EFFECTS OF EXERCISE AND A VEGETARIAN DIET ON CARCASS COMPOSITION, ORGAN WEIGHTS, AND SERUM CHOLESTEROL AND TRIGLYCERIDES

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This is to certify that the

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ABSTRACT

EFFECTS OF EXERCISE AND A VEGETARIAN DIET
ON CARCASS COMPOSITION, ORGAN WEIGHTS, AND
SERUM CHOLESTEROL AND TRIGLYCERIDES

By

Daniel Allen Klein

The purpose of this study was to compare the effects of a strict vegetarian diet and a control diet containing animal protein (5.23%) under various conditions of physical activity. The parameters studied included quantitative responses to exercise, total carcass composition, organ weights, serum cholesterol, and serum triglycerides.

Fifty, twenty-three-day-old male albino rats (Sprague-Dawley strain) were randomly assigned to either a control dietary group or to an experimental vegetarian dietary group. Within each dietary group, the animals were randomly assigned to one of three exercise programs. Seven animals from each dietary group were placed into a sedentary subgroup. Seven animals from each dietary group were placed into a voluntary-exercise program. The remaining eleven animals, from each dietary group, were placed into a forced-exercise program. Six animals were desired in each diet-training subgroup for final analysis. One extra animal was placed in each sedentary and voluntary-exercise subgroup as a contingency against injury or illness. Five extra animals were placed in each forced-exercise subgroup because during a typical forced-exercise training program some of the animals either become injured or fail to respond to the program

and must be dropped from the experiment.

At ninety days of age, blood samples were taken and the animals were sacrificed. The samples were analyzed for serum cholesterol and triglycerides. Wet weights were taken of the liver, kidneys, adrenals, spleen, heart, and testes. The carcasses then were frozen until determinations of body composition were made.

Higher levels of exercise produced animals with higher per cent carcass weight due to water, protein, and ash with a lower per cent carcass weight due to fat.

When the forced-exercise group was compared to the sedentary group, the active animals were found to have significantly lower relative liver weights and significantly higher relative adrenals, heart, and testes weights. Serum cholesterol and triglyceride values were significantly lower in the same animals.

As compared to the control diet, the vegetarian diet produced animals that performed at a lower level on the forced-exercise program; but there was no difference between the two diet groups with respect to voluntary-activity. The vegetarian animals were fatter with lower amounts of ash. The animals that were on the vegetarian diet had larger kidneys, hearts, and smaller adrenals.

Due to the small sample size, the statistical power was less than 0.30 in all analyses where significant differences were not observed. Therefore, failure to demonstrate significance should not be interpreted, at this time, as justification for acceptance of the hypothesis of no treatment effects.

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By

Daniel Allen Klein

A THESIS

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DEDICATION

This thesis is dedicated to my wife, Sharon, for her understanding inspiration, patience, hard work, and many sacrifices and to my mother whose encouragement has made it possible to attain this goal in my education.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

In 1912, Slonaker reported on the effects of an all vegetable diet on laboratory rats (81). McCollum, Wu and others used similar diets with laboratory animals but had little success (68, 107). In general, they found that animals on vegetarian diets were less active, contracted more illness, and did not grow as well as the controls.

The fact that people in China, Japan, and India, and other countries used a vegetarian diet, and were able to stay healthy and active, continued to puzzle these investigators. As an understanding of nutrition broadened and specific nutritional requirements for various species were found, diets were developed that were adequate in terms of both growth and health characteristics.

Exercise also affects the growth and development of animals (13, 49, 93). As the intensity of exercise increases, differences in body weight (13, 49, 93) and carcass composition (49, 93) are increased. With the increased knowledge about nutrition and exercise, it is important that questions about all vegetable diets be studied with respect to various exercise programs.

Purpose of the Study

The purpose of this study was to determine the effects of a strict vegetarian diet, with different levels of exercise, on carcass composition, organ weights, serum cholesterol, and serum triglycerides.

Need for the Study

Previous investigators have looked at the effects of vegetarian diets only from the viewpoint of overall growth or weights gains and voluntary activity (68, 81, 107). Because these variables are easy to measure and tend to show an overall affect on laboratory animals, early investigators ceased to look farther. Changes that take place in carcass composition, organ weights, and serum values would give a more complete picture as to the affects of diet on the whole animal.

Exercise levels were included so diet affect on voluntary as well as forced-exercise programs could be measured. Different exercise levels are necessary to observe diet-exercise interaction effects.

Many times the land area is needed to produce equal amounts of usable protein from animals as from vegetables (36, 64, 105, 106). If vegetarian diets can be developed which are as good as omnivorous diets, more efficient use of our land area can then solve part of the world food problem.

Some vegetable diets have been utilized in reducing serum cholesterol levels (1, 2,,9, 34, 38) which in turn are associated with a lower incidence of atherosclerosis and heart disease in man (12, 17, 21, 47, 50, 51, 58, 84, 85, 91). The results are unclear as to the changes in serum cholesterol levels in man while on an exercise program (27, 53, 66, 71). Although no attempt was made to measure atherosclerosis or heart degeneration, diet-exercise effect in altering serum cholesterol levels might have important implications.

Limitations of the Study

Because of the difficulty of working with an adequate number of humans, male albino rats were used. Male albino rats can easily be kept on various controlled exercise programs which were of interest in this study. Changes that might have taken place in the serum cholesterol and triglycerides with respect to exercise levels and diet groups, could be easily measured. The rat and man appear to utilize cholesterol in a similar manner (43, 77). For these above reasons, it was decided to use the male albino rat for this study. Conclusions drawn from animal studies cannot be directly applied to humans. It will be necessary to repeat the study controlling the dietary intakes of an experimental group of human subjects. It should be noted, however, that in many ways the internal chemistry of man and the rat are similar (73).

The rat requires arginine and histidine in the diet that adult humans do not need (3). Both diets used in this study contained small amounts of both these essential amino acids for the rat.

The control animals were fed Wayne Lab Blox. In this dry block form, the animals had to eat the mixed block composition if they ate anything. The experimental animals were fed food in various forms and containers. Some of the food the experimental animals were fed was dry, some had a high moisture content, and some was in liquid form. It is not known if the difference in feeding procedures affected the results of the study.

The Wayne Lab Blox that were fed the control animals contained approximately 5.26 per cent animal protein. If finances and space had been available, the use of a feed which contained higher levels of an all-animal protein should have been used. If a high-animal protein diet could have been compared directly to a strict vegetable protein diet, the results might have been more definitive.

The Wayne Lab Blox diet contained 4.15 per cent fat. While the vegetable diet fat content was not controlled, it contained approximately twice the fat level of the Wayne Lab Blox. It is not known to what extent the results of the study were affected by this difference, but it was to be expected that the vegetarian animals would be somewhat fatter.

Definition of Terms

Clarification of several terms used in this report will facilitate a better understanding by the reader.

Control Animals

Male albino Sprague-Dawley rats fed the standard laboratory diet of Wayne Lab Blox.

Strict Vegetarian Animals

Male albino Sprague-Dawley rats fed the experimental diet which contained no food of animal origin.

Sedentary Animals

These animals were housed in individual cages approximately ten inches long, eight inches wide, and seven inches high. Their exercise was restricted to movement within their cages.

Voluntary Exercise Animals

These animals were housed in individual cages approximately ten inches long, eight inches wide, and seven inches high. Each cage had an exercise wheel attached so the rats could run at will.

Forced Exercise Animals

These animals were housed in individual cages approximately ten inches long, eight inches wide, and seven inches high. Except for forced exercise training periods, the animals were restricted to movement within their cages.

Force Exercise Program

The medium C-RW exercise program developed at Michigan State University Human Energy Research Laboratory was used (see Appendix C). The total training program requires about eight weeks.

Vegetarian Diet

A vegetarian diet consists of food intake primarily of vegetable origin. Some dairy products as well as eggs are often used to supplement the diet. When these products are used the diet is often referred to as a lacto-ovo-vegetarian diet.

Vegetarian or Strict Vegetarian Diet

A strict vegetarian diet consists of foods only of vegetable origin. No animal products or by-products are used in a strict vegetarian diet.

PER

This term stands for per cent expected revolutions. This is one of the measurements taken from the forced-exercise program.

$\overline{\text{PER}}$

This term stands for the mean of the per cent expected revolutions.

PSF

This term stands for per cent shock free time. This term is one of the measurements taken from the forced-exercise program.

$\overline{\text{PSF}}$

This term stands for the mean of the per cent shock free time.

TRR

This term stands for total revolutions run. This is one of the measurements taken from the forced-exercise program.

$\overline{\text{TRR}}$

This term stands for the mean of the total revolutions run.

CDS

This term stands for cumulative duration of shock. It is one of the measures taken from the forced-exercise program.

$\overline{\text{CDS}}$

This term stands for the mean of the cumulative duration of shock.

VOL

This term stands for the number of voluntary revolutions run in the voluntary exercise program

$\overline{\text{VOL}}$

This term stands for the mean of the voluntary revolutions run in the voluntary exercise program.

N. R. C.

This term stands for National Research Council. This council sets the levels of recommended daily dietary allowances.

CHAPTER II

RELATED LITERATURE

The literature revealed only two types of studies where rats were maintained on strict vegetarian diets. Several studies used rats to test the biological value of specific proteins. They were not, however, concerned with the overall value of a complete diet. Other experiments studied the effects of cholesterol in the diet and blood. Again, they were not concerned with the overall quality of a diet, only cholesterol control.

Therefore, most of the related literature has to do with observations made on people who were on or given a vegetarian diet.

