AN INVESTIGATION OF THE EFFECTS OF A TWELVE WEEK CONDITIONING PROGRAM ON THE ELECTROCARDIOGRAMS OF ALBINO RATS

Thesis for the Degree of M. A.

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Kenneth James Ackerman

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AN INVESTIGATION OF THE EFFECTS OF A TWELVE WEEK CONDITIONING PROGRAM ON THE ELECTROCARDIOGRAMS OF ALBINO RATS

by

KENNETH JAMES ACKERMAN

AN ABSTRACT

Submitted to the College of Education of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

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Statement of the Problem

The problem of this study was to determine the effect of prolonged physical conditioning on the electrocardiograms of albino rats.

Methodology

Forty-eight albino, male, litter-mate rats of the Sprague-Dawley strain were divided into three experimental groups: Groups A and B were swum twice daily for twelve weeks, and Group C remained sedentary. Groups A and C were fed a stock diet, and Group B was fed the same stock food with 30 per cent of their daily caloric in-take coming from powdered whole milk.

Electrocardiograms were taken before and after the conditioning program. The output from a Twin-Viso Sanborn direct writer electrocardiograph was fed into an Oscilloscope to record the ECG's. Records were taken from the Oscilloscope by means of a polaroid camera mounted on the scope face.

At the conclusion of the twelve week conditioning period, the animals were subjected to an all-out swimming performance test. They were then sacrificed and dissected Body organ weights were recorded.

Records from the two recording instruments were compared by means of the Pearson Product-Moment coefficient of correlation and the "t" test.

The simple analysis of variance technique was employed in analyzing the "pre-conditioning" and "post-conditioning" data. The Student "t" was used to compare Groups A and C. Correlations were computed on the ECG data and heart weight, heart rate, and all-out swim time.

Conclusions

1. The direct writer is not adequate for recording the electrocardiograms of rats. The use of the Oscilloscope gives a more accurate reproduction of the rat ECG.

2. The heart rate of the rat decreases with age and is slower in the rats receiving exercise.

3. P-wave and T-wave magnitudes of rats decrease with age. Conditioning tends to retard the decrease.

4. The QRS magnitude is increased or maintained by conditioning; while a sedentary life produces a reduction in this amplitude.

5. The direction of the electrical force in the rat's heart in respect to the P and T-waves changes with age. Conditioning has no effect on this.

6. The P-R and R-T intervals decrease with age. Conditioning has no effect on the P-R interval, but tends to retard the decrease in the R-T interval.

7. The QRS interval lengthens with conditioning, and decreases with a sedentary life.

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CHAPTER I

INTRODUCTION

The electrocardiogram has become one of the most valuable instruments available for the detection of the various abnormal heart conditions. Since Einthoven, in 1903, introduced the string galvanometer for recording electrocardiograms, ECG's have been routinely taken in heart cases.

In the past two decades electrocardiographic evaluation of exercise has become increasingly popular and seems to have considerable value.[1]

I. THE PROBLEM

Importance of the problem. It has been shown that the electrocardiogram of athletes, when in training, show definite changes which fall outside the normal limits.[2]

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[1]Earnest Simonson, M.D., and Ancel Keys, Ph.D., "An Electrocardiographic Exercise Test: Changes in the Scalar EGG and in the Mean Spatial QRS and T Vectors in Two Types of Exercise: Effects of Absolute and Relative Body Weight and Comment on Normal Standards," American Heart Journal, 52:83, July, 1956.

[2]George L. Beckner, M.D., and Travis Winsor, M.D., "Cardiovascular Adaptations to Prolonged Physical Effort," Circulation, 9:844, June, 1954.

The recognition of these as physiologic changes in the heart which result from prolonged, intensive conditioning is important because the resulting changes are similar to those which are associated with disease.[3]

Statement of the problem. The purpose of this was to determine what effects a prolonged conditioning period has on the electrocardiograms of albino rats.

II. DEFINITION OF THE TERMS

The terms used in connection with electrocardiograms are defined in Katz's book on standardized electrocardiographic terminology.[4]

Sedentary group. That group of animals which were confined to their cages with no physical activity for the entire experimental period.

III. LIMITATIONS OF THE STUDY

1. The problem of transfering the results of an animal study to humans is always a limitation.

2. The use of vernier caliphers for measuring the amplitudes and intervals was not precise enough for the small deflections and intervals which were encountered.

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[3]Ibid., p. 835.

[4]Louis Nelson Katz, Electrocardiography (Philadelphia: Lea and Febiger, 1946).

3. Intensity of the conditioning program in a study of this nature is always a problem. It would be better to use a training program where work output could be measured quantitatively.

CHAPTER II

REVIEW OF THE LITERATURE

The swimming of small animals. Wilbur[1] forced guinea pigs to swim to exhaustion with weights attached, varying from 60 to 900 grams (1-10% of body weight), at water temperature of 38° C. He found that if the animals were forced to swim in a group, 70% showed a 50% decrease in swimming time. From these results he suggests that, for the best results, small mammals be swum alone.

In studying the effect of liver supplement to the diet of rats upon their swimming capacity, Ershoff[2] found that all rats, regardless of diet swam for an arbitrary limit of 120 minutes in water at 36° C. However, when the same animals were swum at 20° C, those without the liver supplement swam 13 minutes as compared to 120 minutes for those animals with the liver supplement. He also found that the animals rarely stay submerged more than 5 to 10

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[1]Charles G. Wilbur, "Some Factors Which are Correlated with Swimming Capacity in Guinea Pigs," *Journal of Applied Physiology*, 16: 199-203, March, 1959.

[2]Benjamin H. Ershoff, "Beneficial Effect of Liver Feeding on Swimming Capacity of Rats in Cold Water," *Society for Experimental Biology and Medicine*, 77: 488-491, 1951.

seconds and that animals remaining below the surface for a period longer than 15 seconds drowned in most cases.

The ECG of rats. In studying the electrocardiograms of albino rats in chronic thiamine deficiency, Hundley, Ashburn, and Sebrell[3] used a string galvanometer coupled with a Sanborn "Cardioscope" amplifier in the circuit. The instrument was standardized so 1mV produced 2cm. of deflection. The camera speed was set at 75mm. per second. They took ECG's from Leads I, II, and III with the animals held in their normal position. No anesthesia was used. The ECG's were taken at weekly or bi-weekly intervals.

From this experiment the following "normals" for rat ECG's are reported:

1. Lead I shows a low deflection.
2. The P-R interval ranges from 0.035 second to 0.05 second and increases with age.
3. The QRS interval ranges from 0.006 second to 0.013 second and increases with age.
4. The Q-T ranges from 0.05 seconds to 0.09 second and varies inversely with heart rate.
5. It is common to find the P-wave coming before the T-wave returned to the isoelectric line.

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[3]James M. Hundley, L. L. Ashburn, and W. H. Sebrell, "The Electrocardiogram in Chronic Thiamine Deficiency in Rats," American Journal of Physiology, 144: 404-414, August, 1945.

Waller and Charipper[4] observed the ECG's in normal Thyriodectomized and Thiourea treated rats. They used 50 hooded albino rats; 24 males and 26 females. The animals were given 30 mg. of nembutal/Kg of body weight and the electrocardiograms were recorded by a commercial string galvanometer electrocardiograph with an electronic amplifier.

Using Lead II, the following means were reported:

1. P-R interval - 0.047 Sec. $\pm$ 0.002 (.038-.053)
2. Height of R_2 waves - 0.463 mV $\pm$ 0.097 (.300 -.750)
3. Height of T_2 waves - 0.106 mV $\pm$ 0.029 (.050 -.225)

They also noted low deflections in Lead I, and well formed S-waves in the majority of cases in Leads II and III.

