THE EFFECTS OF SPECIFIC ENDURANCE AND INTERVAL TRAINING PROGRAMS

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ALAN F. BEHNKE

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ABSTRACT

THE EFFECTS OF SPECIFIC ENDURANCE
AND INTERVAL TRAINING PROGRAMS

By

Alan F. Behnke

Ten subjects were divided into three groups: an endurance group, an interval training group, and a control group. The endurance group trained by running approximately two miles at each session, and the interval group trained by running six 50-yard dashes with a five minute rest interval at each session. There were three sessions per week and the training programs were carried on for seven weeks. The control group did not participate in any specific training program. The subjects were retested at the end of the seven week training period.

All subjects were tested on: a standard treadmill run (10 min, 7 mph, 0% grade), an exhaustive treadmill run (10 mph, 9% grade), vertical jump, leg strength, and maximum squat. Pulse rate and oxygen consumption data were collected for both runs and also for recovery periods of ten minutes following the standard run and fifteen minutes following the exhaustive run.

Analysis of variance was used to statistically test the data. Wherever multiple measures on the same subject were available, the sign test was used. The data were also treated graphically.

Exercise and recovery pulse rates in the standard run and exhaustion run were significantly reduced by both training programs. Endurance training produced significantly greater decreases in both exercise and recovery pulse rates for the standard run.

Oxygen debt for the exhaustion run was significantly increased by both training programs. In the standard run the endurance group showed an increase in oxygen intake with a decrease in oxygen debt. Both were found to be significant. The interval group showed decreases in both intake and debt when compared with the controls and also the endurance group. These differences were significant only if the data on intake and debt were combined.

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By

Alan F. Behnke

A THESIS

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and Recreation

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DEDICATION

To my Mother and Father

ACKNOWLEDGMENTS

My sincere appreciation goes to all subjects who participated in this study, to everyone in the lab who helped in the collection of data, and especially to Dr. VanHuss for his guidance and understanding throughout this study.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Great strides have been made in recent decades in the area of exercise and training. One only has to examine the works of Robinson, Dill, Steinhaus, Karpovich, etc., to recognize the increase in the research basis of training. This increase has also permitted more sophisticated speculation in new methods.

Many of the studies have been carried out with the aid of a motor-driven treadmill (3:341). The treadmill has the advantage of keeping the subject in one place while the work is being measured. Also, the rate and the time of the work load may be controlled by the experimenter.

Although metabolic, respiratory, and circulatory studies are numerous, there remains a need for further research in this area. There is still a need to get away from trial and error methods and to utilize the scientific evidence behind our training and coaching methods as well as to extend the research basis.

Statement of the Problem

To determine the effects of specific endurance and interval training programs.

Importance of the Study

The majority of our sports activities call for two basic qualities. One quality is to be able to go for short bursts with maximum effort. The other quality is to be able to continue at a relatively steady pace without fatigue setting in before the contest has been completed. For this reason it is important to learn all we can about the types of training programs which develop these two basic qualities, and also to learn more about the physiological requirements which are involved.

Definitions

Endurance Training

Repetitive activity such as distance running performed on a regular basis.

Interval Training

Power activity such as sprinting or weight lifting performed on a regular basis.

Gross O_2 Intake

The rate of oxygen consumption during the run.

Gross O_2 Debt

Total oxygen consumption during a specified recovery period.

Limitations of the Study

1. The small number of subjects available for this study along with the short amount of time with which to carry it out constitute the major limitations of this study.
2. The motivation factor could not be controlled.
3. It was not possible to control the outside activities of the subjects.
4. The training programs were not strictly controlled.

CHAPTER II

REVIEW OF THE LITERATURE

In this study two groups were subjected to two different training regimens. Efforts were made through various tests to determine what kinds of responses and adaptations were illicited from each of the training procedures. By reviewing those studies which are involved with different kinds of training, some conclusions can be made regarding the types of responses which can be expected from the types of training used in this study.

Physiology textbooks inform us of the many changes which result from regular exercise. It is becoming increasingly evident that these adaptations are specific in nature. A training program consisting of endurance exercises will produce changes that will increase the capacity for performing endurance activities.

A study which illustrates this was conducted by Hollman et al. (9) in which nine gymnasts underwent an endurance training program consisting of ten 200-meter runs three times weekly for a period of five weeks. The results of this study were as follows: Pulse rate decreased at rest and during exercise and recovery phase. Difference was most pronounced with constant work load. Respiratory

minute volume decreased with constant work load from 98.6ℓ before to 66.6ℓ after training. Oxygen consumption decreased at all levels of exercise.

Specificity holds true in power training or speed work as shown in the following study by Thompson and Stull (15). Six groups of subjects were tested to determine if various training programs affected performance in speed in swimming thirty yards. No evidence of improvement was found after one group of subjects had been exposed to absolutely no exercise for six weeks and, also, after a group of subjects had participated in various exercises with weights three times weekly for six weeks. Two groups of swimmers who participated in practicing starts, kicking, arm stroking, and sprinting thirty and sixty yards significantly improved their performances in speed in swimming; one group of subjects followed the preceding program three times weekly and another group used the same routine six times a week. Two other groups, one of which was exposed to weight training and swimming, and one of which was exposed only to thirty-yard sprints and practicing starts, both showed statistically significant differences in performance.

Sinisalo and Juurtola (14) report a study which also shows that training causes specific responses. This time two groups were used. One group trained for endurance while the other group used an interval training program.

Twenty subjects were divided into two groups and given ten physical tests before and after eight weeks of training which included three 60-minute periods per week.* Significant differences between the first test and the second test in the total group of subjects were found in the following tests: breath holding, pulse rate on bicycle ergometer work, recovery pulse, floor push-ups, full squat jumps, agility exercise, time of the skiing race, and time of the last two km. in skiing race. Statistically significant differences between the mean gains were found in breath holding and spurt ability in skiing in favor of the interval training group, and in floor push-ups in favor of the constant speed training group.

One of the best reviews showing that endurance and power training produce specific results is reported by Heusner (8). Data are given showing the changes in the energy metabolism of two athletes produced by two and one-half years of specific interval training. The distance man was trained with the specific intention of increasing his maximum oxygen intake capacity which did in fact improve a remarkable 1.8ℓ per minute. He also made a moderate improvement of 5.1ℓ in maximum oxygen debt tolerance. The sprinter was trained with the specific intention of increasing his maximum oxygen debt tolerance

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*One group trained at a constant speed while the other group used an interval training procedure.

which did increase a striking 9.3ℓ. His oxygen intake capacity improved a moderate 1.0ℓ per minute.

The theory of specificity has been supported and enlarged upon by recent research so that it is now believed that the response to training is even more specific than was generally recognized. For example, if one trains for static strength, the maximal gains will be made at the specific angle at which the individual trains (17). There may be concommitant gains in dynamic strength or even in muscular endurance, but the greatest improvement will be very specific to the static-strength overload. Another example can be shown relative to dynamic strength. If two groups, matched on dynamic strength, are placed on different weight training programs, quite dissimilar responses may be obtained. That is, if one group lifts maximal loads with few repetitions, a progressive improvement in dynamic strength will result. If the other group is placed on a program in which a designated moderate load is to be lifted a maximal number of repetitions, negligable improvement will be found in dynamic strength, but muscular endurance will be increased (16).

In very recent years there have been a few select studies which show a trend which seems to indicate that training can be so specific as to give evidence to specific chronic internal changes. Gordon's work (5) has shown that in adult running rats, there is a trend toward

increase in concentration of sarcoplasmic proteins while weight lifting showed an increase in concentration of actomyosin. Helander's work (7) supports the view that power training increases the myofibrillar content in the exercised muscle.

Another specific adaptation to increased muscle function is the opening of additional capillaries in that muscle. Petren et al. (12) conducted a study in which the animals subjected to strenuous training were shown to have a considerably higher number (146%) of open capillaries in the heart and gastrocnemius muscles than the control animals.

Even more specific results in relation to muscle size and capillarization is reported in a study by Carrow et al. (1). The results of this study indicated that with forced and voluntary exercise programs there was a greater increase in cross-sectional area of the red than of the white fibers. Under the same conditions, the increase in the number of capillaries per fiber was greater for white than for red fibers.