Food Shortages

One of our most pressing problems today is that of adequately feeding the people of the world. A major reason for the acute food shortages is that many times the land area is needed to produce an equal amount of uasble protein in animal form as from vegetables (36, 64, 105, 106). A considerable portion of this problem may be eliminated through the use of vegetable proteins.

Deficiency in Diets

Vegetarian diets can be adequately used by humans but, the most serious drawback appears to be the lack of vitamin B_{12} (7, 24, 40, 46, 78, 79, 80, 82, 102, 103, 106). Vitamin B_{12} anemia is clinically the most common deficiency seen in vegetarians. Whenever it is found, the diet is unbalanced and lacking in several areas (86). Exogenous doses of even 1 microgram per day of B_{12} is sufficient to remove the signs of the anemia (24, 46, 80, 102). Vegetarians apparently are more efficient in the use of the B_{12} that is in the diet than are non-vegetarians. With dietary intake well below recommended levels, most vegetarians show no signs of B_{12} anemia. Some reports show that alterations in the intestinal flora help compensate for the low B_{12} levels in the diet (79, 103). There is little question that a vegetarian diet supplemented with small amounts of eggs and milk is more than adequate from a nutritional standpoint. Several workers have found that a strict vegetarian diet can safely be used if there is variation in intake and sufficient calorie content (23, 24, 36, 37, 46, 74, 75, 103, 105).

Advanced cases of malnutrition have been improved by the use of strict vegetarian diets. Dean (22) and others have shown that recovery from advanced cases of kwashiorkor was complete when such diets were used. In fact, recovery is as fast or faster on the vegetarian diet as when the standard nutritional diet of cows' milk as the main source of protein is used. The protein source can be either soybeans or other high vegetable proteins common to the area (4, 10, 22).

Sanchez, Scharffenberg, and Register (77) make the point that vegetable diets are too low in methionine and or lysine for the rat. Although similar in metabolism, not enough is known about the human need for these amino acids. No ill effects are seen in human subjects, after a prolonged use of a vegetarian diet, that would indicate the need to increase the amounts of lysine and or methionine.

Cholesterol and Diet

The lowering of serum cholesterol has been closely studied in regard to a vegetarian diet. The main control of serum cholesterol levėls seems to be the proportion of fat intake that is in the form of unsaturated fatty acids (1, 2, 5, 9, 34, 38, 41, 55, 60, 61, 62, 63, 78, 90, 95, 97). Most of the unsaturated fatty acids are of vegetable origin. A vegetarian diet apparently keeps the serum cholesterol levels down because of the high amounts of unsaturated fats naturally occurring in the diet. At one time it was thought that the amount of cholesterol in the diet per se controlled the serum levels, however, this view is no longer accepted. Some studies have shown that altering the cholesterol intake in the diet was the controlling factor in maintaining serum cholesterol levels (14, 29, 56). If cholesterol intake is kept within the normal range, serum cholesterol levels are independant of cholesterol intake (48, 57, 59). Generally, serum cholesterol levels vary directly with the percentage of fat intake that is in the form of saturated fatty acids. The apparent control of serum cholesterol by the relative amount of saturated fatty acid in the diet is a real advantage to the vegetarian. Vegetarian diets are low in saturated and high in unsaturated fatty acids. Studies measuring cholesterol levels in vegetarians as compared to controls, have found the vegetarian serum cholesterol levels lower (61, 62, 63, 66, 78, 90, 95, 97, 98).

Diet and Disease

Carlson (12), Conner (17), Hodges (47), Kannel *et al.* (50), and others have shown an association between serum cholesterol levels and cardiovascular diseases. As serum levels rise, so does the risk of coronary heart disease and atherosclerosis. Dayton *et al.* (21) in a

well controlled study on 848 volunteers came to the same conclusion. He divided the volunteers into two matched groups. Control and experimental diets were the same except that the animal fats were replaced by unsaturated vegetable fats in the experimental diet. The experimental diet induced an immediate drop in cholesterol levels which continued throughout the study. Eight years after the start of the study, some of the results were quite conclusive. When death due to coronary and cerebral infarction were combined with non fatal coronary and cerebral infarctions, the experimental dietary group had significantly fewer total attacks. The experimental diet of vegetable fats replacing animal fats seems to offer some protection to the user. The experiment was designed and carried out double blind so that the bias of the examiners was eliminated. Kannel _et_ _al_. (51) has similar data that show, where serum cholesterol levels are high, there is three times the incidence of coronary heart disease in men.

Coronary heart disease and atherosclerosis vary across countries. As a nation ingests more saturated fatty acids the incidence of these diseases rises (52, 58, 65, 85). Coronary heart disease and atherosclerosis also vary within a nation with respect to socio-economic level. As the family income rises, so does the general use of saturated animal fats (90, 91). Although not all the increase in the above diseases can be attributed to dietary intake, certainly some portion can. The use of fewer calories, less saturated fat and more unsaturated fat in the diet will promote good health and reduce the risk of atherosclerosis and coronary heart disease (84, 86).

Vegetable Protein Source

Soybeans are a common cource of proteins in vegetarian diets (18, 32, 35, 39, 64, 104). Other sources have been used (26, 35, 41, 77), but soybeans are widely grown and easy to handle commercially. Isolated soybean protein as a substitute for meat protein can apparently meet all the (N. R. C.) allowances (18, 64).

Nitrogen Balance

Nitrogen balance indicates that humans use plant proteins in essentially the same way as animal proteins (18, 26, 74, 77). Hegsted et al. (44) report that it is unlikely that any protein deficiency will develop in people who are on a vegetarian diet if there are adequate calories and the intake is somewhat varied. This is substantiated in studies by Donath et al. (25), Ellis and Mumford (28), West and Ellis (96), and others, where they show that there are no clinical differences between vegetarians and matched controls in the population (23, 37, 67, 70, 75). Hematological and biochemical tests on the blood and serum are all within normal range.

Exercise and Cholesterol

Physical activity can alter serum cholesterol indirectly. If body weight is maintained, little or no effect is seen in serum cholesterol (27, 53, 71). Montoye et al. (71) report that a drop may be seen in individuals with very high initial serum levels who are on an exercise program. Serum cholesterol levels become lower in exercising individuals probably because they are lowering body fat and total body weight.

CHAPTER III

EXPERIMENTAL METHOD

Fifty male Sprague-Dawley albino rats were purchased from Spartan Breeders. The animals were twenty-three days of age when brought to the Michigan State University Human Energy Research Laboratory.

The animals were randomly assigned to either a control dietary group or to an experimental vegetarian dietary group. Within each dietary group, the animals were randomly assigned to one of three exercise programs. Seven animals from each dietary group were placed into a sedentary subgroup. Seven animals from each dietary group were placed into a voluntary-exercise program. The remaining eleven animals, from each dietary group, were placed into a forced-exercise program. Six animals were desired in each diet-training subgroup for final analysis. One extra animal was placed in each sednetary and voluntary-exercise subgroup as a contingency against injury or illness. Five extra animals were placed in each forced-exercise subgroup because during a typical forced-exercise training program some animals either become injured or fail to respond to the program and must be dropped from the experiment.

For final analysis, one animal was randomly selected from each sedentary subgroup to be discarded from the experiment. One animal from each voluntary subgroup was chosen to be dropped from the experiment on the basis of being the most extreme in voluntary activity. The six most homogenous animals with respect to activity were chosen for final analysis from each voluntary subgroup (see Appendix B). There was one animal in each voluntary subgroup that was extremely high in voluntary activity; both of these extreme animals were discarded. The six animals, in each forced-exercise subgroup, were chosen on the basis of performance in the training program. The six animals, in each forced-exercise subgroup, that performed the best (see Appendix B) in the C-RW program were chosen for final analysis.

Sedentary animals were in sedentary cages from the day they were brought into the laboratory until they were sacrificed.

The voluntary animals were in cages with access to the running wheels from the day they were received until they were sacrificed.

Forced exercise animals were placed in cages, with access to voluntary running wheels for approximately ten days. These animals were allowed the use of exercise wheels so they would learn how to run in a wheel before going into the training program. At thirty-five days of age, these animals were started on the C-RW program. When the animals started in the forced-exercise program, they were changed into sedentary cages. The exercise they received was limited to the running they did in the interval training program.

The control animals were fed Wayne Lab Blox <u>ad libitum</u>. This diet contained: 24.52 per cent crude protein, 4.0 per cent crude fat, and 4.5 per cent crude fiber. In the control diet 21 per cent of the crude protein was in the form of animal protein, thus 5.26 per cent of the total control diet was animal protein. Actual contents of the Wayne Lab Blox are as follows in decreasing quantity: animal liver meal, fish meal, dried whey, corn and wheat flakes, ground yellow corn, ground oat groats, soybean meal, wheat germ meal, wheat middlings, cane molasses, dehydrated alfalfa meal, soybean oil, brewers dried yeast, vitamin A palmitate, irradiated dried yeast D-activated animal sterol, vitamin E supplement, menadione sodium bisulfite, riboflavin supplement, niacin, calcium panthothenate, choline chloride, thiamine, ground limestone, dicalcium phosphate, salt manganous oxide, copper sulfate, iron sulfate, potassium iodate, cobalt carbonate, and zinc oxide.