Ensor,[5] studied the ECG's of rats on a vitamin E deficiency for one year. He used 20 animals and recorded the electrocardiograms with a Sanborn Electrocardiograph with a camera speed set at 5cm./second. The recorder was set so 1mV produced 1cm. deflection. No anesthesia was used and the recordings were taken at 4 week intervals for 24 weeks, then at 8 week intervals. He found that vitamin E deficiency has no effect on the ECG's and reported the following measurements:

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[4]Robert K. Waller and Harry A. Charipper, "Electrocardiographic Observations in Normal Thyroidectomized and Thiourea Treated Rats," American Journal of the Medical Sciences, 210: 443-452, October, 1945.

[5]Charles R. Ensor, "The Electrocardiogram of Rats on Vitamin E Deficiency," American Journal of Physiology, 147: 477-479, November, 1946.

1. P-R interval--4 weeks (0.04 sec.)--1 year (0.45 sec.)

2. QRS interval--4 weeks (0.01 sec.)--1 year (0.015 sec.)

3. T-wave--Lead I--0.02 sec. to 0.05 sec.

   Lead II and III--0.06 sec. to 0.09 sec.

The P-wave was again observed occurring before the T-wave reached the isoelectric line.

Berg[6] studied the ECG's of 144 rats as they advanced in age. He found no change in the P-wave; lengthened P-R and QRS intervals; left axis deviation in 60o/o of the rats 800 days old; and a slowing heart rate.

Effects of exercise on the ECG. There is a multitude of literature on the effects of exercise on the electrocardiogram. However, a large portion of it is concerned with the immediate effects that exercise produces on the ECG. This review is concerned only with that portion connected with prolonged physical conditioning.

Hoogerwerf,[7] in 1928, studied the ECG's of 260 Olympic Athletes using a string galvanometer to record the three

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[6]Benjamin Berg, "The Electrocardiogram in Aging Rats," _Journal of Gerontology_, 10: 420-423, October, 1953.

[7]S. Hoogerwerf, _Ergebnesse der sportaztlichen Untersuchungen bei den IX Olympischen Spielen_, pp. 118-38, Berlin, 1929; "Elektrokardiograhische Untersuchungen der Amsterdamer Olympiade," _Arbeitsphysiologie_, 2:61, 1929, cited by T. K. Cureton, _Physical Fitness of Champion Athletes_ (Urbana: University of Illinois Press, 1951), p. 140.

standard leads. He found that athletes, in the resting state, have a higher T-wave than sedentary individuals, the S-wave is eliminated, the RS-T segment is raised, and generally the P-wave is small.

Tung, et al.,[8] in 1934, conducted a study of 46 healthy Chinese ricksha pullers who had been at that job for a minimum of one year prior to the study. They took ECG's from Leads I, II, and III with the subjects in the recumbent position. The results showed that the electrical axis of the QRS complex was normal in 40 of the subjects and in 16 cases a tall T-wave deflection was observed in one or more leads.

Using 48 athletes, consisting of 4 wrestlers, 7 gymnasts, 9 swimmers, 6 basketball players, and 22 trackmen, Tuttle and Korns,[9] in 1941, observed the effects of conditioning for a season on the electrocardiograms of athletes. They took ECG's at the beginning of the season and again near the conclusion. The results showed no qualitative changes from the beginning to the end of the season in 43 of the subjects. In one case the changes

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[8] C. L. Tung, et al., "The Hearts of Ricksha Pullers: A Study of the Effect of Chronic Exertion on the Cardiovascular System," American Heart Journal, 10:79-100, October, 1934.

[9] W. W. Tuttle and Horace M. Korns, "Electrocardiographic Observations on Athletes Before and After a Season of Physical Training," American Heart Journal, 21:104-107, January, 1941.

that occurred were insignificant, 3 subjects showed an inverted T-wave in Lead III after training, and in one case the P-wave, which was inverted before the season, became upright with training.

In 1951, Foerch[10] compared the electrocardiograms of 20 "top notch" athletes with 20 non-athletes who had never played high school or college athletics. He found that athletes have statistically significant longer Q-T and P-R intervals and greater T-wave amplitudes than non-athletes. The non-athletes showed a longer QRS interval.

Rasch, et al.,[11] in 1958, conducted a study of the electrocardiograms of United States Olympic Free Style wrestlers. There were 74 subjects, ranging from 16 to 47 years old. The ECG's were recorded at the weigh-in time. They concluded that the ECG's of highly trained wrestlers were not different than those of healthy non-wrestlers of the same age. The wrestlers ECG's were compared with published norms. The authors found no evidence that training causes pathologic changes in the normal heart.

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[10] Richard L. Foerch, "A Comparison of Electrocardiographic Measurements of Athletes and Non-Athletes at Michigan State College" (unpublished Master's thesis, Michigan State College, 1951).

[11] Philip J. Rasch, et al., "An Electrocardiographic Study of United States Olympic Free Style Wrestlers," Research Quarterly, 29:46-53, March, 1958.

<u>Effect of sodium pentobarbital on the ECG.</u> Blouin[12] studied the effects of position and anesthesia on the ECG of the normal dog. He anesthetized 20 "normal" mongrel dogs with 30mg./Kg. of body weight of sodium pentobarbital (Nembutal) and used six dogs which were trained to be quiet as controls. He recorded tracings of the trained dogs while they were unanesthesized and anesthesized.

He found that nembutal supressed the Q-waves; as 65% of those dogs which were unanesthetized had Q-waves, but only 12% of those which were anesthetized had Q-waves, Nembutal had little and unpredictable effects on the P and T-waves and when given in large doses (30mg/kg) causes tachycardia, but in lighter doses (20mg/kg) produced normal heart rates.

In regard to heart rate and intervals, he found little difference between durations of the P-R, QRS, and Q-T intervals despite the variation in heart rates.

He concluded that there was no predictable relationship or variation on the ECG's of the trained dogs, either anesthetized or unanesthetized.

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[12]Leonard Thomas Blouin, "Effects of Position and Anesthesia upon the Electrocardiogram of the Normal Dog" (unpublished Master's thesis, Michigan State University, 1956).

Use of direct writer in small animal ECG work. Rappaport and Rappaport[13] report that the commercial electrocardiograph is designed for human work and is not suitable for small animal work. A more exact technique is needed for the work carried on with small animals due to their increased heart rate.

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[13]Maurice B. Rappaport and Irving Rappaport, "Electrocardiographic Considerations in Small Animal Investigations," American Heart Journal, 26:677, November, 1943.

CHAPTER III

DESIGN OF THE EXPERIMENT

This experiment was designed to investigate the effects that a prolonged conditioning program produces on the electrocardiograms of male albino rats.

I. THE SAMPLE

Forty-eight albino, weanling, male, litter-mate rats of the Sprague-Dawley strain were used in this experiment. Each litter was composed of three animals.

The animals were kept confined in cages 5" x 5" x 12" in a thermostatic controlled room with no direct sun light from January to June, 1959. From January to March all animals were kept confined and fed a stock diet.[1]

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[1]Ingredients of the stock diet in percentages:

46.1 ground corn	0.5 Track mineral salt
20.0 soybean oil meal (44% protein)	3.0 corn oil
10.0 fish meal	0.1 Merck B Vitamin
5.0 17% dehydrated alfalfa meal	0.05 Vit. A and D mix
10.0 dried skim milk	.25 Pfizers 9 + Vit. B_{12} Sup. Tocopherol Acetate 20g/100#
5.0 sucrose sugar	

This time was used to allow the animals to pass through the stage of rapid growth. The animals were divided into three experimental groups (A, B, and C) by weighing each animal in the litter and ranking them 1, 2, and 3, according to their respective litter. They were then placed in the three groups by alternating the ranked weights. The animals were numbered and placed in numbered cages. The cages were arranged in a rack so there were two animals from each group in each row. Numbers 1-16 were given Group A; Group B, 17-32; and Group C, 33-48.

Group A was placed on the stock diet plus exercise; Group B was given the stock diet, with 30 per cent of their daily caloric intake coming from powdered whole milk, and exercise;[2] and Group C received the stock diet and served as controls, remaining sedentary throughout the experiment.