Heart size is also specifically affected by different training programs. An endurance program such as distance running will increase heart size which is primarily shown by an increase in size of the left heart (17). Power training such as weight lifting or sprinting in

turn also will slightly increase heart size. However, this is due to a relative greater increase in the right heart size (10).

From what has been reviewed in this chapter, it is evident that training does produce very specific changes. Unfortunately, the scientific evidence available at this time is not sufficient to allow a broad range of specific conclusions as to what can be expected from the training programs used in this study. Certainly one can expect adaptations to take place as a result of both training programs. It is also expected that these adaptation will be specific in that the endurance training will produce increased endurance capacities, while the power training will produce increased strength and improvements in aerobic work capacity.

CHAPTER III

METHODOLOGY

The following methods and procedures were employed in an attempt to determine the effects of a specific endurance training program and a specific interval training program.

Subjects

Thirteen young men volunteered to participate in this study. Eight of these thirteen were taken from a developmental class at Michigan State University. It was felt that having enrolled for this course, they would have some motivation towards participating in a training program. For this reason they were placed in the two experimental groups. Out of the eight experimentals, one did not complete the training program and had to be dropped from the study.

The remaining five subjects were chosen from beginning golf classes to act as controls. They participated in all of the tests but were not involved in any training programs. Of these five, there were two who failed to take the final series of tests. Therefore, the use of their data was nullified for the purposes of this study.

Testing Program

A series of tests was administered to each subject at the outset of this study. The subjects were scheduled to come in on two separate days according to their own convenience. The testing period lasted for approximately one week after which the training programs for the experimental groups began. After seven weeks of training, the subjects were retested. The precedures used were similar for both testing periods and were as follows.

The subject reported to the Human Energy Research Laboratory and immediately changed into suitable attire for running. Each subject ran in athletic shorts and gym shoes without a shirt.

On the first day the subjects were required to run a standard run on the motor-driven treadmill. This involved running at seven miles per hour on the flat for ten minutes. Upon completion of the run the subject sat down and recovery data was collected for another ten minutes.

The second time the subject reported he was required to perform the vertical jump as described by Mathews (11:96). This was followed by three trials on the leg dynamometer. After these were recorded, the subject was again wired with electrodes and proceeded to run on the treadmill at ten miles per hour with a nine per cent grade. The subjects ran to exhaustion and recovery data were collected for fifteen minutes.

Electrodes were applied to the subject as illustrated by Hartman (6). Samples of respiratory gas for oxygen analysis were taken using the Douglas bag technique (2:331). These were analyzed immediately by the flow-through technique with Beckman Oxygen and Carbon Dioxide Analyzers (2:92). Heart beats were amplified and recorded by a Sanborn Twin-Visco Recorder (Sanborn Co.) providing a continuous permanent record of heart rate.

The test for maximum squat had to be administered at a different time because facilities were not available for this in the laboratory. This was carried out in the developmental room of Jenison Field House where weight equipment was available. Subjects were asked to squat with a barbell on their shoulders. The first time the weight was made comparable to their own body weight. Following this the weight was adjusted until the maximum weight with which the subject could complete one squat was determined.

Training Programs

Eight experimental subjects were divided into two groups of four. One group was put on an endurance training program while the other group was put on a specific interval training program. Efforts were made to place them according to their own preference.

The two experimental groups met at 8:00 A.M. on Monday, Wednesday and Friday of each week in Jenison Field

House. Each person was allowed to warm-up as he saw fit. When everybody was ready, they were called together and the endurance group was lined up and started. They would run sixteen laps, which is approximately two miles at each session. They tried to run it as fast as possible at each session and records were kept of each individual's time (Appendix A).

As soon as the endurance group had begun, the interval training group began their workout. This consisted of 50-yard dashes at full speed six times with a rest interval of five minutes between each dash. The rest interval was held constant throughout the study. Records were also kept of their times and are shown in Appendix B.

The training programs were carried out over a period covering seven weeks. Because of the cold weather which predominated during this time, most of the sessions were run in Jenison Field House. However, toward the end of the term with the weather clearing up and since the Field House was being used for other purposes, the subjects moved outdoors for their training.

Statistical Methods

The means of the results were computed and analyzed graphically. Wherever multiple measures on the same subjects were available, i.e., exercise pulse rates, oxygen intakes, ets., the sign test was used. The analysis of variance technique was not applicable to the analysis of

the latter type of data due to the dependency produced by the multiple measures on the same subjects. In many respects the sign test was the superior procedure to use because it presented the consideration of these multiple measures.

Prior to starting the study, it was decided to accept 5% (P = .05) as the significance level.

CHAPTER IV

ANALYSIS AND PRESENTATION OF DATA

Two experimental groups and one control group underwent a testing program involving a standard treadmill run (10 min, 7 mph, 0% grade), an exhaustive treadmill run (10 mph, 9% grade) and various strength tests. These subjects were retested after the two experimental groups had completed seven weeks of separate training programs.

Pulse rate and oxygen consumption data were collected for both treadmill runs. The means of the results of these data along with the data from the strength tests were computed and analyzed graphically. Analysis of variance was used to compare the differences of the means. Because of missing values, two degrees of freedom were lost (data for four subjects were available for the endurance group but only three subjects in the other two groups). When multiple measures on the same subjects were available, the sign test was used. The 5% level ($P = .05$ was used to determine significance.

Standard Run

Pulse Rate

The means of the pulse rate data were analyzed graphically and the results are presented in Chart I. The differences of the means were also computed (Table 1), and the sign test was carried out. The results reveal the exercise and recovery pulse rates being significantly reduced by both the endurance and interval training programs. It was also found that the endurance program reduced the exercise and recovery pulse rates significantly greater than did the interval training program.

Oxygen Intake and Debt

Oxygen measures for the standard run are presented graphically in Chart II. The differences of the means were computed and the results are given in Table 2.

A comparison involving the endurance group with the controls showed that endurance training provides greater decreases in O_2 debt. Both the O_2 intake and debt changes were statistically significant. When the endurance group was compared with the interval training group, it was found that interval training resulted in greater increases of both O_2 intake and debt. However, this was only significant if the two were combined. The same results occurred in the comparison of the interval training group with the controls. The interval training resulted in