The daily strict vegetarian diet for each each experimental animal consisted of:

High Protein		Soy Milk	
Loma Linda Vegeburger	two ounces	Worthington Soyamel	two fluid ounces

Grains	Other	
one part wheat	carrot	small slice
one part barley	green bean	one-third
one part oats	lettuce	four square inches
one part rice	green ripe olive	one-half
one part rye	apple	one-twelfth
one-half part millet	pecan meal	one-quarter teaspoon
one-fourth part peas		

The dry grains were ground and mixed because it was found that the animals would selectively eat certain grains, which would negate the necessary protein complementation (11). The grain mixture was placed in a single container in each cage so the mixture would remain dry. The grain was placed in the container in sufficient quantity so as to be continuously available to each animal. The soy milk was placed in a second small container so it would not be mixed with the other food. The high protein vegeburger and other foods in the diet were placed in a third container.

Both the control and experimental animals had free access to water.

The experimental group's water intake was subjectively observed to be much lower than the control group's. This is probably due to the fact that all the food that the experimental animals had, except the grain, contained a considerable amount of moisture.

Temperature control was maintained in the animal room at 72° F $\pm$ 2°. In the forced-exercise room, the temperature was maintained at 69° F $\pm$ 2° with no attempt to control humidity.

Lighting in the animal room was maintained on a cycle of twelve hours of light and twelve hours of darkness.

Body weight for each animal was recorded at the same hour on Sunday of each week during the experimental period.

The voluntary activity was recorded at the same hour each day as the number of revolutions the animals had run in the previous twenty-four hour period.

The training program for the two forced-exercise subgroups was the medium endurance control running wheel program. This program was developed at the Michigan State University Human Energy Research Laboratory (see Appendix C).

When the animals were approximately ninety days old, blood samples were taken and the animals sacrificed. The method for analyzing serum cholesterol followed the procedure developed by Haung, Wefler, and Raftery (42). The method for analyzing serum triglycerides followed the procedure developed by Van Handel and Zilversmit (92). The animals were prepared for carcass analysis at sacrifice following the procedure developed by Mickelsen and Anderson (69), and selected body organs were removed from the animals and weighed immediately.

Diet and training were used in the analysis as independent variables. The following were used as dependent variables: relative carcass water, fat, protein, and ash: relative adrenal, heart, kidney, liver, spleen, and testes; cholesterol (mg %) and triglycerides (mg %); final body weight, $\overline{\text{PER}}$ last four weeks, $\overline{\text{PER}}$ last five days, $\overline{\text{PSF}}$ last four weeks, $\overline{\text{PSF}}$ last five days, $\overline{\text{VOL}}$ last four weeks, $\overline{\text{VOL}}$ last seven days. The voluntary and forced-training data were divided into values above and below their respective medians and analyzed for differences between the diets on performance level. Since training causes large differences in body weight, comparisons of absolute body composition and organ weights were analyzed to see if growth might be retarded as suggested by previous workers (92). All relative and absolute values were analyzed for differences between the two diet groups as well as differences between the various exercise levels.

Standard one-and two way fixed effects analysis of variance techniques were employed, where appropriate, to analyze the data. The Tukey method for multiple comparisons between means was used wherever necessary. The Sign Test was used to analyze the voluntary and forced-exercise data. The alph level of $p \leq .05$ was chosen because of the small number of animals that were used.

CHAPTER IV

PRESENTATION OF DATA

The purpose of this investigation was to compare the effects of a strict vegetarian diet and a control diet containing animal protein (5.23%) in young albino rats. Two diet groups were used, both groups receiving selected exercise programs. The parameters studied included: quantitative responses to forced exercise, total carcass composition, organ weights, serum cholesterol and serum triglycerides. The experimental design was developed to study the parameters as they relate to physical activity as well as diet.

All of the parameters, except the training data, were analyzed statistically by two-way analysis of variance to determine the effects of diet, physical activity, and the interactions between the two. With two exceptions, there were no significant interaction effects in any of the analyses. This indicated that except for the effects on serum cholesterol and relative carcass ash values, the effects of training were independent of the effects of diet in the variables studied. Since no other significant interaction effects were observed, the exercise and diet effects are presented separately in this chapter.

Exercise Analyses

Responses to Forced Exercise

The effects of diet upon the training responses are shown in Figures 1, 2, 3, 4. These results show that the diet groups signifi-

cantly differed in their responses to training. The per cent of expected revolutions run (PER), per cent shock free time (PSF), and total revolutions run (TRR), were all significantly less (Sign Test $P<0.0001$) for the experimental animals on the all-vegetable diet than for the control-diet animals. The cummulative duration of shock (CDS) was significantly greater for the experimental-diet group ($P<0.0001$). These results clearly indicate that the animals receiving the control diet (5.23% animal protein) responded more favorably to the training program on all measures: TRR, PER, PSF, and CDS.

In each of Figures 1, 2, 3, and 4 there is a break in the program at the eighth training day. Some of the animals were not responding well to the Medium Endurance C-RW program at this time, so the program intensity was reduced and the number of animals being trained simultaneously was lowered from six to two or three. After three weeks of this modified program, the animals had progressed to the level of the nineteenth training day, and the normal training progression was resumed.

Response to Voluntary Exercise

The mean voluntary revolutions run by the two dietary subgroups are shown in Figure 5. The diet groups did not differ in their voluntary activity patterns. The animals in the voluntary exercise groups did not participate in the forced exercise program.

Discussion within Exercise

It is puzzling as to why there should be such a marked difference in the forced-exercise results and no difference in the voluntary-activity results. Certainly the performance of the experimental animals in forced exercise was significantly poorer. This is an important finding, but it cannot be explained from the present design.

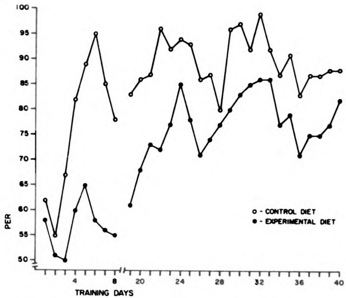

Figure 1 - PERCENT OF EXPECTED REVOLUTIONS (PER)

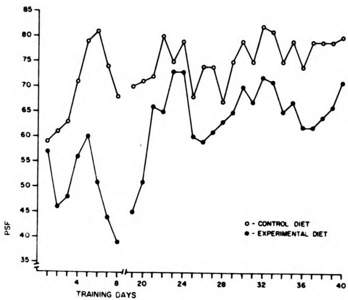

Figure 2 - PERCENT SHOCK-FREE TIME (PSF)

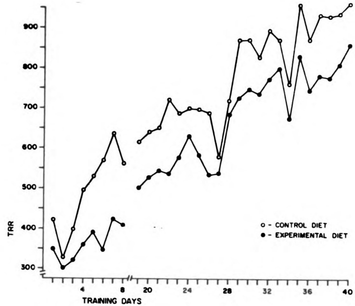

Figure 3 - TOTAL REVOLUTIONS RUN (TRR)

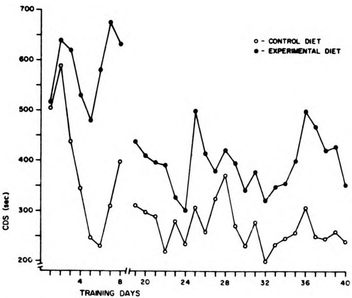

Figure 4 - CUMULATIVE DURATION OF SHOCK (CDS)

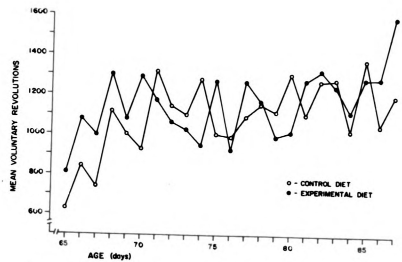

Figure 5 - MEAN VOLUNTARY REVOLUTIONS RUN

Serum Analyses

Two-way analysis of variance tables are listed for all of the rest of the data analyzed.

Diet Effects on Serum Cholesterol and Triglycerides

The results of the analyses of serum cholesterol and serum triglyceride levels by diet and exercise groups are shown in Tables 1 and 2.

The mean values for serum cholesterol and triglycerides were lower for the experimental-diet group, but the difference was not statistically significant (Tables 1 and 2). However, the results are of interest since the control diet contained only 4 per cent animal fat, whereas the experimental diet contained about twice that quantity of vegetable fat.

Exercise Effects on Serum Cholesterol and Triglycerides

With higher intensities of exercise, cholesterol and triglyceride levels are successively lower ($P<0.009$ and $P<0.0005$ respectively). There also was a decrease in total body fat with increasing exercise intensity, possibly the decreases on serum cholesterol and triglycerides were due to lower body fat. The effects of exercise in lowering serum cholesterol and triglycerides are in line with previous work (72).

Interaction Effect on Serum Cholesterol

There was a significant interaction between diet and training with respect to serum cholesterol ($P<0.04$). This was due to the relatively low value found in the sedentary animals which were on the experimental diet.

Body Composition Analyses

Tables 3 and 4 present the body and carcass weight data analyzed by diet and exercise.