The animals were marked for identification by a combination of ear punches and dye markings. This system was necessary because the animals were shipped in two lots of eight litters, with duplicate ear punches. All animals from one lot were given a dye mark on the right leg in order to identify the sixteen litters. The animals were

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[2]Group B was given the 30 per cent milk diet in connection with another aspect of this study designed to study the effects of exercise and milk on performance and organ growth.

then marked for group identification: Group A was marked with two spots on the back, Group B with one spot on the back, and Group C had no back mark.

The animals' cages were rotated one spot daily to compensate for light and temperature deviations which might have existed.

Table I gives a complete resume of how the animals were ranked, numbered, and marked.

II. THE METHODS

Type and amount of exercise. Each animal in the two exercise groups received an equal amount of conditioning. They swam in their respective groups twice daily, Monday through Friday and once on Saturday, for twelve weeks. Two 24" x 24" x 18" metal tubs filled with 13" to 14" of water were used for the swimming.

One week was spent swimming the animals for short periods without attached weights. Experimentation with water temperature was also carried on during this period. One animal drowned at 40° C.

The second and third weeks were spent swimming the animals for periods of 10 minutes with 4% of their body weight attached by means of a harness. Several animals were unable to swim the full 10 minutes and four animals drowned. Two of these animals drowned in the tank set at 40° C. and two in the tank at 37° C.

TABLE I

NUMBER, RANK, AND MARKING OF THE ANIMALS

Group A					Group B					Group C				
No.	Weight Rank in Litter	Ear Punch	Leg Stripe	Back Mark	No.	Weight Rank in Litter	Ear Punch	Leg Stripe	Back Mark	No.	Weight Rank in Litter	Ear Punch	Leg Stripe	Back Mark
1	1	R_0L_0	yes	2	17	2	R_0L_0	yes	1	33	3	R_0L_0	yes	0
2	3	R_0L_0	no	2	18	1	R_0L_0	no	1	34	2	R_0L_0	no	0
3[a]	2	L_1	yes	2	19	3	L_1	yes	1	35	1	L_1	yes	0
4	1	L_1	no	2	20	2	L_1	no	1	36[a]	3	L_1	no	0
5[a]	3	L_2	yes	2	21	1	L_2	yes	1	37	2	L_2	yes	0
6	2	L_2	no	2	22[a]	3	L_2	no	1	38	1	L_2	no	0
7	1	L_3	yes	2	23	2	L_3	yes	1	39	3	L_3	yes	0
8	3	L_3	no	2	24	1	L_3	no	1	40	2	L_3	no	0
9	2	R_1	yes	2	25	3	R_1	yes	1	41	1	R_1	yes	0
10[a]	1	R_1	no	2	26	2	R_1	no	1	42	3	R_1	no	0
11[a]	3	R_2	yes	2	27	1	R_2	yes	1	43	2	R_2	yes	0
12	2	R_2	no	2	28	3	R_2	no	1	44	1	R_2	no	0
13	1	R_3	yes	2	29	2	R_3	yes	1	45	3	R_3	yes	0
14[a]	3	R_3	no	2	30[a]	1	R_3	no	1	46	2	R_3	no	0
15	2	R_1L_1	yes	2	31	3	R_1L_1	yes	1	47	1	R_1L_1	yes	0
16	1	R_1L_1	no	2	32	2	R_1L_1	no	1	48	3	R_1L_1	no	0

[a]Died in the course of the experiment.

Starting with the fourth week of the experiment, the rats were swum without the attached weights. The length of the daily training period was increased to 30 minutes (twice daily) and increased five minutes weekly until one hour was attained. When this was reached, it was held constant through the remainder of the experiment. Water temperature was standardized at 36° C to 37° C.

Procedure for taking the electrocardiograms. Two records were taken on each animal; one before the training period and one near the conclusion. Leads I, II, and III were recorded. It required two days to complete the ECG's on each test session.

The animals were injected with a three per cent solution of Sodium Pentobarbital (Nembutal) in a dosage of approximately .16cc/100 grams of body weight. (The amount of nembutal needed varied with the animal.) When the animal became quiet to the extent that he could not hold his head erect, he was placed upon his back on a flat board and fastened in place by stretching rubber bands from each extremity to hook screws on the board. Needle electrodes were inserted under the skin of each extremity (Figure 1).

Two instruments were used to record the ECG's on the first testing. A Twin-Viso Sanborn direct writing recorder (model-60-1300) was used for the initial pickup. An Oscilloscope (model-130A) with a polaroid camera mounted

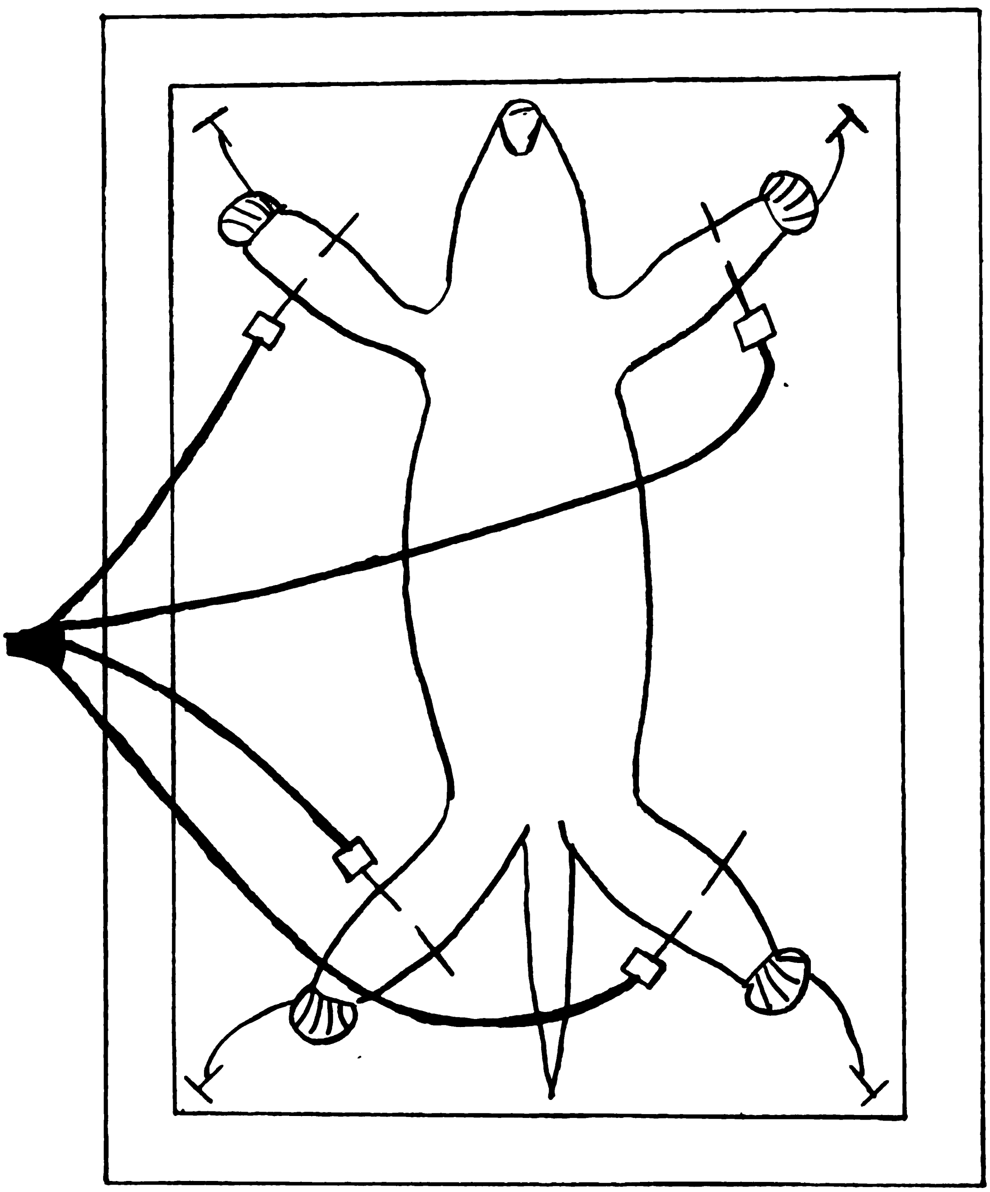

Figure 1. Technique for preparing animals for ECG's recording.

on the screen was hooked into the recorder and pictures were taken of the waves as they passed on the screen. The recorder was set so lmV produced 15mm. of deflection and was operated at a speed of 100mm./sec. The Oscilloscope was calibrated so lmV produced 28mm. of deflection the first day and 29 mm. the second day, and was operated with a sweep time of 50 milliseconds/cm.