CHART I: STANDARD RUN: PULSE RATES

(Standard Run (10 min, 7 mph, 0% grade): Pulse Rates

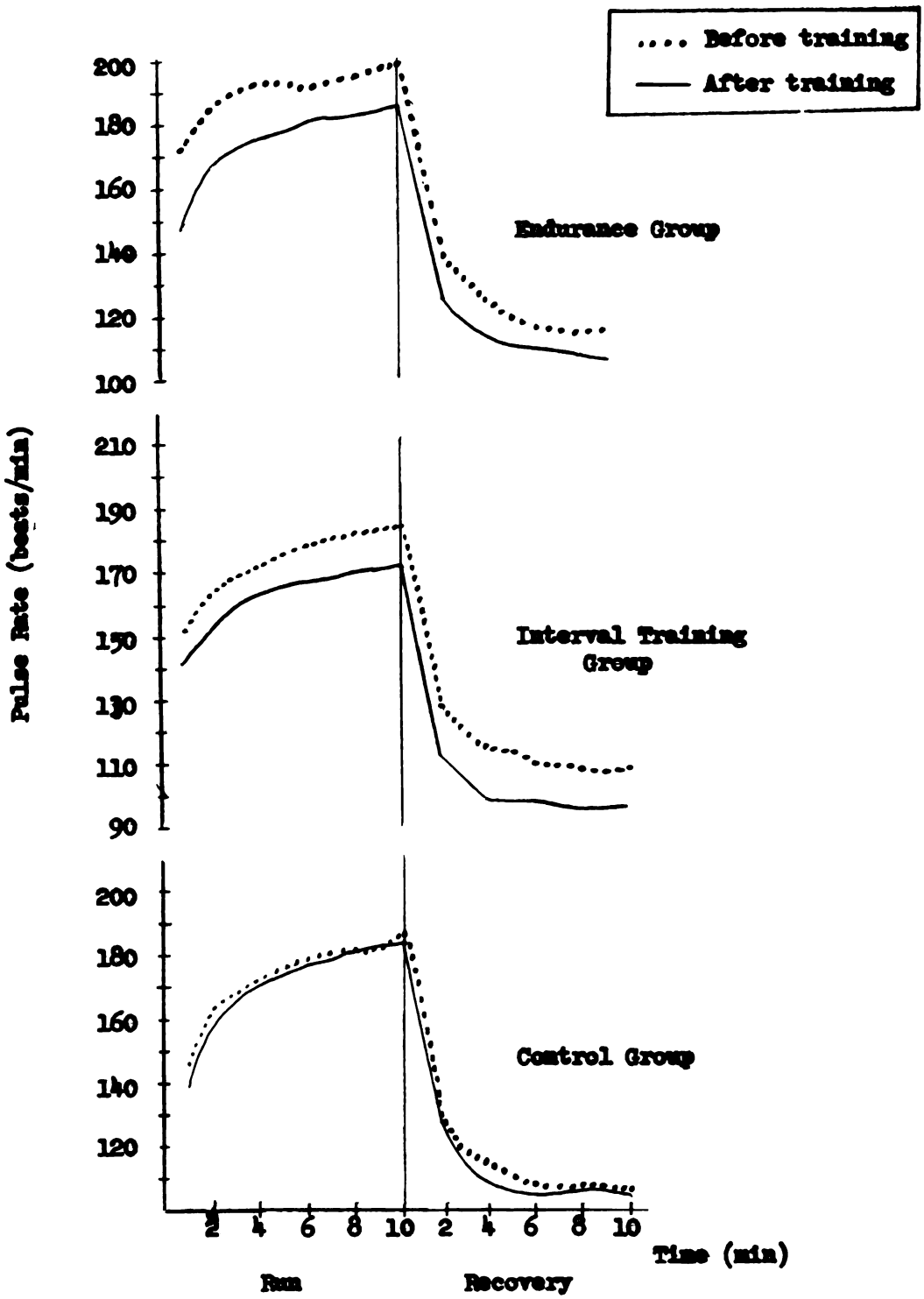


CHART II: STANDARD RUN: OXYGEN MEASURES

Standard Run (10 min, 7 mph, 0% grade): Oxygen Measures

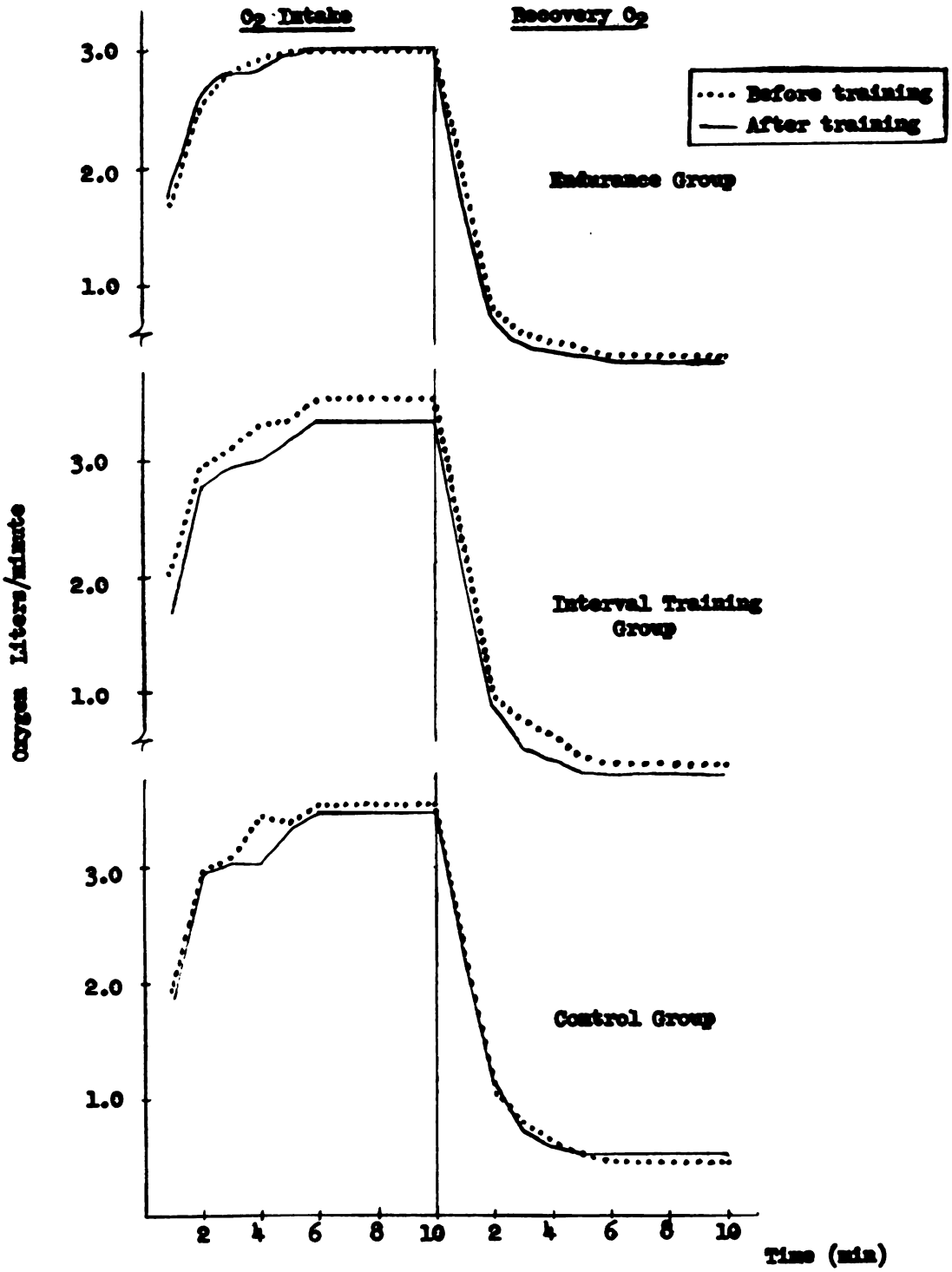


TABLE 1.--Pulse Rate Differences of Means for the Standard Run.

Time	Endurance Group		Interval Group		Control Group	
	Run	Recovery	Run	Recovery	Run	Recovery
:30	8	7	6	9	1	0
1:00	6	6	5	6	1	1
1:30	9	8	5	6	3	3
2:00	9	5	7	8	1	2
2:30	8	5	3	7	1	3
3:00	8	4	4	8	1	4
3:30	8	4	4	8	2	5
4:00	7	4	5	8	1	3
4:30	8	3	6	8	0	3
5:00	7	3	5	6	2	2
5:30	7	2	5	7	1	1
6:00	5	3	6	7	1	1
6:30	4	2	6	6	1	1
7:00	5	3	7	6	1	0
7:30	5	3	6	6	0	1
8:00	6	3	4	7	0	1
8:30	7	2	6	6	0	1
9:00	7	4	6	5	-1	0
9:30	7	4	6	5	0	1
10:00	7	4	6	7	2	1

	level of significance
Endurance vs. Interval group during run: 16 plus, 4 minus	.01
Endurance vs. Interval group during recovery: 18 plus, 1 minus, 1 zero	Less than .001
Endurance vs. Control during run: 20 plus, 0 minus	Less than .001
Endurance vs. Control during recovery: 19 plus, 1 minus	Less than .001
Interval group vs. Control during run and recovery: 20 plus, 0 minus	Less than .001

TABLE 2.--The Differences in Means of O_2 Intake and Debt for the Standard Run.

O_2 Intake			
Time	Endurance	Interval	Control
1:00	-.06	.38	.07
2:00	-.18	.15	.02
2:30	-.02	.17	0
3:00	.01	.11	.07
4:00	.31	.28	.39
5:00	-.01	.16	.03
10:00	0	.16	.08

O_2 Debt			
Time	Endurance	Interval	Control
:30	.22	.35	.15
1:00	.25	.07	.08
2:00	.12	.10	-.04
3:00	.11	.24	.06
4:00	.11	.24	.03
5:00	.07	.13	.02
10:00	.06	.08	-.06

	level of significance
Endurance vs. Control for Intake:	
0 plus, 7 minus	.008
Endurance vs. Control for Debt:	
7 plus, 0 minus	.008
Interval vs. Control for Intake:	
6 plus, 1 minus	.109
Interval vs. Control for Debt:	
6 plus, 1 minus	.109
Endurance vs. Interval for Intake:	
1 plus, 6 minus	.109
Endurance vs. Interval for Debt:	
2 plus, 5 minus	.500

greater increases of O_2 intake and debt, and this was significant only if the two were combined.

