THE EFFECT OF TRAINING AT DIFFERENT WATER TEMPERATURES UPON FOUR PARAMETERS; NAMELY SWIMMING PERFORMANCE, BODY WEIGHT, ADRENAL GLAND WEIGHT, AND HEART WEIGHT OF THE MALE ALBINO RAT

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by

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ABSTRACT

This study was undertaken to determine whether training at water temperatures of 22°C, 29°C or 36°C had any significant effect upon the following four parameters: (1) swim time to exhaustion, (2) body weight, (3) relative adrenal gland weight, and (4) relative heart weight. The relative adrenal gland and heart weights were also compared to a control group of sedentary rats.

The sample (N-46) was randomly divided into ten controls and thirty-six experimental rats. The experimental group was then subdivided into three equal groups with regard to mean swim times as a result of an exhaustive swim with 4% of body weight attached to the tails in water at 29°C. During the training program two rats from each group drowned.

F-test and Newman-Keuls test were employed in the statistical analysis of the data. Insignificant differences were obtained in (1) swim time to exhaustion, (2) relative adrenal gland weight, and (3) relative heart weight between rats trained at water temperatures of 22°C, 29°C and 36°C. The difference in body weight proved to be significant. There was also a significant difference in relative adrenal gland and heart weight between the control group and

experimental groups.

It was also concluded that training at different water temperatures was of no advantage in improving (1) swim time to exhaustion, (2) relative adrenal gland and heart weights but swimming in 36°C water was a factor in keeping body weight significantly lower. It was also determined that swimming produced larger relative adrenal glands and relative heart weights when compared to sedentary controls.

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TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Athletes have always strived for new ways to improve physical performance. Special diets, drugs and other aids have been used with a small degree of success. Many variations of physical training have also been used in order to try and improve performance. One of the more recent variations has been the combination of physical and environmental stress. Researchers have trained people and animals under certain climatic conditions in order for them to withstand a similar climate. For example, soldiers have been acclimatized in hot rooms in order for them to perform in hot climates. Exercise physiologists have studied some of the effects of training in a particular environment in order to perform in a different environment or, in short, the effect of two stressors on the human body. Runners, for example, have trained at high altitudes for competitions at sea level. It has also been suggested that environmental stress alone can alter physical performances. Kreider (40) showed that cold acclimatized rats were 40% better swimmers than non-acclimatized controls. It appeared then extremely important to continue the study of combined environmental and physical stress in order to understand some of the complex adjustment responses in the mammalian body.

Statement of the Problem

The present study was undertaken not only to evaluate the magnitude of the stress of swimming for rats but also to investigate certain physiological responses to exercise by training under varied ambient thermal conditions. This was done through the determination of swimming performance, body weight, adrenal gland weight, and heart weight of rats forced to swim in water at 22°C, 29°C and 36°C.

Hypothesis

1. There is no significant difference in swim times to exhaustion in 29°C water between rats trained at water temperatures of 22°C, 29°C and 36°C.

2. There is no significant difference in body weight between rats trained at water temperatures of 22°C, 29°C and 36°C.

3. There is no signficant difference in relative adrenal gland weight between rats trained at water temperatures of 22°C, 29°C and 36°C.

4. There is no significant difference in relative heart weight between rats trained at water temperatures of

22°C, 29°C and 36°C.

5. There is no significant difference in relative adrenal gland weight between the control and experimental groups.

6. There is no significant difference in relative heart weight between the control and experimental groups.

Statistical Hypothesis

1. $U_1 = U_2 = U_3$

2. $U_1 = U_2 = U_3$

3. $U_1 = U_2 = U_3$

4. $U_1 = U_2 = U_3$

5. $U_c = U_1 = U_2 = U_3$

6. $U_c = U_1 = U_2 = U_3$

U_c = mean of control group

U_1 = mean of 22°C experimental group

U_2 = mean of 29°C experimental group

U_3 = mean of 36°C experimental group

Hypotheses to be tested at $\alpha = 0.05$

Limitations of the Study

1. There were no adjustments made for the

differences in buoyancy of the various rats.

2. The presence of air bubbles in the water may have caused fluctuations in buoyancy.

3. The water temperature fluctuated ± 0.5°C from the desired temperature.

4. The air temperature fluctuated between 72° - 75°F.

Basic Assumptions

1. It was assumed that if subjected to daily bouts of swimming the physical endurance of the rats will be improved.

2. It was assumed that the level of physical endurance may be measured by the length of time the rat is able to swim with weights attached to his body.

3. The assumption was made that all rats were free of respiratory and other diseases throughout the study.

4. The assumption was made that fifteen seconds underwater was a valid and reliable test of exhaustion.

5. The assumption was made that all irrelevant material, especially fat, was removed from the heart and adrenal glands before they were weighed.

6. It was assumed that the commercially supplied rats were of similar ages.

Definition of Terms

Exhaustion - The length of time that the rat could swim before remaining submerged for a period of fifteen seconds while trying to reach the surface.

Training Day - This was a day in which the rat swam either two-thirds of maximum or until exhaustion.

Rest Day - This was considered a day in which the rat rested and took part in no swimming.

Relative Weight of Organs - This was considered to be the raw weight divided by the body weight in grams.

Absolute Weight of Organs - This was considered to be the raw weight.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Forced swimming of small laboratory animals has been widely used for studying the physiology and capacity of the organism in response to stress. One of the most important factors affecting swimming performance is water temperature. Figure one is a compilation of data from literature showing the influence of water temperature upon swimming time of unweighted and untreated laboratory and wild animals. Water temperature above or below the optimum markedly reduced the duration of swims with higher temperatures producing the greatest reduction. Tan (69) found that in water near body temperature rats swam three hundred times longer than in 17°C and over one hundred times longer than in 40°C. It was observed by the author that rats carrying a load on their tails equivalent to 4% of their body weight could swim well between 22°C and 36°C. Performance rapidly decreased outside this temperature zone.

