162	.178	-.143	-.219	.464
REG SPT - No Sugar								
Air Temp (F)	146	75.36	3.02					
Per Humid	146	45.78	6.34	.648				
Bar Press (mmHg)	146	742.78	2.55	-.427	-.355			
Per Body Wt. Loss	146	2.00	.56	.183	.158	-.186		
PEM	146	74.43	23.49	.344	.329	-.337	.106	
PSF	146	83.71	8.33	.275	.254	-.219	.034	.447
HT SPT - Sugar								
Air Temp (F)	137	75.39	2.89					
Per Humid	137	45.79	6.24	.397				
Bar Press (mmHg)	137	742.73	2.52	.178	.505			
Per Body Wt. Loss	137	2.14	.68	.014	.028	.024		
PEM	137	63.46	23.99	.133	.099	.112	.127	
PSF	137	70.28	24.57	.122	.063	.088	.069	.611
HI SPT - No Sugar								
Air Temp (F)	141	75.42	3.02					
Per Humid	141	45.87	6.42	.630				
Bar Press (mmHg)	141	742.85	2.53	-.422	-.710			
Per Body Wt. Loss	141	1.98	.70	.119	.169	-.116		
PEM	141	59.84	30.24	.364	.315	-.335	.356	
PSF	141	68.33	25.54	.350	.252	-.296	.263	.782
REG END - Sugar								
Air Temp (F)	145	75.44	2.99					
Per Humid	145	45.99	6.31	.638				
Bar Press (mmHg)	145	742.70	2.55	-.407	-.708			
Per Body Wt. Loss	145	2.59	.83	.149	.016	.036		
PEM	145	95.86	18.90	.286	.187	-.087	.207	
PSF	145	89.11	9.85	.171	.068	-.080	.159	.311

continued

APPENDIX B--Table B-2--continued

Variable	N[a]	Mean	Standard Deviations	Simple Correlations: Air Temp.	Per Humid	Bar Press	Per Body Wt. Loss	PEM
REG END - No Sugar								
Air Temp (F)	140	75.39	3.02					
Per Humid	140	45.79	6.47	.649				
Bar Press (mmHg)	140	742.79	2.56	-.417	-.711			
Per Body Wt. Loss	140	2.43	.63	.321	.202	-.112		
PEM	140	80.80	24.22	.283	.312	-.265	.351	
PSF	140	77.99	17.16	.075	.086	-.097	.157	.633
HI END - Sugar	87	75.57	3.10					
Per Humid	87	46.34	6.65	.674				
Bar Press (mmHg)	87	742.64	2.61	-.469	-.716			
Per Body Wt. Loss	87	2.90	.75	-.058	-.096	.166		
PEM	87	58.34	34.99	.200	.224	-.255	-.141	
PSF	87	50.71	30.48	.122	.147	-.245	-.193	.918
HI END - No Sugar								
Air Temp (F)	108	75.50	3.00					
Per Humid	108	46.02	6.30	.662				
Bar Press (mmHg)	108	742.75	2.56	-.450	-.715			
Per Body Wt. Loss	108	2.84	.68	.191	.070	.074		
PEM	108	55.67	31.11	.212	.180	-.151	.043	
PSF	108	47.92	29.37	.155	.145	-.190	-.006	.929