Gross O_2 Intake

The gross O_2 intake was computed and the results of the differences were analyzed using analysis of variance. The results are represented in Table 3.

TABLE 3.--Gross O_2 Intake.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	6.37	2	3.19	1.39
Within	16.13	7	2.30	(N.S.)
TOTAL	22.50			

Gross O_2 Debt

The gross O_2 debt was computed and the results of the differences were analyzed using analysis of variance. The results are shown in Table 4.

Exhaustion Run

Recovery Pulse Rate

Recovery pulse rates for the exhaustion run are represented graphically in Chart III. The differences for each group were computed and the results were compared using the sign test. These data are presented in Table 5.

CHART III: EXHAUSTION RUN: RECOVERY PULSE RATES

Exhaustion Run (10 mph, 9% grade): Recovery pulse rates

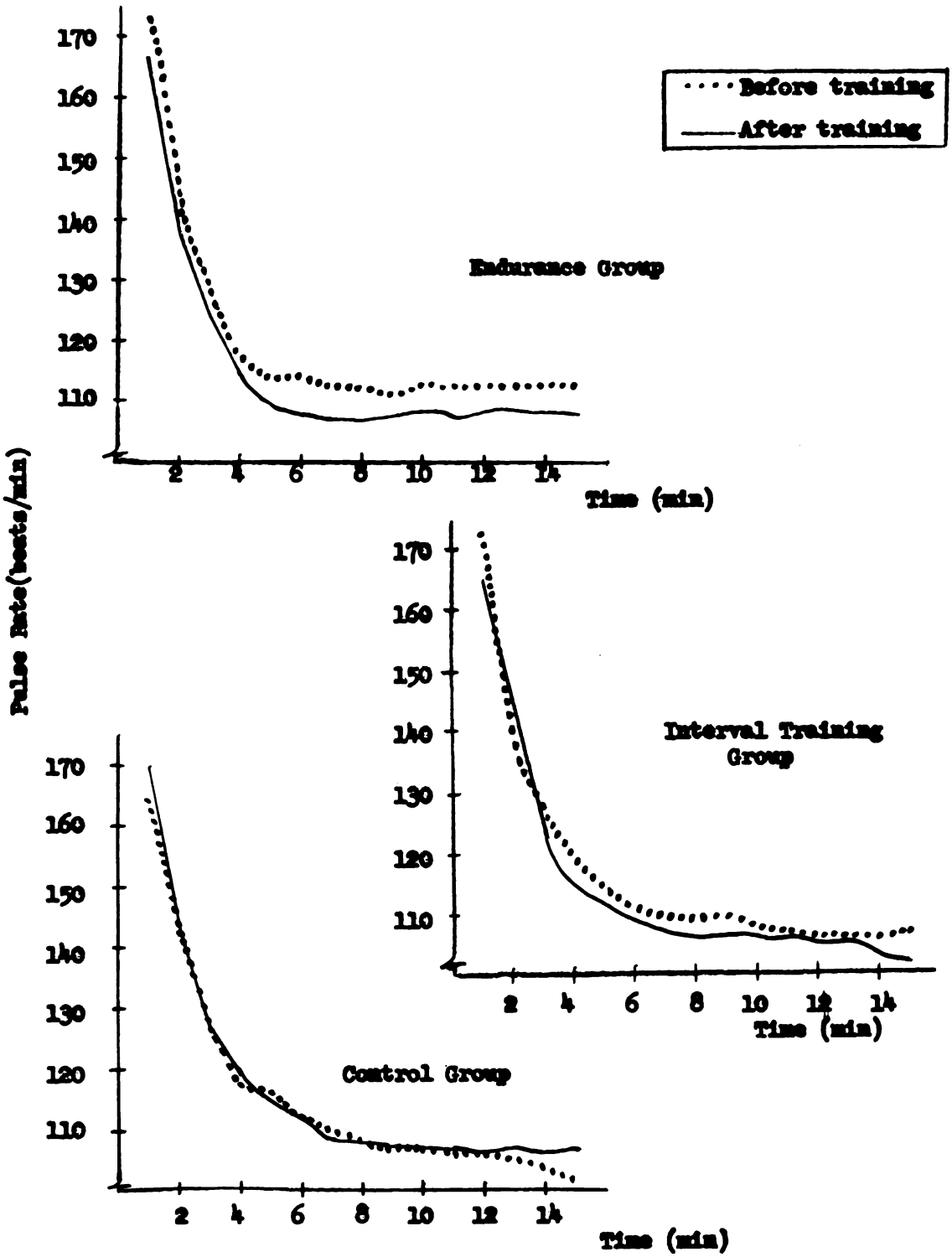


TABLE 4.--Gross O_2 Debt.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	3.90	2	1.95	0.54
Within	25.05	7	3.58	(N.S.)
TOTAL	28.95			

TABLE 5.--The Differences in Means of Pulse Rates During Recovery of the Exhaustion Run.

Time	Endurance	Interval	Control
1	6.50	7.33	-5.67
2	4.00	-4.00	0
3	4.50	3.67	.67
4	3.75	4.00	- .67
5	4.50	2.33	2.00
6	6.50	2.33	2.00
7	5.25	2.67	1.33
8	5.25	3.00	0
9	3.25	3.23	-1.00
10	5.25	2.00	.67
11	5.00	1.00	-1.67
12	4.50	1.00	0
13	4.25	1.00	-2.00
14	2.25	3.33	-3.33
15	4.75	5.00	-5.00

		level of significance
Endurance vs. Interval:	11 plus, 4 minus	.059
Endurance vs. Control:	15 plus, 0 minus	less than .001
Interval vs. Control:	14 plus, 1 minus	.001

The results show that both the endurance training and interval training significantly reduced the recovery pulse rates. The differences produced by the endurance training were greater than those resulting from the interval training. However, these differences were not statistically significant.

Maximum Pulse Rates

Maximum pulse rates for the exhaustion run are represented graphically in Chart IV. An analysis of variance was run on the differences and the results are shown in Table 6.

Exhaustion Run Times

The time for each subject's run was recorded. The means for each group were computed and the differences were found. The results are represented graphically in Chart V. An analysis of variance was run on the differences and the results are shown in Table 7.

Gross O_2 Debt

The values for gross O_2 debt were computed and the results are represented graphically in Chart VI. The differences were analyzed using analysis of variance and results are shown in Table 8.

CHART IV: EXHAUSTION RUN: MAXIMUM PULSE RATES

After Exhaustion Run = (10 mph, 9% grade)