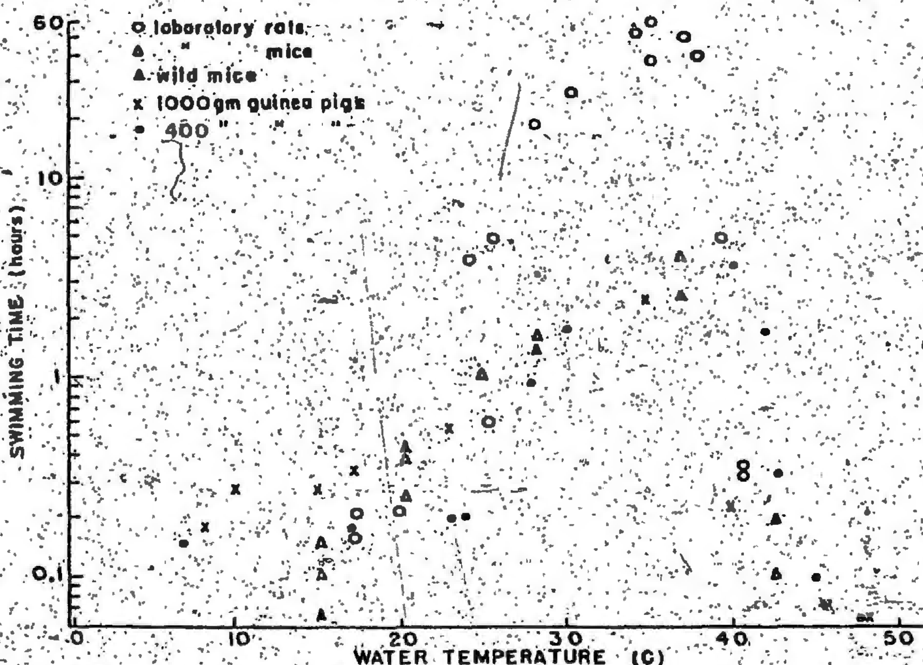

Figure I - Influence of water temperature on the swim time to exhaustion. Data from Dawson and Horvath (14).

Part I

The effects of training on swimming performance are not entirely clear. A number of investigators have reported increased swimming times following repeated swims. Barnes (4) found variability in individual swimming times but the experimental group swam better than the controls. Cowdrey (11) had swim times increase from eight minutes to thirty minutes over a twenty week period. Eranko (17) reported that rats swimming in 37°C water increased swim times from ten minutes to three hours after three weeks. Hanson (23) observed that rats swimming at 35°C gradually increased their swimming time to thirty minutes. Keeney (35) reported that swimming performance increased from fifteen minutes to forty minutes a day after six weeks. Montoye – 1962 (49) observed that when exercised animals were compared with sedentary animals the daily swimming program was seen to result in significant increases in swim time. Hearn (29), McArdle – 1966 (43), Oscai – 1971/1 (51) and Prokop (55) also reported that rats had consistent swim times with only small fluctuations in individual performances.

While many investigators have reported improved performances following training, others have failed to do so. Updyke (71) found that rats swimming daily in 35°C –

$37^{o}C$ water for up to thirty minutes for four weeks actually had a decreased performance as compared with controls on the exhaustive tests. The poorer performance was attributed to the presence of chronic pneumonia and acute respiratory disease found upon post mortem examination. Tura (70) reported that daily swimming to exhaustion in $22^{o}C$ water reduced the swim time of the rats from fifteen minutes to less than ten minutes after one month. He did not explain his criteria for exhaustion but it may have been too severe for the rats since only twenty-nine out of seventy-three were alive at the end of ninety days. Kniazuk and Molitor (39) found no improvement in the performance of an endurance test in rats swimming in $30^{o}C$ water daily for fourteen days. More than two swimming periods per day actually resulted in a decreased performance. Battig (5) observed no improvement in swimming performance on an endurance test with training. The control swimmers gained less than a minute over the forty-five week period swimming the maze. Baker (3) and Richter (58) found some variation in individual swim time due to convulsions of some rats as a result of extreme stress. Richter also observed that some rats appeared to regard their position as hopeless and would rather drown than swim.

Part II

The effect of exercise, especially swimming, on body growth has been of considerable interest to exercise physiologists. A number of training regimens have retarded growth of the rat. Buuck (9) revealed that rats who ran one mile per hour on a rodent treadmill five days a week for eight weeks had a significant lower body weight than the sedentary group. The trained rats weighted 345.8 ± 6.3 grams while the controls weighted 372.8 ± 9.2 grams. Crews - 1969 (13) also pointed out that running animals gained significantly less weight than their free eating controls as a result of both increasedcaloric expenditure and a decrease in food intake. The controls were 465 ± 18 grams while the runners were 339 ± 18 grams.

Jones - 1964 (34) observed that rats swimming in 35°C-37°C water (400 grams) were significantly leaner than the controls (460 grams). Kimeldorf (37) stated that daily exhaustive swimming in 21°C-25°C water from fifteen minutes to thirty minutes duration is capable of significant depression of body weight from that of controls. During the thirty day experimental period the body weight gain of the exercising animals (295 grams) was only 61% of that of the sedentary animals (334 grams). Montoye - 1962 (49) reported that when exercising animals were compared with sedentary animals the daily swimming program was seen to result in a significant decrease in body weight. The experimental group's mean weight was 414.1 grams while the sedentary group's mean weight was 453.4 grams. Oscai - 1971/1 (51) also revealed that rats subjected to swimming exercise gained weight more slowly (245 grams) than sedentary free-eating controls. Similar results were also observed by Oscai 1972/2 (52), Pitts (54), and Van Lierre (72). Hearn (29) reported that all exercising animals gained less weight than controls in that trained animals gained 1.36 grams per day while the controls gained 2.00 grams per day. However he failed to give the raw weights.