The use of the Oscilloscope and polaroid camera adds to the expense of conducting an animal experiment of this nature. However, upon comparing previous pictures with the corresponding direct writer electrocardiograph records, it was felt that the pictures gave the more accurate reproduction of the rat ECG. Differences were especially noted in the R and S-wave deflections. The statistical analysis used to determine the relationship between these instruments is discussed in the Statistical Analysis section of this chapter.

The post-condition ECG's were recorded in the same manner with this exception: The recorder was used for just the heart rates of the animals. Calibrations used on the Oscilloscope were lmV = 28 mm. deflection and lmV = 27 mm. of deflection.

<u>Measurements</u>. The following amplitudes were measured with vernier caliphers in Leads I and III: P-wave, R-wave, S-wave, and T-wave. The algebraic sum of the R and S-waves constituted the QRS complex since no Q-waves were observed.

The intervals were measured with the same instrument and included the following: P-R interval, QRS interval, and R-T interval. The intervals were measured from Lead II on the first test and Lead III on the second. All raw measures were recorded in millimeters; the amplitudes were converted to millivolts and the intervals to seconds (Appendix A).

Heart rates were computed from the Sanborn electrocardiograph by counting the number of beats in three different one second intervals, adding them, and multiplying the sum by twenty.

All amplitudes were measured from the isoelectric line to the peak of the deflection. The intervals were measured by the following procedure: P-R interval, from the point where the P-wave started to the beginning of the R-wave; QRS interval, since no Q-waves were found, the QRS interval was represented by the space from the start of the R-wave to the point where the S-wave intersected the isoelectric line; R-T interval, from the beginning of the R-wave to the point where the T-wave returned to the base line or to the next P-wave.

All-out swim times were obtained by swimming each animal individually in a galvanized container filled with twenty inches of water. Six per cent of the animal's body weight was attached for this test. Each animal was allowed to swim until he could no longer regain the surface after being submerged for approximately 15 seconds.

The animals were sacrificed, dissected, and body organ weights were recorded.

III. STATISTICAL ANALYSIS

Using the pre-condition results, Pearson Product-Moment coefficients of correlation were computed for the data collected on the Oscilloscope and those from the Sanborn direct writer in an effort to determine the degree of relationship between the instruments. The "t" test was used to compare the means from these records.

Vectors for the P-wave, QRS complex, and T-wave were computed from the amplitudes of the "pre-condition," and "post-condition" records. Tables designed for this analyses by Jackson and Winsor[1] were used. Oscilloscope records were used for all final statistical analysis.

F-ratios were computed on the "pre-condition" vectors and intervals, "post-condition" vectors and intervals, and the "individual differences" obtained from pre-condition to post-condition.

The Student "t" was used to compare the means of the "individual differences" of Groups A and C, which were the stock diet animals.

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[1]Charles E. Jackson and Travis Winsor, "Aids for Determining Magnitude and Direction of Electrical Axes of the ECG," Circulation, 1:975-981, April, 1950.

Correlations were calculated on the post-condition ECG's and heart weight, heart rate after conditioning, and all-out swim time (see Appendix B for these raw measures).

CHAPTER IV

PRESENTATION AND DISCUSSION OF DATA

This study was undertaken to determine the effects of a prolonged conditioning period on the ECG's of albino rats.

Forty-eight animals were divided into three groups. Two groups were subjected to a swimming conditioning program and one group remained sedentary. Electrocardiograms were taken before and after a twelve week conditioning period.

I. RESULTS: CORRELATION OF TEST INSTRUMENTS

A Summary of the results is presented in Table II. Statistically significant "t's" at the 0.01 level were found in the R-wave (I), S-wave (I), and the R-wave (III). Differences in the S-wave (III), T-wave (III), and R-T interval were significant at the 0.001 level.

In all instances except the R-T interval, the larger mean was obtained from the Oscilloscope records. The author feels the reversal noted in the R-T interval was caused by the failure of the T-wave on the direct writer records to return to the base line before the following heart beat started. The records from the Oscilloscope

TABLE II

RESULTS OF THE CORRELATION BETWEEN THE DIRECT WRITER AND OSCILLOSCOPE

Amplitudes (mV)	Recorder			Oscilloscope				
	M	S.D.	N	M	S.D.	N	t	r
P-wave (I)	.044	.026	48	.046	.039	48	.35	.60
R-wave (I)	.139	.071	48	.186	.079	48	3.10*	.75
S-wave (I)	.056	.056	48	.093	.066	48	2.92*	.83
T-wave (I)	.043	.046	48	.051	.046	48	.86	.63
P-wave(III)	.169	.031	48	.172	.035	48	.40	.64
R-wave(III)	.346	.109	48	.421	.139	48	2.88*	.87
S-wave(III)	.020	.065	48	.090	.109	48	3.76**	.64
T-wave(III)	.297	.074	48	.300	.078	48	8.13**	.81
Intervals (secs.)								
P-R(II)	.048	.006	48	.050	.057	48	1.24	.63
QRS(II)	.018	.002	48	.018	.003	48	.61	-.09
R-T(II)	.080	.011	48	.066	.007	48	7.45**	.24

*Significant at the .01 level.[1] **Significant at the .001 level.

[1]Significance levels taken from Table E of Quinn McNemar, Psychological Statistics (New York: John Wiley and Sons, Inc.; Chapman and Hall, Ltd. London, 1955), Appendix, p. 388.

showed that the T-wave did return to the base line in most cases. Therefore, due to the method used for measuring the R-T interval, it was found to be longer in the direct writer records.

Because the correlations were generally low and the differences in the means were statistically significant in many of the measures, it was concluded that the direct writer does not record the ECG of the rat accurately. Hence, the effects of conditioning on the ECG of the rat were studied using the oscilloscope records.

II. RESULTS: EFFECTS OF CONDITIONING ON ECG'S

Analysis of variance. The F-ratios are presented in Tables III, IV, and V.

The analysis of variance revealed significant differences between the groups in the "pre-condition" QRS interval (.001 level) and in the "individual differences" obtained in the QRS interval (.001 level). The negative means indicate a decrease from "pre-condition" to "post-condition" values.

The fact that a significant difference existed in the QRS interval before conditioning and not after indicates that a change did occur during the conditioning program. Observation of the data reveals that those animals which were conditioned increased the duration of the QRS interval; while the sedentary animals decreased.

TABLE III

ELECTROCARDIOGRAM MEASUREMENTS: PRE-CONDITION MEANS, STANDARD DEVIATIONS, AND F-RATIOS

Magnitudes	Group A			Group B			Group C			F-Ratio
	M	S.D.	N	M	S.D.	N	M	S.D.	N	
P-wave	.32	.06	11	.33	.04	14	.37	0	15	2.12
QRS complex	.45	.11	11	.51	.16	14	.52	.19	15	.74
T-wave	.43	.09	11	.44	.11	14	.50	.11	15	2.27
Direction (degrees)										
P-wave	62.4	20.5	11	64.9	20.1	14	62.6	17.4	15	.06
QRS complex	56.9	29.1	11	68.9	24.5	14	68.3	24.0	15	.76
T-wave	73.4	16.0	11	77.1	12.8	14	70.4	11.3	15	.85
Intervals (secs.)										
P-R	.047	.004	11	.052	.006	14	.048	.005	15	2.67
QRS	.016	.002	11	.018	.002	14	.020	.002	15	8.00*
R-T	.065	.009	11	.066	.006	14	.066	.007	15	0.00

*Significant at the .001 level.[1]

[1]Same as reference in Table II of this study, p. 389.