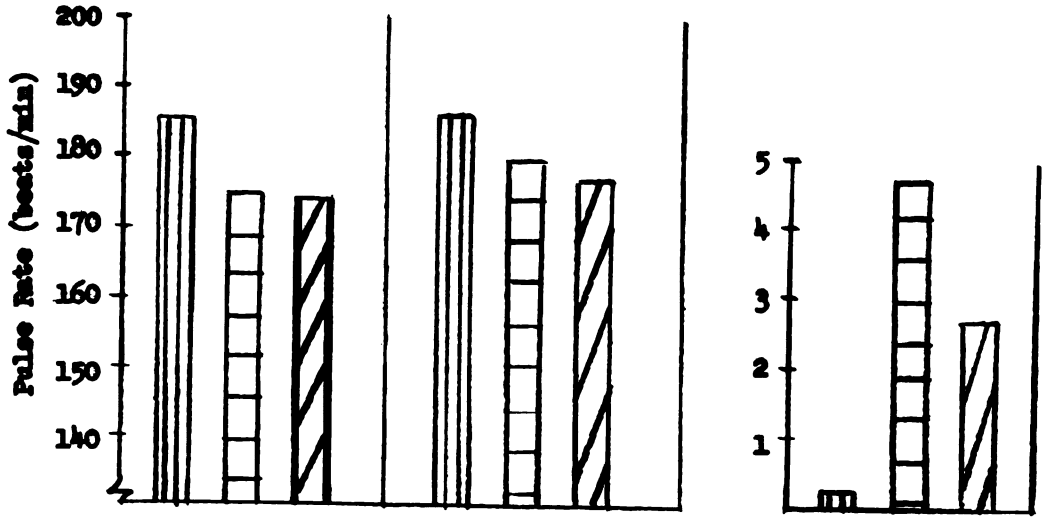


CHART V. EXHAUSTION RUN: TIMES

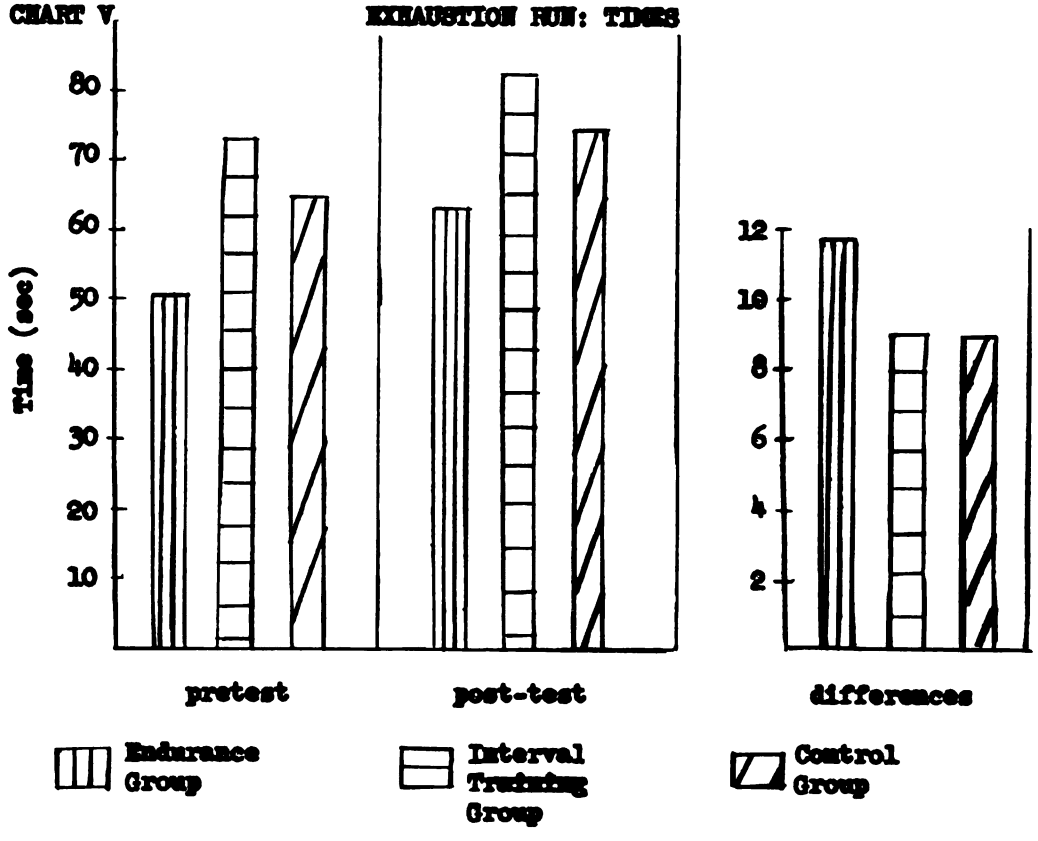


TABLE 6.--Maximum Pulse Rates.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	19	2	9.5	0.17
Within	394	7	56.3	(N.S.)
TOTAL	413			

TABLE 7.--Exhaustion Run Times.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	20	2	10	0.04
Within	1675	7	239	(N.S.)
TOTAL	1695			

TABLE 8.--Gross O_2 Debt.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	10.29	2	5.15	1.93
Within	18.66	7	2.67	(N.S.)
TOTAL	28.95			

Maximum Oxygen Consumption

The means for the maximum O_2 consumption for each group in the exhaustion run were computed and the results are represented graphically in Chart VII. An analysis of variance was run on the differences and the results are shown in Table 9.

TABLE 9.--Maximum Oxygen Consumption.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	.15	2	.08	2.00
Within	.31	7	.04	(N.S.)
TOTAL	.46			

Oxygen Debt

O_2 debt values for the exhaustion run were plotted as shown in Chart VIII. The sign test was run on the differences of the means and the results are given in Table 10.

Strength Measures

Vertical Jump

The means of the values for the vertical jump were computed and the results are represented graphically as shown in Chart IX. The differences were analyzed using analysis of variance and the results are shown in Table 11.

CHART VI: EXHAUSTION RUN: RECOVERY OXYGEN

Exhaustion Run (10 mph, 9% grade)