Few researchers have reported that the exercising rats gained more weight than the sedentary rats. Donaldson - 1932 (16) and Donaldson - 1933 (15) stated that body weight increased by twelve per cent in male rats. Hatai (28) also noted a slight increase in the body weight of exercising rats (6.76%). However he suggested this could be due to the fact that the control rats had lung disease while the exercising rats did not. Ring (59) reported that rats who did a minimum amount of exercise reached a mean weight of 148 grams while the maximum exercising rats revealed a mean of 174 grams. The amount of time that each group exercised was not given.

Other researchers have concluded that exercise does not affect body weight. Altland (1) observed that rats who exercised daily on a rotating drum for six hours for 1, 3, 7, 15 or 19 successive days had an initial loss of body weight for the first five days but this was restored near control level during the fifteenth to nineteenth days of exercise. Aros (2) found that after three hundred hours there was no significant difference in body weight between sedentary controls (272 grams) and the exercising group (279 grams). Barnes (4) also reported that the body weights of the control and experimental groups were similar. Cowdrey (11) found that rats who swam a maximum of thirty minutes a day over a twenty week period showed a slightly lower body weight (491 grams) than the non-exercising group (498 grams). Crews - 1967 (12) reported that rats who swam at 33^{o}C six hours a day six days a week had no significant difference in body weight (275 grams) when compared to sedentary control rats (274 grams). Similar findings included studies by Donaldson - 1933 (15), Eranko (17), Hanson (23), Jones - 1961 (33), McAtee (46), Montoye - 1960 (48), Riccio (57) and Stevenson (68).

It was very difficult to compare the above literature as well as the adrenal and cardiac literature since the testing procedures of the experimenters were quite varied with regard to water temperature, length of swimming and exercising time, and addition of weights to the rats. These numerous variations resulted in different levels of physical stress which affected the four parameters. Oscai -1971 (52) tried to vary the levels of physical stress by increasing the exercising time. He concluded that less strenuous exercise resulted in a non-significant difference in body weight. However when the program was strenuous there was a significant decrease in body weight of the exercising animals. Therefore in order to accurately compare each study, the levels of physical stress would have to be standardized.

Part III

Adrenal and cardiac hypertrophy has been the result of strenuous exercise. A number of investigators have found increases in adrenal and cardiac weights as a result of exercising small laboratory animals especially rats. Altland (1) found that rats who exercised daily on a rotating drum for six hours for 1, 3, 7, 15 or 19 successive days showed evidence of cardiac and adrenal hypertrophy. After seventeen days of training relative adrenal gland and relative heart weight remained at increased levels of 38% and 18% respectively. Aros (2) observed that there was a significant difference in raw heart weights of rats who swam at 33°C for six hours per day six days a week. The control's mean heart weight was 0.73 ± 0.08 grams while the swimmer's mean heart weight was 1.09 ± 0.108 grams. Crews - 1967 (12) reported that rats who swam six hours per day six days a week had a mean heart weight of 1.206 grams while the controls had a mean value of 0.90 grams. This difference was significant. However there was no significant difference between adrenal gland weight. The mean value of the controls was 0.062 grams while that of the swimmers was 0.064 grams. Donaldson - 1932 (16) and Donaldson - 1933 (15) indicated that there was adrenal and cardiac hypertrophy but the raw scores were not given. Eranko (17) stated that rats who swam in 37°C water for a maximum of three hours showed a significant increase in adrenal weight. Frenkl - 1962 (19) reported that rats who swam with 4.5% body weight at 29°C showed adrenal hypertrophy after six weeks. Montoye - 1962 (49) observed that when exercised animals were compared with sedentary ones the daily swimming program was seen to result in significant increases in heart and adrenal gland weight. Oscai - 1973 (53) reported that the mean heart weight (1.03 grams) of the exercised animals were significantly higher than the sedentary animals (0.81 grams).

All experiments did not necessarily show a significant difference in mean adrenal and mean heart weights between swimmers and sedentary animals. The difference usually occurred when the organ weight was measured per gram of body weight since many exercising animals gained less weight than their controls. Another variation, making comparison difficult, was that some experimenters gave only the mean weights while others gave only the organ weight as a percentage of body weight.

In past research the effects of training on swimming has been unclear. Some investigators have reported increased swimming times following repeated swims. Other researchers have found that training decreased performance which was mainly attributed to the presence of chronic pneumonia or acute respiratory disease or both. The effect of exercise on body weight has also been uncertain. A number of training regimes have reported retarded growth of the rats while others have concluded that exercise does not affect body weight. Few researchers have reported that the exercised rats gained more weight than the sedentary rats. The majority of researchers have observed that exercise has also resulted in adrenal and cardiac hypertrophy although, as previously mentioned, some investigators observed no significant difference in mean adrenal gland or mean heart weight or both.

CHAPTER III

METHODOLOGY

CHAPTER III

METHODOLOGY

I. Experimental Design

Experiments were conducted so that the swimming performances of rats at three different water temperatures could be compared. Forty-six male Sprague-Dowley rats, weighing approximately 270 grams, were randomly divided into two groups, ten in the control group and thirty-six in the experimental group. The experimental group was then subdivided into three equal groups based on their performance during an exhaustive swim in water at 29°C with 4% of body weight attached to their tails. The control group was sacrificed at the beginning of the experiment in order to measure relative adrenal gland and relative heart weights.

II. Animal Care

All rats were kept in plastic cages approximately nine inches high, ten inches wide and eighteen inches long. The room temperature was between 72°-75° Farenheit. All animals were fed ad libitum on Purina Rat Chow and water.

III. Instruments and Apparatus

Three commercial plastic garbage containers with a diameter of twenty-four inches were divided into four equal compartments by one-half inch plexyglass dividers. The water depth was approximately twenty-two inches. A Mettler H64 analytical balance was used to measure the adrenal gland and heart weights to the nearest 10^{-5} of a gram.