TABLE IV

ELECTROCARDIOGRAM MEASUREMENTS: POST-CONDITION MEANS, STANDARD DEVIATIONS, AND F-RATIOS

Magnitudes	Group A			Group B			Group C			F-Ratio
	M	S.D.	N	M	S.D.	N	M	S.D.	N	
P-wave	.28	.08	11	.30	.07	14	.28	.05	15	0.00
QRS complex	.46	.15	11	.51	.18	14	.43	.11	15	0.80
T-wave	.29	.06	11	.30	.05	14	.30	.06	15	0.00
Direction (degrees)										
P-wave	54.9	22.2	11	54.4	25.5	14	60.9	22.7	15	.31
QRS complex	62.0	18.1	11	65.1	15.2	14	42.3	28.1	15	2.49
T-wave	63.2	20.1	11	58.8	33.3	14	62.7	30.3	15	.08
Intervals (secs.)										
P-R	.046	.005	11	.048	.005	14	.045	.006	15	.67
QRS	.019	.003	11	.019	.001	14	.017	.002	15	.75
R-T	.061	.006	11	.060	.008	14	.056	.009	15	1.67

TABLE V

ELECTROCARDIOGRAM MEASUREMENTS: MEANS, STANDARD DEVIATIONS, AND F-RATIOS OF THE DIFFERENCES, BEFORE AND AFTER CONDITIONING

Magnitude	Group A			Group B			Group C			F-Ratio
	M	S.D.	N	M	S.D.	N	M	S.D.	N	
P-wave	-.02	.08	11	-.03	.09	14	-.09	.08	15	1.86
QRS complex	-.02	.14	11	-.01	.13	14	-.09	.13	15	2.22
T-wave	-.14	.11	11	-.14	.10	14	-.20	.12	15	1.15
Direction (degrees)										
P-wave	-7.5	28.5	11	-10.3	34.2	14	- 1.3	24.9	15	.33
QRS complex	5.1	29.5	11	- 3.9	29.2	14	-25.8	38.7	15	2.86
T-wave	-10.0	24.7	11	-18.3	35.5	14	- 7.7	33.6	15	.39
Intervals (secs.)										
P-R	-.001	.006	11	-.005	.007	14	-.003	.005	15	.91
QRS	.003	.002	11	.001	.003	14	-.003	.003	15	16.99*
R-T	-.004	.011	11	-.007	.009	14	-.010	.011	15	.75

*Significant at the .001 level.[1]

[1]Same as reference in Table II of this study, p. 389.

This is substantiated by the significance found in the "individual differences" of the QRS interval.

"T" test. The "t" test, used to compare the means of the "individual differences" of Groups A and C, revealed significance in the QRS interval (.001 level) and in the direction of the force of the QRS complex (.05 level). These data are presented in Table VI. The direction of the electrical force changed only slightly with conditioning; while the sedentary animals showed a sizable change.

Intercorrelations. A summary of the correlations is reported in Table VII. The "r's" were too low to account for any appreciable amount of variance.

III. DISCUSSION: EFFECTS OF CONDITIONING

From Figure 2 it can be seen that the magnitude of the electrical force decreased in the P-wave and T-wave in all three groups. Perhaps this drop is due to the aging of the animals. It should be noted that a more marked drop occurred in the sedentary animals; possibly indicating that conditioning retards the aging process.

The results show that the QRS complex magnitude is maintained or slightly increased with conditioning; while the sedentary life of the animals in Group C experienced a sharp drop in this magnitude. Again, conditioning may inhibit aging effects on the heart.

TABLE VI

ELECTROCARDIOGRAM MEASUREMENTS: COMPARISON OF "DIFFERENCES" BETWEEN GROUPS A AND C

Magnitude	Group A		Group C		"t"
	M	N	M	N	
P-wave	-.02	11	-.08	15	1.85
QRS complex	-.02	11	-.09	15	2.02
T-wave	-.14	11	-.20	15	1.34
Direction (degrees)					
P-wave	-7.5	11	-1.3	15	.57
QRS complex	5.1	11	-25.8	15	2.13*
T-wave	-10.0	11	-7.7	15	.18
Intervals (secs.)					
P-R	-.001	11	-.003	15	.97
QRS	.003	11	-.003	15	5.11**
R-T	-.004	11	-.010	15	1.15

*Significant at .05 level.[1]
**Significant at .001 level.

[1]Same as reference in Table II.

TABLE VII

CORRELATIONS BETWEEN THE ELECTROCARDIOGRAM MEASURES AND HEART WEIGHT, HEART RATE, AND ALL-OUT SWIM TIMES

ECG Measure	Heart Weight	Heart Rate	Swim Time
Magnitude			
P-wave	.09	.02	.11
QRS complex	.08	-.13	.11
T-wave	-.03	.11	-.05
Direction (degrees)			
P-wave	-.20	.21	-.08
QRS complex	.25	-.09	.15
T-wave	-.30	-.04	.01
Intervals (sec.)			
P-R	.08	.02	.08
QRS	.06	-.16	.23
R-T	.29	.03	.02