Table 1 --- Serum Analysis: Cholesterol (milligrams per cent)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	58.6	62.1	60.5			
	s	6.0	2.8	4.5			
	n	4	5	9			
Voluntary	$\bar{X}$	69.4	72.0	70.7			
	s	5.9	6.6	6.1			
	n	6	6	12			
Sedentary	$\bar{X}$	87.5	66.4	76.0			
	s	22.3	11.2	19.5			
	n	5	6	11			
Overall Values by Diet	$\bar{X}$	72.6	67.1		0.21	0.65	none
	s	17.3	8.5				
	n	15	17				
AOV Results by Activity	F			5.63			
	P			0.009			
Significant Comparisons between Activity Groups				F<S			

Table 2 --- Serum Analysis: Triglycerides (milligrams per cent)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	55.5	21.1	34.9			
	s	66.6	6.6	42.7			
	n	4	6	10			
Voluntary	$\bar{X}$	59.2	63.2	61.2			
	s	43.5	38.3	31.2			
	n	6	6	12			
Sedentary	$\bar{X}$	109.2	134.8	152.0			
	s	71.5	70.6	72.9			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	99.5	73.1		0.93	0.34	none
	s	79.0	67.1				
	n	16	18				
AOV Results by Activity	F			13.37			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<S V<S			

Table 3 --- Body Weight (gms)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	330.0	320.3	325.2			
	s	14.3	11.1	13.2			
	n	6	6	12			
Voluntary	$\bar{X}$	372.3	387.7	380.0			
	s	28.4	13.2	22.6			
	n	6	6	12			
Sedentary	$\bar{X}$	439.0	430.0	434.5			
	s	7.6	19.7	15.0			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	380.4	379.3		0.04	0.84	none
	s	49.4	48.6				
	n	18	18				
AOV Results by Activity	F			134.07			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 4 --- Carcass Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	266.7	256.7	261.7			
	s	18.3	6.4	14.1			
	n	6	6	12			
Voluntary	$\bar{X}$	292.3	309.2	300.8			
	s	24.1	9.3	19.5			
	n	6	6	12			
Sedentary	$\bar{X}$	354.2	357.8	356.0			
	s	31.3	25.0	27.1			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	304.4	307.9		0.27	0.60	none
	s	44.6	45.0				
	n	18	18				
AOV Results by Activity	F			66.86			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Diet and Exercise Effects on Body Weight and Carcass Weight

There was no significant difference between the two diet groups with respect to body weight or carcass weight.

Exercise had a significant effect on both body weight and carcass weight. Mean body and carcass weights were progressively lower with greater exercise intensities.

Diet Effect on Carcass Composition

The summary results of the analyses of both relative and absolute carcass water, fat, protein and ash are shown in Table 5. The two-way analyses for individual variables are in Tables 7 through 14.

There were significant mean differences between the two diet groups with respect to both fat and ash. The experimental diet used in this study resulted in a significantly fatter animal. The reason the experimental animals were fatter was probably due to the higher fat content in their diet.

The animals on the experimental diet had a significantly lower level of ash than the control group. The difference observed in the ash content can not be explained from the current data. The difference may be due to greater skeletal development in the controls or merely to a greater quantity of other residue. The difference in the ash content between the diet groups is not a result of greater activity in the control forced-exercise group. The difference between the two diet groups is consistent and similar in magnitude at all three levels of exercise Table 13 and 14).

Exercise Effects on Carcass Composition

The summary results of the analyses of both relative and absolute carcass water, fat, protein and ash are shown in Table 6. The two-way

Table 5 --- Carcass Composition Data by Diet Groups

	Group Means: Control (N=18) $\bar{X} \pm s$	Group Means: Experimental (N=18) $\bar{X} \pm s$	F Value	Probability	Mean Comparison
Body Wt. (gms)	380.4 ± 49.4	379.3 ± 48.6	0.04	0.84	N
Carcass Wt. (gms)	304.4 ± 44.6	307.9 ± 45.0	0.27	0.61	N
Relative Carcass Composition (per cent carcass weight)					
Water	61.74 ± 2.86	60.96 ± 3.26	2.16	0.15	N
Fat	12.00 ± 4.35	14.16 ± 4.50	8.16	<0.008	S
Protein	21.75 ± 1.00	21.63 ± 1.23	0.19	0.66	N
Ash	3.75 ± 0.59	2.80 ± 0.42	152.2	<0.0005	S
Absolute Carcass Composition (Grams)					
Water	186.88 ±19.57	186.57 ±19.93	0.008	0.93	N
Fat	38.18 ±19.59	45.24 ±20.45	4.76	<0.04	S
Protein	65.81 ± 6.84	66.17 ± 6.80	0.12	0.73	N
Ash	11.23 ± 1.20	8.45 ± 0.61	87.14	<0.0005	S

Table 6 --- Carcass Composition Data by Exercise Level

	Group Means: Forced (N=12) $\bar{X} \pm s$	Group Means: Voluntary (N=12) $\bar{X} \pm s$	Group Means: Sedentary (N=12) $\bar{X} \pm s$	F Value	Probability Value	Mean Comparisons: F vs. V	F vs. S	V vs. S
Body Wt. (gms)	325.2 ± 13.2	380.0 ± 22.6	434.5 ± 15.0	134.1	0.0005	S	S	S
Carcass Wt. (gms)	261.7 ± 14.1	300.8 ± 19.5	356.0 ± 27.1	66.96	0.0005	S	S	S
Relative Carcass Composition (per cent carcass weight)								
Water	63.67 ± 1.26	62.58 ± 1.13	57.81 ± 2.34	45.77	0.0005	N	S	S
Fat	9.25 ± 2.13	11.86 ± 2.09	18.13 ± 3.17	48.44	0.0005	S	S	S
Protein	22.69 ± 0.75	21.73 ± 0.50	20.65 ± 0.91	20.74	0.0005	S	S	S
Ash	3.83 ± 0.60	3.18 ± 0.65	2.80 ± 0.43	59.86	0.0005	S	S	S
Absolute Carcass Composition (Grams)								
Water	166.61 ± 9.89	188.17 ± 12.18	205.40 ± 11.65	43.43	0.0005	S	S	S
Fat	24.21 ± 5.63	35.85 ± 7.61	65.06 ± 14.97	56.40	0.0005	S	S	S
Protein	59.34 ± 3.22	65.29 ± 3.51	73.34 ± 3.66	63.54	0.0005	S	S	S
Ash	10.03 ± 1.75	9.54 ± 1.85	9.96 ± 1.57	1.04	0.37	N	N	N

Table 7 --- Carcass Water (per cent carcass weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	64.1	63.3	63.7			
	s	0.5	1.7	1.3			
	n	6	6	12			
Voluntary	$\bar{X}$	62.9	62.2	62.6			
	s	.5	1.5	1.1			
	n	6	6	12			
Sedentary	$\bar{X}$	58.3	57.4	57.8			
	s	2.1	2.7	2.3			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	61.7	61.0		2.16	0.15	none
	s	2.9	3.3				
	n	18	18				
AOV Results by Activity	F			45.18			
	P			<0.0005			
Significant Comparisons between Activity Groups				F>S V>S			

Table 8 --- Carcass Water (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	170.8	162.4	166.6			
	s	12.0	5.3	9.9			
	n	6	6	12			
Voluntary	$\bar{X}$	184.0	192.4	188.2			
	s	15.6	6.3	12.2			
	n	6	6	12			
Sedentary	$\bar{X}$	205.8	205.0	205.4			
	s	12.7	11.7	11.7			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	186.9	186.6		0.01	0.93	none
	s	19.6	19.9				
	n	18	18				
AOV Results by Activity	F			43.43			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 9 --- Carcass Fat (per cent carcass weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	8.3	10.2	9.3			
	s	1.0	2.6	2.1			
	n	6	6	12			
Voluntary	$\bar{X}$	10.4	13.3	11.9			
	s	1.3	1.8	2.1			
	n	6	6	12			
Sedentary	$\bar{X}$	17.3	19.0	18.1			
	s	3.1	3.3	3.2			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	12.0	14.2		8.16	<0.008	C<E
	s	4.4	4.5				
	n	18	18				
AOV Results by Activity	F			48.44			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 10 --- Carcass Fat (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	22.2	26.2	24.2			
	s	3.4	6.9	5.6			
	n	6	6	12			
Voluntary	$\bar{X}$	30.6	41.1	35.9			
	s	5.1	5.0	7.6			
	n	6	6	12			
Sedentary	$\bar{X}$	61.7	68.4	65.1			
	s	15.1	15.4	15.0			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	38.2	45.2		4.76	<0.04	C<E
	s	19.6	20.4				
	n	18	18				
AOV Results by Activity	F			56.40			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 11 --- Carcass Protein (per cent carcass weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	22.6	22.8	22.7			
	s	0.5	1.0	0.8			
	n	6	6	12			
Voluntary	$\bar{X}$	21.9	21.6	21.7			
	s	0.6	0.4	0.5			
	n	6	6	12			
Sedentary	$\bar{X}$	20.7	20.6	20.7			
	s	0.8	1.1	0.9			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	21.7	21.6		0.19	0.66	none
	s	1.0	1.2				
	n	18	18				
AOV Results by Activity	F			20.74			
	P			<0.0005			
Significant Comparisons between Activity Groups				F > V F > S V > S			

Table 12 --- Carcass Protein (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	60.3	58.4	59.3			
	s	3.8	2.5	3.2			
	n	6	6	12			
Voluntary	$\bar{X}$	63.9	66.7	65.3			
	s	4.4	2.0	3.5			
	n	6	6	12			
Sedentary	$\bar{X}$	73.2	73.5	73.3			
	s	4.4	3.2	3.7			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	65.8	66.2		0.12	0.73	none
	s	6.8	6.8				
	n	18	18				
AOV Results by Activity	F			63.54			
	P			<0.0005			
Significant Comparisons between Activity Groups				F < V F < S V < S			

Table 13 --- Carcass Ash (per cent carcass weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	4.4	3.3	3.8			
	s	0.3	0.3	0.6			
	n	6	6	12			
Voluntary	$\bar{X}$	3.7	2.6	3.2			
	s	0.4	0.1	0.7			
	n	6	6	12			
Sedentary	$\bar{X}$	3.1	2.5	2.8			
	s	0.3	0.3	0.4			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	3.7	2.8		152.22	<0.0005	C > E
	s	0.6	0.4				
	n	18	18				
AOV Results by Activity	F			59.86			
	P			<0.0005			
Significant Comparisons between Activity Groups				F > V F > S V > S			

Table 14 --- Carcass Ash (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	11.6	8.5	10.0			
	s	0.8	0.5	1.8			
	n	6	6	12			
Voluntary	$\bar{X}$	11.0	8.1	9.5			
	s	1.5	0.4	1.8			
	n	6	6	12			
Sedentary	$\bar{X}$	11.1	8.8	10.0			
	s	1.3	0.7	1.6			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	11.2	8.5		87.14	<0.0005	C > E
	s	1.2	0.6				
	n	18	18				
AOV Results by Activity	F			1.04			
	P			0.37			
Significant Comparisons between Activity Groups				none			

analyses for individual variables are in Table 7 through 14.