IV. Pre-Test

The thirty-six experimental animals were marked by having their tails colored so that they could be individually identified. Each rat was weighed prior to the exhaustive swim in order to adjust the tail weight to 4% of the body weight. The weight was attached to the rat's tail by using a small clip which was padded by tape in order to prevent pain and unnecessary trauma.

The plastic containers were filled immediately prior to swimming by mixing hot and cold water in order to achieve the desired water temperatures of 22°C, 29°C or 36°C. The water depth was approximately twenty-two inches which was necessary in order to prevent the rats from resting on the bottom and pushing up to the surface when air was needed. The water temperature was constantly measured throughout the session and, if necessary, water was added (between swim groups) to correct the temperature.

The weights were clipped to the rat's tail and the animals were placed in the water. Four rats per group, a total of twelve rats, swam in their own individual section. Three commercial stop watches, one per group, were started as soon as the rats were placed in the water and time ended when each rat reached exhaustion and could no longer reach the surface. After the swim the rats were dried with a towel and placed back into their cages.

These rats' thirty-six swim times were then matched so the mean group swim times were equal. The rats were then remarked and placed into the 22°C, 29°C or 36°C groups. The containers were then emptied, cleaned, and stored until the next swimming session.

V. Experimental Procedure

The rats were given one rest day after the pre-test exhaustive swim. The rest day was followed by an exhaustive swim at their own water temperature that being 22°C, 29°C or 36°C. The pre-test swimming procedures were used at each exhaustive swimming session and the only variation during the regular swimming sessions was that the animals swum for two-thirds of their maximum swimming time. The mean swim time of each group was calculated and two-thirds of this mean swim time of each group was used as a training time. The exhaustive swim at experimental temperature was followed by a rest day which was in turn followed by another exhaustive swim at the neutral water temperature that being 29°C. Following the preliminary exhaustive swims the animals trained as scheduled in Table one. The experiment lasted forty-six training days and the animals had exhaustive swims on every thirteenth and fifteenth day as illustrated by Table one. All swimming was conducted seven days a week between 5:00-7:00 P.M. and the only non-swimming days were the scheduled rest days. During the training program two rats from each experimental group drowned. The final exhaustive swim for all rats was in neutral (29°C) water.

VI. Sacrifice Procedure

The rats were sacrificed within forty-eight hours of their final swim. All animals were weighted immediately prior to death in order to obtain organ weights per gram of body weight. The animals were individually sacrificed in a small beaker by an overdose of ether.

VII. Dissection Procedure

The animals were immediately dissected and wet adrenal gland weights and heart weights were obtained on

TABLE I

Training Procedure

	Pre-Test	
	Rest Day	
	Day 1 -	exhaustive swimming at experimental temperature
	Day 2 -	rest day
	Day 3 -	exhaustive swimming in neutral (29°C) water
	Day 4 -	swimming at two-thirds of maximum at experimental temperature
	Day 5 -	"
one cycle	Day 6 -	"
	Day 7 -	"
	Day 8 -	"
	Day 9 -	"
	Day 10 -	"
	Day 11 -	"
	Day 12 -	"
	Day 13 -	exhaustive swimming at experimental temperature
	Day 14 -	rest day
	Day 15 -	exhaustive swimming at neutral (29°C) water

The training procedure included four complete cycles (Day 1 - Day 12) plus two final exhaustive swims similar to Day 13 to Day 15.

the Mettler analytical balance. All blood vessels and other irrelevant material was cut from the heart and all fat was removed from the adrenal glands.

VIII. Treatment of Data

The F-test was used to see if there was any significant difference between the group means in swimming performance, body weight gain, relative adrenal gland weight and relative heart weight. The Newman-Keuls test was used to locate the difference.

CHAPTER IV

RESULTS AND DISCUSSION

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RESULTS AND DISCUSSION

This study was conducted to determine if training at water temperatures of 22°C, 29°C, and 36°C had any significant effect upon four parameters, namely, swim time to exhaustion, body weight, relative adrenal gland weight and relative heart weight. The control group's relative adrenal gland weight and relative heart weight were also compared to the experimental group.

The sample (N-46) was randomly divided into ten controls and thirty-six experimental rats. The experimental group was then subdivided into three equal groups based on mean group swim times as the result of an exhaustive swim with 4% of body weight at a water temperature of 29°C.

The F-test, used to see if there was any significant difference between the means of the above four parameters, and the Newman-Keuls test, used to locate the difference between the means, were employed in the statistical analysis of the data. There was no significant difference in (1) swim time to exhaustion, (2) relative adrenal gland weight, and (3) relative heart weight between rats trained at water temperatures of 22°C, 29°C and 36°C. The difference in body weight proved to be significant. There was also a significant difference in relative adrenal gland weight and relative heart weight between the control group and experimental groups. The above results were presented in table and figure form.

Table two indicated that there was no significant difference in the swim time to exhaustion in water at 29°C of rats trained at water temperatures of 22°C, 29°C and 36°C.

TABLE II

F-test for final exhaustive swim data

Source	Degrees of Freedom	S.S.	M.S.	F
Between Groups	2	209.2	104.6	0.209
Within Groups	27	13,492.7	499.7	
Total	29	13,701.9	604.3	

Not significant at the .05 level. F value required (3.35).

Table three indicated that there was a significant difference in body weight between rats trained at water temperatures of 22°C, 29°C and 36°C. Table four revealed that the rats trained at 36°C were significantly lighter.

TABLE III

F-test for final body weight data

Source	Degrees of Freedom	S.S.	M.S.	F
Between Groups	2	10,760.87	5,380.44	4.57*
Within Groups	27	47,969.80	1,176.66	
Total	29	48,730.67	6,557.10	

*Significant at the .05 level. F value required (3.35).