N = 40

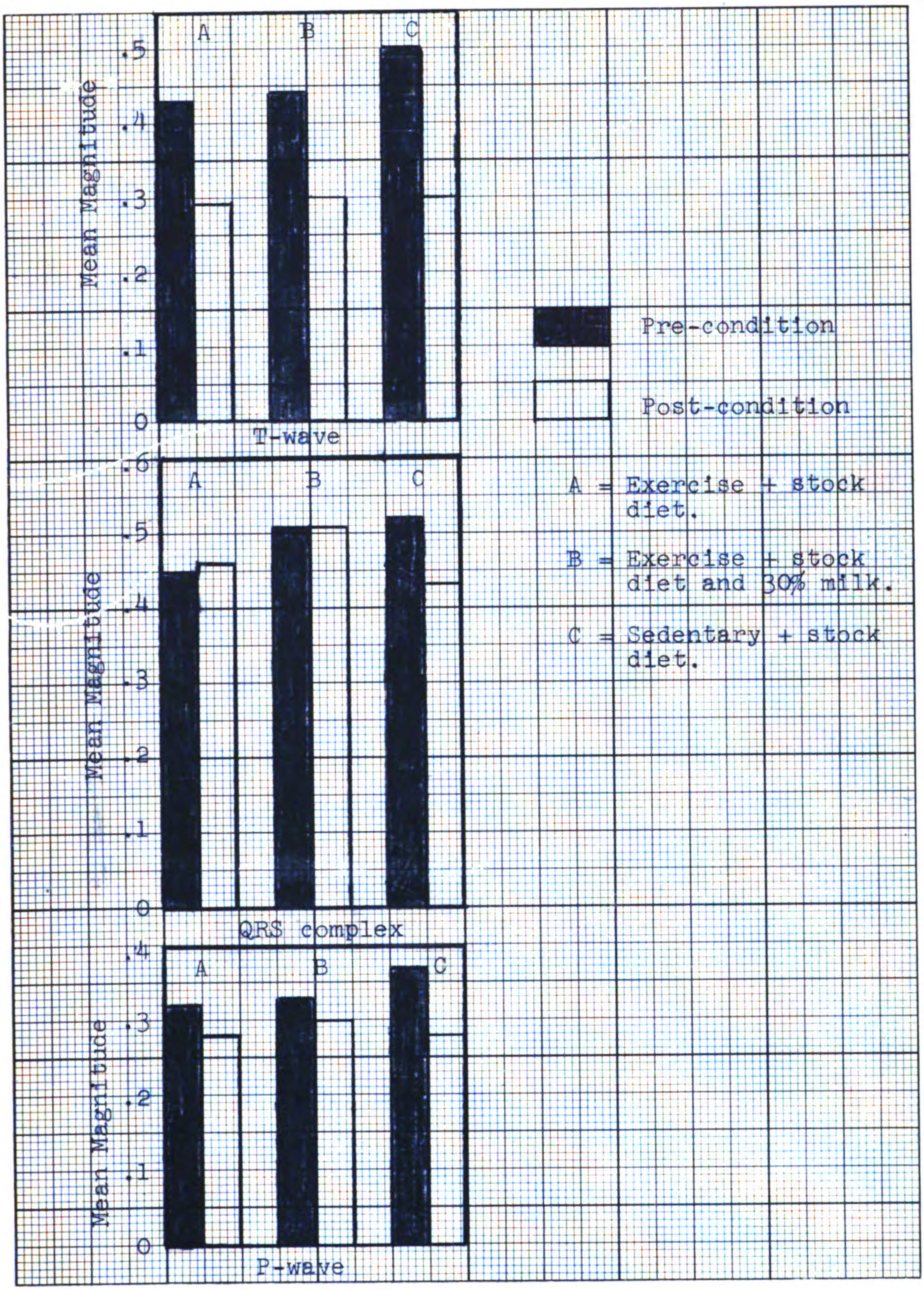

Figure 2. Comparison of ECG Magnitudes.

A previous study on the aging effect on rat ECG's revealed no change in the P-wave.[1] In human ECG work, two points of view are expressed: Conditioning produces a smaller P-wave and a higher T-wave;[2] or no changes.[3]

Direction of electrical force. Changes in the direction of the electrical force are illustrated in Figure 3. It appears that the change found in the P-wave is due to training since the sedentary animals experienced only a very slight change as opposed to the larger change in the conditioned animals.

The sedentary animals experienced a sharp change in the QRS complex; while conditioning produced only slight variations. The difference between Group A and Group C was significant.

T-wave changes were nearly the same in all animals. Apparently conditioning has no effect on this portion of the rat ECG; the major factor causing the changes being age.

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[1] Benjamin Berg, "The Electrocardiogram in Aging Rats," Journal of Gernotology, 10:420-423, October, 1953.

[2] S. Hoogerwerf, Ergebnesse der spotaztlichen Untersuchungen bei den IX Olympischen Spielen, pp. 118-38, Berlin, 1929; "Elektrokardiograhische Untersuchungen der Amsterdamer Olympiade," Arbeitsphysiologie, 2:61, 1929, cited by T. K. Cureton, Physical Fitness of Champion Athletes (Urbana: University of Illinois Press, 1951), p. 140.

[3] W. W. Tuttle and Horace M. Korns, "Electrocardiographic Observations on Athletes Before and After a Season of Physical Training," American Heart Journal, 21:104-107, January, 1941.

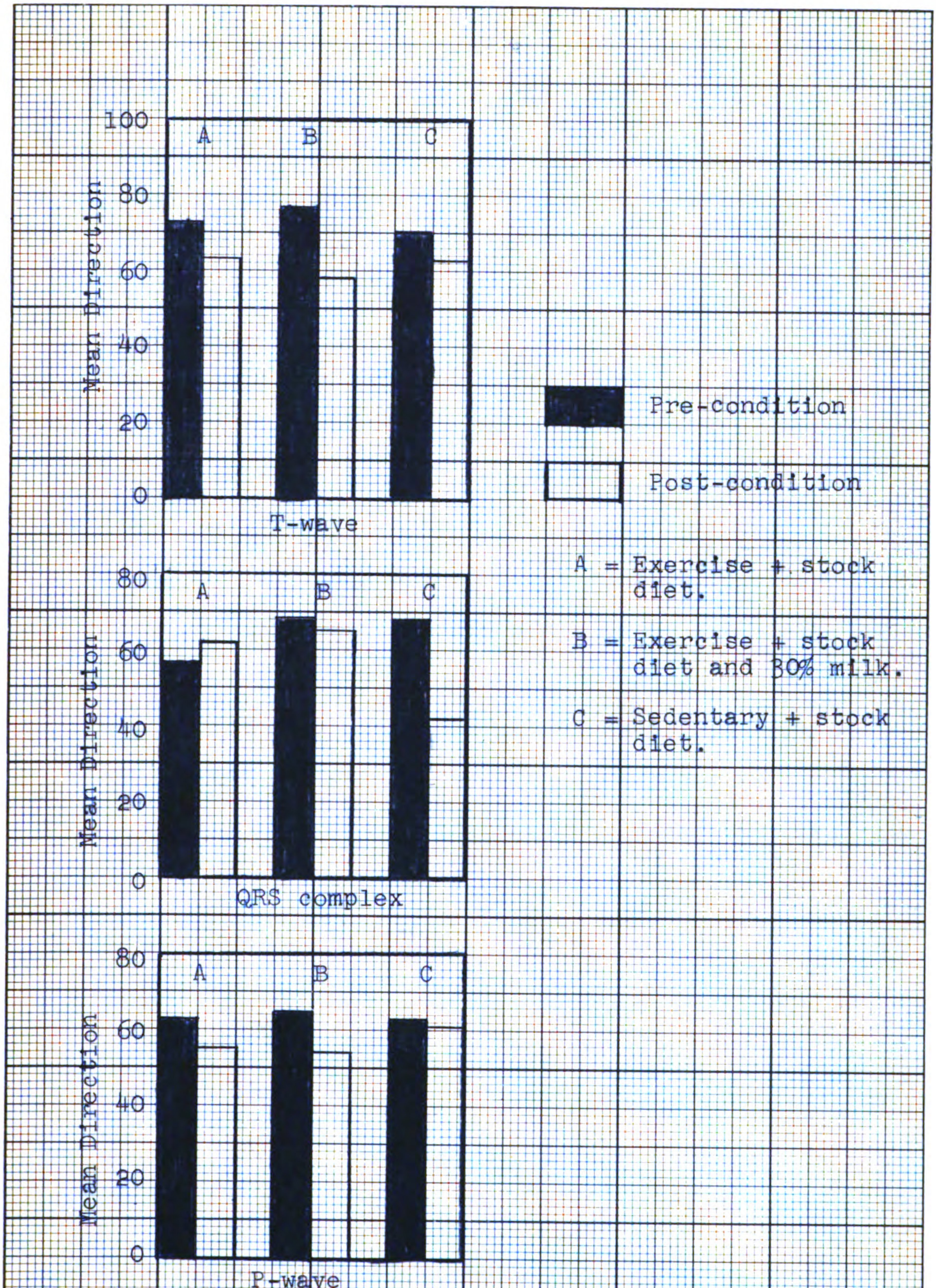

Figure 3. Comparison of ECG Directions in Degrees

Berg[4] reported left axis deviation in aging rats. Deviations obtained in this study were to the right. Tung,[5] _et al._, reported that strenuous physical activity produced no change in the electrical axis of the QRS complex of humans.

Intervals and heart rate. Figures 4 and 5 present graphic illustrations of these results.

The P-R and R-T intervals decreased in all three groups. The QRS interval decreased in the sedentary animals, but increased in the conditioned animals. The differences in the QRS interval were significant.

Heart rates decreased in all three groups during the experiment. The conditioned groups showed slower heart rates than the sedentary animals. Berg[6] also noticed slower heart rates in rats as they advanced in age.

Other studies on rats have indicated that the intervals of the ECG increase with age.[7]

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[4]Berg, _op. cit._, pp. 420-423.

[5]C. L. Tung, _et al._, "The Hearts of Ricksha Pullers: A Study of the Effects of Chronic Exertion on the Cardiovascular System," _American Heart Journal_, 10:79-100, October, 1934.