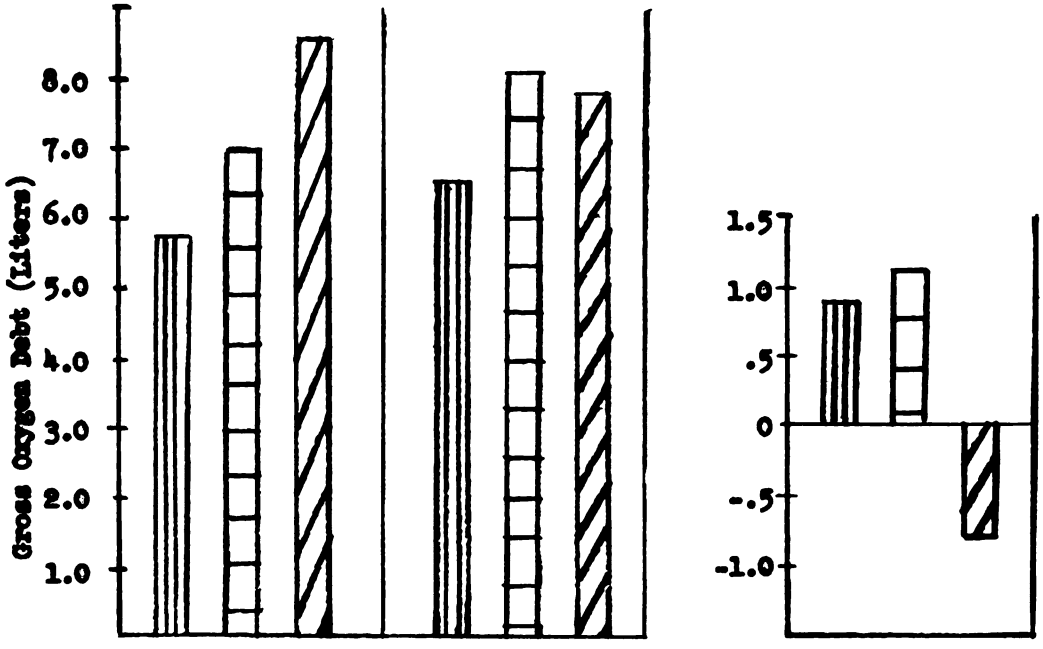


CHART VII EXHAUSTION RUN: MAXIMUM OXYGEN

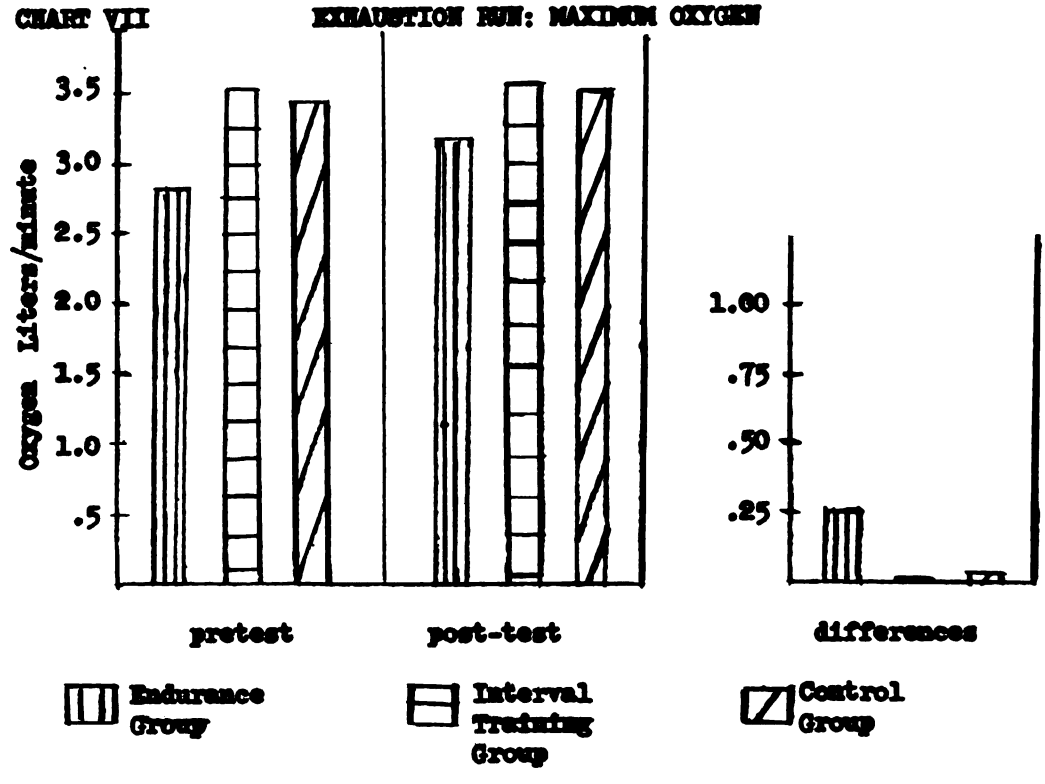


CHART VIII: EXHAUSTION RUN: RECOVERY OXYGEN

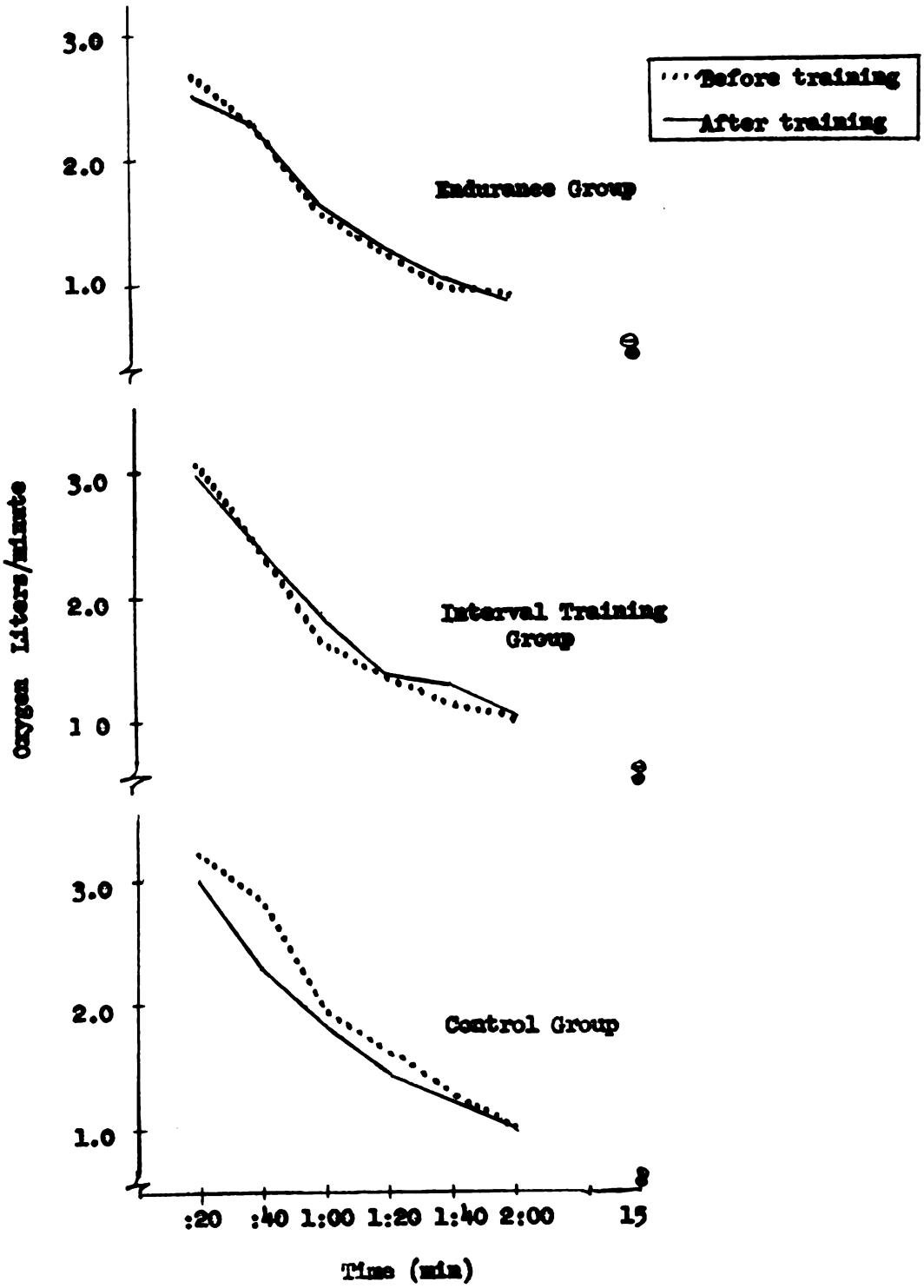


TABLE 10.--The Differences in the Means of the O_2 Debt for the Exhaustion Run.

Time	Endurance	Interval	Control
:20	.16	.09	.22
:40	.02	.02	.31
1:00	-.09	-.21	.10
1:20	-.05	-.01	.16
1:40	-.09	-.14	.17
2:00	.04	.01	.07
15:00	-.06	-.08	.04

		level of significance
Endurance vs. Interval:	5 plus, 1 minus, 1 zero	.109
Endurance vs. Control:	0 plus, 7 minus	.008
Interval vs. Control:	0 plus, 7 minus	.008

TABLE 11.--Vertical Jump.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	11.1	2	5.6	2.00
Within	19.7	7	2.8	(N.S.)
TOTAL	30.8			

Leg Strength

The means of the values obtained on the leg dynamometer were computed and the results are represented graphically in Chart X. The differences were compared by means of analysis of variance and the results are shown in Table 12.

TABLE 12.--Leg Strength.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	19,518	2	9,759	4.60
Within	14,806	7	2,115	(N.S.)
TOTAL	34,324			

Maximum Squat

The means of the values obtained from the maximum squat were computed and the results are represented graphically in Chart XI. An analysis of variance was used on the differences and the results are shown in Table 13.

TABLE 13.--Maximum Squat.

Source of Variation	Sum of Squares	df	Estimate of Variance	F
Between	2,133	2	1067	0.66
Within	11,392	7	1627	(N.S.)
TOTAL	13,525			

Discussion

Analysis of variance were run on the following: Standard run--gross O_2 intake, and gross O_2 debt; Exhaustion run--maximum pulse rate, run times, maximum