TABLE IV

Newman-Keuls test for body weight data

Means	$\bar{X}$ 36°C	$\bar{X}$ 29°C	$\bar{X}$ 22
$\bar{X}$ 36°C	–	3.40*	3.94*
$\bar{X}$ 29°C	–	–	0.54
$\bar{X}$ 22°C	–	–	–

*Significant at the .05 level (2.92)

Table five showed a significant difference in relative adrenal gland weight between control rats and rats trained at water temperatures of 22°C, 29°C and 36°C. However Table four showed that there was no significant difference in relative adrenal gland weight between rats trained at 22^{o}C, 29^{o}C and 36^{o}C.

TABLE V

F-test for relative adrenal weight data

Source	Degrees of Freedom	S.S.	M.S.	F
Between Groups	3	12,445.68	4,148.56	17.49*
Within Groups	36	8,534.70	237.08	
Total	39	20,980.38	4,385.64	

*Significant at the .05 level. F value required (4.39).

TABLE VI

Newman-Keuls test for relative adrenal weight data

Means	$\bar{X}$ control	$\bar{X}$ 29^{o}C	$\bar{X}$ 22^{o}C	$\bar{X}$ 36^{o}C
$\bar{X}$ control	-	-	-	-
$\bar{X}$ 29^{o}C	6.67*	-	-	-
$\bar{X}$ 22^{o}C	7.97*	1.29	-	-
$\bar{X}$ 36^{o}C	9.49*	2.81	1.52	-

*Significant at the .05 level (4.07)

Table seven showed that a significant difference occurred in the relative heart weight data. Table eight showed that the difference occurred between the control group and experimental groups. There was no significant difference between the relative heart weights of the three experimental groups.

TABLE VII

F-test for relative heart weight data

Source	Degrees of Freedom	S.S.	M.S.	F
Between Groups	3	1.98	0.66	22*
Within Groups	36	1.24	0.03	
Total	39	3.22	0.69	

*Significant at the .05 level. F value required (4.39).

TABLE VIII

Newman-Keuls test for relative heart weight data

Means	$\bar{X}$ control	$\bar{X}$ 36°C	$\bar{X}$ 22°C	$\bar{X}$ 29°C
$\bar{X}$ control	-	-	-	-
$\bar{X}$ 36°C	8.36*	-	-	-
$\bar{X}$ 22°C	9.64*	-	-	-
$\bar{X}$ 29°C	10.00*	1.64	0.36	-

*Significant at the .05 level (4.07)

Figures two and three are graphs which show the changes in swimming performance and the changes in body weight during the experimental period. These and other results are discussed more fully in the discussion part of the paper.

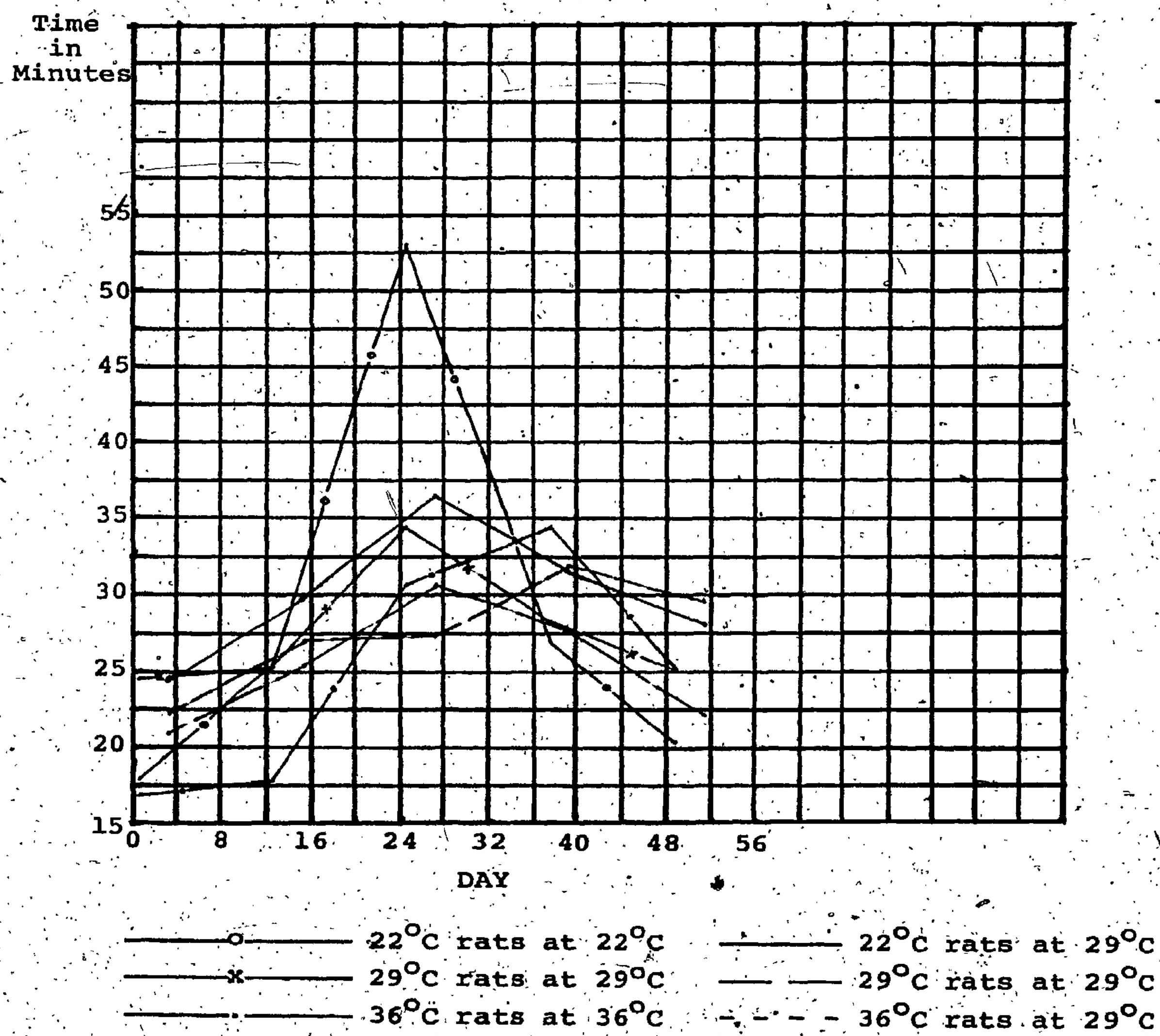

Figure II - Swim times to exhaustion of all experimental animals at experimental and neutral temperatures