[6]Berg, _op. cit._, pp. 420-423.

[7]James M. Hundley, L. L. Ashburn, and W. H. Sebrell, "The Electrocardiogram in Chronic Thiamine Deficiency in Rats," _American Journal of Physiology_, 144:404-414, August, 1945; Charles R. Ensor, "The Electrocardiogram of Rats on Vitamin E Deficiency," _American Journal of Physiology_, 147: 477-479, November, 1946; Berg, _op. cit._, pp. 420-423.

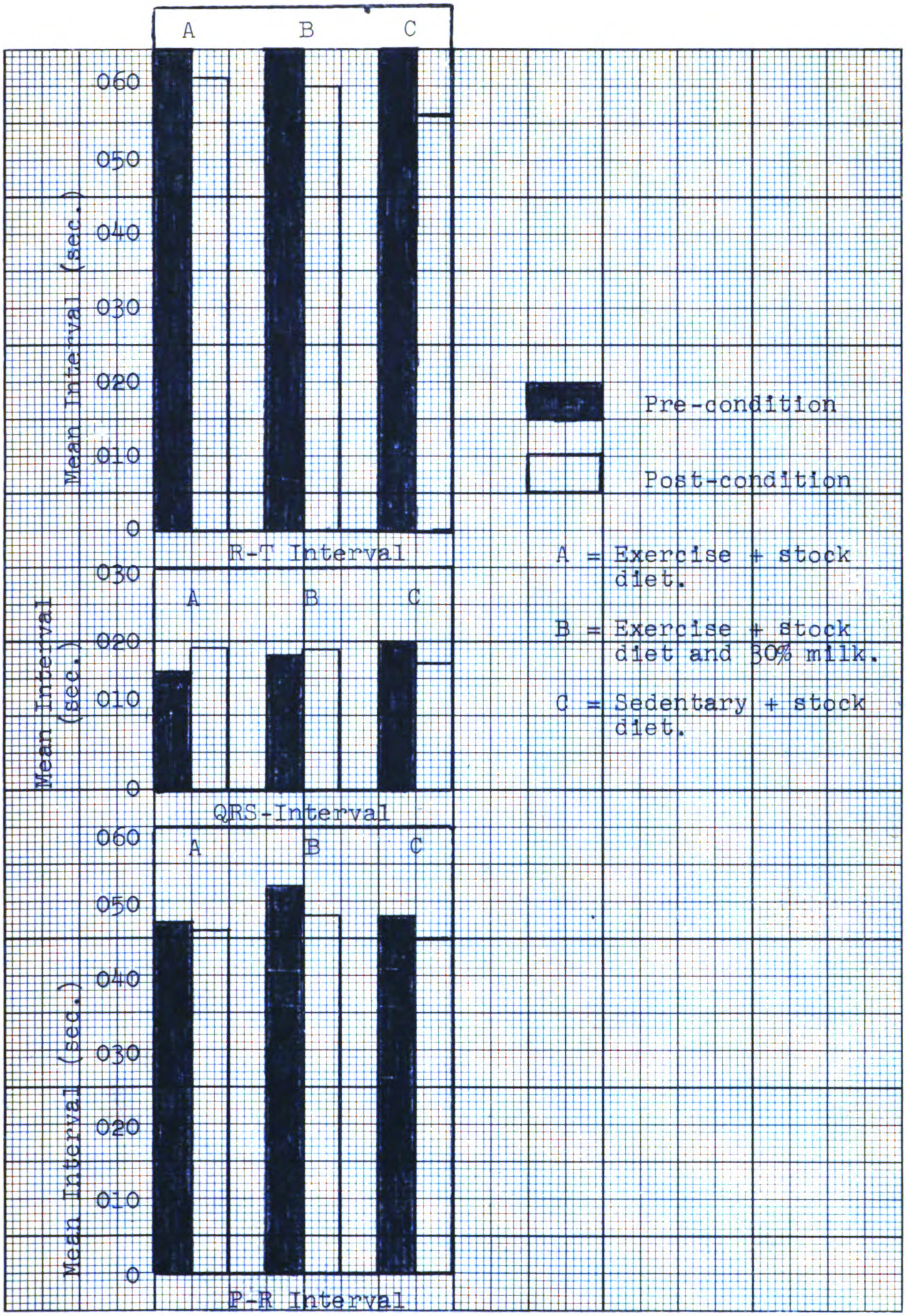

Figure 4. Comparison of ECG Intervals

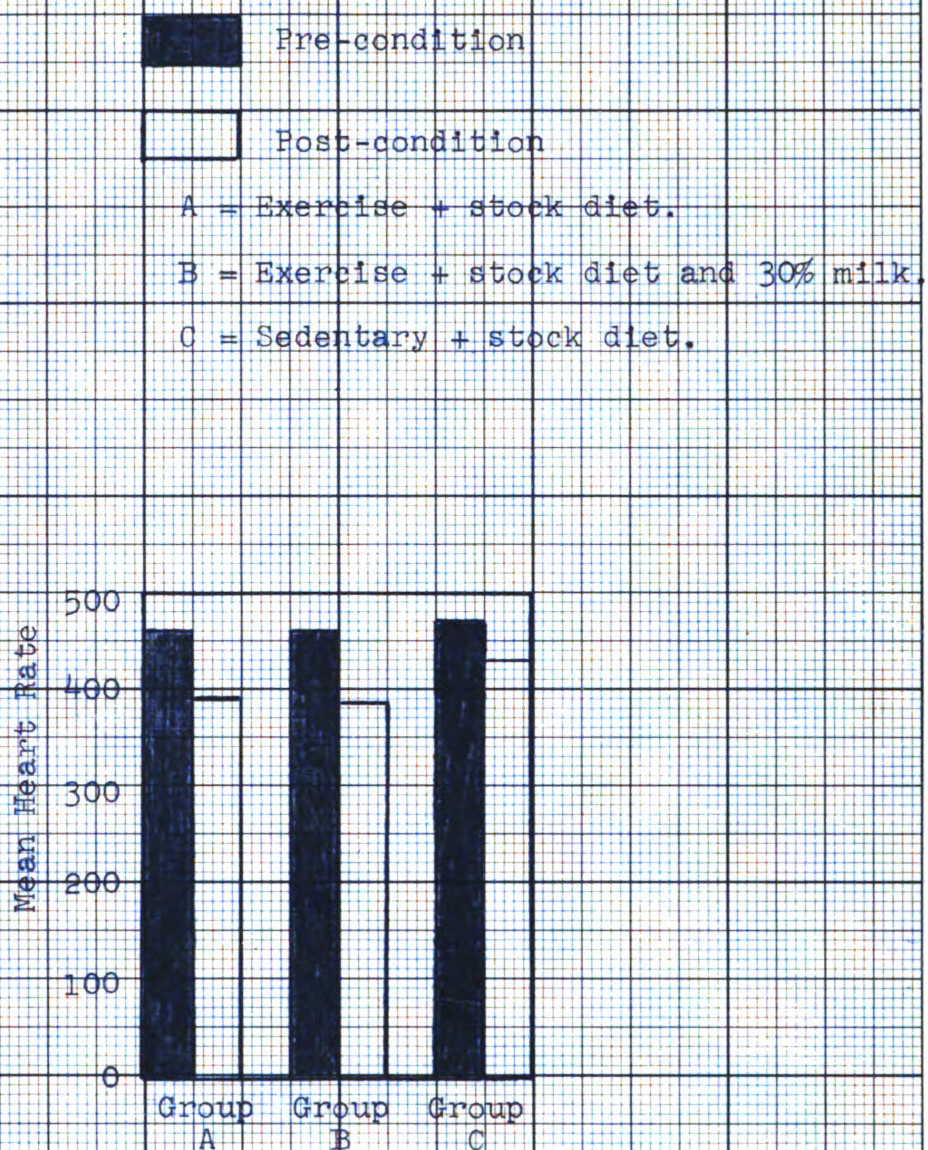

Figure 5. Comparison of Heart Rates

In an effort to explain these different results, the T-P segment of the isoelectric line was measured. It was found that this segment increased with age in all groups, thus accounting for the decreased interval times with a slower heart rate. The total cycle length (P-wave to P-wave) of the exercise groups increased, while the sedentary group remained essentially the same. This is explained by the slower heart rate and lengthened QRS interval in the conditioned animals.