The activity levels used in this study resulted in typical responses by exercise groups. Relative fat values were lower and relative water, protein, and ash values were higher with increased levels of exercise intensity. Overall changes and all but one of the paired comparisons were significant, with the results appearing to be on a continium. If the sample size had been larger, the results might have been more clearly delineated.

The absolute values for carcass composition in Table 6 raise the question of whether stunted growth occurs with higher intensities of exercise. The absolute values for water, fat, and protein all show significantly lower values with increased exercise intensity.

The smaller forced-exercise animals had essentially the same mean ash level as the significantly larger voluntary animals. Ash levels appeared to be affected by level of activity rather than body size.

The absolute protein level was significantly lower with each increase in exercise intensity. This could indicate that growth was impaired or merely a decreased need for usable protein, because of the lower levels of water and fat, in the lighter forced-exercise animals. Comparing the sedentary and forced-exercise groups, the difference in weight due to fat and water accounted for approximately 80 grams of the 95 grams difference in total carcass weight. Especially in view of the absolute ash values, it is possible that the lower level of protein in the smaller body size was related to the lower levels of fat and water, rather than to the stunted growth.

Discussion on Carcass Composition

There was no significant difference observed between the two diet groups with respect to relative or absolute carcass water and protein. The significantly higher level of carcass fat in the experimental animals was probably due to the higher percentage of fat in their diet. The experimental animals were significantly lower in carcass ash values. The reason for this difference is unclear at this time. Since the difference in ash values can be seen at all three levels of exercise, between the two diet groups, the results can not be attributed to the greater exercise of the forced-exercise control group. Probably, there was something inherently lacking in the experimental diet that resulted in this lower value for the experimental animals at all levels of exercise.

Relative water, protein, and ash values were significantly higher with greater exercise intensities. Relative fat values were significantly lower with greater exercise intensities. These results are all in line with previous work (49, 93).

Organ Weight Analyses

The summary results of the relative and absolute organ weight analyses are shown in Tables 15 and 16. The two-way analyses for individual variables are in Tables 17 through 28.

Diet Effect on Organ Weight

Relative and absolute heart and kidney weights were greater while the adrenal weights were smaller for the animals on the experimental diet. These results are seen at each level of exercise intensity used in this study.

The significant difference in mean heart weight indicates that some-

Table 15 --- Organ Weight Data by Diet Groups

	Group Means: Control (N=18) $\bar{X}$ ± s	Group Means: Experimental (N=18) $\bar{X}$ ± s	F Value	Probability	Mean Comparison
Body Wt. (gms)	380.4 ± 49.4	379.3 ± 48.6	0.04	0.84	N
Relative Organ Weight (per cent of Body Wt.)					
Liver	4.23 ± 0.60	4.46 ± 0.49	2.2	0.15	N
Kidney	0.75 ± 0.059	0.82 ± 0.059	14.5	<0.001	S
Adrenal	0.015 ± 0.0025	0.013 ± 0.0025	13.8	<0.001	S
Spleen	0.22 ± 0.022	0.22 ± 0.022	0.02	0.89	N
Heart	0.31 ± 0.033	0.33 ± 0.033	8.6	<0.007	S
Testes	0.94 ± 0.150	0.93 ± 0.155	0.07	0.79	N
Absolute Weight (gms)					
Liver	16.2 ± 3.9	17.1 ± 3.9	1.6	0.22	N
Kidney	2.8 ± 0.42	3.1 ± 0.47	7.3	<0.012	S
Adrenal	0.056 ± 0.0057	0.049 ± 0.0053	16.8	<0.0005	S
Spleen	0.84 ± 0.154	0.83 ± 0.149	0.04	0.84	N
Heart	1.16 ± 0.134	1.24 ± 0.094	4.2	<0.05	S
Testes	3.53 ± 0.476	3.47 ± 0.464	0.17	0.68	N

Table 16 --- Organ Weight Data by Exercise Level

	Group Means: Forced (N=12) $\bar{X}$ ± s	Group Means: Voluntary (N=12) $\bar{X}$ ± s	Group Means: Sedentary (N=12) $\bar{X}$ ± s	F Value	Probability Value	Mean Comparison: F vs. V	Mean Comparison: F vs. S	Mean Comparison: V vs. S
Body Wt. (gms)	325.2 ± 13.2	380.0 ± 22.6	434.5 ± 15.0	134.1	<0.0005	S	S	S
Relative Organ Weights (per cent Body Weight)								
Liver	3.99 ± 0.45	4.23 ± 0.035	4.80 ± 0.51	10.0	<0.001	N	S	S
Kidney	0.80 ± 0.063	0.77 ± 0.066	0.78 ± 0.082	0.81	0.46	N	N	N
Adrenal	0.017 ± 0.0018	0.014 ± 0.0017	0.012 ± 0.0017	34.1	<0.0005	S	S	S
Spleen	0.22 ± 0.019	0.22 ± 0.024	0.22 ± 0.025	0.1	0.91	N	N	N
Heart	0.35 ± 0.025	0.31 ± 0.022	0.29 ± 0.021	26.0	<0.0005	S	S	S
Testes	1.02 ± 0.141	0.96 ± 0.119	0.81 ± 0.112	8.3	<0.002	N	S	S
Absolute Organ Weight (Grams)								
Liver	13.0 ± 1.6	16.1 ± 1.9	20.9 ± 2.6	44.3	<0.0005	S	S	S
Kidney	2.6 ± 0.24	2.9 ± 0.36	3.4 ± 0.41	17.8	<0.0005	S	S	S
Adrenal	0.054 ± 0.0061	0.053 ± 0.0054	0.051 ± 0.0079	0.94	0.40	N	N	N
Spleen	0.71 ± 0.068	0.83 ± 0.130	0.96 ± 0.121	17.6	<0.0005	S	S	S
Heart	1.15 ± 0.092	1.18 ± 0.125	1.27 ± 0.112	4.5	0.022	N	S	S
Testes	3.32 ± 0.462	3.64 ± 0.408	3.53 ± 0.496	1.8	0.18	N	N	N

Table 17 --- Adrenal Weight (per cent of body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	X̄	0.018	0.016	0.017			
	s	0.001	0.002	0.002			
	n	6	6	12			
Voluntary	X̄	0.015	0.013	0.014			
	s	0.002	0.001	0.002			
	n	6	6	12			
Sedentary	X̄	0.013	0.011	0.012			
	s	0.001	0.001	0.002			
	n	6	6	12			
Overall Values by Diet	X̄	0.015	0.013		13.76	<0.001	C > E
	s	0.002	0.003				
	n	18	18				
AOV Results by Activity	F			34.09			
	P			<0.0005			
Significant Comparisons between Activity Groups				F > V F > S V > S			

Table 18 --- Adrenal Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	X̄	0.058	0.050	0.054			
	s	0.004	0.005	0.006			
	n	6	6	12			
Voluntary	X̄	0.054	0.051	0.052			
	s	0.007	0.004	0.005			
	n	6	6	12			
Sedentary	X̄	0.057	0.046	0.051			
	s	0.006	0.006	0.008			
	n	6	6	12			
Overall Values by Diet	X̄	0.056	0.049		16.84	<0.0005	C > E
	s	0.006	0.005				
	n	18	18				
AOV Results by Activity	F			0.94			
	P			0.40			
Significant Comparisons between Activity Groups				none			

Table 19 --- Heart Weight (per cent of body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	X̄	0.34	0.37	0.35			
	s	0.03	0.02	0.02			
	n	6	6	12			
Voluntary	X̄	0.29	0.32	0.31			
	s	0.02	0.01	0.02			
	n	6	6	12			
Sedentary	X̄	0.29	0.30	0.29			
	s	0.02	0.02	0.02			
	n	6	6	12			
Overall Values by Diet	X̄	0.31	0.33		8.61	<0.007	C < E
	s	0.03	0.03				
	n	18	18				
AOV Results by Activity	F			26.05			
	P			<0.0005			
Significant Comparisons between Activity Groups				F > V F > S V > S			

Table 20 --- Heart Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	X̄	1.13	1.17	1.15			
	s	0.11	0.07	0.09			
	n	6	6	12			
Voluntary	X̄	1.10	1.25	1.18			
	s	0.13	0.05	0.12			
	n	6	6	12			
Sedentary	X̄	1.26	1.28	1.27			
	s	0.11	0.12	0.11			
	n	6	6	12			
Overall Values by Diet	X̄	1.16	1.24		4.18	<0.05	C < E
	s	0.13	0.09				
	n	18	18				
AOV Results by Activity	F			4.47			
	P			<0.02			
Significant Comparisons between Activity Groups				F < S V < S			