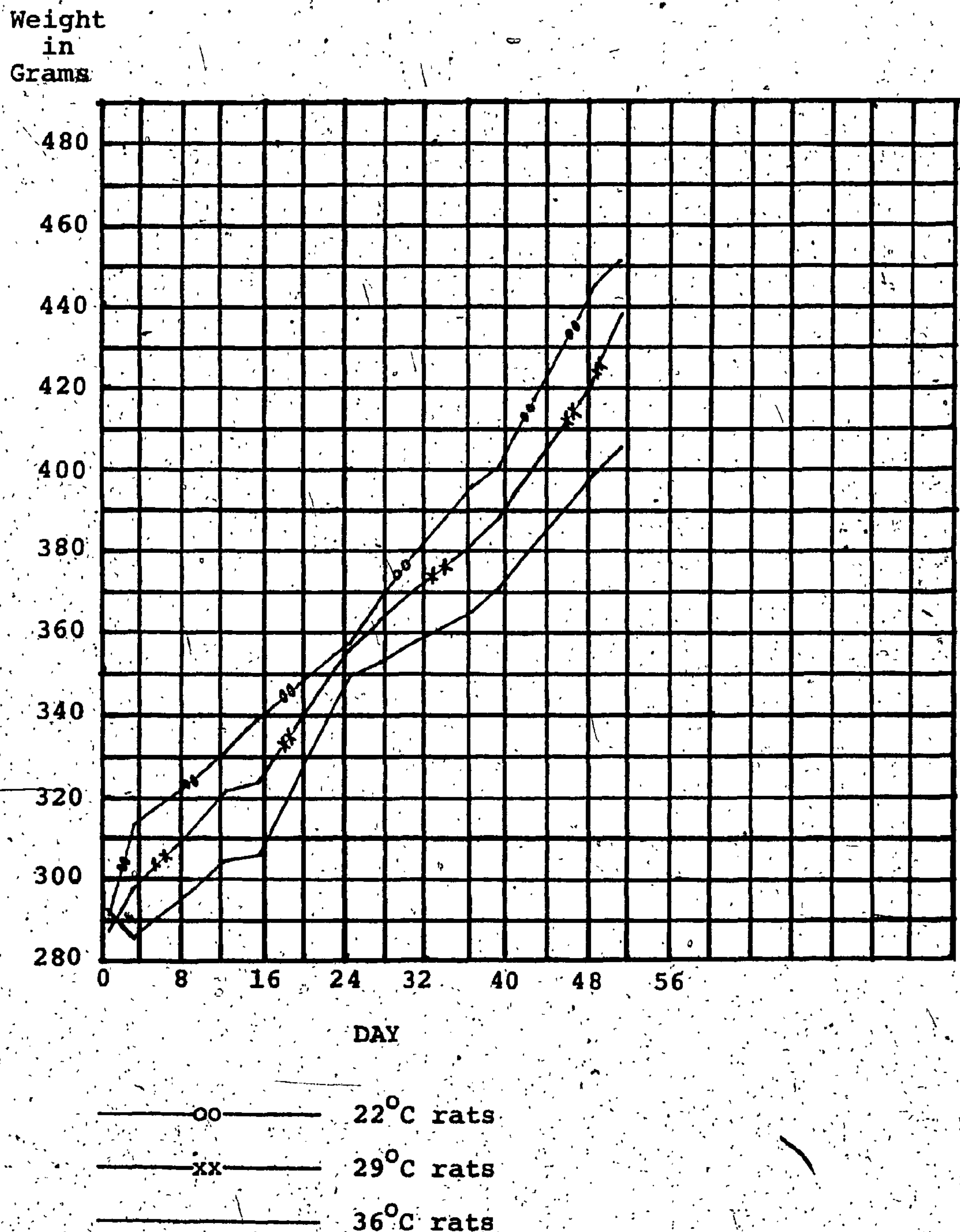

Figure III - Changes in body weight of all experimental animals.

DISCUSSION

As shown by Table two there was no significant difference in swim times to exhaustion in 29°C water between rats trained at water temperatures of 22°C, 29°C and 36°C. However the findings of this study tended to support past research that training does improve swimming performance (4, 11, 17, 35, 49, 29, 43, 51, 55). The swimming improvement was greatest over a twenty day period with a gradual decrease until the end of the experiment. The final exhaustive swim times were not significantly better according to a T-test for correlated samples, than the pre-test swim times. However there was a small net improvement in swim times.

McArdle and Montoye (43,44) found that the duration of the swim to exhaustion in 34°C-35°C water was significantly lower in heavier rats, when weights were attached according to percentage of body weight. It was then possible that the animals' swim times decreased as a result of an increased body weight. However it appeared, for some unknown reason, that this increase in body weight did not decrease swimming performance, especially with the 22°C rats, until after twenty to thirty days. It is also possible that the decrease in swimming performance was the result of chronic pneumonia and acute respiratory disease similar to that reported by Updyke (71)

As shown in Table three there was a significant difference in body weight between rats trained at water temperatures of 22°C, 29°C and 36°C. Table four revealed that the 36°C rats were significantly lighter than the 22°C or 29°C rats. Previous researchers have indicated that exercising rats were significantly lighter than their sedentary controls (9, 13, 34, 37, 49, 51, 52, 54, 72, 29).