TABLE VIII

COMPARISON OF MEAN T-P SEGMENTS AND MEAN TOTAL CYCLE LENGTHS (SECONDS)

Group	Mean T-P Segment		Mean Total Cycle	
	(Before)	(After)	(Before)	(After)
A	.018	.033	.146	.159
B	.022	.035	.158	.172
C	.018	.032	.152	.150

Intercorrelations. The fact that no relationship was found between the ECG's and heart rate, heart weight, and all-out swim time shows clearly the individuality of each animal.

Blouin[8] also found no relationship between heart rate and ECG intervals of dogs.

---

[8] Leonard Thomas Blouin, "Effects of Position and Anesthesia Upon the Electrocardiogram of the Normal Dog" (unpublished Master's thesis, Michigan State University, 1956).

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

This study was designed for the purpose of studying the effects of prolonged conditioning on the electrocardiograms of albino rats.

The literature in regard to the ECG's of rats is limited and there seems to be no information on the effects of exercise on small animal electrocardiograms. Most of the rat ECG literature relates to the effects of aging. The general opinion is that the intervals of the rat ECG increase with age, and slower heart rates are observed.

The effects of conditioning on human ECG's is reported. There is a difference of opinion in regard to the effects of prolonged training on the electrocardiograms. Some authorities find no qualitative changes with conditioning, while others found statistically significant effects. The latter maintain that the T-wave is larger in athletes, the P-wave is generally smaller, and the P-R and Q-T intervals are lengthened with conditioning.

The use of Sodium Pentobarbital on animals seems to have no effect on the electrocardiogram according to the reported literature.

Forty-eight albino, weanling, male, litter-mate rats were divided into three experimental groups: Group A received a stock diet and twelve weeks of conditioning, Group B received a stock diet mixed with powdered whole milk, constituting 30% of their daily caloric intake, and conditioning, and Group C received a stock diet and remained sedentary throughout the experiment.

Groups A and B were swum twice daily for equal periods in metal tanks filled with 13" to 14" of water. Water temperature was maintained at 36° C to 37° C.

Electrocardiograms were recorded from the three standard leads before and after the twelve weeks of conditioning. Two recording instruments were used. A Sanborn direct-writer was used for the initial pick-up and an Oscilloscope with a polaroid camera mounted on the screen was hooked into the direct writer and served as the second test device. Correlations and "t's" were computed on the data from these instruments. The results showed that the Oscilloscope gave the more accurate record of the rat ECG and, therefore, was used for the final test. All final analyses were computed from the Oscilloscope records.

The following ECG data were collected: P, R, S, and T-wave amplitudes, and P-R, QRS, and R-T intervals. Measurements were taken with vernier caliphers and recorded in millimeters. The amplitudes were converted to millivolts and the intervals to seconds.

Heart rates were computed before and after conditioning.

All-out swim times were obtained by swimming each animal with six per cent of his body weight attached.

The animals were sacrificed, dissected, and body organ weights tabulated.

Vectors were computed from Leads I and III. F-ratios were computed on the "pre-condition" vectors and intervals, the "post-condition" vectors and intervals, and on the differences" from pre-conditioning to post-conditioning. Using the "t" test, the means of the "individual differences" between Groups A and C were compared. Correlations were computed on the ECG data and heart weight, heart rate after conditioning, and all-out swim times.

II. CONCLUSIONS

The following conclusions are derived from the data reported in this paper:

1. The direct writer is not adequate for recording the electrocardiograms of rats. The use of the Oscilloscope gives a more accurate reproduction of the rat ECG.
2. The heart rate of the rat decreases with age and is slower in rats receiving exercise.
3. P-wave and T-wave magnitudes of rats decrease with age. Conditioning tends to retard the drop.

4. The QRS complex magnitude is increased or maintained by conditioning, while in a sedentary life this magnitude is reduced.
5. The direction of the electrical force in the rat's heart changes with age regardless of the effect of conditioning in the P and T-waves. The change noted in the QRS complex is not as marked in the conditioned animals as that of the sedentary group.
6. The P-R and R-T intervals decrease with age, conditioning having no effect on the P-R; but retarding the decrease in the R-T interval.
7. The QRS interval lengthens slightly with conditioning, and decreases with a sedentary life.
8. There is diversified opinion in regard to the effects of conditioning on the human ECG.

III. RECOMMENDATIONS

The following recommendations are made for further study in this area:

1. A similar experiment should be conducted by exercising rats on a treadmill at two different intensities. This would allow control of work output.
2. For additional studies using swimming for the exercise, the use of deeper tanks would provide

a better control for the exercise. Also the use of round containers would be advisable as the animals soon learn to rest in the corners of a rectangular tank.

3. A study of older animals with the design of this investigation would give more light on the effects conditioning has upon the aging heart.

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APPENDIX

APPENDIX A

CONVERSION FORMULAS USED IN THIS EXPERIMENT

Conversion of picture size to actual screen size:

Actual size of screen--100mm.
Picture size of screen--54.4mm.

$$\frac{100\text{mm.}}{54.4\text{mm.}} = 1.84$$

1.84 x picture measure = actual screen size

Conversion to millivolts(mV):

Pictures:

calibrations used: 27mm. = 1mV (.0370)
28mm. = 1mV (.0357)
29mm. = 1mV (.0345)
calibration x measure = mV

Electrocardiograph:

calibration used: 15mm. = 1mV (.0667)
calibration x measure = mV

Conversion to seconds:

Pictures:

sweep time = 50 milliseconds/cm.
50 milliseconds/cm. = .005 sec./mm.
.005 x measure = interval in seconds

Electrocardiograph:

speed of machine (actual) = 96.2mm./sec.

$$\frac{1\text{ sec.}}{96.2\text{mm./sec.}} = .0104\text{ sec./mm.}$$

.0104 x measure = interval in seconds

APPENDIX B

SWIM TIMES, HEART RATES, AND HEART WEIGHTS

Animal Number	Swim Time (sec)	Heart Rate (before)	Heart Rate (after)	Heart Weight (grams)
1	312	420	402	1.407
2	768	468	366	1.433
4	400	420	372	1.303
6	277	420	408	1.555
7	212	450	354	1.495
8	358	456	354	1.265
9	287	450	426	1.357
12	212	510	420	1.469
13	360	534	456	1.438
15	300	426	348	1.600
16	270	498	438	1.401
17	505	414	426	1.621
18	324	504	420	1.488
19	335	480	378	1.459
20	569	408	360	1.350
21	444	474	378	1.401
23	337	432	384	1.478
24	470	432	324	1.219
25	494	462	384	1.436
26	172	402	390	1.470

APPENDIX B--Continued

Animal Number	Swim Time (sec)	Heart Rate (before)	Heart Rate (after)	Heart Weight (grams)
27	339	480	366	1.913
28	255	486	432	1.358
29	900	474	420	1.573
31	416	480	414	1.561
32	299	480	414	1.360
33	237	426	450	1.415
34	126	486	366	1.145
35	294	480	420	1.261
37	131	540	468	1.275
38	145	420	438	1.336
39	103	480	438	1.556
40	112	450	408	1.350
41	138	474	444	1.390
42	217	468	414	1.285
43	131	504	420	1.406
44	141	492	468	1.316
45	145	468	450	1.250
46	135	462	408	1.489
47	180	558	480	1.269
48	99	420	464	1.267

K.J. Ackerman 1959
M.A.