Table 21 --- Kidney Weight (per cent of body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	0.77	0.84	0.80			
	s	0.06	0.05	0.06			
	n	6	6	12			
Voluntary	$\bar{X}$	0.73	0.81	0.77			
	s	0.07	0.03	0.07			
	n	6	6	12			
Sedentary	$\bar{X}$	0.74	0.82	0.79			
	s	0.05	0.09	0.08			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	0.74	0.82		14.49	<0.001	C<E
	s	0.06	0.06				
	n	18	18				
AOV Results by Activity	F			0.81			
	P			0.46			
Significant Comparisons between Activity Groups				none			

Table 22 --- Kidney Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	2.5	2.7	2.61			
	s	0.24	0.23	0.24			
	n	6	6	12			
Voluntary	$\bar{X}$	2.7	3.2	2.95			
	s	0.40	0.15	0.36			
	n	6	6	12			
Sedentary	$\bar{X}$	3.2	3.5	3.39			
	s	0.26	0.50	0.41			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	2.84	3.13		7.31	<0.01	C<E
	s	0.42	0.47				
	n	18	18				
AOV Results by Activity	F			17.83			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 23 --- Liver Weight (per cent body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	4.0	4.0	4.0			
	s	0.6	0.2	0.5			
	n	6	6	12			
Voluntary	$\bar{X}$	4.0	4.4	4.2			
	s	0.3	0.3	0.4			
	n	6	6	12			
Sedentary	$\bar{X}$	4.7	4.9	4.8			
	s	0.6	0.4	0.4			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	4.2	4.5		2.24	0.15	none
	s	0.6	0.5				
	n	18	18				
AOV Results by Activity	F			10.00			
	P			<0.001			
Significant Comparisons between Activity Groups				F<S V<S			

Table 24 --- Liver Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	13.2	12.8	13.0			
	s	2.1	1.1	1.6			
	n	6	6	12			
Voluntary	$\bar{X}$	15.0	17.2	16.1			
	s	1.4	1.7	1.9			
	n	6	6	12			
Sedentary	$\bar{X}$	20.5	21.2	20.9			
	s	3.1	2.3	2.6			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	16.2	17.1		1.61	0.21	none
	s	3.9	3.9				
	n	18	18				
AOV Results by Activity	F			44.30			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 25 --- Spleen weight (per cent of body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	0.23	0.21	0.22			
	s	0.02	0.02	0.02			
	n	6	6	12			
Voluntary	$\bar{X}$	0.21	0.23	0.22			
	s	0.02	0.02	0.02			
	n	6	6	12			
Sedentary	$\bar{X}$	0.23	0.22	0.22			
	s	0.02	0.03	0.02			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	0.22	0.22		0.02	0.84	none
	s	0.02	0.02				
	n	18	18				
AOV Results by Activity	F			0.10			
	P			0.91			
Significant Comparisons between Activity Groups				none			

Table 26 --- Spleen Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	0.74	0.68	0.71			
	s	0.06	0.07	0.07			
	n	6	6	12			
Voluntary	$\bar{X}$	0.77	0.89	0.83			
	s	0.15	0.09	0.13			
	n	6	6	12			
Sedentary	$\bar{X}$	1.00	0.93	0.96			
	s	0.10	0.14	0.12			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	0.83	0.83		0.04	0.84	none
	s	0.15	0.15				
	n	18	18				
AOV Results by Activity	F			17.60			
	P			<0.0005			
Significant Comparisons between Activity Groups				F<V F<S V<S			

Table 27 --- Testes Weight (per cent of body weight)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	1.01	1.03	1.02			
	s	0.15	0.14	0.14			
	n	6	6	12			
Voluntary	$\bar{X}$	0.97	0.95	0.96			
	s	0.15	0.08	0.12			
	n	6	6	12			
Sedentary	$\bar{X}$	0.83	0.80	0.81			
	s	0.08	0.14	0.11			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	0.94	0.93		0.07	0.79	none
	s	0.15	0.15				
	n	18	18				
AOV Results by Activity	F			8.31			
	P			<0.002			
Significant Comparisons between Activity Groups				F>S V>S			

Table 28 --- Testes Weight (grams)

Activity Groups		Diet Groups: Control	Diet Groups: Experimental	Overall Value by Activity	AOV Results by Diet: F	AOV Results by Diet: P	Significant Comparisons between Diet Groups
Forced	$\bar{X}$	3.34	3.29	3.32			
	s	0.49	0.48	0.46			
	n	6	6	12			
Voluntary	$\bar{X}$	3.60	3.69	3.64			
	s	0.54	0.26	0.41			
	n	6	6	12			
Sedentary	$\bar{X}$	3.64	3.42	3.53			
	s	0.42	0.58	0.50			
	n	6	6	12			
Overall Values by Diet	$\bar{X}$	3.53	3.47		0.17	0.68	none
	s	0.48	0.46				
	n	18	18				
AOV Results by Activity	F			1.81			
	P			0.18			
Significant Comparisons between Activity Groups				none			

thing inherent in the experimental diet must bring about an increase in heart size even at the lower intensities of exercise. Whether this is a beneficial or a detrimental effect should be investigated further. This difference in heart weights may be due to greater fat deposited within the hearts of the experimental group.

The difference in kidney size is possibly due to the vegetable proteins placing a greater filtering load upon the kidneys. Histological work to identify structural differences responsible for the increased weight is needed before proceeding to any hypothetical explanation.

The adrenal weight differences are most interesting because they were evident at each of the levels of exercise intensity used. This fact might indicate the experimental vegetarian diet enabled the animals to make a more desirable stress response. The adrenal weights were lower in the experimental group inspite of the fact that the animals were fatter, which might have resulted in heavier organ weights.

Exercise Effect on Organ Weights

Relative heart, adrenal, and testes weights were all greater and liver weights were lower with higher exercise intensities. These responses were similar to the results of previous work (49, 93).

Absolute weights for the heart, liver, spleen and kidneys were all significantly lower with increased exercise intensities. These differences probably reflect the smaller body weights found at the higher exercise levels. The absolute organ-weight results are also in line with previous work (49, 93).

Discussion

The organ-weight and body-composition effects of exercise found in this study were completely in line with previous work in the same area

(49, 93). Relative protein, water and ash value were higher and relative fat values lower with greater exercise intensities. Relative adrenal, heart and testes values were higher and relative liver values lower with greater exercise intensities. Serum cholesterol and triglyceride values were lower with increased exercise levels. Since these data are so closely in accord with previous work, they tend to support the validity of the diet data.

Following is a brief summary of the comparisons between the two diet groups which were deemed to be important:

Table 29 --- Comparisons of Two Diets

Variable	Control	Vegetarian	Interpretation
Weight	0	0	No difference
Fat	-	+	Control animals leaner
Ash	+	-	Control animals more ash
Kidney	-	+	Control-smaller kidneys
Adrenal	+	-	Control-larger adrenal
Heart	-	+	Control-smaller heart
Cholesterol	+	-	Control higher (not sig.)
Forced-Exercise	+	-	Controls ran more
Shock	-	+	Controls got less shock
Voluntary Activity	0	0	No difference

In the body composition results, it is likely that the carcasses of the experimental animals contained more fat because of the higher level of fat in the diet. The differences observed in the ash content can not be explained from the current data.

The serum cholesterol and triglyceride levels were slightly lower for the experimental animals (not significant), in spite of the fact that the experimental animals were fatter. It has been shown that relative fatness of the body is positively related to serum cholesterol levels (72). This contradiction with previous work indicates that constituents of the control diet (saturated fats) have a greater influence on serum cholesterol levels than does body fat.

The adrenal weights were significantly lower and the heart weights significantly higher in the experimental animals. These differences were found at every exercise level, in spite of the fact that the experimental animals experienced more shock and ran less on the forced-exercise program. There was no difference between the two diet groups in activity on the voluntary-exercise program or, of course, in the sedentary program. Yet, the differences in adrenal and heart size were found at both of these activity levels. The differences in the adrenal and heart weight were most interesting and clearly deserve further investigation. It may be the experimental diet served to block the stress reaction in some way as evidenced by the smaller adrenals and the lower cholesterol levels. However, such hypothetical explanations are premature until analysis of the adrenal gland for ascorbic acid and cholesterol concentration can be carried out.

Any hypothesis of a direct diet effect on heart hypertrophy is also premature. The amount of fat in the carcasses of the experimental animals was significantly greater than in the control animals and might have resulted in fatty deposits within the heart.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to compare the effects of a strict vegetarian diet and a control diet containing animal protein (5.23%) under various conditions of physical activity.

Fifty, twenty-three-day-old male albino rats (Sprague-Dawley strain) were randomly assigned to either a control dietary group or to an experimental dietary group. Within each dietary group, the animals were randomly assigned to one of three exercise programs. Seven animals from each dietary group were placed into a sedentary subgroup. Seven animals from each dietary group were placed into a voluntary-exercise subgroup. The remaining eleven animals, from each dietary group, were placed into a forced-exercise subgroup. Six animals were desired in each diet-training subgroup for final analysis. One extra animal was placed in each sedentary and voluntary-exercise subgroup as a contingency against injury or illness. Five extra animals were placed in each forced-exercise subgroup because during a typical forced-exercise training program some of the animals either become injured or fail to respond to the program and must be dropped from the experiment.

At ninety days of age, blood samples were taken for serum cholesterol and triglyceride analyses, and the animals were sacrificed. Wet weights were taken on the following organs: adrenals, heart, kidneys, liver, spleen and testes. The carcasses then were frozen until determinations of body composition were made.