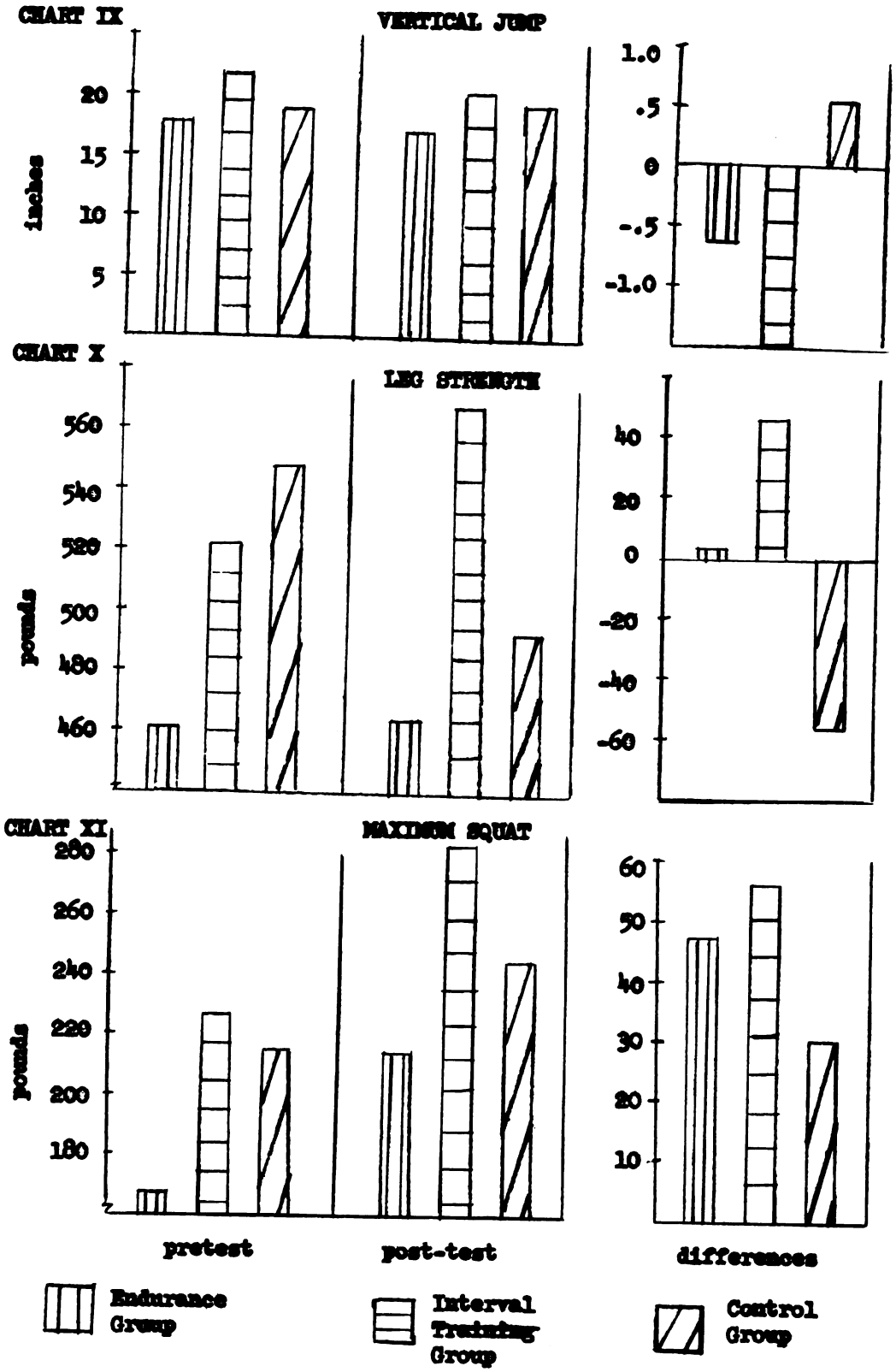


CHART IX
VERTICAL JUMP
inches
20
15
10
5
1.0
.5
0
-.5
-1.0
CHART X
LEG STRENGTH
pounds
560
540
520
500
480
460
40
20
0
-20
-40
-60
CHART XI
MAXIMUM SQUAT
pounds
280
260
240
220
200
180
60
50
40
30
20
10
pretest
post-test
differences
Endurance Group
Interval Training Group
Control Group

O_2 consumption, and gross O_2 debt; Strength tests--vertical jump, leg strength, and maximum squat.

None of these were found to be significant although leg strength was very close at F = 4.60 (P = 4.72). This does not mean to say that the training programs do not result in any changes. The lack of significance is more likely due to the small size N and the variability within groups.

With pulse rate, O_2 intake and debt data, for which multiple measures were available, the sign test was used. This technique revealed valuable information, and in an attempt to get a clear picture of what took place, Table 14 was constructed.

Both experimental groups underwent some definite adaptations to the training programs. A reduction in pulse rate is evidenced for both groups in both treadmill runs. Exercise and recovery pulse rates were reduced significantly more in the endurance group than in the interval training group. While this may be due to an increased adaptation to the endurance run, it is more likely a result of the limitation of unmatched subjects. The endurance group was found to have higher pulse rates in the pretest, hence there was more room for improvement.

The O_2 intake and debt results present an interesting picture. In the exhaustion run, an increase in O_2 debt is evident in both groups. This is clearly illustrated by

TABLE 14.--Table of Significance.

Standard Run	Exercise Pulse Rate	Recovery Pulse Rate	O_2 Intake	O_2 Debt	O_2 Intake and Debt Combined
Endurance vs. Control	S-	S-	S+	S-	N
Interval vs. Control	S-	S-	N	N	S-
Endurance vs. Interval	S-	S-	N	N	S+

Exhaustion Run	Recovery Pulse Rate	O_2 Debt
Endurance vs. Control	S-	S+
Interval vs. Control	S-	S+
Endurance vs. Interval	N-*	N-**

S = significant
N = not significant
* P = .059
** P = .109

The sign indicates the direction of the change for the group mentioned first.

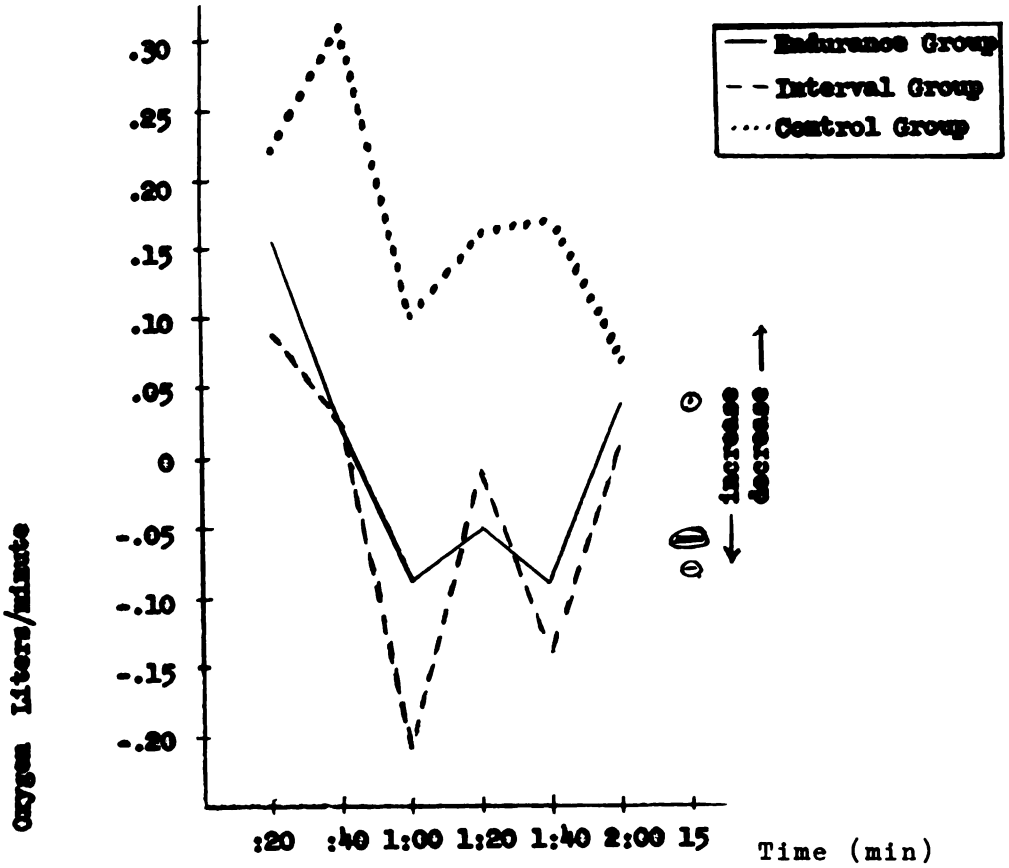
The probability levels are included for use by any future researchers in this area.