Brobeck (8) suggested that animals eat to keep warm and stop eating to prevent hyperthermia. He pointed out that shaved rabbits in winter ate more than fully intact rabbits. Rats, cattle, pigs and goats all ate less with increased environmental temperature. Hamilton (22) stated that it is a well established fact that mammals reduce food intake in the heat and show an increase in the cold. He pointed out that food intake in male rats fell with increasing temperatures. Herous (30) observed that the body weight of cold acclimatized rats (6°C) was significantly higher than that of rats acclimatized to higher (30°C) temperatures. Hart - 1950 (25) reported that during activity the weight loss averaged 2.0 grams per mouse at -9.6°C to 32°C, but at 37°C the loss was 2.6 grams per mouse. Mayer (42) observed that for low durations of exercise (20 minutes to 1 hour) there was no corresponding increase in food intake ~~and body weight~~ was decreased. However from 1-5 or 6 hours food intake increased linearly and weight was maintained.

Therefore from the above data it appeared that weight loss of the 36°C rats was due to decreased caloric intake as well as weight loss due to activity in the warmer water.

In the 22°C and 29°C water the weight loss from exercise was less. This is probably due to the fact that food intake increases with decreasing environmental temperature. It is possible that this counteracted the Mayer food intake curve since the exercising rats generally swum for low durations (20 minutes to 1 hour).

There was no significant difference in relative adrenal gland weights of rats trained at water temperatures of 22°C, 29°C and 36°C. However there was a significant difference in relative adrenal gland weight between the control group and experimental groups as revealed by Table five. Table six showed where the difference occurred. The findings of this study tended to support past research that exercise resulted in increased adrenal weight when compared to sedentary animals (1, 15, 16, 19, 49). The exercised rats were under far greater stress than the controls.

Sufficient stress according to Selye (61) produced an enlargement of the adrenal glands.

The exercising rats trained at two-thirds of their maximum thereby stabilizing their levels of stress. This was a combination of physical and environmental stress. It would appear that a more stressful environment, in this particular case water temperature, would hinder physical performance and that a more suitable environment would enhance physical performance. Therefore both physical and environmental stress may have balanced each other out. Thus swimming at two-thirds of maximum would stabilize the stress load and thus the adrenal weights should have been similar and this was indeed the case.

There was no significant difference in relative heart weight between rats trained at water temperatures of 22°C, 29°C and 36°C. However there was a significant difference in relative heart weights between the control group and experimental groups as revealed by Table seven. Table eight pointed out where the difference occurred. These findings also tended to support past research that exercise resulted in increased heart weights when compared to sedentary animals (1, 2, 12, 15, 16, 49, 53). As previously mentioned the exercise rats were under similar stress therefore their hearts hypertrophied at approximately the same pace.

CHAPTER V

SUMMARY AND CONCLUSIONS

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The purpose of this study was to see if training at water temperatures of 22°C, 29°C and 36°C had any significant effect upon the following four parameters: (1) swim time to exhaustion, (2) body weight, (3) relative adrenal gland weight, and (4) relative heart weight. The relative adrenal gland and heart weights were also compared to a control group of sedentary rats.

The sample was forty-six male albino rats. They were randomly divided into two groups, ten in the control group and thirty-six in the experimental groups. The experimental group was subdivided into three equal groups based on swimming performance during an exhaustive swim with 4% of body weight in water 29°C. The experimental groups then trained by swimming at 22°C, 29°C or 36°C water temperatures to see if there would be any significant difference in the above four parameters. During the training program two rats from each experimental group drowned.

The statistical analysis employed in this study was the F-test which enabled the researcher to determine if there was a significant difference in (1) exhaustive swim times, (2) body weight gain, (3) relative adrenal gland weight, and (4) relative heart weight between rats trained at water temperatures of 22°C, 29°C and 36°C. The Newman-Keuls test was then used to see where the significant difference occurred. The F-test was significant (α 0.05) with regard to training and body weight. It also showed a significant difference (α 0.05) in the relative adrenal gland and relative heart weights between the control group and experimental groups.

The results obtained led to the conclusions that there was no significant difference in (1) swim times to exhaustion at a water temperature of 29°C, (2) relative adrenal gland weight, and (3) relative heart weight between rats trained at water temperatures of 22°C, 29°C and 36°C. There was a significant difference in body weight between rats trained at water temperatures of 22°C, 29°C and 36°C. There was also a significant difference in relative adrenal gland and relative heart weights between the control group and experimental groups.

Therefore:

Hypotheses

1. $U_1 = U_2 = U_3$ was accepted.

2. $U_1 = U_2 = U_3$ was rejected.

3. $U_1 = U_2 = U_3$ was accepted.

4. $U_1 = U_2 = U_3$ was accepted.

5. $U_c = U_1 = U_2 = U_3$ was rejected.

6. $U_c = U_1 = U_2 = U_3$ was rejected.

U_c = mean of control group.

U_1 = mean of 22°C experimental group.

U_2 = mean of 29°C experimental group.

U_3 = mean of 36°C experimental group.

Hypotheses tested at $\alpha = 0.05$.

RECOMMENDATIONS

Within the limitations of this study, the conclusions arrived at were considered valid. However there are a number of areas which needed much more emphasis before any practical implications can be suggested.

A study similar to this should be conducted having a larger number of control and experimental rats which would enable the researcher to sacrifice both groups of animals periodically throughout the study in order to measure the gradual increase in adrenal gland and heart weights, and perhaps to shed some light on why performance peaked at twenty to thirty days of training.

A similar study should be carried out measuring the caloric intake of the animals in order to determine if caloric intake was the cause of the differences in body weight.

Further research should be conducted using a treadmill rather than a swimming program because treadmill running results in a more accurate workload.

A similar study should be conducted using a greater range of temperatures and varying workloads in order to find a more definite relationship between physical and environmental stress.