Conclusions

The results of this study, presented with respect to exercise, are completely in line with previous work (49, 93). Higher levels of exercise produced animals with higher per cent carcass weight due to water, protein, and ash with a lower per cent carcass weight due to fat. When the forced-exercise group was compared to the sedentary group, the active animals were found to have lower relative liver weights and significantly higher relative adrenals, heart, and testes weights. There also were significantly lower serum cholesterol and triglyceride values in the forced-exercise group.

When the data were analyzed by diet groups, some unusual results were seen. The mean values for serum cholesterol and triglycerides were lower for the experimental (vegetarian) dietary group, though the difference between the means was not statistically significant. However, the results are of interest since the control diet contained only 4 per cent animal fat, whereas the experimental diet contained twice that quantity of vegetable fat. The experimental dietary group also was significantly fatter which, from previous work, should have resulted in higher serum values (72).

Mean adrenal weight was lower for the experimental dietary group at each level of exercise used. This fact might indicate the experimental vegetable diet enabled the animals to make a more desirable stress response. The adrenal weights were lower in spite of the fact that the animals were fatter, which might have resulted in heavier organ weights.

Mean kidney and heart weights were significantly higher in the experimental animals. These differences were found at each intensity of exercise. This difference might have been related to the change in the adrenal weights or it may have been due to fatty deposits in the kidney and heart.

Due to the small sample size, the statistical power was less than 0.30 in all analyses where significant differences were not observed. Therefore, failure to demonstrate significance should not be interpreted, at this time, as justification for acceptance of the hypothesis of no treatment effects.

Recommendations

A similar study is needed to confirm the results of this study.

The use of various levels of proteins and fats (animal and vegetable) should be included to determine their effects on serum cholesterol and triglyceride.

Ascorbic acid determinations on the adrenal gland should be done to help indicate its activity. Various kinds of stress could also be used to help stimulate larger changes in adrenal activity.

Histological work on the kidney should be done to try and identify any structural changes that might be responsible for the increased weight in the experimental dietary group.

Histological work on the heart should be done to try and identify any structural changes or fatty deposits that would account for the increased weight in the experimental dietary group.

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APPENDIX

APPENDIX A

TABLE A1

DATA ON BODY AND ORGAN WEIGHTS
CONTROL ANIMALS (WAYNE LAB BLOX)

ABSOLUTE BODY AND ORGAN WEIGHTS							RELATIVE ORGAN WEIGHTS					
BOD WT. GMS	LIVER WT. GMS	KID. WT. GMS	ADR. WT. GMS	SPL. WT. GMS	HEART WT. GMS	TEST. WT. GMS	PER. LIV.	PER. KID.	PER. ADR.	PER. SPL.	PER. HRT.	PER. TEST
FORCED EXERCISE ANIMALS												
330	10.832	2.712	.053	0.815	1.241	3.685	3.28	0.82	0.016	0.25	0.38	1.12
312	11.102	2.091	.058	0.739	0.935	3.268	3.56	0.67	0.019	0.24	0.30	1.05
352	13.718	2.700	.058	0.709	1.142	3.720	3.90	0.77	0.016	0.20	0.32	1.06
318	14.362	2.537	.058	0.662	1.080	2.474	4.52	0.80	0.018	0.20	0.34	1.09
330	16.380	2.694	.055	0.736	1.174	3.504	4.96	0.82	0.017	0.22	0.36	1.06
338	12.623	2.464	.066	0.795	1.211	2.402	3.73	0.73	0.020	0.24	0.36	0.71
VOLUNTARY EXERCISE ANIMALS												
362	15.340	2.299	.052	0.652	1.006	3.690	4.24	0.64	0.014	0.18	0.28	1.02
344	14.554	2.724	.049	0.709	1.064	3.418	4.23	0.79	0.014	0.21	0.31	0.99
418	17.264	3.380	.046	1.038	1.331	4.171	4.13	0.81	0.011	0.25	0.32	1.00
384	15.524	2.718	.056	0.831	1.020	2.619	4.04	0.71	0.015	0.22	0.27	0.68
382	13.521	2.962	.065	0.751	1.187	3.716	3.54	0.78	0.017	0.20	0.31	0.97
344	13.546	2.359	.055	0.660	0.990	3.961	3.94	0.69	0.016	0.19	0.29	1.15
SEDENTARY ANIMALS												
442	20.198	3.469	.048	0.988	1.279	3.378	4.57	0.78	0.011	0.22	0.29	0.76
438	20.562	3.209	.052	0.961	1.224	3.400	4.69	0.73	0.012	0.22	0.28	0.78
452	26.458	3.519	.065	1.108	1.457	4.450	5.85	0.78	0.014	0.25	0.32	0.98
430	19.425	3.407	.058	1.115	1.194	3.660	4.52	0.79	0.013	0.26	0.28	0.85
434	19.223	2.894	.059	0.855	1.302	3.336	4.43	0.67	0.014	0.20	0.30	0.77
438	17.372	2.989	.059	0.963	1.129	3.626	3.97	0.68	0.013	0.22	0.26	0.83

APPENDIX A

TABLE A2

DATA ON CARCASS COMPOSITION, SERUM CHOLESTEROL, AND SERUM TRIGLYCERIDES
CONTROL ANIMALS (WAYNE LAB BLOX)

ABSOLUTE VALUES					RELATIVE VALUES				SERUM VALUES	
CAR WT. GMS	WATER WT. GMS	FAT WT. GMS	PROT. WT. GMS	ASH WT. GMS	PER. WATER	PER. FAT	PER. PROT.	PER. ASH	SER. CHOL. MGPER	SER. TRIGL MGPER
FORCED EXERCISE ANIMALS										
268	171.44	20.53	61.13	12.62	63.97	07.66	22.81	4.71	059.4	024.1
245	156.78	19.84	55.42	10.93	63.99	08.10	22.62	4.46	050.0	033.9
270	171.34	22.68	62.61	11.85	63.46	08.40	23.19	4.39	.	.
249	161.10	18.13	57.42	10.98	64.70	07.28	23.06	4.41	063.0	155.4
296	191.45	24.45	66.04	12.31	64.68	08.26	22.31	4.16	062.2	009.8
272	172.75	27.58	59.16	10.83	63.51	10.14	21.75	3.98	.	.
VOLUNTARY EXERCISE ANIMALS										
279	173.15	32.98	60.68	11.24	62.06	11.82	21.75	4.03	058.6	039.9
269	169.20	27.92	58.86	10.57	62.90	10.38	21.88	3.93	071.4	044.0
330	207.93	36.50	70.95	12.31	63.01	11.06	21.50	3.73	075.0	065.8
293	183.77	31.61	64.46	11.66	62.72	10.79	22.00	3.98	072.2	144.0
311	197.42	32.81	66.27	11.97	63.48	10.55	21.31	3.85	072.2	031.2
272	172.48	21.92	62.40	08.21	63.41	08.06	22.94	3.02	067.2	030.2
SEDENTARY ANIMALS										
367	216.35	58.10	75.93	12.77	58.95	15.83	20.69	3.48	074.2	144.5
367	206.25	73.36	73.84	11.19	56.20	19.99	20.12	3.05	082.1	203.5
399	222.48	81.07	80.04	11.97	55.76	20.32	20.06	3.00	080.0	208.4
343	205.49	52.14	71.62	11.66	59.91	15.20	20.88	3.40	126.8	269.0
343	197.36	66.30	70.11	09.40	57.54	19.33	20.44	2.74	074.2	120.4
306	187.12	39.29	67.69	09.61	61.15	12.84	22.12	3.14	.	069.5

APPENDIX A

TABLE A3

DATA ON BODY AND ORGAN WEIGHTS EXPERIMENTAL ANIMALS (VEGETARIAN DIET)

ABSOLUTE BODY AND ORGAN WEIGHTS							RELATIVE ORGAN WEIGHTS					
BOD WT. GMS	LIVER WT. GMS	KID. WT. GMS	ADR. WT. GMS	SPL. WT. GMS	HEART WT. GMS	TEST. WT. GMS	PER. LIV.	PER. KID.	PER. ADR.	PER. SPL.	PER. HRT.	PER. TEST
FORCED EXERCISE ANIMALS												
308	12.214	2.623	.055	0.712	1.110	3.170	3.97	0.85	0.018	0.23	0.36	1.03
326	13.412	2.701	.043	0.574	1.216	3.578	4.11	0.83	0.013	0.18	0.37	1.10
312	11.154	2.495	.046	0.650	1.059	3.630	3.58	0.80	0.015	0.21	0.34	1.16
314	12.308	2.504	.054	0.649	1.199	2.390	3.92	0.80	0.017	0.21	0.38	0.76
338	14.270	3.114	.056	0.760	1.214	3.342	4.22	0.92	0.017	0.22	0.36	0.99
324	13.572	2.738	.049	0.721	1.243	3.637	4.19	0.85	0.015	0.22	0.38	1.12
VOLUNTARY EXERCISE ANIMALS												
396	17.508	3.392	.057	0.895	1.231	3.323	4.42	0.86	0.014	0.23	0.31	0.83
404	19.274	3.122	.046	0.917	1.283	3.784	4.77	0.77	0.011	0.23	0.32	0.94
398	18.794	3.208	.051	1.010	1.269	3.719	4.72	0.81	0.013	0.25	0.32	0.93
374	17.114	2.931	.054	0.872	1.195	4.002	4.58	0.78	0.014	0.23	0.32	1.07
374	14.946	3.151	.052	0.731	1.221	3.867	4.00	0.84	0.014	0.20	0.33	1.03
380	15.677	3.142	.047	0.902	1.320	3.447	4.13	0.83	0.012	0.24	0.35	0.91
SEDENTARY ANIMALS												
438	22.198	3.699	.054	0.969	1.248	3.623	5.07	0.84	0.012	0.22	0.28	0.83
392	17.296	2.659	.041	0.812	1.160	3.459	4.41	0.68	0.010	0.21	0.30	0.88
436	21.047	3.262	.042	0.776	1.204	3.696	4.83	0.75	0.010	0.18	0.28	0.85
438	24.302	4.090	.051	1.142	1.344	2.261	5.55	0.93	0.012	0.26	0.31	0.52
428	20.548	3.692	.047	0.855	1.252	3.842	4.80	0.86	0.011	0.20	0.29	0.90
448	22.123	3.768	.041	1.016	1.499	3.642	4.94	0.84	0.009	0.23	0.33	0.81