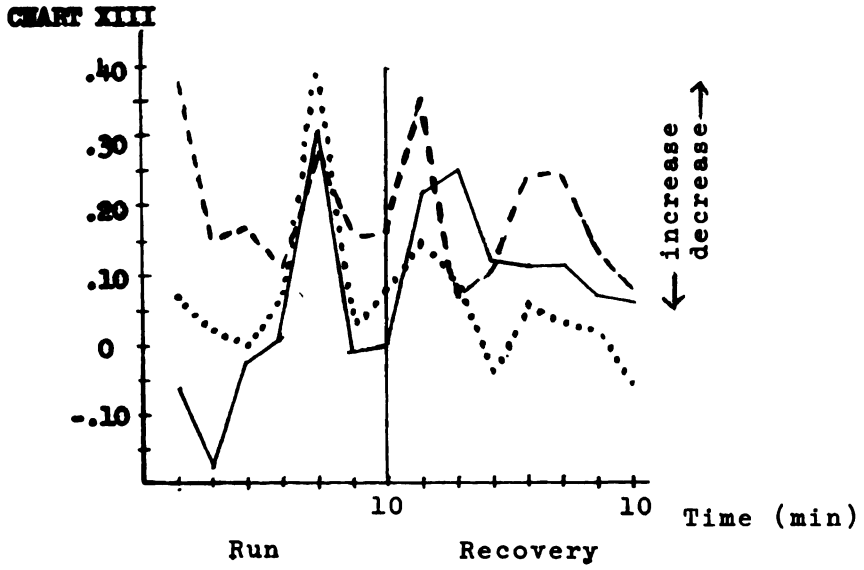
the graph in Chart XII. The greater increase by the interval training group was not significant when compared with the endurance group. The conclusion to be drawn from this is that both training programs resulted in increases in O_2 debt capacity. This would not be expected from an endurance training program. However, during training the rate of work was not held constant for the endurance group in this study, and they would often sprint the last 200 yards. It is possible that this would produce the adaptation for anaerobic work.

In the standard run, an increase in intake and a decrease in debt is evidenced on the part of the endurance group when compared with the controls. This is what would be expected. They were able to run the endurance run more efficiently by utilizing more oxygen during the run and building up less of an oxygen debt. The interval training program appears to have caused greater decreases in both intake and debt than either endurance training or not training at all (Chart XIII). However, these results were only significant if both intake and debt were combined.

CHART XII: DIFFERENCES OF OXYGEN MEASURES

Exhaustion Run (10 mph, 9% grade): Differences of Oxygen Measure





Standard Run (10 min, 7 mph, 0% grade): Differences of Oxygen Measures

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Ten subjects were divided into three groups: an endurance group, an interval training group, and a control group. The endurance group trained by running approximately two miles at each session, and the interval group trained by running six 50 yard dashes with a five minute rest interval at each session. There were three sessions per week and the training programs were carried on for seven weeks. The control group did not participate in any specific training program. The subjects were retested at the end of the seven week training period.

All subjects were tested on: a standard treadmill run (10 min, 7 mph, 0% grade), an exhaustive treadmill run (10 mph, 9% grade), vertical jump, leg strength, and maximum squat. Pulse rate and oxygen consumption data were collected for both runs and also for recovery periods of ten minutes following the standard run and fifteen minutes following the exhaustive run.

Analysis of variance was used to statistically test the data. Wherever multiple measures on the same subject were available the sign test was used. The data were also treated graphically.

Exercise and recovery pulse rates in the standard run and exhaustion run were significantly reduced by both training programs. Endurance training produced significantly greater decreases in both exercise and recovery pulse rates for the standard run.

Oxygen debt for the exhaustion run was significantly increased by both training programs. In the standard run the endurance group showed an increase in oxygen intake with a decrease in oxygen debt. Both were found to be significant. The interval group showed decreases in both intake and debt when compared with the controls and also the endurance group. These differences were significant only if the data on intake and debt were combined.

Conclusions

1. Both training programs produced adaptations to exercise.
2. The endurance training program produced significant improvements in aerobic work capacity.
3. The endurance training produced significantly lower pulse rate responses to standard exercise than the interval training.

Recommendations

It is not practical to draw any further conclusions at this time. It would be interesting to speculate since

the data do appear to show certain trends. The best procedure, however, would be to repeat the study with the limitations removed and then draw some definite conclusions. For this reason the following recommendations are made for anyone who desires to pursue a study of this nature.

1. This study should be carried out with a much greater number of subjects. Too much within group variability results from such a small size N.
2. The groups should train for a longer period of time.
3. The training programs could be more controlled. For example, if the endurance group trained right on the treadmill, their distance and rate could be rigidly controlled.
4. The outside activities should be kept as minimal as possible. The ideal situation would be one in which all outside activities could be controlled. In this way the results could not be influenced by any extra work done on the subject's own time.

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APPENDICES

APPENDIX A

TWO MILE TIMES

	Subjects			
Training Day	P.D.	B.B.	H.S.	J.C.
4/15	13:48	16:40	15:22	16:45
4/18	13:55	15:25	16:12	17:25
4?20	12:28	14:19	-----	16:30
4/22	12:16	12:47	14:33	16:55
4/25**	12:46	13:43	16:39	19:20*
4/27	11:56	-----	14:30	*
4/29	11:52	12:40	14:08	*
5/2	11:52	12:45	14:43*	19:08*
5/4	-----	13:43	*	17:04
5/6	-----	12:21	14:13	15:08
5/9	11:53	-----	*	15:15
5/11	12:07	12:36	*	14:39
5/13	-----	12:44	13:56	13:43
5/16	-----	13:20	*	15:08
5/18	11:54	12:23	*	13:47
5/20	11:32	12:52	16:39	14:45
5/23**	12:03	13:38	16:15	15:32
5/25**	11:56	13:42	15:00	14:51
5/27**	-----	13:18	16:32	15:11

-- training days missed

* days when subject was ill or injured

** days when training was done outside

APPENDIX B

INTERVAL TRAINING: 50-YARD DASH TIMES

Day	Subject						
	L.G.	6.40	6.42	6.40	6.38	6.54	6.50
4/15	L.L.	7.32	--	7.30	7.35	7.32	7.40
	P.K.	6.70	6.90	6.50	6.74	6.70	6.70
	L.G.	6.52	6.52	6.70	6.50	6.70	6.88
4/18	L.L.	7.00	7.20	7.10	7.08	7.10	7.30
	P.K.	7.05	6.88	6.80	6.89	6.95	7.10
4/20	L.G.	6.30	6.38	6.40	6.35	6.35	6.30
	L.L.	6.80	6.90	7.01	7.00	7.00	6.90
4/22	L.G.	6.20	6.35	6.55	6.30	6.55	6.45
	L.L.	7.00	7.00	7.05	7.55	7.30	7.45
4/25	L.G.	6.85	6.60	6.85	6.75	6.95	6.70
outside	L.L.	7.6-	--	*			
	P.K.	6.90	6.80	6.90	7.20	7.10	
4/27	L.G.	6.25	6.70	6.60	6.50	6.25	6.25
	L.L.	7.10	7.30	7.10	7.40	*	
4/29	L.G.	6.45**	6.60**	6.55**	6.20	6.10	6.20
	L.G.	6.30	6.10	6.10	6.40	6.20	6.40
5/2	L.L.	6.85	7.10	7.20	7.25	7.40	7.45
	P.K.	6.80	6.80	6.85	6.70	6.80	6.80
	L.G.	6.20	6.15	6.45	6.35	6.20	
5/4	L.L.	7.50	7.35	7.10	7.20	7.50	
	P.K.	6.70	6.75	7.20	*		
	L.G.	6.20	6.20	6.10	6.20	6.25	6.30
5/6	L.L.	7.20	7.00	6.90	7.10	7.20	7.40
	P.K.	*					
	L.G.	***					
5/9	L.L.	6.90	6.90	6.85	7.10	7.15	6.80
	P.K.	7.00	7.00	6.80	7.05	6.90	6.70
	L.G.	6.00	6.30	6.05	6.05	6.10	6.20
	L.L.	7.10	7.10	7.05	6.70	6.75	6.80
	P.K.	*					

APPENDIX B (cont.)

Day	Subject	1	2	3	4	5	6
5/13	L.G.	6.40	6.50	6.20	--	6.30	6.20
	L.L.	6.90	7.00	--	6.90	7.10	--
	P.K.	*					
5/18	L.G.	6.50	6.40	6.15	6.20	6.15	6.15
5/20	L.G.	6.30	6.30	6.30	6.35	6.30	
	L.L.	6.75	6.85	6.60	6.85	6.65	
5/23	L.G.	5.80	6.10	6.40	--		
	L.L.	6.65	6.95	--	6.90		
5/25	L.G.	6.30	6.30	6.30	--	6.30	
	P.K.	6.60	6.75	--	6.75	6.80	
5/27	L.C.	5.95	6.00	6.10	6.10	--	6.05
	L.L.	6.85	6.70	6.50	--	6.60	6.80
	P.K.†	6.80	6.90	6.80	6.85		

-- time was not taken

* tight leg muscles

** started from finish line

*** sickness

† ran some dashes on his own time