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APPENDICES

APPENDIX A

THE EFFECT OF TRAINING AT DIFFERENT WATER TEMPERATURES UPON FOUR PARAMETERS; NAMELY SWIMMING PERFORMANCE, BODY WEIGHT, ADRENAL GLAND WEIGHT, AND HEART WEIGHT OF THE MALE ALBINO RAT

by

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APPENDIX B

RAW DATA

Rat	Final Swimming Time (Min.) at 29°C	Increase in Body Wt. (Gm.)	Absolute Adrenal Wt. (Gm.)	Relative Adrenal Wt. (Micrograms)	Absolute Heart Wt. (Gm.)	Relative Heart Wt. (Milligrams)
C1*	-	-	-	-	-	-
C2	98.03	155	.05355	122	1.32359	3.01
C3	65.22	239	.06265	121	1.20158	2.32
C4	19.98	210	.05889	119	1.39233	2.81
C5*	-	-	-	-	-	-
C6	23.73	227	.07493	141	1.71553	3.23
C7	10.27	133	.05765	132	1.16469	2.67
C8	17.42	94	.03573	89	1.03759	2.59
C9	21.60	159	.06360	151	1.16590	2.76
C10	2.77	93	.05860	156	1.01613	2.71
C11	23.62	117	.05138	124	0.97068	2.35
C12	1.25	152	.05288	118	1.02616	2.30
Group Mean	28.39	157.9	.05699	127.3	1.20142	2.68
N1	44.12	162	.05619	122	1.31324	2.86
N2	18.22	188	.05255	113	1.16718	2.50
N3	22.93	124	.04480	115	1.02755	2.64
N4	49.88	156	.06651	145	1.23617	2.69
N5	26.45	190	.06447	129	1.22586	2.46
N6	25.47	98	.05704	146	1.19441	3.06
N7*	-	-	-	-	-	-
N8	4.58	214	.05701	116	1.34284	2.74
N9	23.70	114	.04195	104	1.17407	2.92
N10	14.73	134	.04160	109	1.03986	2.72
N11	2.53	140	.04718	111	1.02529	2.41
N12*	-	-	-	-	-	-
Group Mean	23.26	152.0	.05293	121.0	1.17465	2.70

C = rats who swam at 22°C

* = rats deceased

N = rats who swam at 29°C

W = rats who swam at 36°C

Z = control group sacrificed at the beginning of the study

RAW DATA (Cont'd)

Rat	Final Swimming Time (Min.) at 29°C	Increase in Body Wt. (Gm.)	Absolute Adrenal Wt. (Gm.)	Relative Adrenal Wt. (Micrograms)	Absolute Heart Wt. (Gm.)	Relative Heart Wt. (Milligrams)
W1	30.87	120	.05747	136	1.14611	2.72
W2	39.85	140	.05976	139	1.15581	2.68
W3	48.12	196	.06674	133	1.25969	2.51
W4	25.25	96	.04720	119	1.04522	2.65
W5	23.27	87	.05059	127	1.08804	2.74
W6	32.47	84	.05702	142	0.97731	2.44
W7	66.95	109	.05023	123	1.03341	2.52
W8*	–	–	–	–	–	–
W9*	–	–	–	–	–	–
W10	10.47	97	.05254	143	0.89484	2.43
W11	7.52	136	.05643	131	1.21812	2.82
W12	7.62	86	.05802	154	0.98964	2.63
Group Mean	29.24	115.1	.05560	134.7	1.08082	2.61
Z1	–	–	.02737	95	0.66480	2.31
Z2	–	–	.02170	78	0.55075	1.98
Z3	–	–	.03012	112	0.61407	2.29
Z4	–	–	.02062	79	0.61580	2.35
Z5	–	–	.03200	117	0.51537	1.88
Z6	–	–	.02004	70	0.62461	2.18
Z7	–	–	.02344	87	0.54669	2.03
Z8	–	–	.01964	69	0.58926	2.07
Z9	–	–	.02332	87	0.61102	2.29
Z10	–	–	.02453	91	0.58319	2.16
Group Mean	–	–	.02428	88.5	0.59156	2.15

C = rats who swam at 22°C

N = rats who swam at 29°C

W = rats who swam at 36°C

Z = control group sacrificed at the beginning of the study

* = rats deceased

Rat	Starting Body Weight (Gm.)	Final Body Weight (Gm.)	Pre-Test Swimming Performance (Min.)
C1*	263	-	38.22
C2	289	444	32.60
C3	275	514	44.18
C4	289	499	27.63
C5*	305	-	18.95
C6	304	531	21.50
C7	305	438	19.97
C8	305	399	19.22
C9	275	434	21.18
C10	286	379	11.10
C11	301	418	8.20
C12	301	453	12.18
Group Mean	291.5	450.9	22.91
N1	320	482	38.43
N2	292	480	32.60
N3	273	397	40.63
N4	307	463	21.67
N5	300	490	21.70
N6	297	395	21.87
N7*	283	-	20.08
N8	276	490	20.15
N9	288	402	19.93
N10	249	383	13.35
N11	275	415	14.12
N12*	298	-	9.93
Group Mean	288.17	439.7	22.87

C = rats who swam at 22°C   * = rats deceased

N = rats who swam at 29°C

W = rats who swam at 36°C

Z = control group sacrificed at the beginning of the study

Rat	Starting Body Weight (Gm.)	Final Body Weight (Gm.)	Pre-Test Swimming Performance (Min.)
W1	292	412	34.52
W2	280	420	35.62
W3	289	485	33.45
W4	290	386	32.15
W5	298	385	32.08
W6	312	396	18.15
W7	291	400	18.08
W8*	294	-	15.53
W9*	309	-	16.43
W10	285	382	13.42
W11	288	424	18.23
W12	286	372	8.42
Group Mean	292.8	406.2	23.00

C = rats who swam at 22°C

N = rats who swam at 29°C

W = rats who swam at 36°C

Z = control group sacrificed at the beginning of the study

* = rats deceased

BODY WEIGHT OF CONTROL GROUP

	Body Weight (Gm.)
Z1	288
Z2	278
Z3	268
Z4	262
Z5	274
Z6	286
Z7	269
Z8	285
Z9	267
Z10	270