APPENDIX A

TABLE A4

DATA ON CARCASS COMPOSITION, SERUM CHOLESTEROL, AND SERUM TRIGLYCERIDES EXPERIMENTAL ANIMALS (VEGETARIAN DIET)

ABSOLUTE VALUES					RELATIVE VALUES				SERUM VALUES	
CAR WT. GMS	WATER WT. GMS	FAT WT. GMS	PROT. WT. GMS	ASH WT. GMS	PER. WATER	PER. FAT	PER. PROT.	PER. ASH	SER. CHOL. MGPER	SER. TRIGL MGPER
FORCED EXERCISE ANIMALS										
249	160.61	18.90	59.76	09.19	64.50	07.59	24.00	3.69	061.5	022.6
260	165.62	24.78	59.49	08.29	63.70	09.53	22.88	3.19	.	021.4
255	165.14	22.62	58.34	08.82	64.76	08.87	22.88	3.46	062.2	017.8
250	156.05	28.23	56.10	08.35	62.42	11.29	22.44	3.34	061.5	012.1
265	169.76	23.85	61.61	08.51	64.06	09.00	23.25	3.21	066.5	032.2
261	157.28	38.97	54.97	07.62	60.26	14.93	21.06	2.92	058.6	020.7
VOLUNTARY EXERCISE ANIMALS										
317	203.10	36.36	68.54	08.31	64.07	11.47	21.62	2.62	079.3	051.6
31	195.38	46.11	67.57	08.74	61.44	14.50	21.25	2.75	068.0	125.0
318	191.37	47.83	68.37	03.30	60.18	15.04	21.50	2.61	075.0	049.6
300	190.89	34.17	66.57	07.71	63.63	11.39	22.19	2.57	060.8	094.1
301	188.64	36.00	65.47	07.77	62.67	12.16	21.75	2.58	072.8	028.9
301	184.72	45.42	63.39	07.68	61.37	15.09	21.06	2.55	075.8	030.3
SEDENTARY ANIMALS										
355	212.18	57.47	76.32	07.70	59.77	16.19	21.50	2.17	072.2	194.5
322	181.41	65.40	67.43	08.95	56.34	20.31	20.94	2.78	077.9	087.4
375	208.31	80.70	72.90	08.44	55.55	21.52	19.44	2.25	064.2	251.4
354	207.98	60.32	75.22	08.78	58.75	17.04	21.25	2.48	064.2	145.7
346	208.53	53.32	74.18	09.58	60.27	15.41	21.44	2.77	046.5	057.7
395	211.36	93.30	74.81	09.40	53.51	23.62	18.94	2.38	073.6	072.4

APPENDIX B
TABLE B1

RAW DATA - ACTIVITY RECORD
FORCED EXERCISE ANIMALS

	PERCENT EXPECTED REVOLUTIONS MEAN LAST FOUR WEEKS	PERCENT EXPECTED REVOLUTIONS MEAN LAST FULL WEEK	PERCENT SHOCK FREE TIME MEAN LAST FOUR WEEKS	PERCENT SHOCK FREE TIME MEAN LAST FULL WEEK
CONTROL ANIMALS	098	101	083	088
	092	087	078	077
	096	086	073	072
	101	088	082	080
	089	087	083	086
	075	075	067	067
	075	075	067	067
EXPERIMENTAL ANIMALS	100	097	081	090
	067	064	055	050
	065	066	057	058
	107	103	083	086
	067	068	058	060
	062	059	053	045

TABLE B2

RAW DATA - ACTIVITY RECORD
VOLUNTARY ANIMALS

	VOLUNTARY REVOLUTIONS MEAN LAST FOUR WEEKS	VOLUNTARY REVOLUTIONS MEAN LAST WEEK
CONTROL ANIMALS	1677	1954
	2980	3949
	0746	0828
	1414	1684
	1477	1371
	0888	1015
EXPERIMENTAL ANIMALS	1263	1321
	1366	2046
	1452	1374
	3288	3917
	0387	0701
	1519	1117

APPENDIX C

STANDARD EIGHT-WEEK, MEDIUM-DURATION, MODERATE-INTENSITY 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 Bet-ween Bouts (min)	Shock (ma)	Run Speed (ft/ sec)	Total Time of Prog. (min: sec)	Total Exp. Revo-lu-tions *TER*	Total Work Time (sec) *TWT*
1	1=M	1	1.0	00:10	5	40	3	5.0	1.2	2.0	39:45	600	1200
	2=T	2	1.0	00:10	5	40	3	5.0	1.2	2.0	39:45	600	1200
	3=W	3	1.0	00:10	5	40	3	5.0	1.2	2.0	39:45	600	1200
	4=T	4	1.0	00:10	10	28	4	5.0	1.2	2.5	51:40	700	1120
	5=F	5	1.0	00:10	10	28	4	5.0	1.2	2.5	51:40	700	1120
2	1=M	6	1.0	00:10	10	28	4	5.0	1.2	2.5	51:40	700	1120
	2=T	7	1.0	00:10	10	27	4	5.0	1.2	3.0	50:20	810	1080
	3=W	8	1.0	00:10	10	27	4	5.0	1.2	3.0	50:20	810	1080
	4=T	9	1.0	00:10	10	27	4	5.0	1.2	3.0	50:20	810	1080
	5=F	10	1.0	00:10	10	27	4	5.0	1.2	3.0	50:20	810	1080
3	1=M	11	1.0	00:10	10	27	4	5.0	1.2	3.0	50:20	810	1080
	2=T	12	1.5	00:10	10	26	4	5.0	1.0	3.5	49:00	910	1040
	3=W	13	1.5	00:10	10	26	4	5.0	1.0	3.5	49:00	910	1040
	4=T	14	1.5	00:10	10	26	4	5.0	1.0	3.5	49:00	910	1040
	5=F	15	1.5	00:10	10	26	4	5.0	1.0	3.5	49:00	910	1040
4	1=M	16	1.5	00:10	10	26	4	5.0	1.0	3.5	49:00	910	1040
	2=T	17	1.5	00:15	15	19	4	5.0	1.0	3.5	52:00	997	1140
	3=W	18	1.5	00:15	15	19	4	5.0	1.0	3.5	52:00	997	1140
	4=T	19	1.5	00:15	15	19	4	5.0	1.0	3.5	52:00	997	1140
	5=F	20	1.5	00:15	15	19	4	5.0	1.0	3.5	52:00	997	1140
5	1=M	21	1.5	00:15	15	19	4	5.0	1.0	3.5	52:00	997	1140
	2=T	22	1.5	00:15	15	14	5	5.0	1.0	4.0	53:45	1050	1050
	3=W	23	1.5	00:15	15	14	5	5.0	1.0	4.0	53:45	1050	1050
	4=T	24	1.5	00:15	15	14	5	5.0	1.0	4.0	53:45	1050	1050
	5=F	25	1.5	00:15	15	14	5	5.0	1.0	4.0	53:45	1050	1050
6	1=M	26	1.5	00:15	15	14	5	5.0	1.0	4.0	53:45	1050	1050
	2=T	27	1.5	00:20	20	11	5	5.0	0.8	4.0	55:00	1100	1100
	3=W	28	1.5	00:20	20	11	5	5.0	0.8	4.0	55:00	1100	1100
	4=T	29	1.5	00:20	20	11	5	5.0	0.8	4.0	55:00	1100	1100
	5=F	30	1.5	00:20	20	11	5	5.0	0.8	4.0	55:00	1100	1100
7	1=M	31	1.5	00:20	20	11	5	5.0	0.8	4.0	55:00	1100	1100
	2=T	32	1.5	00:25	25	9	5	5.0	0.8	4.0	55:25	1125	1125
	3=W	33	1.5	00:25	25	9	5	5.0	0.8	4.0	55:25	1125	1125
	4=T	34	1.5	00.25	25	9	5	5.0	0.8	4.0	55:25	1125	1125
	5=F	35	1.5	00:25	25	9	5	5.0	0.8	4.0	55:25	1125	1125
8	1=M	36	1.5	00:25	25	9	5	5.0	0.8	4.0	55:25	1125	1125
	2=T	37	1.5	00:30	30	8	5	5.0	0.8	4.0	57:30	1200	1200
	3=W	38	1.5	00:30	30	8	5	5.0	0.8	4.0	57:30	1200	1200
	4=T	39	1.5	00:30	30	8	5	5.0	0.8	4.0	57:30	1200	1200
	5=F	40	1.5	00:30	30	8	5	5.0	0.8	4.0	57:30	1200	1200